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Technology Mapping of Industry 4.0 to Logistics

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May 2022

Abstract

There is no doubt that the world as it is today is heavily industrialised and advancements in technology remains an important factor in this phenomenon. Most companies in a bid to stay relevant and competitive have had to adopt current technology in order to improve processes. Therefore this study assesses how the use of technology in the current fourth industrial revolution (industry 4.0) affect the logistics performance of companies. This was carried out by analysing the influence of some nine pillars of Industry 4.0 on selected Key Performance Indicators (KPIs) of logistics using expanded DEMATEL to examine the bidirectional cause and effect relationship. The researchers found the pillars of industry 4.0 as the cause factors and the KPIs of logistics as the effect factors with warehouse cost coming up as the most important factor to consider in logistics management. The result thus implies that using current technology in industry 4.0 essentially improves logistics performance.

Keywords: Industry 4.0, Logistics, Technology, Key Performance Indicators, Warehouse, Transportation, Digitalisation, Automation, Multi Criteria Decision Making, DEMATEL.

Acknowledgment

We are grateful to the Almighty God for a successful completion of our studies. We also thank our supervisor, Professor Sorooshian for his time, inputs and encouragement throughout this study. We would further like to thank our respondents Ole, Wolfgang, Emmanuel and Bilal for their wonderful insights and making this study possible. Finally, we want to appreciate our spouses, children, family and friends for being there for us every step of the way.

Contents

1 Introduction

In this first chapter, a background to the problem under investigation and it's relevance in the current state of affairs is provided. The research problem statement which explains the necessity of such a research is also given. Next is the purpose of research in which the problem is narrowed down to a research question. Here the nature of organisations to be used for the study are described. Further, the scope and delimitation are stated with the final section being about the disposition of the thesis.

1.1 Background

The world through the ages has evolved especially with respect to the mode of creating and manufacturing products. By the end of the 18th century, the onset of technology redefined in a major way the process of production brought about by so-called industrial revolutions. Every single one of these industrial revolutions (to be briefly discussed in-depth later) made a huge impact in the past as they marked critical periods for which all aspects of everyday life were affected. The invention of the steam engine, discovery of electricity and the computer age gave rise to the first, second and third industrial revolutions respectively. In recent times, fierce global competition coupled with constantly changing market requirements are demanding that industrial production be modified to quickly adapt to suit evolving trends. The answer to this phenomenon was advanced technology which has propelled the globe into the current fourth industrial revolution also known as industry 4.0.

The term, industry 4.0 was first introduced by Professor Wolfgang Wahlster, Director and CEO of the German Research Centre for Artificial Intelligence (AI), during his opening speech at Hannover Fair in 2011 (Efthymiou & Ponis, 2021). Since its launch in Germany, the concept has spread worldwide with various countries adopting their own names for this advanced technological development. For instance, in France, it is called “La nouvelle France industrielle (The new industrial France)”, in Singapore, “Research, innovation and enterprise”, in the United Kingdom, “Future of Manufacturing”, in the United States, “Advanced Manufacturing Partnership”, in China “Made in China 2025”, in South Korea, “Innovation in manufacturing 3.0”, in Italy, “Impresa 4.0”, in Brazil, “Rumo à Industia (Towards Industry 4.0)”, and in Morocco, “l’industrie, locomotive de la croissance et de l’emploi (industry, engine of growth and employment)”, (Gallab *et al.*. 2021). The literature on industry 4.0 lists nine pillars that are pivotal in its adoption and these include; Autonomous robots, Big Data Analytics, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things (IoT), The Cloud, Additive Manufacturing, Augmented Reality (AR), and Cyber Security.

Logistics, which is obviously an essential part of every organisation, is one of the industries that has been greatly affected by industry 4.0 as it serves as a ‘backbone’ of all functioning of the supply chain. The question this creates will be how organisations will have the smooth change to digitization and automation of their ‘logistics processes’ (Efthymiou & Ponis, 2021). According to Holubčík, Koman & Soviar (2021), employing industry 4.0 technologies in logistics will help in the ‘optimization of transport routes’, as well as making an efficient use of storage capacity and planning. This is evidenced in the fact that with the development of industry 4.0 in logistics, all the various phases in the logistics processes will be connected and the entire supply chain being automated. The endless activities right from manufacturing to consumption will be greatly affected.

Thus, there are several impacts industry 4.0 will have on the logistics industry, this includes smart logistics, where the entire work processes will be automated through a computer system. All the processes handled by the computer system will be done independently. With the twenty-first-century network of technology, which helps different people interact, 'cargo, storage, distribution and transport' will change as compared to how they are currently being managed and handled (Khiem, 2018). The second impact will be the creation of smart factories with the help of this new technology, with some characteristics like 'independent module's components and their inter-communication ability under the support of information systems. Here, humans will assist with carrying-out the production procedure. There are basically three (3) phases of 'operating the smart factory', these are suppliers, manufacturing process and customers, and all these require certain factors to function effectively (Khiem, 2018).

Radziwon *et al.* (2014), defines smart factory in a comprehensive way, saying: "A smart factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity." The solution referred above can be automation which can either be hardware and/or mechanics, software or combination of both, which will help in optimising processes that will lead to a decrease in misuse of resources and labour (Radziwon *et al.* 2014). Another impact worth mentioning is the high quality of human resources needed, with the development and growth in smart factories due to industry 4.0. There will be the need for competence in this area, since high quality labour with adequate knowledge and skills will be needed to manage and run the supply chain effectively and efficiently (Khiem, 2018).

1.2 Research Problem Statement

It is clearly evident that the ability to make correct forecasts with regards to demand versus supply and cutting down manufacturing lead-time is now a universal task faced by manufacturers and thus, being furnished with suitable amenities and techniques alongside the technologies in industry 4.0 is necessary to revolutionise products and offer superior services. The world we currently live in is hugely defined by competition in business and as such, for organisations, trade-offs for cost, quality, efficiency and customer service level no longer exist. All these dimensions require simultaneous considerations. Achieving such a feet is no mean task and demands that parts of or the entire supply chain and logistics distribution network be redesigned to be fully optimised.

1.3 Research Purpose

One way to reach this optimisation discussed in the previous section is the advanced use of technology. Therefore, in this study, the purpose is to examine the following research question (RQ);

- **RQ:** How does the adoption of the technology in industry 4.0 in logistics management (transportation and warehousing included) improve the performance of companies.

In order to fully examine and answer the above research question, the study will focus on manufacturing companies, transportation industry, shipping industry, third party logistics companies (3PLs), last mile delivery partners and any other company whose activities are defined by providing logistics services of any form. The aim is to possibly interview at least two experts who are well acquainted with the day-to-day activities within the organisation. This investigation will be conducted using the multi-criteria-decision-making (MCDM) approach and specifically, the method of decision making trial and evaluation laboratory (DEMATEL) where the nine pillars of industry 4.0 are the criteria and the KPIs of logistics are the factors. The intention is to analyse the relationship between the nine pillars and the KPI's in order to make informed decisions as to which respective technology to employ for a specific task to obtain efficiency in operations.

1.4 Scope and Delimitation

The current fourth industrial revolution coupled with globalisation has necessitated a high drive in technology to achieve efficiency in systems and therefore, exploring how the performance of logistics processes can be improved through technology is a step in the right direction. In such a study, time is of the essence as a considerable amount of it is required to effectively examine the relationship between technology and performance. The researchers only had barely 4 months to carry out this project. Also, due to the time constraint, the geographic location of companies selected for the study is Europe and specifically in the country, Sweden. Due to the nature of the research, contact persons with some level of knowledge regarding the technology involved are used. Further, the researchers are based in cities different from the location of contact persons with no access to funding so interviews were restricted to Zoom and Microsoft Teams. There was also no on-site experience to observe first-hand the functioning of the technologies under discussion. Last but not least, the mathematical method of DEMATEL is analysed through the conventional group decision making method since fewer than ten respondents agreed to take part in the study.

1.5 Disposition of Thesis

This report is partitioned into five chapters and begins with the introduction in chapter one. The theoretical background follows in chapter two where we provide an overview of both industry 4.0 and logistics as well as results of literature review on the subject by various authors. The methodology used for the study is presented in the third chapter followed by the results and analysis of the work in chapter four. The final chapter comprises of the discussion, conclusions drawn from the study and recommendations for further research.

2 Theoretical Background

This chapter consists of descriptions of industry 4.0 and logistics processes. In the former, the researchers write on its origin, concept, production system, challenges, and pillars. The latter discusses manufacturing, distribution along the SC, warehousing and transportation. The researchers further outline empirical evidence from literature on the impact of industry 4.0 on logistics and also write on some KPIs that measure the strength of the impact. Materials used for this chapter include academic literature, scientific journals and articles mostly sourced from the University's Library database and online.

2.1 Industry 4.0: A Brief Overview

2.1.1 Origin

The fourth industrial revolution also known as industry 4.0 has its origins from Germany and shot to prominence after three industrial transformations which began in the latter parts of the eighteenth century. The mechanisation of manufacturing/production processes coupled with an enhanced economic system pioneered by Adam Smith characterised the first revolution. The former, which was as result of the invention of steam engines by James Watt, meant substitution of human work by machines and the positive consequence was gains in productivity and reduced travel times for both humans and produced goods (Gallab *et al.* 2021).

The start of the nineteenth century saw the unearthing of electricity by Alessandro Volta which resulted in a switch from water and steam power to electrical power. This superior alternative led to more operational efficiency with the added opportunity to venture into the mass production of goods as assembly lines were built around this period. This era defined the second industrial revolution and lasted through to the latter parts of the 1960's when the start of the computer epoch was launched. The computer age ensured digitalization with the introduction of microelectronics and a feature of automation into production lines through the adoption of Programmable Logic Controller (PLC) and software and thus, there was flexibility in production lines. This state of affairs was termed the third industrial revolution but the deficiency here was the lack of flexibility in production quantities (Gallab *et al.* 2021, Rojko, 2017).

From 1988 to present, computers have dominated technologies employed in production/manufacturing in industry especially in the area of drawing, programming of machines and robots and improvement in automation. This extensive development of Information and Communication Technology (ICT) has permitted a change in manufacturing strategies to Lean, Agile and Just in Time (JIT) manufacturing from the previously used mass production. Thus, we are currently in the fourth industrial revolution whose technological foundation is rooted in smart automation of cyber-physical systems (Gallab *et al.* 2021, Rojko, 2017). A diagrammatic representation of the industrial revolutions is given by figure 1.

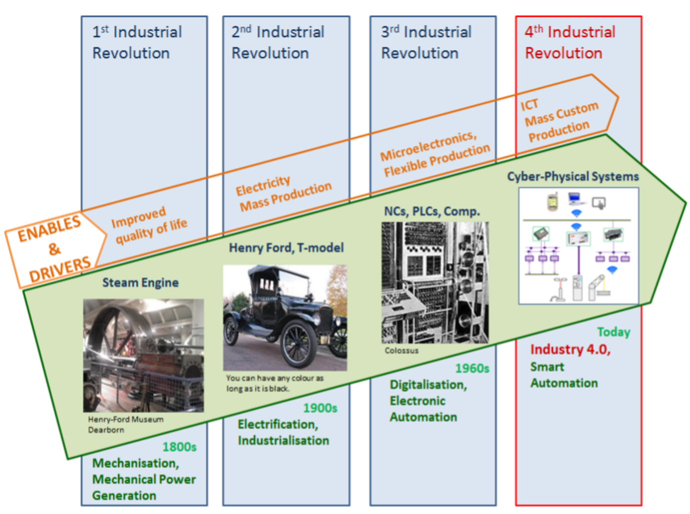

Figure 1: Industrial Revolutions (Rojko, 2017)

2.1.2 Concept

Industry 4.0, also referred to as future intelligent factory/smart or advanced manufacturing, is heavily defined by automation and the interchange of data in technologies for manufacturing to increase operational efficiencies (Gallab *et al.* 2021). According to Lasi et al. 2014, the concept is pivoted on two dispositions for development of which the first is an enormous application-pull that arouses important demand for adjustment warranted by changing operative framework conditions. Some Socio-economic and political factors driving this demand are flexibility, decentralisation, resource efficiency, individualization on demand, and short development periods. The second is an outstanding technology-push and some identified approaches for this instance are further increasing mechanisation and automation, digitalization and networking, and miniaturisation (Lasi *et al.* 2014).

Conceptually, Rojko, 2017 posits that the principal idea of industry 4.0 is to utilise the possibilities of modern technologies and notions such as "

- availability and use of the internet and IoT,
- integration of technical processes and business processes in the companies,
- digital mapping and virtualization of the real world,
- 'Smart' factory including 'smart' means of industrial production and 'smart' products.".

She (Rojko, 2017) further states that it is a means through which profit can be increased in industrial manufacturing as the following decreases can occur as a result of its (industry 4.0) introduction:

- "production costs by 10-30%,
- logistic costs by 10-30%,

- quality management costs by 10-20%."

Other benefits also listed by Rojko, 2017 include: (1) a shorter time-to-market for the new products, (2) an improved customer responsiveness, (3) enabling a custom mass production without significantly increasing overall production costs, (4) more flexible and friendlier working environment, and (5) more efficient use of natural resources and energy.

2.1.3 Production System

In the industry 4.0 smart factory, the basic principle is to convert from digital to physical in a reconfigurable system of manufacturing as depicted in Figure 2. Here, the use of manufacturing systems which are reconfigurable enables adaptation of both hardware and software components to conform to the constantly evolving market demand of brand and the required number of products. Machines in this factory consist of Cyber-Physical Systems (CPS) and physical systems merged with ICT components that are autonomous in making decisions through the use of machine learning algorithms and real-time data capture, analytics results, and recorded successful past behaviours (Rojko, 2017). Products here are also smart, having embedded sensors for measuring their state and conditions in the environment. Equipped with control and processing capabilities, they are able to monitor their logistical path through production. Aside from their physical depiction, production elements have a virtual identification which is a data object stored in the data cloud.

Additional elements in industry 4.0 are those of interoperability and connectivity where there is exchange of information between devices and components as well collaboration between machines and humans (Rojko, 2017).

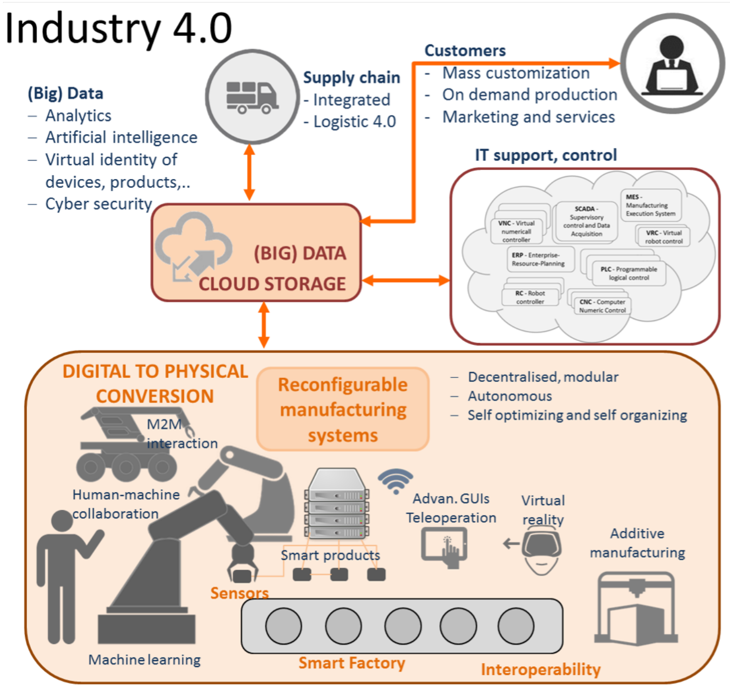

Figure 2: Industry 4.0 smart factory (Rojko, 2017)

2.1.4 Challenges

Notwithstanding the benefits of industry 4.0, it is not devoid of deficiencies and prime amongst them is cybersecurity. The rise in connectivity of components and rapid sharing of information has ensured the importance of security. It is therefore necessary that when employing smart factories, a good know-how protection exists. Another challenge is the changing of the status quo to reorient towards digitisation and accepting the technology. As it is with human nature, changing to new systems is no mean task and sometimes met with fierce resistance by employees. It is therefore important that consultations be made with all employees concerned and they be adequately prepared for any new systems introduced by the organisation. Last but not least is the scarcity of skilled workforce and employee training which poses a major challenge in the adoption of new functions. This calls for investment in training employees to manage the new systems (Gallab *et al.* 2021).

2.1.5 Pillars of Industry 4.0

The vast literature available on the subject of industry 4.0 configures its vision on the definition of nine pillars that remain critical to new business models and dimensions induced by the concept for the creation of new strategies. These the researchers believe are capable of improving performance at all levels of application of which the logistics industry is no exception (Erboz, 2017). As mentioned earlier, the latter parts of this study will examine how these pillars affect all aspects of logistics processes by examining performance through the measurement of some key performance indicators (KPIs). The write-up that follows describes into detail the nine pillars. The main sources used for the text are Erboz, 2017; Vaidya *et al.*, 2018; and Roche, 2019.

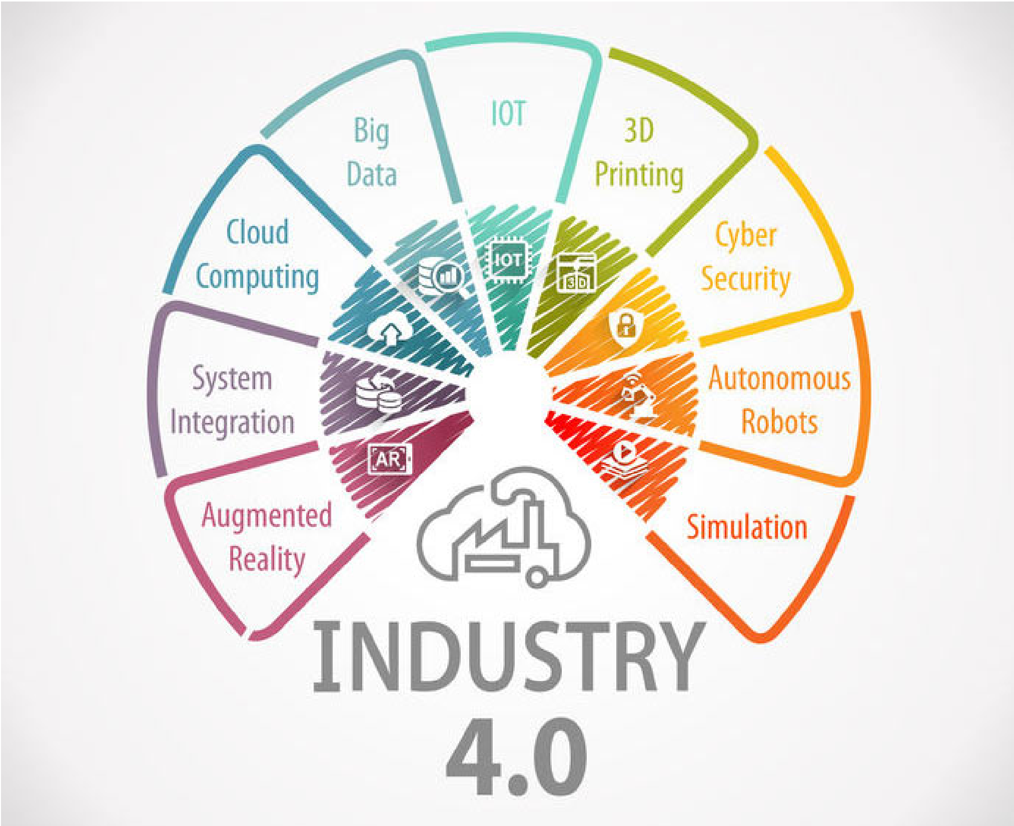

Figure 3: Pillars of Industry 4.0 (Roche, 2019)

Big Data and Analytics (BDA): Big data is a notion that refers to the collection of enormous, varying and complex datasets from sources such as production and equipment systems in addition to enterprise and customer management systems. The data is further evaluated and standardised to assist real-time decision making regarding the strategy of a company. Erboz 2017 categorises the framework of big data as "data as a tool (solve traditional value chain problems by existing capabilities), data as an industry (new ventures and develop software systems for handling big data) and data as a strategy (building data resources by developing new innovative business models)". When managed effectively, big data creates a competitive advantage that is good for operations, marketing, customer experience and many more (Erboz, 2017; Vaidya *et al.*, 2018).

Autonomous Robots (ABT): There exist complex duties in manufacturing industries which are not easily executed by humans and in such cases, robots have proven to be helpful. The use of autonomous robots has allowed for full execution of JIT strategies which previously was not possible through traditional manufacturing. Robot technology has been developed to be flexible and cooperative with both humans and other machines. Industry 4.0 has contributed to the rise of the use of industrial robots and fields such as production, logistics and distribution activities heavily engage them since control is enabled by their human interactive features. New robotic technology being advanced by companies such as Kuka has the capacity to learn from humans as well as monitor, optimise and record tasks by the aid of cloud systems (Erboz, 2017; Vaidya *et al.*, 2018).

Simulation (S): Simulation tools help in production related functions by advancing sustainable forms of manufacturing well suited for the environment. Due to the increasing nature of competition in business, simulation provides modifications into complex systems by designing the operations since knowledge and information and correct estimates regarding the system are known (Erboz, 2017). Additional benefits include decreasing downtimes and cutting down production failures at the point of start-up (Vaidya *et al.*, 2018).

Horizontal and Vertical System Integration (HVSI): The level of connectivity between flexible and reconfigurable systems within a factory to attain agility is what is referred to as vertical integration. The case of horizontal integration deals with the connectivity between partners within the supply chain (SC). Big data is collected by the industrial network for optimization of the system's network which is further transported into the cloud. Thus, manufacturing systems are configured to be self-organised structures that connect all physical objects by means of smart networks. The advantage of cloud based systems is that vertical partners are able to connect with each other through a common platform. At the same time, SC partners can also observe the product and procedural flows (Erboz, 2017).

The Industrial Internet of Things (IoT): Vaidya *et al.*, 2018 defines IoT as "a worldwide network of interconnected and uniformly addressed objects that communicate via standard protocols". IoT depends on cloud based systems to provide solutions for computations and analytics and it is currently seen as the next technological revolution according to Erboz, 2017. The work of IoT is to connect the internet by gathering information from physical objects. Using IoT provides agility in business and also creates competitive advantage on the basis of SC. Thus, companies seeking agility in operations and efficient systems would have to strengthen their potential in IoT (Erboz, 2017).

The Cloud (C): Cloud computing (CC) is advantageous to the ICT model as it aids SCs to automate and merge as well as expedite management and administration. In industry 4.0, there is the need for increased data sharing across the sites and firms to achieve faster reaction times. Erboz, 2017 describes three models of cloud computing namely; Software as a Service (SaaS) where the access depends on the customer purchase such as Enterprise Resource Planning (ERP); Platform as a Service (PaaS) where customers are allowed to access their applications on the cloud such as software developers; and Infrastructure as a Service (IaaS) which offers the basic activities such as storing capabilities (Erboz, 2017; Vaidya *et al.*, 2018).

Additive Manufacturing (AM): Additive manufacturing involves techniques through which customer specifications are incorporated to manufacture customised goods to suit their preferences and this possibility is as a result of the flexibility gained from industry 4.0. Commonly used methods by firms are the prototype and 3D printing methods which are employed to manufacture minimum quantities in batches to avoid overproduction. Unlike conventional manufacturing methods which are subtractive and end in the wasting of raw materials, additive manufacturing does the opposite of eliminating or reducing the waste. To expedite continuous smartphone pursuits, companies such as Apple and Motorola heavily utilise 3D printing to reduce lead times and production quantities while at the same time increasing mass customisation and staying agile (Erboz, 2017; Roche, 2019).

Augmented Reality (AR): Erboz, 2017 defines AR as "the interactive technology that enables harmony between the virtual world and its users while the virtual world is being used as the part of the real surroundings". AR based systems support diverse services including, equipping workers with real-time guidance to enhance decision making and work routines, and choosing parts in a warehouse and conveying repair guidance over mobile devices. AR technology improves human-machine collaboration, remote control on maintenance tasks which involves a virtual provision of the human's visual inspection (Erboz, 2017; Vaidya *et al.*, 2018).

Cyber Security (CS): Cyber Security is another crucial subject that has the tendency to negatively impact the business environment considering the damaging aim of terror attacks. Solutions to avert these adverse situations and defence systems have therefore become important to fight off terror events. Considering the connectivity of systems and the advance use of communication tools associated with Industry 4.0, the issue of protecting essential industrial systems and manufacturing lines from cyber security threats has increased considerably. One way through which these cyber terror attacks are countered is through examining prior attacks via radiation control before later attacks happen. Employee training to guard against cyber attacks as well as national defence systems are all important in the tackling of cyber war. The solutions come at a cost to companies but this is nothing compared to the total costs to be incurred should an attack actually occur (Erboz, 2017; Vaidya *et* *al.*, 2018).

2.2 Logistics Processes

In the competitive business world in which we find ourselves today, businesses need to come up with innovative and efficient ways of meeting the needs of their customers by delivering the value needed by their customers. Since the business world is dynamic, companies compete in various ways with their competitors in terms of cost, quality, products, and services. This has led to the development of logistics systems that are more advanced instead of the traditional method, to meet the growing and changing needs of customers. Over the years the focus of logistics has moved towards a corporate level as compared to its previous focus on operational level, since there is the need to have an effective and efficient logistics system that aids in cost reduction and improving service delivery (IIMM, 2020).

According to Sun *et al.*, (2021) logistics as a word came about over a century ago and was more linked to the movement of supplies needed by the military and troops. With time, logistics has been generally used to 'describe the movement of physical goods among different locations. Logistics is a cycle which includes pre-production, in-production, and post-production activities. Logistics involves some activities, and these include purchasing of raw materials, parts and components, handling and storage of inventories and the transportation of goods to and from different locations, this is all to meet the needs of the customers in a satisfactory way.

Efthymiou *et al.* (2021) also stipulates that logistics is made up of all various lifecycle and stages that a product or service goes through, from the initial stage of acquiring the raw materials, which goes through the various stages of production, transportation, storage, delivery to the consumer and the reversal of these products for recycling or disposal, that is to say logistics basically has the sole responsibility of ensuring that all the activities within the supply chain functions effectively.

Rushton *et al.* (2017) are also of the opinion that, there is no pragmatic way or 'true definition' for the concept of logistics as the principles covered can vary. They further mentioned that each industry or sector is made of different characteristics and within these sectors are major differences in terms of strategy, size, their market coverage etc. Logistics is 'therefore a diverse and dynamic function that has to be flexible and has to change according to the various constraints and demands imposed upon it and with respect to the environment in which it works', thus 'Logistics = Materials Management + Distribution' (Rushton *et al.*, 2017). It was emphasised that supply chain and logistics are not just about the flow of physical materials to the final stage of distribution of the finished products, but it also includes the flow of information and storage. An important element worth mentioning is that of reverse logistics this refers to the 'the flow of used products and returnable packaging back through the system' (Rushton *et al.*, 2017).

Definition: The issue of what the right definition of logistics is one that is interesting, as there are a lot of definitions in various textbooks, on the internet etc. Below are some definitions:

"Logistics is the management of the flow of things between the point of origin and the point of consumption to meet the requirements of customers or corporations" (Wikipedia, 2022).

"Logistics is defined as the time-related positioning of resources. It is also described as the 'five rights.' Essentially, it is the process of ensuring that goods or services are: in the right place, at the right time, in the right quantity, at the right quality, at the right price" (Chartered Institute of Logistics and Transport (UK), 2016).

"Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customers requirements" (Council of Supply Chain Management Professionals, 2016).

From the various definitions above, we can say logistics is all about movement of goods from source through production to its destination and back in a cost-effective way. Some key components of logistics will be discussed below.

2.2.1 Warehousing

A warehouse is an essential part of the current supply chain. They are part of the different stages of the 'sourcing, production and distribution of goods, from the handling of raw materials, work in progress through to the finished products' (Rushton *et al.*, 2017 & Accorsi et al., 2014). Accorsi et al., 2014 posits that, the purpose of a warehouse includes 'receiving inbound products (from inbound or manufacturing lines), to store materials until they are requested, and then to extract products from inventory and ship them in response to the customers' orders"Warehouse play a crucial role in the supply chain and with the recent trends, these include increase in market volatility, product range proliferation and reducing lead times of customers. The design and operations of a warehouse must be in line with a specific requirement within the supply chain. In view of the nature of the warehouse, the equipment and staff needed, it makes them one of the most expensive parts of the supply chain and in terms of both service and cost, it is very essential to successfully manage and plan effectively (Rushton *et al.*, 2017).

According to Rushton *et al.*, (2017), & Accorsi et al., (2014) there are different classifications of the nature of a warehouse that can be adopted. These include:

- By the stage in the supply chain: materials, work in progress, finished goods or returned goods

- By geographic area: A global warehouse may serve the whole world, a regional warehouse may serve several countries, a national warehouse may serve just one country and a local warehouse may serve a specific region of a country.
- By product type: for example, small parts, large assemblies (e.g., car bodies), frozen food, perishables, security items and hazardous goods.
- By function: for example, as inventory holding or sortation (e.g., as a 'hub' of a parcel carrier)
- By ownership: owned by the user (e.g., the manufacturer or retailer) or by a third-party logistics company.
- By company usage: for example, a dedicated warehouse for one company, or a shared-user warehouse handling the supply chains for several companies.
- By area: This ranges from 100 square metres or less to over 100,000 square metres.
- By height: ranging from warehouses about 3 metres high through to 'high-bay' warehouses that may be over 45 metres in height.
- By equipment: from a largely manual operation to a highly automated warehouse.

The primary purpose of a warehouse is to help move goods through the supply chain to the final user. There are lots of supply chain initiatives that help to reduce the need to hold inventory, these include flexible manufacturing systems, express delivery, and supply chain visibility. A typical example is the just-in-time (JIT) operation, irrespective of all these, if the demand for a particular product is continual and the 'supply lead time is greater than the demand lead time' then there is the need to hold some inventory (Rushton *et al.*, 2017 & Accorsi et al., 2014).

According to Tompkins & Smith (1998), in the last decade (20th century) there has been a reduction in traditional warehousing due to the emergence of Just in time (JIT) manufacturing. This JIT technique is to help improve the return on investment (ROI) ‘of a business by mitigating in-process inventory’. The idea of the JIT is to basically move finished goods directly to the stores or retail outlets without necessarily going through a warehouse. But this is not so in instances of offshoring and outsourcing where there is a distance between manufacturer and the retailer, which increases with this, there is the need to have at least one warehouse in a region or country for the product within the supply chain (Tompkins & Smith, 1998).

There are other purposes or role of the warehouse apart from holding inventory, a warehouse also serves as;

Consolidated centre, where different product lines ordered by customers are put together before sending them through to the customer. These different products could come from the inventory of the warehouse or from another place within the supply chain (Van Den Berg, 2007 & Rushton *et al.*, 2017)

Cross-dock centre, with this, goods received from the manufacturer directly or from another warehouse that will be used to fulfil the needs of a customer are sent here to be cross-docked. ‘This implies that the goods are transferred directly from the incoming vehicle to the outgoing vehicle through the goods-in and -out bays without being placed into storage’(Van Den Berg, 2007 & Rushton *et al.*, 2017).

Sortation centre, this is like a cross-dock centre ‘but this term is used for parcel carrier depots’, goods brought to the warehouse are solely to be sorted and sent to a specified customer or region. In the fashion industry where goods are ‘pushed’ out to stores, goods brought to the warehouse are sorted and sent out in vehicle loads (Van Den Berg, 2007 & Rushton *et al.*, 2017).

Assembly facility, here when production must be postponed to a further date and time, down in the supply chain to reduce inventories, this is used. Here the warehouse serves as 'a final assembly point for the product, which includes activities such as knitting, testing, cutting and labelling' (Van Den Berg, 2007 & Rushton *et al.*, 2017).

Trans-shipment point, they basically serve 'outlying regions of a country'. With this, orders are moved from a national distribution centre and sent to a 'stockless' trans-shipment centre, here all the goods are sorted and sent out with smaller vehicles for delivery to final customers (Van Den Berg, 2007 & Rushton *et al.*, 2017).

Returned goods centre, here, goods that are returned by customers are sorted here for either recycling or disposal. Due to the growth of e-commerce and online shopping, there has been an increasing rate of returns and how these returns are handled is very important. (Van Den Berg, 2007 & Rushton *et al.*, 2017).

Most often, a warehouse fulfils a mix of the various roles listed above and it is very essential to know the type of role each warehouse plays in the supply chain. Some names given to a warehouse include and these differentiate the different roles they perform; 'supplier consolidation centre, JIT sequencing centre, customer service centre, fulfilment factory, e-fulfillment centre and 'dark store' (Rushton *et al.*, 2017 and Edgar & Tanyildiz, 2009).

There is the need to differentiate between a warehouse and a distribution centre, according to Rushton *et al.*, (2017) and Edgar & Tanyildiz, (2009) the former is said to stockpile goods and the latter being said to be high-velocity flow-through operations. Although warehouses are planned to meet certain specific requirements, there are some operations that are common, whether the warehouse is a traditional one or fully automated. For a typical inventory holding warehouse, below are some functions;

- Receiving
- Put away
- Reserve storage
- Order picking and Sortation
- Collation, added value services and packaging
- Marshalling and dispatch (Rushton *et al.*, 2017 and Edgar & Tanyildiz, 2009).

According to IIMM, 2020, any company that can manage its warehouse well can use their customer service as a competitive tool, as customers will be informed about the status of their orders.

In a modern warehouse, one of the most essential concept is warehouse management system (WMS). The WMS 'interfaces with the company's main transaction system, typically an enterprise resource planning (ERP) or a legacy system to access information such as purchase orders and to download customer orders', in return, information such as goods received and sent out will be fed back into the WMS. The warehouse management system 'is used to control all the operations in the warehouse and issues instructions to subsidiary systems, for example equipment control systems, often known as warehouse control systems (WCS)' (Rushton *et al.*, 2017).

2.2.2 Transportation

Transportation is one of the key components of logistics. The movement of goods, and services as well as people from one geographical location to another is what Anderson (1999) terms as transport. He further postulates that for any given economy to achieve economic and social needs, it is through an effective transport system. The most common modes of transportation in logistics are road (trucks & vans), air (planes & aircraft), rail (train), water (sea, lakes, rivers/canals), multimodal and intermodal transport. In Chase & Jacobs's (2018) book, operations & supply chain management, they stated highway (truck), water (ship), air, rail (train), pipelines and hand delivery as the modes of transportation (Anderson 1999; Chase & Jacobs, 2018).

Road: This mode of transportation is the most dominant amongst the various modes of transportation for many countries for short and medium distances (Savy, 2009). With this mode of transportation, there is great flexibility as goods can be moved to any 'location that is not separated by water' (Chase & Jacobs, 2018). Products with different sizes, weight can be transported by road, as well as bulky and liquid products (Chase & Jacobs 2018; Savy, 2009).

Rail: One of the most eco-friendly ways of transporting goods is by rail. It is cheap as compared to the other modes of transportation, but the transit time can be lengthy, though you can transport large volumes of products making the price per load very low. Most of the rail infrastructure in the European countries are well developed making rail transportation very attractive unlike the United States and other countries, this makes using rail transport very unattractive (Savy, 2009).

Water: With this mode of transportation, bulky items can be moved, including liquids, chemical products that are harmful, coal, etc. Most parts of the world are not covered by water making such places impossible to access by this mode of transportation, transit time is also very slow (Savy, 2009).

Air: This is the fastest way to transport goods but also very expensive. In addition to that, large volumes of goods cannot be moved by air as the aircraft is not designed to move oversized freight. During the Covid-19, most of the vaccines and PPEs were transported by air (Savy, 2009).

Intermodal & ***Multimodal transport:*** This is a combination of road, rail, sea, or air using a single shipment. This mode of transportation is very efficient if the shipper has a very difficult route. Though each mode of transportation has its own pros and cons, intermodal and multimodal can benefit the shipper in terms of price and flexibility (Savy, 2009).

2.3 Key Performance Indicators - logistics

Key performance indicators (KPI) are basically 'performance measurement that is used by logistics managers to track, visualise and optimise all relevant logistics processes in an efficient and transparent way' (Raja & Pakistan, 2022). According to Trigo (2015), KPIs help companies identify activities that are not performing well, and further help them make informed decisions due to consolidated information. Below are some KPIs for the logistics sector.

Shipping Time (ST): This refers to the 'ratio of orders that have been shipped on or before the requested ship date divided by the total number of orders'(Raja & Pakistan, 2022). In order to help measure the performance of your supply chain, the first KPI to help do this is the on-time shipping performance. If the time between when a customer places an order and the time it takes the order to be shipped is too long, this will create problems in the supply chain process that needs to be fixed. According to Raja & Pakistan, (2022), once we get to know a 'benchmark of the average time needed to ship certain type of order, the company can set a target shipping time relative to each product'.

Order Accuracy (OA): This is also another important logistics metric that measures the total number of orders that are processed, shipped and sent out without any occurrences while shipment was in transit. It is always to any company's advantage once they adhere to shipping and delivery times and also get the right product ordered to the customer, this shows how efficient the company's supply chain is. This leads to customer satisfaction as the customers will be satisfied with your services, always be willing to come back and further refer your company to others. Once a business has a higher rate of accuracy, it is to their advantage of being in continuous business (Raja & Pakistan, 2022).

Delivery Time (DT): This refers to the time it takes for an order to be placed, correctly prepared and sent to the designated location. The 'average time of delivery is measured from the moment an order is placed to be shipped and the moment it is delivered to the customer or post office'. It is always ideal to decrease your average time of delivery once you know how long it takes to move from your warehouse to the final delivery location. It is very essential for a company to be precise in their delivery time. Informing customers their orders will arrive in '4-5 business days is more ideal than saying it will arrive in 1-to-5 business days. Precision in delivery time and hours is of great importance as this will help customers know how and when to pick or receive their orders and make the necessary arrangement for that (Raja & Pakistan, 2022).

Transportation cost (TC): This refers to the cost incurred from when an order is placed till the order is delivered. Therefore the "average transportation cost calculates an overall of the expenses involved in processing an order from the beginning to the end". The breakdown related to this KPI according to distinct categories includes; the order processing, the administrative, the inventory carrying, the warehousing and the actual transportation cost. Once all these calculations have been made, you can know the percentage each stage depicts to figure out if it is more or within budget. In addition to this, the transportation cost 'relative to a product' can also be calculated to know how much a product costs in comparison with how much profit comes in. The basic aim is to reduce the cost of transportation while keeping or increasing a high quality of delivery (Raja & Pakistan 2022)

Warehouse cost (WC): It is very essential to take into account all expenses incurred in managing the warehouse. The warehousing cost refers to the money allocated to the goods moved into or outside the warehouse'. Some of the expenses include equipment and energy cost, ordering cost, storing cost, loading & unloading goods cost, labour cost, shipment cost and delivery cost. Warehousing cost is part of the total transportation cost which is also another KPI of logistics. Raja & Pakistan, (2022) posits that "measuring these costs is not an easy one but once it is done effectively, it will facilitate the overall management and add more value, which is something senior management and investors will appreciate". Measuring and reviewing warehousing cost will help improve efficiency in operations (Raja & Pakistan, 2022).

Number of shipments (NS): This basically refers to the number of orders shipped out of a warehouse'. In as much as you can measure the number of orders placed by customers that are shipped out (on time shipping), you can equally measure the number of shipments going out as well. Once this is done well, you have the required information and also know the trend to be able to deal with 'rush seasons' such as (Christmas etc), as this will help you make projections and allocate resources where needed (Raja & Pakistan, 2022).

Inventory accuracy (IA): This refers to where physical inventory in the warehouse corresponds to what is in your records or database. Having discrepancies between physical goods and what is in your database will affect the business as it will lead to high overall cost and unexpected backorders (Raja & Pakistan, 2022).

Inventory turnover (IT): This KPI measures the frequencies of how inventory has been sold over a period of time, i.e. having a system in place that tracks the number of times inventory is sold. Since there are variations in industries, the rate of turnover will also vary. A grocery shop will have a high turnover as compared to a company who is into the sale of vehicles (Raja & Pakistan, 2022).

Inventory to sales ratio (ISR): This KPI helps in determining whether you have overstock or not. It measures 'the ratio between the available inventory for sale against the actual quantity of inventory sold". According to Raja & Pakistan, (2022), this KPI also helps businesses determine if such business has the capacity to face circumstances that are unexpected.

2.4 A Review of Literature on The Impact of Industry 4.0 on Logistics

The fourth industrial revolution is impacting trends in all sectors of society in various fields such as systems of production, management, business administration to the whole economy of a country, and the labour market. The logistics industry is one major area that has not escaped the impact of industry 4.0 especially considering the fact that the advanced technologies employed are greatly aiding firms to have quick response to changes in market demands and are able to provide customised products with improved efficiency in operations (Khiem, 2018; Gallab *et al.* 2021). A lot of studies have been conducted to examine the aforementioned impact and in the write-up that follows, a number of these studies will be discussed to critically assess the performance of the logistics industry in the face of smart cyber physical systems.

Hofmann & Rűsch, 2017 in their study to examine the current status of industry 4.0 as well as future prospects on logistics admits that the incorporation of cyber physical systems and IoT into logistics has the potential to allow real-time tracking of material flows, enhanced handling of transportation and precise management of risk. In their approach, they examined four logistics concepts namely; Just-in-Time (JIT)/Just-in-Sequence (JIS), Kanban (cross-company-oriented approach), Vendor Managed Inventory (VMI) and Cross-docking and their potential implications of industry 4.0 where they drastically assessed usage of the pillars of industry 4.0 in these concepts. The study revealed that indeed opportunities arising from industry 4.0 exist for logistics in terms of decentralisation, self-regulation and efficiency and these include; "an improved demand assessment, dynamic and more efficient milkruns, shortened cycle times, reduced bullwhip effects, highly transparent and integrated supply chains, improvements in production planning, end-to-end supply chain transparency in terms of real time information flows and improvements in flexibility helping companies to optimise value-creation" (Hofmann & Rűsch, 2017).

Manalavan & Jayakrishna, 2019 in their review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements outline global competition, lack of adaptability, delayed entry into market as factors influencing uncertainties in supply chain (SC) management but the use of IoT curbs these challenges. To state a few examples, IoT "can be leveraged to track the consignment location and speed of the vehicle so that the users are alerted by late deliveries, deployed on monitoring the condition of an equipment from a remote location, and temperature sensitive products can be monitored with sensors and the data can be communicated through the internet". All these culminate to bring more value to the SC and reduce wastage. They posit that the fundamental essence of IoT is to connect physical and digital objects aided by the use of the internet and information systems. In their paper, logistics operations are regarded as a key function of SCM where asset tracking or in-transit components are complex but IoT aids to monitor the process. The study revealed that by using IoT, "stakeholders are equipped with technology to manage their resources efficiently and remotely", they are also "motivated to make environment-friendly products by using renewable raw materials, establish close loop supply chains and recover the end-of-life products to reduce the carbon footprints and increase their economic performance". Further, investment in technology improves overall operational efficiency consequently increasing margins and also, firms are able to integrate in real-time with suppliers, manufacturers, retailers, and customers in Industry 4.0 environment (Manalavan & Jayakrishna, 2019).

Sun *et al.*, 2022 reviewed the literature on the application of industry 4.0 technologies in sustainable logistics and found that there is increasing globalisation and changing market dynamics for which industry 4.0 is vital to improve sustainability in production operations, purchasing decisions, and resource planning. They acknowledge the wide use of smart warehouse management by some large companies where "combination of both IoT and CPS provides a quick interconnection of smart assets in a warehouse, e.g., pallets, forklifts, machines, and robots which enables real-time data collection and system monitoring of goods, equipment, and personnel, thereby improving warehousing operations, decision making, safety, and resource utilisation". Regarding transportation, they state that "big data analytics and AI provide computational powers for processing a large amount of multi-sourced data collected from IoT sensors and selecting the right quality and quantity of data for different decision-support tools, which has led to an increasing focus on data-driven sustainable transportation planning and logistics optimization". Also, according to them, industry 4.0 technologies have changed the ways of goods delivery where focus on smart and self-driving vehicles, i.e. autonomous trucks and lorries, has shown the potential to reduce costs, accident rates, and CO2 emissions (Sun *et al.*, 2022).

Holubčík, Koman & Soviar, 2021 assessed industry 4.0 in logistics by conducting a case study of Bottega Veneta, an Italian global luxury goods house, and the manufacturing process, in particular regarding its supply chain. They use the design of a single data model by all actors in the manufacturing process to gather and represent huge amounts of data integrated with the Decision Support System (DSS) production process to organise production and prioritise on various scenarios eventually resulting in making valuable decisions.The findings included the fact that errors were eliminated by employees to reduce cost for the company, the production line itself notified any arising issues such that workers responded quickly in dealing with them, and the smart factory concept enabled customisation of products to match consumer preference. Further, the huge amount of data and information in the possession of the company made possible by industry 4.0 allowed for better decisions to be made in real-time and the safety of workers was also assured as strenuous and dangerous tasks will be performed by machines controlled by AI and also communicate with workers to guarantee smooth flow of production (Holubčík, Koman & Soviar 2021).

3 Methodology

In this chapter of the work, the researchers present the methodologies used in this study. The researchers employ a qualitative research approach of conducting qualitative interviews combined with mathematical methods for analysis. The latter is an MCDM procedure where the researchers use DEMATEL as stated earlier. The sections that follow provide more depth on the qualitative methods, and DEMATEL technique as well as a description of the process of the interviews conducted with selected companies to assist in the research. Materials used are mainly from Collis & Hussey, 2014, Majumder, 2015, Si *et al.*, 2018 and a youtube video by Manoj Mathew in 2019.

3.1 Research Strategy - Paradigms

A research paradigm according to Collis & Hussey (2014) "is a philosophical framework that guides how scientific research should be conducted". They further defined philosophy as "a set or system of beliefs stemming from the study of the fundamental nature of knowledge, reality and existence". Overtime, there has been changes "in the ideas about reality and the nature of knowledge" and due to this, a new research paradigm has evolved because of the ascertained insufficiencies of the prior paradigm. The two types of paradigms are positivism and interpretivism (Collis & Hussey, 2014).

Positivism is centred on the theory that social reality is distinctive and objective and there is no form of influence when an investigation is conducted. It was the first paradigm that evolved, and it is in this same paradigm that researchers have discovered insufficiencies. The second paradigm that emanated due to the censure of positivism was interpretivism. It is based on the theory that the social real world is all found in our minds which is "subjective" and diverse, thus as a result, the real world needs to be investigated (Collis & Hussey, 2014). Positivism is linked with quantitative means of investigation which has its basis on statistical analysis of "quantitative research methods", due to the fact that "social phenomena can be measured". On the other hand, the result of an interpretive research is not attained through "statistical analysis of quantitative data" but rather through "qualitative method of analysis based on the interpretation of qualitative research data" (Collis & Hussey, 2014)

3.1.1 Qualitative Research

Ospina (2004) defines qualitative research as "a form of systematic empirical inquiry into meaning". By using the word systematic, she implies "planned, ordered, and public", adhering to stated rules and regulations consented to by representatives of the qualitative research public. By empirical, Ospina (2004), means that the investigations are established in a society of occurrence. According to Denzin & Lincoln (2000), qualitative research entails an "interpretive and naturalistic approach" where the researcher investigates issues in their natural environment, trying to make meaning of the issue or decipher happenings relating to how they are interpreted by people. Some features of qualitative research according to Collis & Hussey, 2014 include elements that it has a natural location, produces "rich, subjective, qualitative data", and makes use of small samples. In addition, there is low reliability but high validity with this type of research and results from this research can be used in the same setting.

3.1.2 Relevance of Qualitative Research for This Study

Taking the research topic into consideration and as literature has revealed, the manufacturing sector has gone through evolutions and we are currently operating in the so-called 4th industrial revolution. Therefore, conducting this research using the qualitative approach is ideal since it involves change processes with manufacturers adopting new technologies in doing things. Also for such a research, it is always better to get views from the people working with these changes to give us the real situation on the ground with respect to how these new changes and the new technologies are helping them improve their performance as compared to a quantitative approach.

3.2 Multi Criteria Decision Making (MCDM)

According to Majumder 2015, "Decision Making is the act of choosing between two or more courses of action". He further states the bane of MCDM is the designing and finding of solutions to decision and planning problems encompassing multiple criteria. Here, the existence of an optimal unique solution is not probable but then, it is important to use the predispositions of the decision maker to distinguish between solutions (Majumder, 2015). The steps to making a decision coupled with the working principle are given by Majumder, 2015 as follows;

- "Identifying the objective/goal of the decision making process
- Selection of the Criteria/Parameters/Factors/Decider: Must be coherent with the decision, independent of each other, represented in same scale, measurable and not unrelated with the alternatives
- Selection of the Alternatives: Must be available, comparable, real not ideal and practical/feasible
- Selection of the weighing methods to represent importance: The weight determination methods can be either compensatory or outrankable
- Method of Aggregation: Can be a product, an average, or a function. The result of this aggregation will actually separate the best alternative from the

available options

- Decision making based on the Aggregation results”

In the next section, the type of MCDM method referred to as DEMATEL which test the causal relationship between factors of a system is explained.

3.2.1 DEMATEL

Definition and Relevance: The classical DEMATEL approach used for this study is an MCDM method which has the fundamental assumption that criteria/factors are mutually dependent and influence other criteria/factors indicating an inter-dependence among them. The suitability of DEMATEL for this project is that it is used to examine the “cause and effect relationships” among the elements of any given system. DEMATEL can be used to explore and decipher complex and twisted problems or situations. The Geneva Research Centre of the Battelle Memorial Institute was the first centre to develop this method to know ‘causal relationships by the help of matrixes and graphs (Sheng-Li *et al.*, 2018). DEMATEL enables us to know the interdependencies among elements in a complex system which helps in ranking them for long-term strategic decision making and indicating improvement scopes. It further helps in the development of a map to reflect relative relationships within them, which is similar to the connection we seek to investigate. This is because it is obvious the nine pillars of industry 4.0 are connected with logistics performance for any particular system, establishing and drawing on this interdependence offers an effective mode of improving performance on all fronts. Other advantages exist in using DEMATEL, and due to this, a lot of researchers have used this method in finding solutions to complex systems problems in various areas (Sheng-Li *et al.*, 2018).

Formulating Steps: Given that the relationship between the nine pillars and KPIs is examined, three formulating steps are involved which are described as follows;

Step 1: Generate the direct influence matrix

Here, the relationship between factors are assessed by asking an expert to indicate the influence between factors using an integer scale of “no influence (0),” “low influence (1),” “medium influence (2),” “high influence (3),” and “very high influence (4).” Consequently, the individual direct influence matrix is then formed. In case of group decision making, the average of responses by the decision makers are taken for each cell such that for n decision makers, we have the direct influence matrix given by the relation,

$$A = \frac{1}{n}\sum_{k=1}^{n} A_{ij}^{k}, \quad i, j = 1, 2, ..., n \tag{1}$$

Step 2: Establish the normalised direct influence matrix

The direct relation matrix in step 1 is normalised using the following formula;

$$X = k \cdot A \tag{2}$$

$k = \frac{1}{max \sum_{j=1}^{n} a_{ij}}, \quad$ as $i, j = 1, 2, ..., n$

Where all elements in the matrix X lie between 0 and 1, both bounds inclusive and a_{ij} is the sum of the respective rows in the direct relation matrix.

Step 3: Construct the total-influence matrix

The total influence matrix T which provides information on how one criteria or factor affects another is computed from the normalised direct influence matrix in step 2 by summing the direct effects and all of the indirect effects using the equation,

$$T = X + X^2 + X^3 + X^4 + ... + X^h = X(I - X)^{-1}, \quad \text{as } h \to \infty \tag{3}$$

In equation (3), I denotes the identity matrix.

Next, we compute the vectors R and C which are respectively the sum of rows and columns of the matrix T in step 3 and they are given by the following relations;

$$R = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \quad \text{and} \quad C = [c_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}^{T} \tag{4}$$

where r_i is the ith row sum in the matrix T and shows the sum of the direct and indirect effects transmitting from factor F_i to the other factors. Similarly, c_j is the jth column sum in the matrix T and indicates the sum of direct and indirect effects that factor F_j receives from the other factors. Now, suppose $i = j$ such that $i, j \in 1, 2, ..., n$, then $(R+C)$ is the vector on the horizontal axis called "prominence" and it displays the strength of influences that are given and received of the factor. Similarly, $(R - C)$ is the vector on the vertical axis called "relation" and it displays the net effect that the factor provides to the system. A positive $(r_j - c_j)$ implies factor F_j has a net influence on the other factors and can be classified into a cause group; on the other hand if $(r_j - c_j)$ is negative, it means other factors have an influence on factor F_j and thus, it should be classified into an effect group.

Expanded DEMATEL: Since the criteria/factors belong to two different brands and have a bidirectional relationship, the traditional DEMATEL explained above is insufficient and demands additional computations to achieve prominence and relation therefore the expanded DEMATEL technique proposed by Falatoonitoosi *et al.*, 2014 is used where the researchers have also used their adaptations and notations. In their comprehensive procedure equation 5 is of utmost importance to achieve prominence and relation.

$$\begin{aligned}(R+C)_W &= R_W + C_W \\ (R-C)_W &= R_W - C_W\end{aligned} \tag{5}$$

3.3 Data Collection

In this study, the decision is to use qualitative interviews to aid in collecting primary data. According to Grimsholm & Poblete (2010), there are several ways qualitative interview differs from quantitative interview, and examples are that there is less structure and it is very flexible. Here, the intention is to carry out a semi-structured interview in this study and make use of some "open-ended" questions for the interviewees. With these type of questions, there are no restrictions and adjustments can be made at any point in time during the interview. Closed questions which are restrictive in nature will be used for the aspect of DEMATEL. The purpose of this structure is to get some questions on the topic for our research and ask other questions that might come up during the interview in relation to the study being done. In addition to this, the researchers wanted the interviewees to freely give their opinions in connection with the study. The interview was conducted online with the help of Microsoft teams and Zoom. Secondly, the closed questions are used because the researchers have a list of answers or responses the researchers will like our interviewees to choose from (Collis & Hussey, 2014).

3.3.1 Company Profile – Lufthansa Cargo AG

On January 6th, 1926, Deutsche Lufthansa AG was founded and during its first year of operation, they transported about 258 tons of cargo. When it comes to airfreight, Lufthansa cargo is one of the leaders in the world, with a turnover of about 3.8 billion euros and "a transport performance of 7.2 billion freight ton kilometres in 2021". Lufthansa Cargo has an employee base of 4,200 worldwide and their focus

Table 1: **Details of Interviews**

Interviewee	**Company**	**Role**	**Type of Interview**
Ole Bergman	Lufthansa Cargo	Key Accounts Manager	Online / Questionnaire
Wolfgang Buellow	Lufthansa Cargo	Key Accounts Manager	Online / Questionnaire
Bilal Charif	Nowaste Logistics AB	Bus.Dev./Project Manager	Online / Questionnaire
Emmanuel B. Kwofie	Scania	Business Consultant	Online / Questionnaire

is on airport-to-airport business. They have about 300 destinations in more than 100 countries and this accounts for both cargo capacity and passengers, operated by Lufthansa, Austrian airlines, Brussels airlines, Eurowings Discover and SunExpress. Most of the cargo business is overseen through Frankfurt Airport. As a company, they are working towards becoming the world's most sustainable cargo airline. To achieve this, they depend heavily on state-of-the-art technologies and unrelenting investments in line with sustainability (Lufthansa-cargo.com, 2022).

3.3.2 Company Profile – Nowaste Logistics AB

Nowaste is a third-party logistics company that offers logistics solutions with unconventional high-quality tailor made solutions to its current and prospective customers. It is the company's vision to "be a logistics partner that challenges the industry through the development of innovative automation solutions and has broad experience in several segments" (nowastelogistics.com,2022). As a company they are value-driven and has core competences in automation, IT, and staff. Nowaste believes in having all the expertise in-house as such they continually organize training and development programs for their staff as a way of equipping them with the necessary tools to help attain company goals as well as individual goals (nowastelogistics.com,2022).

3.3.3 Company Profile – Scania

Scania is an automobile company which is the world leader in the provision of transport solutions, they have about 54, 000 employees in over 100 countries. In collaboration with their partners and customers, they are moving towards the provision of sustainable transport systems. They manufacture trucks, buses, engines for ships and heavy-duty machines to help enhance the businesses of their customers. In terms of innovation, Scania is mainly concerned with moving towards 'low-carbon transport solutions, where it requires the 'investment in sustainable transport solution that are very practical in today's world, these includes efficient power trains using renewable fuels, in addition to this, in the long term or future, they are looking at the development of 'autonomous and electrified transport technologies' (Scania.com, 2022).

4 Empirical Analysis

In this chapter, the researchers presents the results and analysis obtained from the interviews which include both the explorative part of the qualitative interviews and the mathematical analysis with DEMATEL. It should be noted that various requests were sent by email to contacts in eight different companies but only three of these companies agreed to work with us. Some companies cited reasons of deficiencies in technological know how whereas others failed to respond even after we had sent follow-up emails.

4.1 Results of Qualitative Interviews

In this section, the researchers present the responses elicited from the qualitative interviews conducted with the various representatives of the companies involved. The questions encompass the general mode of operations of companies, knowledge of industry 4.0, usage of some or all of the pillars considered in this study, performance measurement with KPIs and the impact of the pillars of industry 4.0 on performance. It should be noted that in this study, the researchers contacted eight experts from various companies but only three of them agreed to work with us.

4.1.1 Lufthansa Cargo

The company is into the business of transportation with the main goal being the movement of cargoes from point A to B. Some of their key account customers include DHL, GEODIS, UPS, FedEx, and DB Schenker who in turn work with owners of the shipments such as Volvo, Astra Zeneca, Ericsson, etc. Our two contacts are well informed with 48 and 32 years of experience in the company. Over the years, they have been in charge of accepting cargoes in the warehouse, made bookings and rebookings, and checked flights to see if they are correctly loaded and that the right shipments came into the right containers on the aircraft so the cargo is not too much mixed. Currently, they have moved to inside sales by taking more bookings and handed over to the warehouse some jobs that were usually done in order to concentrate more on the customers. Regional sale steering and budget steering also form part of their responsibilities.

The company has good knowledge of industry 4.0 and is doing a lot with it. According to our respondents, the Air cargo industry is traditionally very conservative with a move into digitalisation just a few years back and the company is a frontrunner within the cargo community. It means heavy investment has been made in digitalisation which includes e-booking, e-documents, and e-freights. Air way bills are no longer in use and all documents are now processed electronically. The target is a paper free transportation of goods. In case any form of contact with customers such as forwarders is required, it will be to answer more complex issues such as importation or certain traffic, but all standard bookings are done electronically. The connection is either directly by them, their portal, or Shipping Application Programming Interface (API). Other e-platforms exist where other airlines are included. But they admit that digitalisation is a work in progress that is happening now and will continue.

The main hub of Lufthansa cargo is in Frankfurt and there are plans to have it fully automated. A lot of robotics will be in the soon to be completed new warehouse and this will continue through other major hubs down to remote locations in order to get things secured with ease and faster out processes. Previously, it took about 5 to 7 days for goods to move from shipper to consignee. With digitalisation, transit times have been cut down to a day and the shipping process also optimised. The presence of E-services speeds up documentation as they are checked long before shipments are delivered to them at the warehouses. Measures aimed at speeding the transportation cycle involve a process called pre-check which is conducted at acceptance to ensure all things are in proper order. This effectively enables physical acceptance as the driver scans the shipment upon arrival at the warehouse. In this way, everything is checked beforehand so that the shipment is not stopped in anyway. Previously, when cargo came to the warehouse, the prefix 020 identified Lufthansa cargo, which were marked up from the agents and delivered to their place in the warehouse. A long list was then printed for flights and trucks that left on a particular day. The workers had to run within the cargo to determine which goods go where, be it on a flight or truck. But now with automation, goods are just scanned and where to put it exactly is known which saves a lot of time and reduces mistakes. The only disadvantage is when the system breaks down which is rarely the case. Digitalisation has improved processes as information is now sent in real time. The transition took some time to a certain point and afterwards moved smoothly.

The company makes use of almost all the pillars described in this study. Big data consists of its own and that from independent bodies of the air freight industry such as the International Air Transport Association (IATA). The company also conducts its own analytics, but big data is not being used heavily. ABT is something being looked into to handle all the data and processing. The future plan is for robots to work in the new warehouse in Frankfurt such that all physical moments are handled by robots. Few people will be working in the system when this happens as the robots will take over. Simulation pertains more to the manufacturers such as boeing. HVSI is connectivity within the SC for which an example is the API. When a customer makes a booking, the shippers create the booking and this is sent it to their system. The cloud, has been beneficial as information is loaded onto two different platforms for customers to choose what best suits them i.e. cargo one and cargo net. Bookings are made in four different ways; either customers come directly to them, go to their homepage or use the two platforms which are independent and used by other airlines as well. This offers customers the chance to choose the rate and service of any airline that best suits them. They also intend to get on digital forwarding platforms and hopefully, transport more goods. Plans have also been far advanced to start an E-commerce company wholly owned by Lufthansa cargo. Additive manufacturing is not necessarily their business but they collaborate with manufacturers in designing to streamline their packages in such a way that transporting goods can be optimised. Augmented reality is used to facilitate and enhance workers in these environments. And finally, cyber security is heavily used by the information technology (IT) department.

Regarding performance measurement, cargo IQ is used. It measures different movements such as accepted, flown as planned, and delivered. It also ensures that bookings from customers equals what is received. KPIs are also measured but generally, performance has a lot to do with quality regarding notified, flown as planned and then delivered. Lots of KPI's are used by the company but our contacts mainly work with financial KPIs such as budget monitoring, measurement of yields, sales performance in tonnage, and revenue including air freight surcharges. The area with the most money implies the most profitable ones. Ways of measuring profitability are through the coupon equivalent rate (CER). Recently, the numbers have increased exponentially with the best of business being seen due to COVID-19. They managed to increased capacity during the peak of COVID-19 since there were not much air travels and passenger compartments were converted to cargo space.

In conclusion, it is always a challenge with change but obviously, advantages exist in using the digitalised tools. It saves lots of time and provide better quality. Regarding cost, infrastructure is costly and heavy investments are required. You either upgrade or completely change and train employees when necessary. In the worst-case scenario, some employees completely lose their jobs as robots take over.

As part of automatization, Lufthansa cargo invested in a one-time system globally with huge costs, but it has paid off considering the benefits. In concluding this part of the interview, our respondents noted that the future is for robots to handle cargo but this involves various decision making such as what technology is needed, and who takes part in the investment, is it the airline or customers or warehouses?

4.1.2 Nowaste Logistics AB

Nowaste is a third party logistics (3PL) that work with a broad variety of customers, such as the fruits and vegetables industry (Ever Fresh), companies that handle industrial materials for building, furniture companies (Trademax) and a lot of e-customers. They have most of their warehouses (8 of them) in Helsingborg. They also have a few warehouses spread around the country. Our interviewee is a project leader and business development manager at Nowaste Logistics AB, where he has worked 4 years with very mixed roles since his employment with the company.

The company is well aware about the concept of industry 4.0 of which our correspondent is a business leader and started looking into it about 2-3 years ago. He categorises industry 4.0 into two main parts namely business intelligence and robotics and automation. At Nowaste, industry 4.0 enables a lot of automation of information, and a major advantage is that they own and support their own Warehouse Management System (VMS) which is used in all their warehouses. This sets them apart from other competitors. Long before the term industry 4.0 was advanced, the company have always had an eye for automation and digitalization which is all about owning their own systems, and having all the expertise in house instead of consulting.

Majority of the pillars of industry 4.0 considered in this study are employed by Nowaste. BDA is highly used for the business intelligence aspect of the company.

What is being done is that new databases are built into the cloud to process all their information and make it visual for the end user. ABT was started 20 years ago and its getting better with time. They use it for the designing of pallets to suit small and big goods. Forecast is utilized as a tool in simulation to predict the way forward and how to conduct business today. They are on the journey of moving to the cloud to redo everything they have done before but in a better and smooth way and simulation is key to how they calculate the predictive information they want to use today about tomorrow. Regarding HVSI, they are currently integrating with the platforms being built into the cloud for better connection within the SC. IoT was already in use by the company, but when COVID -19 hit, it gained a lot of prominence as everybody started using it as a means to work together. At Nowaste, it has enhanced communication between employees and customers. The company plans to move parts of their VMS to the cloud. These include the interface and the user experience. The movement which began last year is gradual and they aim to complete the process within a few years. AR forms part of the user experiences they are building. The vision they have as a company is that processes should be very interactive for the end user. The intention is to go a step further where solutions will be generated from the computer, that is, the computer detects a problem and then goes ahead to calculate the best possible solutions to provide the user an option of how to handle the problem. Finally, cyber security has been contracted to a third party and it involves very strict protocols.

Performance at the company is measured with KPI's on the entire chain of processes, that is, on the first level of working through handling to the bigger scale. One aspect that is measured is productivity on both individual and group levels. On the individual level, performance of employees working in the warehouse are measured in order to follow up on issues that may arise. On the group level, performance is measured by looking at things that are wrongly executed in the warehouses. Some measurements such as delivery time are used by customers against them, but they as a company do not measure them as they always ensure strict time disciplines.

In giving us a brief insight to the daily activities in a warehouse, our respondent described their different warehouses as having different methods and processes, but three basic activities pertain to all and they are, inbound, warehousing and outbound. Inbound is where they take and receive all the different types of products for their customers, warehousing consist of storing all these products, which are usually items in the picking zone, buffer zone or in transit dock, and outbound is where they deliver the goods be it business to business (B2B) or business to consumer (B2C). He further admitted to changes in processes currently as they shift more into automation and digitalisation and this has made things more efficient, although the onset is sometimes gradual and a bit difficult. The aim is always to get goods from A to B within the shortest possible time and also optimise the use of computers.

Regarding the costs involved, he acknowledged the costly nature of new technology but notwithstanding, the tradeoff has always proved beneficial for them. At Nowaste, efficiency is carried out in two parts. The first is human labour where they need to make things easier for their personnel and the second part is to raise productivity where productivity in KPIs is directly bounded with the cost. So at the end of the day, they ensure that changes in processes effectively lead to cost reduction. In the matter of employee retention with the advent of new technology, the nature of their company (a 3PL) ensures that when an offer is made on a tender, the number of people needed is already known and therefore investment in automation is made with that figure in mind hence, there are no casualties. But the case might be different for manufacturers where machines are likely to entirely replace some of the workforce.

In a different perspective such as business intelligence and robotics, the company has started to examine a number of processes, most of them already in their headquarters where there are lots of white collared people working. These employees will be mainly affected but the company has in mind that, instead of monetizing the work that needs to be done, people will have to change the description of what they do, such as analysing what the computer has already done. That is how they become better and by so doing, the company will not lay employees off. According to him it is an investment into the future as there is the need to stay competitive, and that, people are the ones that make them competitive.

4.1.3 Scania

Scania is an automotive company which produces trucks and buses to enhance their customers' business. The company also has some environmental role it seeks to achieve. The main products are trucks, buses, engines for ships and some heavy-duty machines. Our contact works as a business consultant for the global purchasing team. Within purchasing, they seek to buy everything and all the materials that are used in manufacturing the trucks, buses, and engines. He supports the purchasing team as a business controller. According to our respondent, he has heard about the concept of industry 4.0 in bits and pieces, especially when some aspects relate to what he does, and he tends to focus on that area to know how best he can affect his work with that.

As maintained by our respondent, digitization and automation of processes are currently ongoing, and in logistics, the systems have been employed in reducing cost when transporting materials within and outside the company. They are also using it in efforts to decreasing CO2 gas emissions where there is a zero emission target by the year 2030. With respect to cost, automation of processes equip them with fore knowledge of when to ship items to and fro to be cost efficient. They have also been able to use this to map the routes in transporting goods to warehouses and production sites to reduce the environmental footprints.

Scania is using all the pillars being examined in this study, and yes, there has been improvement, ever since the company adopted these new technologies. They are more efficient with time and there has also been improvements in quarterly, monthly, and yearly results. The obvious challenge mentioned was the change from an old process to a new one or the moving from one system to another. Sometimes, there is lack of adequate information or tools to enable users to utilise the new system.

In terms of how the company measures performance, our respondent answered from a purchasing perspective. From purchasing they have some KPI's and the main ones are savings and performance. They tend to measure how much they have saved from the budget, and for performance, they measure based on the best bid. Operations in their work have improved with the use of these technologies allowing purchasers to be able to perform at their peak. In order to negotiate and use these tools, there is a system called GPS on Dutch sticker, which helps the purchaser conduct a better negotiation to cut down cost as much as possible. Aside from that, they also have non-financial KPIs, like gender equality, health attendance and employee turnover.

They have been able to use these new technologies to map out routes, for instance if they are buying something from China, and they need it to get to the production site in the UK, the technology will be able to tell them which route to use that will save them cost. They also buy a lot of materials and other stuff from suppliers both within and outside Sweden, so this technology maps which route to use to save cost and reduce the impact on the environment as well. Industrial revolution has brought a lot of impact to them as a company. Taking it from a cost perspective, compared to how much they were paying without this technology, they have been able to save a lot of money based on the new routes they are using. Environmental wise, they have been friendly compared to how they use to transport the materials in times past.

4.2 Results of Expanded DEMATEL

In this section, the researchers represent the pillars of industry 4.0 and KPIs of logistics with the abbreviations **PI** and **KL** respectively. Now, since the researchers test the bidirectional relationship between these two categories of elements, the researchers let "a" represent the fact that criteria PI have direct influence on factors KP and "b" represent the direct influence of KP on PI. Before the results are presented, the following representations for the pillars and KPIs should be noted.

Pillars	BDA	ABT	S	HVSI	IoT	C	AM	AR	CS
Notation	PI1	PI2	PI3	PI4	PI5	PI6	PI7	PI8	PI9

KPIs	ST	OA	DT	TC	WC	NS	IA	IT	ISR
Notation	KL1	KL2	KL3	KL4	KL5	KL6	KL7	KL8	KL9

After gathering data from the experts regarding the level of influence between criteria and factors, and using (1) to (3), the direct influence matrix, normalised direct influence matrix and total-influence matrix were generated for both "a" and "b" as follows;

For "a" - criteria PI have direct influence on factors KL:

$$A_a = \begin{bmatrix} & KL1 & KL2 & KL3 & KL4 & KL5 & KL6 & KL7 & KL8 & KL9 \\ PI1 & 3.3333 & 3.3333 & 3.0000 & 3.3333 & 3.3333 & 3.3333 & 2.667 & 3.3333 & 2.6667 \\ PI2 & 3.0000 & 3.0000 & 2.6667 & 2.6667 & 3.6667 & 3.0000 & 3.3333 & 3.0000 & 3.0000 \\ PI3 & 3.3333 & 3.3333 & 3.0000 & 3.3333 & 2.6667 & 3.0000 & 3.0000 & 3.0000 & 2.6667 \\ PI4 & 3.333 & 3.0000 & 2.6667 & 2.6667 & 3.6667 & 3.000 & 2.6667 & 2.6667 & 2.6667 \\ PI5 & 3.0000 & 3.3333 & 2.6667 & 3.3333 & 3.0000 & 2.6667 & 2.6667 & 2.3333 & 3.0000 \\ PI6 & 3.6667 & 3.0000 & 2.6667 & 2.6667 & 3.0000 & 3.0000 & 3.0000 & 2.6667 & 3.0000 \\ PI7 & 2.6667 & 2.6667 & 2.0000 & 3.0000 & 3.0000 & 2.6667 & 2.6667 & 3.0000 & 3.3333 \\ PI8 & 2.6667 & 3.0000 & 2.6667 & 3.0000 & 3.3333 & 3.0000 & 2.3333 & 2.6667 & 2.6667 \\ PI9 & 3.6667 & 3.0000 & 3.3333 & 3.3333 & 3.3333 & 3.3333 & 3.3333 & 2.6667 & 2.6667 \end{bmatrix} \quad (6)$$

$$X_a = \begin{bmatrix} & KL1 & KL2 & KL3 & KL4 & KL5 & KL6 & KL7 & KL8 & KL9 \\ PI1 & 0.1163 & 0.1163 & 0.1047 & 0.1163 & 0.1163 & 0.1163 & 0.0930 & 0.1163 & 0.0930 \\ PI2 & 0.1047 & 0.1047 & 0.0930 & 0.0930 & 0.1279 & 0.1047 & 0.1163 & 0.1047 & 0.1047 \\ PI3 & 0.1163 & 0.1163 & 0.1047 & 0.1163 & 0.0930 & 0.1047 & 0.1047 & 0.1047 & 0.0930 \\ PI4 & 0.1163 & 0.1047 & 0.0930 & 0.0930 & 0.1279 & 0.1047 & 0.0930 & 0.0930 & 0.0930 \\ PI5 & 0.1047 & 0.1163 & 0.0930 & 0.1163 & 0.1047 & 0.0930 & 0.0930 & 0.0814 & 0.1047 \\ PI6 & 0.1279 & 0.1047 & 0.0930 & 0.0930 & 0.1047 & 0.1047 & 0.1047 & 0.0930 & 0.1047 \\ PI7 & 0.0930 & 0.0930 & 0.0698 & 0-1047 & 0.1047 & 0.0930 & 0.0930 & 0.1047 & 0.1163 \\ PI8 & 0.0930 & 0.1047 & 0.0930 & 0.1047 & 0.1163 & 0.1047 & 0.0814 & 0.0930 & 0.0930 \\ PI9 & 0.1279 & 0.1047 & 0.1163 & 0.1163 & 0.1163 & 0.1163 & 0.1163 & 0.0930 & 0.0930 \end{bmatrix} \quad (7)$$

$$T_a = \begin{pmatrix} & KL1 & KL2 & KL3 & KL4 & KL5 & KL6 & KL7 & KL8 & KL9 & R_{PI} \\ PI1 & 1.7910 & 1.7343 & 1.5450 & 1.7116 & 1.8130 & 1.6927 & 1.5910 & 1.5950 & 1.5924 & 15.0660 \\ PI2 & 1.7180 & 1.6635 & 1.4805 & 1.6309 & 1.7624 & 1.6233 & 1.5598 & 1.5293 & 1.5501 & 14.5178 \\ PI3 & 1.7326 & 1.6777 & 1.4946 & 1.6560 & 1.7308 & 1.6263 & 1.5507 & 1.5324 & 1.5403 & 14.5415 \\ PI4 & 1.6742 & 1.6100 & 1.4329 & 1.5776 & 1.7059 & 1.5710 & 1.4866 & 1.4685 & 1.4881 & 14.0148 \\ PI5 & 1.6452 & 1.6042 & 1.4178 & 1.5835 & 1.6655 & 1.5430 & 1.4714 & 1.4415 & 1.4838 & 13.8559 \\ PI6 & 1.7079 & 1.6308 & 1.4518 & 1.5984 & 1.7049 & 1.5919 & 1.5180 & 1.4884 & 1.5192 & 14.2114 \\ PI7 & 1.5713 & 1.5207 & 1.3412 & 1.5130 & 1.6026 & 1.4846 & 1.4153 & 1.4093 & 1.4398 & 13.2978 \\ PI8 & 1.5914 & 1.5521 & 1.3815 & 1.5318 & 1.6339 & 1.5147 & 1.4217 & 1.4153 & 1.4344 & 13.4768 \\ PI9 & 1.8232 & 1.7423 & 1.5738 & 1.7313 & 1.8330 & 1.7117 & 1.6325 & 1.5902 & 1.6110 & 15.2489 \\ C_{KL} & 15.2547 & 14.7355 & 13.1191 & 14.5341 & 15.4521 & 14.3592 & 13.6470 & 13.4698 & 13.6592 & \end{pmatrix} \quad (8)$$

The matrix A_a is the direct influence matrix of criteria PL on factors KL. This is the average of the matrices provided by the experts regarding this influence. X_a is the normalised matrix of A_a where the researchers divide through the matrix A_a by the maximum value. Finally, the total influence matrix T_a is formed by summing all direct and indirect influences of the matrix X_a (see (3)).

For "b" - criteria KL have direct influence on factors PI:

$$A_b = \begin{bmatrix} & PI1 & PI2 & PI3 & PI4 & PI5 & PI6 & PI7 & PI8 & PI9 \\ KL1 & 1.6667 & 1.3333 & 1.3333 & 2.0000 & 2.0000 & 1.6667 & 1.0000 & 1.3333 & 2.0000 \\ KL2 & 2.0000 & 1.6667 & 1.6667 & 1.6667 & 1.6667 & 1.6667 & 1.0000 & 1.3333 & 1.3333 \\ KL3 & 1.6667 & 1.6667 & 1.0000 & 2.0000 & 1.6667 & 1.6667 & 1.3333 & 1.0000 & 1.6667 \\ KL4 & 2.0000 & 1.0000 & 1.0000 & 1.6667 & 1.6667 & 2.0000 & 1.3333 & 1.0000 & 1.6667 \\ KL5 & 2.3333 & 2.3333 & 1.3333 & 2.0000 & 2.3333 & 2.0000 & 2.0000 & 1.3333 & 1.6667 \\ KL6 & 1.6667 & 1.6667 & 1.3333 & 1.6667 & 1.3333 & 1.6667 & 1.6667 & 1.0000 & 1.6667 \\ KL7 & 2.0000 & 1.6667 & 1.3333 & 1.6667 & 1.3333 & 2.3333 & 1.6667 & 1.3333 & 2.0000 \\ KL8 & 1.6667 & 1.3333 & 1.3333 & 1.6667 & 1.3333 & 1.6667 & 2.0000 & 1.0000 & 1.6667 \\ KL9 & 2.0000 & 1.0000 & 1.3333 & 1.3333 & 2.0000 & 1.6667 & 2.0000 & 1.0000 & 1.3333 \end{bmatrix} \quad (9)$$

$$X_b = \begin{bmatrix} & PI1 & PI2 & PI3 & PI4 & PI5 & PI6 & PI7 & PI8 & PI9 \\ KL1 & 0.0962 & 0.0769 & 0.0769 & 0.1154 & 0.1154 & 0.0962 & 0.0577 & 0.0769 & 0.1154 \\ KL2 & 0.1154 & 0.0962 & 0.0962 & 0.0962 & 0.0962 & 0.0962 & 0.0577 & 0.0769 & 0.0769 \\ KL3 & 0.0962 & 0.0962 & 0.0577 & 0.01154 & 0.0962 & 0.0962 & 0.0769 & 0.0577 & 0.0962 \\ KL4 & 0.1154 & 0.0577 & 0.0577 & 0.0962 & 0.0962 & 0.1154 & 0.0769 & 0.0577 & 0.0962 \\ KL5 & 0.1346 & 0.1346 & 0.0769 & 0.1154 & 0.1346 & 0.1154 & 0.1154 & 0.0769 & 0.0962 \\ KL6 & 0.0962 & 0.0962 & 0.0769 & 0.0962 & 0.0769 & 0.0962 & 0.0962 & 0.0577 & 0.0962 \\ KL7 & 0.1154 & 0.0962 & 0.0769 & 0.0962 & 0.0769 & 0.1346 & 0.0962 & 0.0769 & 0.1154 \\ KL8 & 0.0962 & 0.0769 & 0.0769 & 0.0962 & 0.0769 & 0.0962 & 0.1154 & 0.0577 & 0.0962 \\ KL9 & 0.1154 & 0.0577 & 0.0769 & 0.0769 & 0.1154 & 0.0962 & 0.1154 & 0.0577 & 0.0769 \end{bmatrix} \tag{10}$$

$$T_b = \begin{pmatrix} & PI1 & PI2 & PI3 & PI4 & PI5 & PI6 & PI7 & PI8 & PI9 & R_{KL} \\ KL1 & 0.6257 & 0.4996 & 0.4384 & 0.6010 & 0.5977 & 0.6028 & 0.4895 & 0.3983 & 0.5808 & 4.8339 \\ KL2 & 0.6299 & 0.5086 & 0.4485 & 0.5703 & 0.5649 & 0.5890 & 0.4756 & 0.3905 & 0.5309 & 4.7082 \\ KL3 & 0.6007 & 0.4988 & 0.4027 & 0.5778 & 0.5547 & 0.5795 & 0.4867 & 0.3646 & 0.5399 & 4.6052 \\ KL4 & 0.6076 & 0.4512 & 0.3944 & 0.5483 & 0.5443 & 0.5875 & 0.4783 & 0.3573 & 0.5308 & 4.4997 \\ KL5 & 0.7780 & 0.6503 & 0.5176 & 0.7061 & 0.7193 & 0.7320 & 0.6372 & 0.4693 & 0.6628 & 5.8726 \\ KL6 & 0.5987 & 0.4976 & 0.4210 & 0.5573 & 0.5331 & 0.5782 & 0.5044 & 0.3637 & 0.5391 & 4.5931 \\ KL7 & 0.6765 & 0.5446 & 0.4619 & 0.6115 & 0.5865 & 0.6729 & 0.5536 & 0.4187 & 0.6108 & 5.1369 \\ KL8 & 0.5996 & 0.4791 & 0.4213 & 0.5581 & 0.5336 & 0.5798 & 0.5252 & 0.3643 & 0.5406 & 4.6014 \\ KL9 & 0.6249 & 0.4670 & 0.4252 & 0.5456 & 0.5787 & 0.5856 & 0.5305 & 0.3685 & 0.5275 & 4.6536 \\ C_{PI} & 5.7416 & 4.5968 & 3.9309 & 5.2759 & 5.2129 & 5.5072 & 4.6810 & 3.4951 & 5.0632 & \end{pmatrix} \tag{11}$$

The matrix A_b is the direct influence matrix of criteria PL on factors KL. This is the average of the matrices provided by the experts regarding this influence. X_b is the normalised matrix of A_b where the researchers divide through the matrix A_b by the maximum value. Finally, the total influence matrix T_b is formed by summing all direct and indirect influences of the matrix X_b (see (3)).

From the new rendering of expanded DEMATEL, the researchers further have the following equations that enable us achieve prominence and relation;

$$\begin{aligned}(R+C)_{PI} &= R_{PI} + C_{PI} \\ (R-C)_{PI} &= R_{PI} - C_{PI}\end{aligned} \tag{12}$$

$$\begin{aligned}(R+C)_{KL} &= R_{KL} + C_{KL} \\ (R-C)_{KL} &= R_{KL} - C_{KL}\end{aligned} \tag{13}$$

As posited by Falatoonitoosi *et al.* 2014, one criteria with its factors are reasonably more intense than the other and effectively become the cause group with the other criteria settling for the effect group. The following relations define these two groups.

$$\begin{cases} \text{if} \quad (r_i - c_i) \geq 0, \text{factor belongs to cause group} \\ \text{if} \quad (r_i - c_i) \leq 0, \text{factor belongs to effect group} \end{cases} \tag{14}$$

Table 2:
Results of Expanded DEMATEL for Cause and Effect groups

	Effect group			Cause group	
KPIs	$(R+C)_{KL}$	$(R-C)_{KL}$	Pillars	$(R+C)_{PI}$	$(R-C)_{PI}$
KL1	20.0886	-10.4209	PI1	20.8076	9.3243
KL2	19.4438	-10.0273	PI2	19.1146	9.9210
KL3	17.7244	-8.5139	PI3	18.4725	10.6106
KL4	19.0338	-10.0344	PI4	19.2907	8.7390
KL5	21.3247	-9.5795	PI5	19.0688	8.6430
KL6	18.9523	-9.7661	PI6	19.7185	8.7042
KL7	18.7839	-8.5102	PI7	17.9788	8.6168
KL8	18.0712	-8.8685	PI8	16.9719	9.9817
KL9	18.3128	-9.0055	PI9	20.3121	10.1857

In Table 2, the vectors that demonstrates Prominence $(R+C)$ and Relation $(R-C)$

are given for all factors/criteria. $(R + C)$ displays the strength of influences given by or received of a factor whereas $(R - C)$ displays the net effect provided by a factor to the system. Since DEMATEL establishes the causal relationship between factors, this bidirectional relationship has the pillars of industry 4.0 as the cause group (positive $(R - C)$) and the KPIs of logistics as the effect group (negative $(R - C)$).

4.3 Analysis of Results

Table 2 presents the results of expanded DEMATEL in this bidirectional relationship between the pillars of industry 4.0 and some selected KPIs in logistics. All values of $(R - C)_{PI}$ are positive implying that the pillars of industry 4.0 make up the cause group in this study whereas the values of $(R - C)_{KL}$ are less than zero indicating that the KPIs of logistics constitute the effect group. The implication is that the pillars of industry 4.0 are more powerful and greatly influence logistics performance. Thus, companies are better off adopting current technology in the fourth industrial revolution as this will consequently result in improvements in performance especially in Logistics. This observation is clearly substantiated in the responses garnered from our contacts as they all talk of improvements made with the help of technology such as cutting down transit times, optimising transport routes to reduce cost and be sustainable, high level of quality and enhanced productivity through the use of robots.

Assessing the values of $(R + C)$ across all criteria and factors, warehouse cost with the highest figure remains the most important factor and this comes at no surprise because all the companies are actively engaged in systems that improves operations in the warehouse. It is obvious the operations within the warehouse remain central to logistics processes and managing them effectively can prove beneficial and even provide some form of competitive advantage for firms. Lufthansa Cargo is a front-runner within the air cargo community with future plans of fully automated warehouses. Nowaste logistics on the other hand owns and manages their own VMS which gives them a slight upper hand over competitors because it is easier for them to enhance processes and further adopt new technologies for efficiency. A further feature that makes the aspect of warehousing a significant component in logistics especially after COVID-19 is the rise in e-commerce. This trend has necessitated the acquisition of ultra modern warehouses by companies and in some cases, brick-and-mortar stores have been converted to make room for this demand. Consequently, having a good WMS in place for efficiency will prove to be cost effective. Notwithstanding, it should be noted that the values are not very far apart which indicates that for overall good performance, all factors/criteria should be treated with importance.

Another important aspect observed in this study is that most of the pillars considered overlap and draw on each other for optimal use. It was revealed during the interview that the ability for companies to connect with customers and suppliers remains an effective tool and this connectivity defines the HVSI pillar. The Cloud consequently enables the link as companies put their services there and customers in turn access those services. We should also bear in mind that all of these processes involve a high level of business intelligence which essentially is an automation of processes.

It is obvious that venturing into new technology comes at a cost but the study shows that the benefits far outweighs the cost. The major roadblock is the initial investment to be made but once this hurdle is crossed, the improvements that arise prove profitable. And aside profitability is also the environmental advantage. Some of these technologies are aimed at improving systems for sustainability leading to a more friendly environment and general improved well-being of individuals.

One major disadvantage recognised in this study is the event of physical robots replacing human employees. Even though robot technology currently consist mainly of those that assist humans for increased efficiency, the possibility exist that in the near future, robots will absolutely take over some tasks and render human employees redundant. A pillar that also proved to be challenging is cyber security. The nature of operations in business intelligence especially with most connections being moved to the cloud has increased and thus, enforced the need to put in strict protocols to guard against cyber threats. Aside the costs incurred, it places considerable strain on companies as they need to be alert at all times and ensure that all measures taken are carefully adhered to.

5 Discussion, Conclusion and Recommendation

5.1 Answer To The Research Question

In answering the research question posed in section 1.3, it can be asserted that the adoption of various technologies can help companies improve performance. This claim is derived from the various experts interviewed and the expanded DEMATEL technique employed in the study. All the nine pillars of industry 4.0 considered for this study are heavily utilised by these logistics companies. With their aid the companies are able to conduct business electronically to faster out processes.

Big data and analytics: Is used both for business intelligence where databases are built into the cloud to process information and make it visual for the end user. The companies make use of both own data and that of independent bodies in their operations.

Autonomous Robots: Are employed to handle both data and processes. This technology handle difficult physical moments in especially warehouses where they work either independently or collaborate with humans.

Simulation: Is used for predicting the way forward to give an idea as to how to conduct business in the present time. Manufacturers also utilise this tool to produce

Horizontal and Vertical System Integration: The companies use this system to connect within the upstream and downstream SC and this ensures the smooth dissemination of information in going about their business. It is enabled through various digital applications through which customers gain access to the services provided.

The Industrial Internet of things: This technology has become particularly an effective after COVID-19 as it has stood out as a means through which people work together. Due to this, there is improved communications between employees and customers.

The Cloud: Companies load information on different platforms within this technology where customers are able to conduct business with them. WMS including interface and user experience are major systems also being moved to the cloud.

Additive Manufacturing: aids in producing customised goods to suit the needs of consumers. Also, this helps to structure products such that, packaging and transportation is made efficient. It also helps to produce sustainable systems to reduce the environmental footprint.

Augmented Reality: AR is a key driving force in building enhanced user experience. With this, companies are working towards a system where computers will generate solutions after detecting a problem to help provide users options to handle encountered problems.

Cyber Security: IT is basically the driving force behind industry 4.0 technology and therefore CS is of prime importance to companies. It is a way through which cyber threats are dealt with and it involves procedures that are strictly adhered to.

Various companies across industry assess the performance of these technologies through defined KPIs and the nine selected for this study proved relevant in all the industries contacted. Accordingly, there was overwhelming affirmation regarding the improvement of processes and the efficiencies gained from using them. Productivity was at an all-time high, there was efficient use of raw materials improved coupled with progress in advancing sustainable practices. After testing the bidirectional relationship between pillars of industry 4.0 and the KPIs, technology proved powerful as its usage effectively improved logistics performance. Thus, companies are better off in using the technology defining industry 4.0 to meet the current needs of society.

5.2 Conclusion

The world evolving through industrial revolutions has necessitated the adoption of new technologies across all industries. And this is especially so in the field of logistics, from manufacturing through warehousing to distribution. These new technologies potentially lead to increase in performance, productivity and the overall efficiency and effectiveness of processes. Adapting to these new systems provide companies with some form of competitive advantage as they are able to match the ever-changing consumer demands as well as respond to critical issues that confront the environment.

Varying technologies support industry 4.0 and it is clear from this study and previous research that they are not necessarily mutually exclusive. Moreover, considering the fact that companies have their core defined operations, for example Lufthansa cargo in the Air transport sector, their logistics operations involve diverse aspects such as warehousing and transportation by trucks. Therefore, it is important for companies to combine the technologies governing industry 4.0 to maximise their potentials and achieve extensive benefits.

Notwithstanding the advantages gained from the advanced technology in industry 4.0, it also has its downsides and some notable ones are the possibility of job losses as robots take over certain duties, and the reluctance to change by individuals, especially when there is inadequate training for them to be able to adapt to new systems. It is worth mentioning that what might be considered negative in one company might not be so in another company and all these were highlighted by the various experts we interviewed. Overall, we can say that technology creates room or opportunities for companies to get better at what they do but the far extent to which a company can get depends on how deep they are willing to venture into these new systems.

5.3 Recommendations for Further Research

In this study, it was sought to examine the impact of current technology on the logistics performance of companies. Conclusions were drawn based on interviews with personnel from three different companies and by extension, three industries. For further research, the researchers believe additional companies from various industries will provide a more thorough conclusion on the subject. Also, only nine pillars of industry 4.0 were considered for the purposes of this research although in some literature, twelve pillars are listed. Thus, it will be interesting to consider all twelve pillars or more if they exist to examine whether performance will be enhanced as technology increases. Last but not least, the researchers were unable to have on site experience in the duration of this study therefore this aspect should be considered in any further research.

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