

APPLICATION TOP FIVE EXPONENTIAL LOGISTIC TECHNOLOGIES DURING THE COVID-19 PANDEMIC

Abstract. In a pandemic situation such as Covid-19, it is essential to keep contact to a minimum, but it is also important to maintain an acceptable supply level to the population. This paper presents a general analysis of selected exponential logistics technologies, particularly the possibilities of their use in the implementation of logistics chains, or the segment related to storage and distribution during a pandemic. Exponential technologies are those whose performance doubles yearly, but whose cost is halved. Five logistics technologies have been selected that meet the exponentiality criteria and can address pandemic-related issues under certain conditions. Each of these technologies can be used in specific segments of logistics systems. The technologies meet the exponentiation criterion and contribute to increased performance, efficiency, and process automation. These technologies are becoming part of a new approach to logistics and are directly related to the advent of Industry 4.0. This paper analysis and subsequent application concern logistics technologies such as internet of things, automated guided vehicles, drones, digital twins, and artificial intelligence.

Keywords: Covid-19 pandemic, logistic technologies, internet of things, artificial intelligence, drones.

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Introduction

One of the fundamental pillars of Industry 4.0 is exponential logistic technologies. Exponential technologies are those whose performance and speed must double every year while at the same time usually halving in price. These technologies are built on the foundations of primary technologies. They have become an integral part of a new approach to understanding logistics. Exponential logistics technologies are closely related to automation and robotics in production, warehousing, or distribution. Some exponential logistics technologies are already part of everyday production and distribution, such as the digital twin, robotization, and automatization, e.g., automated guided vehicles), drones, internet of things, etc. Other exponential technologies are still being successfully developed, tested, and awaiting their broader application in practice, e.g., nanotechnology, augmented reality, and others (Javaid et al, 2020).

The paper presents a general analysis of selected exponential logistics technologies. Based on this analysis, as well as the advantages and disadvantages of these technologies, the possibilities of their use in solving the problems related to the pandemic Covid-19 are proposed. During a pandemic, it is essential to limit physical contact to a minimum to address the health situation, the mobility of the population, etc. However, from the point of view of the national economy, it is also essential to keep production and distribution at an adequate level (Ghobakhloo et al, 2022).

The application of exponential logistics technologies in times of pandemics is a complex process that requires, among other things, legislative adjustments, and the necessary technological support of primary logistics technologies in individual logistics segments. However, these technologies' tools can significantly help address many of the problems associated with the Covid-19 pandemic.

1. Research background

Exponential technologies have been given this designation due to their considerable increases in performance and decreases in price. It is not explicitly stated what time interval is needed to multiply the performance of the technologies, but in this context, the often-used Moore's law speaks of an interval of 18 months. However, the validity of this law is currently under review, an interval of 1 year can be discussed (Hecl et al, 2020).

Digitizing is information and database that can be digitized and managed by computers. After digitizing, the increase in the performance of the technology is initially relatively small, but this is deceptive because the exponential function only increases when the fundamental constant reaches an integer value ($a = 1$). Once it is exceeded, growth reverses rapidly, and the technology becomes more powerful and desirable. Once the value of the integrated function is surpassed, the market efficiency and market costs of the new technology become distorted, disrupting existing technologies. This effect is also discussed in Moore's Second Law (or Rock's Law). The market will adjust to this change, but it takes time (Moore's Law, 2022). The dematerialization phase occurs when the price falls (exponentially) to the cost level, which contributes to its broader availability on the market. The market has adapted to the new lower price, and the technology has become more affordable, therefore mass diffusion is occurring (Kačoušková, 2022). Having gone through all the previous steps, the technology has moved from being available only to the privileged to being available to the public (Toman, 2019).

Several relevant studies have influenced the selection of technologies suitable for addressing or eliminating the problems associated with the Covid-19 pandemic. One of the backgrounds was the Gartner analysis (Gartner IT Symposium in Orlando), which lists the Top 10 Strategic

Technology Trends for 2019, as shown in Table 1. (Gartner, 2022). The Scientific Foresight Unit's 2020 research study for the European Parliament and the European Parliamentary Research Service (EPRS), entitled "Ten technologies to fight coronavirus", reports the application of 10 technologies, but partly different from the previous study (EPRS analysis, 2022), see in Table 1.

Table 1. Ten technologies from selected research

No	<i>Gartner's analysis</i>	<i>EPRS analysis</i>
1.	Internet of things	Artificial intelligence
2.	Augment analytics	Open-source technologies
3.	AI-Driven development	Telehealth technologies
4.	Digital twins	Drones
5.	Empowered edge	Nanotechnology
6.	Immersive experience	Robots (Automated guided vehicles)
7.	Blockchain	Blockchain
8.	Smart spaces	Synthetic biology
9.	Digital ethics and privacy	Gene-editing technologies
10.	Quantum computing	Three-dimensional printing

(Source: Autor by the Gartner's and EPRS analysis)

It also goes on to outline not only the possibilities for the application of logistics technologies but also the proportions of technology use during a pandemic in different areas of logistics. The latter is further illustrated in Table 1, where the Internet of Things technology has the largest share of use. Another significant share is barcode scanning technology, which is also closely linked to the use of information technology in warehouse management, which considerably speeds up these processes and significantly simplifies the technology from the receipt of products to the actual receipt of products.

Based on above-mentioned research studies (Gartner's analysis and EPRS analysis), as well as other relevant sources (Javaid et al, 2020, Ghobakhloo et al, 2022 and Hecl et al, 2020), five technologies were selected. They partly come from relevant research and were selected mainly those that correspond with research area, which means they can apply in Covid-19 pandemic problem solving.

These exponential logistic technologies are going to be analyzed:

1. Internet of Things (IoT).
2. Automated guided vehicles (AGVs).
3. Drones.
4. Digital Twins (DTw).
5. Artificial intelligence (AI).

1.1. Internet of Things

Internet of Things (IoT) represent technology that connects individual devices (machines, objects) via the Internet without human participation (Dunlap, 2021). The basis of the technology is collecting data from many locations, which is carried out through various sensors or transducers. The next step is to process and share the data via the Internet. The data is evaluated and then used for a specific purpose (Dunlap, 2021).

The Internet of Things finds its application in all links of the logistics chain. In manufacturing, where the IoT can be used to collect and process information about all steps of the production process. In warehousing, all processes related to material handling can be managed, such as stowage of goods, retrieval, loading and unloading, etc. In distribution, it is the processing and evaluation of a multitude of data related to optimizing the delivery of goods. In times of pandemics IoT helps to prevent the spread of the virus by not requiring direct contact between downstream subsystems of the logistics chain, not even direct contact within a subsystem.

The warehousing subsystem manages processes automatically without direct human involvement, thanks to data collection. Similarly in the distribution subsystem, IoT actively helps distribute without direct contact between supplier and customer. For example, it can be a parcel vending machine system where distribution works non-stop, parcel vending machines are easily accessible, secure, and flexible (Luk, 2022). When dealing with a pandemic, IoT can passively ensure that all infected individuals are quarantined. The monitoring system ensures that all, but especially high-risk patients, are monitored via the internet network. The monitoring tracks all important biometric measurements such as blood pressure, heart rate and glucose levels (Dunlap, 2021).

Some problems that arise with IoT applications are the scope for cyber threats, loss or theft of data, or inadvertent sharing of data. From the above analysis, it is evident that IoT technology has an important role to play at the time of dealing with pandemic situation. However, the technology is also applicable to logistics processes such as distribution, manufacturing, warehousing, transportation, etc. (Karhanová, 2020).

1.2. Automated guided vehicles

Automated guided vehicles (AGV) are devices that do not need a human to drive them but are controlled automatically via a control and navigation system. It is a mobile robot that can be used mainly for transport and handling operations such as intra-company transport, warehouse operations, loading operations, etc. It is advantageous for applications where frequent repetitive handling is required for material flows with higher frequency and for such processes where material flow monitoring is important (Benevides et al, 2021). AGVs facilitate material handling activities and, by their independence, increase efficiency and reduce the cost of human operators in logistics processes (Stentoft et al, 2020).

AGVs orient themselves in space using navigation, and several guidance systems can be used, such as gyroscopic, inductive, optical, magnetic, laser and GPS guidance. The appropriate type of guidance is selected based on the tasks performed by the mobile robot.

In recent years, thanks to the rationalization of logistics processes, AGVs have become so-called user-friendly, which is why they belong to the exponential logistics technologies. The use of AGVs in logistics has many advantages, for example, it eliminates human errors, works more accurately, is more efficient and reliable than humans (Chia et al, 2021).

The following benefits of AGVs can be highlighted in the context of dealing with a pandemic situation: reducing the need for human labor, reducing operating costs, increasing productivity and reliability, increasing safety at work, and reducing direct contact between workers to a minimum. The economic advantage of the technology is that technology appears to be economically advantageous for frequently repetitive operations (Barios et al, 2019, and Benevides et al, 2021).

During pandemic, AGVs autonomy and application in automated processes in production and warehousing ensure the elimination of personal contacts and thus contribute to reducing the risk of disease transmission. Like other robots, AGVs do not require any "personnel care" and in case of hospitalization of operational workers, they can work, even in environments with increased risk of infection (Hamilton, 2021). However, AGVs can also be used to distribute drugs and food in the public sphere (see Fig. 1.).



Fig. 1. AGV for drug and food distribution
(Source: Hamilton, 2021)

AGVs must be equipped with AI features. By recognizing objects together with some of the navigation systems (usually GPS), the vehicles can deliver parcels without the presence of a driver (Chia et al, 2021).

1.3. Drones

A drone is an unmanned aircraft or also an unmanned aerial vehicle (UAV) that can come in a variety of shapes, sizes, and characteristics (Science, 2018). It can be controlled remotely, fly autonomously based on pre-programmed flight plans, or use more complex dynamic autonomous systems (Hardis Group, 2022). Drones were originally created for military purposes but are now also useful in the civilian sphere for delivery of goods, search, monitoring, filming, etc. (Byrtusová, 2019).

By design, drones can be divided into aircraft-like drones, which have wings, and helicopter-like drones, which use propellers to stay in the air and give direction. According to the control, drones are divided into autonomous and remote-controlled. Autonomous drones operate like flying robots where a task is programmed, and the drone performs it autonomously (Novotný, 2017). Remote-controlled drones are manually operated by a

human operator, where the operator sends commands to the drone via radio waves. The drones are usually equipped with a camera or other monitoring and data collection system (Hamilton, 2021). In logistics, drones find applications in warehouse management (e.g., inventory), transportation (for shipment distribution) but also in manufacturing (Novotný, 2017).

In recent years, also due to the impact of pandemic, the application of drones has expanded to a wide range of activities, from the disinfection of premises to the monitoring of private and public spaces, and the delivery of food and medicine to quarantine areas (Move, 2022). Advantages of drone application include coverage of hard-to-reach areas, ease of deployment, simple automation, high quality aerial imagery, accuracy, and safety. Disadvantages include limited payload capacity, undefined flight paths, misuse of drones for private purposes limiting privacy and legislative barriers (Stock Logistic, 2019).

In the context of preventing the spread of the Covid-19 pandemic, or to protect the population and prevent possible danger, drones can be used for:

- Humanitarian aid and disaster relief - locating victims, damage monitoring, disaster prevention.
- Disease control - monitoring sites, capturing, testing, and evaluating areas at risk.
- Healthcare - rapid distribution of medical aid to hard-to-reach areas (see Fig. 2.).



Fig. 2. Drone parcel delivery
(Source: Chorvát, 2015)

- Urban monitoring - collecting data in densely populated areas on population movements.
- Food ordering and delivery - food delivery from fast food outlets allows for reduced physical effort and direct customer contact, while making deliveries faster, more hygienic, and cheaper (Karim, 2020).

The use of drones at the time of the Covid-19 pandemic facilitates the implementation of the tasks and control of the regulations in the enforcement of the relevant measures. Drones allow for minimal human physical intervention, reducing their likelihood of contracting the virus. It turns out that it is the systematic deployment of drones in the aforementioned areas such as monitoring, reconnaissance, delivery, search, etc. that can be crucial in the containment of the Covid-19 pandemic (Chorvát, 2015, Novotný, 2017).

1.4. Digital Twins

The digital twin (DTw) represents just one of several cyber layers that enable the convergence of the physical environment with the virtual one. Within cyber-physical systems, physical and software components are intertwined, each operating on different spatial and temporal scales, but interacting with each other (Wu et al, 2020).

The digital twin technology is enhanced with features that allow the object to function independently and interact with other digital twins in virtual space. This type of digital twin is called an intelligent information agent because it has some artificial intelligence. As a result, the agent can take the initiative, to act on its own on the environment and the objects in it, and to decide on a sequence of operations to achieve the most efficient result, and in an optimal way.

Although simulations and digital twins use digital models to replicate various system processes, the digital twin is a virtual environment, making it significantly richer for study. The difference between a digital twin and a simulation is largely a matter of scale. While a simulation typically studies one process, a digital twin can run any number of useful simulations on its own to study multiple processes (Abideen, 2021).

For example, a digital twin can simulate various problematic scenarios and then simulate the corresponding reactions. In the event of a prediction error, this is analyzed and, in many cases, eliminated using artificial intelligence or corresponding algorithms. In this way, errors can be prevented in the individual systems of a real logistics chain (Solidpixels, 2021).

The advantages of DTw are: increased efficiency and productivity, the possibility of testing new systems before their introduction, cost savings, reduced time to commission new products, predictive maintenance, simulation of processes beyond reality. The disadvantages, which can be considered as the danger of data leakage in virtual environments and relatively high technology implementation costs (IBM, 2022).

Digital twin technology has great potential in the logistics sector. The involvement of digital twins will lead to significant improvements in logistics operations, optimizing the planning, organization, and process of supply chains, from specific facilities and shipments to overall global supply networks (Novotný, 2018). It will also raise the level of decision-making in the physical world, fundamentally changing supply chains and logistics processes. The highest level of application of the technology is the digital twin of the entire supply chain. Implementing technology at this scale is challenging and requires close collaboration between all partners along the chain (Továřna, 2022).

During of a pandemic, the technology allows for creating digital twins of problem locations in a virtual environment, where their potential resilience to the effects of a pandemic or other dramatic event can be tested and simulated. DTw on a virtual model helps to understand how best to adapt to such situations and assists in finding optimal problem-solving approaches. DTw can be leveraged to build 'smart cities' where technology helps to monitor, understand, and optimize the functions of all physical entities and provide continuous feedback to

people in smart cities to improve their quality of life (Sarkis, 2020).

Another application may be health services. Just as products can be profiled using digital twins, so can the patients who are offered health services. The same data collection and generation system used for the object can also be used to track various health indicators in patients. This information is then paired with their artificial intelligence augmented virtual DTw. Based on this, a sort of individualized digital twin of each patient is created. The individualized digital twin thus created is then compared with the real patient. The more accurate a representation of the patient's health trajectory is developed; the more precise the patient's disease progression predictions are. Subsequently, the system enables the generation of key insights into the patient's future condition. Health risks are thus assessed before the disease manifests itself. Doctors would thus know exactly when and whether to intervene. A similar system can be used for a group of patients in a problem location (Wu et al, 2020).

1.5. Artificial Intelligence

Artificial intelligence (AI) is the ability of a device to exhibit human-like abilities such as reasoning, learning, planning and creativity. Thanks to AI, technical systems can distinguish their environment and solve what they recognize as a problem. The computer receives data prepared or collected by its sensors (e.g., cameras), processes it and responds to it to achieve a specific goal. Based on the collection of relevant data, AI systems can operate autonomously and adapt their behavior to some extent based on the analysis of previous actions (Gartner, 2018). The goal of AI is not to replace humans, but only to increase their capabilities and usefulness in each environment. The main goals of artificial intelligence in logistics systems are to achieve an automated, proactive, predictive and personalized logistics process in operational activities, customer contact, understanding and orientation in a given situation. Technologies can focus on image recognition in logistics operations to monitor the status of the object under study (equipment, shipments, people, etc.), provide fully autonomous distribution, or anticipate fluctuations in the logistics chain before they occur (Duggal, 2022).

Artificial intelligence is used to transform logistics processes through the predictive analysis of big data, robotics, or autonomous vehicles. Another application of artificial intelligence in logistics is the analysis of the vast amount of structured and unstructured data that is generated throughout the logistics process (Oracle, 2022). Artificial intelligence has become an integral part of almost all logistics processes, primarily used for forecasting and planning, warehousing, robotics and automation, operational efficiency of systems, and customer service.

The Indisputable advantages of AI In the fight against pandemic include high speed decision making, cybersecurity, reliability, monitoring of at-risk entities and objects, impartial intelligent decisions, and autonomy. Aspects such as: high accuracy with a minimal error rate, the possibility to use a digital personal assistant (Mob, PC, etc.), online processes (e.g., shopping, etc.) can also be crucial in problem solving. Partial disadvantages may be

the relatively high investment and operational costs and, in the case of entity monitoring, legislative obstacles (Zhang, 2021).

2. Discussion

In the fight against the Covid-19 pandemic, exponential technologies can play an important role. However, it is important to note that the outcome of the action must be consistent with values such as transparency, accountability, explain ability, auditability and traceability, and neutrality or fairness. In the absence of EU legislation on the deployment of certain technologies (drones, AI) or their components (automation, robotics), particular attention must be paid to the need to establish a certain scheme for the ethical management of these technologies.

General data protection regulations hamper wider deployment of some technologies. This is not necessarily limited to personal data, but also applies to the collection, use and sharing of data for reasons of public interest, e.g., in the field of public health. The European Data Protection Board (EDPB) has warned public authorities against the systematic and general monitoring and collection of health-related data. It recommends that, for example, location data should be processed anonymously (ERPS analysis, 2022). Although many of the exceptional measures controlling the use of certain logistics technologies (e.g., drones, AI, etc.) are based on emergency powers to be used only temporarily in emergencies, specific rules should be introduced that could be used only temporarily in emergencies so that full protection of personal data is provided once the emergency is lifted.

Five exponential logistics technologies have been selected that meet the exponentiality criteria and can address pandemic-related issues under certain conditions. Each of these technologies can be used in specific segments of logistics systems. The technologies meet the exponentiation criterion and contribute to increased performance, efficiency, and process automation.

All the exponential technologies analyzed can be used to address the problems associated with the Covid-19 pandemic, however, each technology has different benefits for application in this area. Table 2 summarizes the focus areas that each technology can address during the pandemic.

Table 2. Possibilities of applying technologies to solve problems during pandemic

<i>Technology</i>	<i>Solution areas</i>
Internet of Things	Tracking of persons in quarantine, monitoring of persons, biometric measurements of basic functions of affected persons.
Automated guided vehicles	Elimination of personal contacts, working in a risky environment, kiss-contact distribution
Drones	Humanitarian assistance, monitoring sites, locating people, assessing risk areas, distributing medical aid, delivering food, monitoring population movements.
Digital Twins	Testing and prediction of problem areas, crisis management, simulation of potential

	pandemic resilience, health services in disease prediction.
Artificial Intelligence	Thermal imaging monitoring of people in public places, identification of at-risk subjects, tracking of people's movements, prediction of the spread of contagion, regulation of misinformation on social networks.

(Sources: author)

It is clear from previous research that the application of logistics technologies in times of pandemic is essential. Appropriate logistics technologies can solve a significant part of the problem areas related to the Covid-19 pandemic. It is also important to note that logistics technologies can greatly increase efficiency when combined appropriately. For example, the combination of artificial intelligence with drones or with a digital twin appears to be highly effective. When implementing exponential technologies to solve a specific problem, it is necessary to start from a thorough analysis of the problem area, then design the appropriate technology or combination of technologies, and finally evaluate the effects of this implementation.

Conclusion

Exponential logistic technologies have recently become rapidly in demand in terms of their benefits for implementation in logistics processes. This paper explores the potential application of exponential logistics technologies during the Covid-19 pandemic. Five logistics technologies were selected that meet the criteria of exponentiality and that, under certain conditions, can address the problems associated with the pandemic.

Based on the analysis of individual technologies, their advantages and disadvantages, applications have been proposed that can solve specific problems to a certain extent, not only in logistics chains, but also in crisis situations such as the pandemic. Just as the coronavirus pandemic was spreading, technological applications and initiatives were proliferating to control the situation, treat patients in an efficient manner and facilitate the efforts of health professionals.

Logistics technologies cannot replace medical and political measures, but they can play an important role in emergency situations such as the Covid-19 pandemic. Paradoxically, this epidemic presents an excellent opportunity for policy and regulatory makers to reflect on the current legislation, the ethical soundness, and the effectiveness of the deployment of logistics technologies during crisis.

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