ANALYSIS OF THE INTERCONNECTION BETWEEN INDUSTRY 4.0 AND LOGISTICS 4.0

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Abstract. Since the mid-1990’s when the Internet emerged and the Web came along, it started a massive transformation in commerce, trade and economic landscape. Innovative technologies, intelligent assistants, smart devices are surrounding us in everyday life. They help us, anticipate us, make everyday life and tasks more manageable. For example, the logistics industry has changed dramatically since World Wide Web emerged. Manufacturing, transportation, last-mile delivery – all these areas and services have improved exponentially and keep getting better and more intelligent with the emergence of technologies and Artificial Intelligence.

Industrial revolutions have affected the whole manufacturing and service industry, and it led to improvements in productivity and quality of service without a doubt. But together with progress and quality, some challenges accumulate in the companies, such as adopting new technologies and new concepts such as robotics, cybersecurity and artificial intelligence. These technologies are the "plants" of Industry 4.0.

This paper aimed to present a comprehensive analysis of the interconnection between Industry 4.0 and Logistics 4.0, their impact on production, service delivery, working conditions, and how technological development creates a competitive advantage. To achieve the article's aim, the analysis is based on the literature review of scientific researchers and authors whose results contribute to science.

Keywords: Industrial revolution, Logistics 4.0, Industry 4.0, Smart logistics, New technologies, Digitization, Competitive advantage.

JEL Classification: O14; O33

Introduction

Paul G. Krugman, an American economist, professor, and columnist, said, “The world got smaller between 1840 and 1914, but it got bigger again for much of the 20th century. Thus, there have been two waves of globalization:
- The first wave relied on the railroad, steamship, and telegraph
- The second wave relied on jets and the Internet.

The Internet makes instant and accessible communication between people thousands of kilometres apart. Aeroplanes made it possible to allow quick physical access to all parts of the globe. In the opinion of Krugman and Obstfeld (2003), "World trade is a moving target. The direction and composition of world trade are quite different from what it was a generation ago and even more different from what it was a century ago. (Krugman & Obstfeld, 2003)

The emergence of digital technologies and the rapid technological advancements in digitization have transformed the business and operational landscape of the global logistics and freight
industry. (Global Freight Transportation Industry: The Key Trends & Applications of AI - Forecast to 2025, 2020)

Speed and communication are crucial factors in the logistic sector. For logistics companies and freight forwarders to ship products quickly and without spoilage is the main target. Companies must hold communication with their customers to high standards, and customers need to track their shipment at any time. Being great at being fast and communicate well can bring your business to the high grounds. To perform competently, companies have several ways to do it. That involves improved communication capabilities as well as data collection and analysis through software available on the market.

The application of new technologies by any industry or any player can generate more productivity, connectivity, safety, efficiency, flexibility. Industry 4.0 helps to improve all these mentioned factors. According to several authors (Rüßmann et al., 2015), “Industry 4.0 also lays the foundation for adopting new business models, production and innovation”.

Uckelmann, in his research paper “A Definition Approach to Smart Logistics” from 2008, refers to Industry 4.0 and Logistics 4.0 as “Smart Logistics”. As “Smart Logistics” will change according to the actual technology used, it has a time dependency; thus, it is essential to seek out state-of-the-art technology”. (Goos et al., 2008)

Industry 4.0, Logistics 4.0 equals “Smart” or “use of smart technologies” or “digitization”. Smart logistics or Logistics 4.0 brings companies closer to customer needs. It gives innovations such as intelligent containers, intelligent warehouses, autonomous trucks, and AI-driven technologies to increase velocity and enhance customer service. For logistics companies’ agility, cost-saving, and customer satisfaction is the leading force of the business.

This paper analyzes the interconnection of Industry 4.0 and Logistics 4.0 how technologies offer a wide range of capabilities to logistics companies, from autonomous machines to artificial intelligence. From the invention of the steam engine and the automated digital production, all industrial revolutions and mainly the 4th one, have led to significant changes in the logistics process.

Sustainable and automated processes have emerged and reshaped the industry. This paper discusses the frameworks of Industry 4.0 and Logistics 4.0. And based on the literature review, definitions and concepts, the empirical analysis is conducted and presented.
1. **The Framework of Industry 4.0**

The integration of physical operations in industrial production, information, and communication technologies is called Industry 4.0. (Paksoy et al., 2021)

The industrial revolution is counted as one of the main historical events of development in human history. (Stearns, 2012) It shaped how people work and live, how things are manufactured, transported and sold. And it continues to shape the industries and the world.

**The shift in action**

“In 1985, the Cray-2 supercomputer was the fastest machine in the world. The iPhone 4, released in June 2010, had the power equivalent to the Cray-2; now, the Apple Watch has the equivalent speed of two iPhone 4s just five years later. With the consumer retail price of smartphones tumbling to below $50, processing power skyrocketing and adoption in emerging markets accelerating, nearly everyone will soon have a literal supercomputer in their pocket”. (Schwab, 2017)

1.1 **Industry development stages**

Innovation in logistics began long ago with the mechanization of transport enabled by trains, cargo vessels, and automobiles. However, after being evolved to the systemization of logistics, based on electronic communications, logistics is increasingly moving towards automation with the help of crucial Industry 4.0 technologies such as IoT, AI, Big data and Blockchain.

### Industrial Revolution Development Stages

<table>
<thead>
<tr>
<th>Industry 1.0</th>
<th>Industry 2.0</th>
<th>Industry 3.0</th>
<th>Industry 4.0</th>
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<tr>
<td>The First Industrial Revolution began in 1784 by introducing mechanical production facilities running on water and steam power. It gave considerable advantage for logistics.</td>
<td>The Second Industrial Revolution began in the beginning of 20th century with mass production powered by electrical energy.</td>
<td>The Third Industrial Revolution began after the ’80s by implementing electronic and IT systems in production. It was the beginning of automation.</td>
<td>The Fourth Industrial Revolution showed a massive degree of complexity in automation after 2000 using cyber-physical systems such as IoT, AI, Big Data, and Robots.</td>
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Figure 2. Industrial revolution development stages, adopted from multiple sources.

The Industry 4.0 initiative has attracted stakeholder’s attention due to its ability to apply a bundle of technologies to execute more efficient production systems. This initiative has been accepted as the Fourth Industrial Revolution by many due to its high potential. Connecting physical items such as sensors, devices, and enterprise resources to the internet are major attributes for industrial manufacturing in Industry 4.0. (Alexopoulos, 2016)

1.2 **Technological pillars of Industry 4.0**

Today, the world is connected more than ever, and the growth of data generation has been exponential with intelligent devices and process automation. Data-driven insights help freight operators move forward and gain a competitive advantage over their peers by being **productive, connected, safe, efficient and flexible**.

Industry 4.0 comprises multiple digital technologies that are reshaping production and facilitating the digitalization of core processes. (Brunelli et al., 2017)

Those are **9 Technological pillars of Industry 4.0**:
Figure 3. Technological pillars of Industry 4.0 (Rüßmann et al., 2015)

- **Augmented Reality or AR**
  It is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory.³

- **Internet of Things IoT**
  It describes the network of physical objects—a.k.a. "things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.⁴

- **Multi-Agent Systems: Autonomous robots and Artificial Intelligence**
  It is a computerized system composed of multiple interacting intelligent agents. AI- is a branch of computer science dealing with the simulation of intelligent behaviour in computers.⁵

  An autonomous robot, also known as simply an **Auto robot** or Autobot, is a robot that performs behaviour or tasks with a high degree of autonomy (without external influence). Autonomous robotics is usually considered to be a subfield of AI, robotics and Information engineering.⁶

- **Big Data Analytics**
  Big data is a field that treats ways to analyze, systematically extract information from, or otherwise, deal with data sets that are too large or complex to be dealt with by traditional data-processing application software.⁷

- **Simulation software**
  It is based on the process of **modelling** a real phenomenon with a set of mathematical formulas. It is, essentially, a program that allows the user to observe an operation through simulation without actually performing that operation.⁸

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⁵ [https://en.wikipedia.org/wiki/Artificial_intelligence](https://en.wikipedia.org/wiki/Artificial_intelligence)
⁷ [https://en.wikipedia.org/wiki/Big_data](https://en.wikipedia.org/wiki/Big_data)
Measures are taken to protect a computer or computer system (as on the Internet) against unauthorized access or attack.  

- **Cloud Computing**  
It is the practice of storing regularly used computer data on multiple servers that can be accessed through the Internet.  
Cloud computing delivers computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet (“the cloud”) to offer faster innovation, flexible resources, and economies of scale.  

- **Additive Manufacturing or 3D printing**  
Instead of the old approach of carving a usable part out of a large block of material, additive manufacturing builds an object up layer by layer.  
Leading companies are implementing these technologies to accelerate the business impact of operational improvement programs, such as lean management. Frontrunners do not typically regard Industry 4.0 as a new production paradigm but rather as a lever to maximize and accelerate the benefits of other programs. Implementers most commonly make processes more efficient (remove “waste” in lean terminology) and then deploy Industry 4.0 technologies within these processes to maximize performance and sustain it at a high level. (Brunelli et al., 2017)  

2. **Definition and concept of Logistics**  
**Logistics** is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through cost-effective fulfilment of orders. (Christopher, 2005)  
**Logistics** is a **science** dealing with the integrated management of all material flow from the supplier to the end consumer. Transformation of inputs to the outputs where value for a customer is created.  
**The 7R’s of Logistics**  
The definition that reflects the 7 R’s of Logistics is: Getting the **Right** product, in the **Right** quantity, in the **Right** condition, at the **Right** place, at the **Right** time, to the **Right** customer, at the **Right** price. (The Chartered Institute of Logistics & Transport UK 2019) *(The 7 Rs of Logistics*, n.d.)  
The process of planning, implementing, and controlling the efficient and effective forward and reverse flow and storage of goods, services, and related information from the point of origin to the point of consumption to meet customer requirements. (Council of Logistics Management 1991)* *(The 7 Rs of Logistics*, n.d.)

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10 [https://www.merriam-webster.com/dictionary/cloud%20computing](https://www.merriam-webster.com/dictionary/cloud%20computing)  
The essential way to ensure that a company’s supply chain work processes are operating at the highest possible level is with a well-oiled logistics team. With the growing digitization of the professional world, more and more companies are adding the newest technologies to their operations to maximize their resources by reducing the time and money spent on figuring out how, where, when, and how to send a package. (Utermohlen, 2018)

3. The Framework of Logistics 4.0

Logistics 4.0 is an element of Industry 4.0, and these two cannot be thought of as independent from each other. (Wang, 2016)

As an element of Industry 4.0, Logistics 4.0 creates possibilities for new business models. Instantaneous information exchange, computerized business solutions, and real-time big data analysis capability are some of the features that companies enjoy adopting Logistics 4.0. The combined use of all these features of Logistics 4.0 is changing the way companies do their business. This transformation is expedited by the Industry 4.0 technologies such as CPS (physical systems), IoT, IoS, smart products and smart processes. (Strandhagen, 2017)

Logistics 4.0 development stages
Vital elements of Logistics 4.0 are:

**Visibility**- logistics companies can achieve this by digitizing and transforming logistics processes.

**Smart Utilities**- meaning, adoption of smart technologies, such as a smart container.

**Data analytics**- data collection and analysis. It also real-time data collection.

Figure 6 represents the Interconnection between Industry 4.0 and Logistics 4.0. For example, Visibility for upstream and downstream processes can be achieved by using IoT, AI and Big Data and Analytics. Smart Offices are equipped with Artificial Intelligence AI and Robotic Process Automation RPA to achieve quality, safety, and less error. Data analytics provide real-time data to increase delivery speed, service quality and cost-saving.
### Analysis of the Interconnection

#### Industry 4.0

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<td><strong>Advanced robots - Autonomous, cooperating industrial robots, with integrated sensor and standardized interfaces</strong></td>
<td>The use of automated vehicles in the logistics industry promises to save time and money, and could reduce accident rates.</td>
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</tbody>
</table>
| **Additive Manufacturing**                                  | - 3D printers, used predominantly to make spare parts and prototypes  
- Decentralized 3D printing facilities, which reduce transport distances and inventory |
| **Augmented Reality**                                       | - Digital enhancement, which facilities maintenance, logistics, and SOPs Display devices, such as glasses |
| **Simulation**                                              | - Network simulation and optimization, which use real-time data from intelligent systems |
| **Horizontal and vertical system integration**              | - Data integration within and across companies using a standard data transfer protocol  
- A fully integrated value chain (from supplier to customer) and organization structure (from management to shop floor) |
| **Internet of Things (IoT)**                               | - A network of machines and products  
- Multidirectional communications among networked objects |
| **Cloud Computing**                                         | - The management of huge volumes of data in open systems - Real-time communication for production systems |
| **Cyber Security**                                          | - The management of heightened security risks due to a high level of networking among intelligent machines, products, and systems |
| **Big data and analytics**                                 | - The comprehensive evaluation of available data (from CRM, ERP, and SCM systems, for example, as well as from an MES and machines  
- Support for optimized real-time decision making |

#### Logistics 4.0

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<td><strong>Artificial Intelligence in combination with Robotic Process Automation (RPA)</strong></td>
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| **Intelligent and Automated Warehousing**                   | Data collection inventory processes, demand prediction, planning of logistics well in advance.  
Lower transportation costs.  
- Warehouse automation systems  
- The leading technology used in these systems is computer vision that can identify and help organize the inventory.  
- Autonomous quality control.  
These systems can also optimize inventory and transportation between warehouses. |
| **Data-driven insights**                                    | Help freight operators move forward and gain a competitive advantage over their peers. |
| **AI powered systems in conjunction with other digital technologies such as internet of things and big data analytics utilize data to its full potential to anticipate events for freight operators, aiding them to avoid risks and create innovative solutions.** | |
| **Smart Roads**                                             | Examples of this technology include highways with solar panels powered LED lights. Solar panels assist in producing the electricity while LED lights are used to alert drivers about the road conditions. Faster deliveries and safer road conditions. |
| **Computing Power and Speed**                               | Development of the GPU (Graphical Processing Units) to expand the CPU (customer pick-up) functionalities to a great extent. |
| **Demand Prediction**                                       | AI provides various algorithms that can predict trends. This means lower inventory and simpler warehouse management. |
| **Back Office**                                             | Artificial Intelligence in combination with Robotic Process Automation (RPA) provides the workers with an opportunity to increase their quality of work. |
Conclusions

Technological ability is the most critical factor for companies, and Digitization brings benefits such as agility, velocity, and transparency to the business operations. And traditional business models or non-digitized businesses struggling with frictions, delays, inefficiencies, lack of transparency, and agility.

The world of logistics and the supply chain is a complicated one that requires a lot of planning, resilience and the ability to adjust when unforeseen circumstances happen. (Utermohlen, 2018)

The Industry 4.0 technologies offer logistics companies a wide range of capabilities, from autonomous machines to predictive analytics.

Companies, big and small that embrace Logistics 4.0 will gain a competitive advantage since it will provide AI, Internet of Things (IoT) and Big Data analytics to improve processes successfully, analyse big data faster, and reduce human errors and labour. The results include a comparative advantage and tangible benefits for their customers, improved cost-saving, agile supply chain, and optimization of logistics processes.

The complete transformation of the logistics industry due to Industry 4.0 innovative technologies is imperative in the near future. Because the goal is to achieve competitive advantage through both cost reduction and service enhancement. (Christopher, 2005)

Research Limitations
- The analysis is based on a literature review, and the results might be biased. A specific methodological research method/method has to be selected to support the results of the analysis.
- The sample size is not present.
- Numerical and descriptive data is not present.
- The scope of the paper.

Practical implications
Based on the performed analysis, it is on the record that technology gives companies the ability to compete. For business strategy, it is a must to go along with the technological strategy to succeed and gain a competitive advantage. Industry 4.0 and Logistics 4.0 make one’s way and interconnect in multiple ways. Integration of Industry 4.0 into logistics has an enormous impact on business processes. But with all the benefits, there are specific negative impacts companies should be aware of, such as accountability, liability, job losses, processes elimination, network structure change, cybercrimes and many more.
References:


