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"Logistics 4.0: Technologies, Trends, Applications and Challenges"

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Preface

"When something is important enough, you do it even if the odds are not in your favor."

-Elon Musk

This master thesis has been performed at the Department of Financial and Management Engineering of the University of The Aegean. It has been supervised by Dr. Vasileios Zeimpekis.

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Finally, I would like to thank my parents and my girlfriend for their unconditional support and encouragement.

Είμαι συγγραφέας αυτής της Μεταπτυχιακής Διπλωματικής Εργασίας και κάθε βοήθεια την οποία είχα για την προετοιμασία της είναι πλήρως αναγνωρισμένη και αναφέρεται στην εργασία. Επίσης, έχω αναφέρει τις όποιες πηγές από τις οποίες έκανα χρήση δεδομένων ή ιδεών, είτε αυτές αναφέρονται ακριβώς είτε παραφρασμένες. Επίσης, βεβαιώνω ότι αυτή η εργασία προετοιμάστηκε από εμένα προσωπικά, ειδικά για τη συγκεκριμένη μεταπτυχιακή διπλωματική εργασία.

Table of Contents

List of Figures

List of Tables

Nomenclature

AR	Augmented Reality
AS/AR	Automated Storage/ Automated Retrieval
ASN	Advance Shipping Notice
BI	Business Intelligence
CRM	Customer Relations Management
EDI	Electronic Data Interchange
EPOS	Electronic Point of Sale
ERP	Enterprise Resource Planning
EU	European Union
FIFO	First in First Out
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HR	Human Resources
ICT	Information and Communication Technology
IT	Information Technology
IoT	Internet of Things
KPI	Key Performance Indicators
LLOP	Low-Level Order Picking
MODE	Maintenance on Demand
M2M	Machine to Machine
M2P	Machine to Person
NPS	Net Promoter Score
NPT	Network Planning Tools
ORION	On-Road Integrated Optimization Network
OT	Operational Technology
POD	Proof of Delivery
PSS	Product-Service System
QSR	Quick Service Restaurant
RF	Ring Finger

RORO	Roll-on Roll-off
RFID	Radio Frequency Identification
SCM	Supply Chain Management
SKU	Stock Keeping Unit
UAV	Unmanned Aerial Vehicle
VNA	Very Narrow Aisle
VPS	Visual Positioning System
VR	Virtual Reality
WIP	Work-in-Progress
WMS	Warehouse Management System
3PL	Third Party Logistics

Abstract

Current logistics operations and information systems used cannot deal with the emerging challenges. Globalization, the rise of e-commerce, cyberthreats, cumbersome organizational structures, startups disrupting the business landscape and constantly higher customer demands push companies into adopting emerging technologies which enable them to increase digitalization and automation.

These challenges have been exploiting the limits of currently utilized warehouse technologies and practices, highlighting the inefficiencies that exist. As for freight transportation, fleet management systems and routing software solutions are utilized at a great extend and success already, but one thing highlighted through the case studies analysis is the necessity for real-time monitoring and visibility throughout the goods' journey from dispatching to the customer.

The fourth industrial revolution, Industry 4.0, enables companies to proceed in digitalizing their operations, as building a flexible organizational structure is a challenge that needs to be addressed and adopting the digital enterprise model is a crucial step before implementing the new age technologies, as companies must add the elements of flexibility and adaptability in order to deal with the challenges at hand.

Logistics 4.0, a term derived from the combination of Industry 4.0 technologies and innovations and their application on inbound and outbound logistics is a narrower concept than Industry 4.0, as it focuses on typical features, such as automation and digitalization. The technologies most commonly utilized are the Internet of Things (IoT), Big Data analytics, Augmented Reality (AR), Unmanned Aerial Vehicles (UAVs) and Advanced Robotics. IoT is the pinnacle of those technologies, as it enables new data streams creation from sources previously being non-exploitable and allows companies to monitor and control mechanizations, fleets etc. by a central system. Big Data analytics provide a powerful tool to companies, as the new data streams generated by IoT produce much greater amounts of data which common software cannot process. Advanced Robotics revolutionize logistics operations due to increasing automation. AR offers numerous advantages for warehouse workers distributors. Lastly, UAVs present a revolutionary technology in many different ways as they possess a wide array of applications, such as facility patrolling, warehouse assistance, stock counting and last-mile delivery.

The Master thesis presents a framework that companies may follow for a Logistics 4.0 technologies implementation. The framework presents five necessary phases for the implementation, enabling the company to properly deal with the challenges that emerge. Resistance to change, high investment costs, HR-related issues, data privacy issues, IT infrastructure requirements, the public's opinion about revolutionary technologies and regulations are challenges that must be dealt with for the implementation to be smoothly completed.

The case studies analysis that follows showcase the advantages and benefits of implementing Logistics 4.0 technologies. Finally, the outcome of the Master thesis is that the framework may be tested in a real-world environment for further research on the subject.

Επιτελική Σύνοψη

Η υφιστάμενη κατάσταση στον τομέα των λειτουργιών των Logistics και τα πληροφοριακά συστήματα που χρησιμοποιούνται δεν μπορούν να αντιμετωπίσουν τις προκλήσεις που προκύπτουν. Η παγκοσμιοποίηση, η άνοδος του ηλεκτρονικού εμπορίου, οι απειλές εκ του διαδικτύου, οι πολύπλοκες οργανωσιακές δομές, οι νεοσύστατες επιχειρήσεις που διαταράσσουν το επιχειρηματικό τοπίο και οι συνεχώς υψηλότερες απαιτήσεις των πελατών ωθούν τις εταιρείες στην υιοθέτηση αναδυόμενων τεχνολογιών που τους οδηγούν προς την ψηφιοποίηση και την αυτοματοποίηση.

Αυτές οι προκλήσεις φανερώνουν τις αδυναμίες των υφιστάμενων τεχνολογιών που χρησιμοποιούνται στην αποθήκευση. Όσον αφορά τις εμπορευματικές μεταφορές, τα συστήματα διαχείρισης στόλου και οι λύσεις λογισμικού δρομολόγησης χρησιμοποιούνται ήδη σε μεγάλη έκταση και με επιτυχία, αλλά ένα πράγμα που επισημαίνεται στην ανάλυση μελετών περίπτωσης είναι η αναγκαιότητα παρακολούθησης και ορατότητας σε πραγματικό χρόνο καθ’όλη τη διάρκεια του ταξιδιού των εμπορευμάτων μέχρι τον πελάτη.

Η τέταρτη βιομηχανική επανάσταση, εν συντομία Industry 4.0, επιτρέπει στις επιχειρήσεις να προχωρήσουν στην ψηφιοποίηση των λειτουργιών τους, καθώς η δημιουργία μιας ευέλικτης οργανωτικής δομής και η υιοθέτηση του ψηφιακού επιχειρηματικού μοντέλου είναι ένα κρίσιμο βήμα πριν την εφαρμογή αναδυόμενων τεχνολογιών.

Τα Logistics 4.0, ένας όρος που προκύπτει από το συνδυασμό των τεχνολογιών και καινοτομιών του Industry 4.0 και της εφαρμογής τους στις εισερχόμενες και εξερχόμενες λειτουργίες logistics, επικεντρώνεται σε τυπικά χαρακτηριστικά όπως αυτοματοποίηση και ψηφιοποίηση. Οι τεχνολογίες που χρησιμοποιούνται συνήθως είναι το Διαδίκτυο των πραγμάτων (IoT), τα Big Data analytics, η επαυξημένη πραγματικότητα (AR), τα μη επανδρωμένα σκάφη (UAVs) και η προηγμένη ρομποτική. Το IoT επιτρέπει τη δημιουργία νέων ροών δεδομένων από πηγές οι οποίες προηγουμένως ήταν μη εκμεταλλεύσιμες, καθώς και την παρακολούθηση και τον έλεγχο μηχανισμών, στόλων κλπ. από ένα κεντρικό σύστημα. Τα Big Data αποτελούν ένα ισχυρό εργαλείο για τις εταιρείες, καθώς οι νέες ροές δεδομένων που παράγονται από το IoT παράγουν πολύ μεγαλύτερα σετ δεδομένων τα οποία δεν μπορούν να επεξεργαστούν με χρήση κοινού λογισμικού. Η προηγμένη ρομποτική φέρνει την επανάσταση στις λειτουργίες logistics λόγω της αύξησης της αυτοματοποίησης. Το AR προσφέρει πολυάριθμα πλεονεκτήματα στους εργάτες μίας αποθήκης, καθώς και στους διανομείς. Τέλος, τα UAVs διαθέτουν ευρύ φάσμα εφαρμογών, όπως περιπολία εγκαταστάσεων, απογραφές και παράδοση τελευταίου μιλίου.

Η μεταπτυχιακή εργασία παρουσιάζει ένα πλαίσιο το οποίο οι εταιρείες μπορούν να ακολουθήσουν για την εφαρμογή τεχνολογιών Logistics 4.0. Το πλαίσιο αυτό παρουσιάζει πέντε απαραίτητες φάσεις για την εφαρμογή, επιτρέποντας στην εταιρεία να αντιμετωπίσει σωστά τις αναδυόμενες προκλήσεις. Η αντίσταση στην αλλαγή, το υψηλό κόστος επένδυσης, τα θέματα που σχετίζονται με το ανθρώπινο δυναμικό, τα ζητήματα ιδιωτικού απορρήτου των δεδομένων, οι απαιτήσεις σε λογισμικό και υλισμικό, η γνώμη του κοινού σχετικά με τις επαναστατικές τεχνολογίες και οι νομοθεσίες αποτελούν προκλήσεις που πρέπει να αντιμετωπιστούν για την ομαλή ολοκλήρωση της εφαρμογής τεχνολογιών Logistics 4.0.

Η ανάλυση των μελετών περίπτωσης που ακολουθεί μετέπειτα, παρουσιάζει τα πλεονεκτήματα και τα οφέλη της εφαρμογής τεχνολογιών Logistics 4.0. Τέλος, προτείνονται τρόποι αξιοποίησης του πλαισίου που αναπτύχθηκε σε αυτή την μεταπτυχιακή εργασία με τεστάρισμα του σε αληθινό περιβάλλον.

Chapter 1 Introduction

Supply chain management has been continuously becoming more complex (Doz, 2017). There is a need for faster and more individualized services due to the increased customer demand regarding delivery time and availability (Witkowski, 2017). Furthermore, globalization keeps on being a significant drive, security awareness has become a trend due to cyber threats, social and environmental challenges emerge (e.g. the aim for less CO_2 emissions) (DHL, 2016) and the rise of e-commerce pushes companies to consider integrating emerging technologies which shall drive them towards digitalization and innovation (Doz, 2017). However, companies should consider making fundamental changes to their organizational structures in order to prioritize the optimization of their logistics operations and add elements such as flexibility and adaptability in order to insert smoothly into the digital age and implement emerging technologies (Noronha et al., 2016). Industry 4.0 and especially Logistics 4.0 (i.e. technologies that support the digital transformation of logistics operations) facilitate those changes and allow companies to completely digitize and automate several operations and processes.

1.1 The Role of Information Technology in Logistics Operations

The role of Information Technology has become more critical nowadays than ever before due to the need for digitalization and innovation being more prominent. Logistics operators and companies with in-house logistics have been using technological aids and systems such as Voice Picking, Warehouse Management Systems, Fleet Management Systems, Routing software solutions, etc., however these technologies and systems cannot always face challenges, such as the aforementioned globalization, cyber-threats, e-commerce's rise and increased customer demands (Baretto et al., 2017). For example, a worker wearing the voice-picking wearables still has to hold a handheld scanner and wears a ring-scanner in order to confirm his every move, thus reducing his productiveness.

Logistics 4.0 offers a solution, in most cases, as its technologies facilitate greater digitalization and automation in logistics operations, such as the above, thus driving companies towards the digital age with increased capabilities for innovation (Hülsmann, 2015). As a result, Logistics 4.0 can be defined as a data-driven logistics concept in which individual subsystems interwind and communicate in order to create a digital network that enables increased efficiency and productivity (Szymanska et al., 2017). It operates under the same principles as Industry 4.0, but with different component parts, as it utilizes smart means, such as containers, vehicles, pallets, and transportation systems. By creating the digital network, Logistics 4.0 offers supply chain managers, shippers, drivers, freight forwarders etc. real-time visibility and traceability, thus enabling the optimization of logistics operations, such as warehousing and freight transportation (Hoey, 2018). A digital supply chain produces immediate results which can be seen due to real-time data processing offering greater and more responsive insights (PwC, 2016). For example, in an IoT-based warehouse all goods are embedded with sensors, so that managers can monitor their condition (e.g. temperature) and location, which means that if a product was on the verge of being damaged managers would know early enough to develop countermeasures and take precautions (Hoey, 2018).

Other technological applications such as Augmented Reality devices (e.g. for Vision picking) can recognize the surroundings and display visual information to the operator while enabling scanning without a handheld device, thus reducing travel time through the warehouse and decreasing the risk for injury while simultaneously optimizing the worker's productivity, making vision picking faster than other picking technological aids (DHL, 2015; Goettler, 2018). Another revolutionary technology which was briefly mentioned above is The Internet of Things and its subsidiary technologies, such as sensor technology, with the ability to connect individual components of the supply chain together into a central system in order to enable digitalization and optimize processes (Macaulay et al., 2015). IoT enables the creation of multiple data streams which results in a more massive amount of data being available, which deems Big Data analytics the most suitable solution, as it enables real-time data processing of datasets much bigger in variety, velocity, volume and size, thus optimizing decision making and generating greater insights (Jeske et al., 2013). Advanced Robotics can streamline day-to-day processes and tasks in the warehouse, while they can aid in optimizing package delivery (Bonkenburg, 2016). Finally, unmanned aerial vehicles (UAVs) present an opportunity to totally transform delivery processes, while enabling intralogistics applications, such as facility overwatch and labor assistance (DHL, 2014).

1.2 Scope and Objectives of the Thesis

The main scope of this Master thesis is threefold: a) review the current logistics operations with emphasis on the Information Systems used, b) investigate how logistics operations may be transformed by adopting logistics 4.0 technologies such as IoT, Big Data, Advanced Robotics, Augmented Reality, and UAVs and, c) propose a framework that a company may follow in order to digitally transform its logistics operations and then showcase an application of that framework for an implementation of UAVs in a warehouse.

The individual objectives of the thesis are as follows:

1- Review the current status of warehouse and freight transportation operations.
2- Present current information systems used in logistics operations and examine their inefficiencies, thus highlighting the need for Logistics 4.0 technologies.
3- Make an in-depth explanation of emerging Logistics 4.0 technologies and determine in which way they may revolutionize warehouse and freight transportation operations.
4- Examine ten (10) individual case studies in which companies have successfully implemented the technologies mentioned above and showcase their results.
5- Propose a framework of how warehouse and transport operations can be transformed via Logistics 4.0 technologies and showcase an example of applying the framework for the implementation of UAVs for inventory management and facility patrolling.

1.2 Methodology

The methodology that was followed for the preparation of this Master thesis is as follows:

The first step was to describe all the strengths and weaknesses of current logistics operations, how they are performed and present the information systems used along with their inefficiencies, as well as the technologies utilized. It is evident that warehouse operations are still largely manual in nature with many workers spending valuable labor time in repetitive tasks and activities, thus decreasing productivity and operational efficiency (Bonkenburg, 2016). On the other hand, freight transportation has accepted automation at a faster rate, although implications regarding routing, scheduling and last-mile delivery are still posing as a huge challenge (Malindretos, 2015).

The next step was to present and describe emerging Industry 4.0 technologies and their application on logistics operations (i.e. Logistics 4.0 technologies in warehousing and freight transportation). The emerging technologies mentioned above have the potential to drive the logistics industry towards digitalization and automation, which will sequentially lead to increased productivity and operational efficiency (Noronha et al., 2016).

Then, a framework under which companies need to operate in order to adopt Logistics 4.0 technologies was developed with an example of the framework in a UAVs warehouse implementation. Finally, ten (10) case studies were chosen to be examined, five (5) regarding warehousing and five (5) regarding freight transportation, which showcase the effectiveness and impact Logistics 4.0 technologies have on logistics operations.

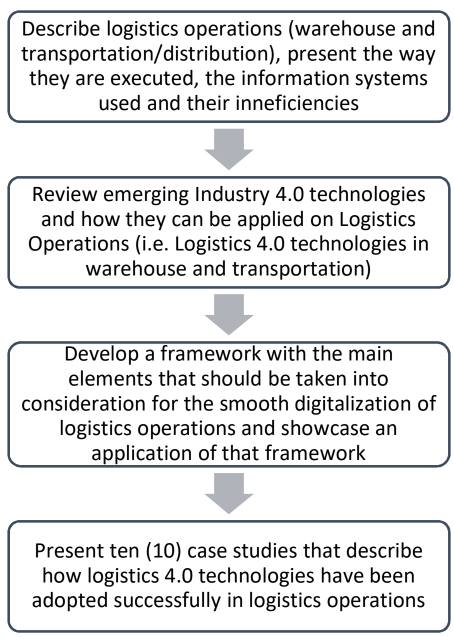

Figure 1.1 A flow chart depicting the methodology followed in the Master thesis.

1.4 Thesis Outline

The master thesis is comprised of six (6) main chapters. Each chapter's content is analyzed as follows:

The first chapter is a general introduction to the main theme of the thesis. The methodology followed throughout the Master thesis is presented.

The second chapter is examining currently performed logistics operations and information technology systems utilized. An analysis of the technologies used was also performed, showcasing their limitations.

The third chapter is a historic review of the industrial revolutions and a more comprehensive introduction to the Logistics 4.0 technologies mentioned above. Each industrial revolution is described, leading up to Industry 4.0.

The fourth chapter is a more in-depth analysis of how Logistics 4.0 technologies revolutionize warehouse and freight transportation operations. A framework for Logistics 4.0 adoption was also developed with an application displayed, regarding the implementation of UAVs for inventory management and warehouse patrolling.

In the fifth chapter, ten (10) case studies were analyzed, five (5) dealing with warehouse operations and five (5) regarding freight transportation. The outcome of implementing Logistics 4.0 technologies is reviewed in each case.

Finally, the sixth chapter summarizes the advantages of implementing these emerging technologies and reviews the conclusions of the Master thesis, as well as the way forward for the logistics industry.

Chapter 2 Logistics Operations: Processes and Characteristics

2.1 Introduction

Technology is evolving in a very fast rate and along with it supply chain and logistics management need to constantly adapt in order to enable the integration of new technologies and practices. Current logistics operations have their advantages, but the increasingly higher customer demands, globalization, the need for reformed organizational structures, startups constantly innovating with new business models to disrupt the logistics industry, the rise of e-commerce and cybersecurity awareness are all great issues demanding attention, thus challenging the way logistics companies do business.

In this chapter we will do a thorough review of the way warehouse and transportation operations and processes are handled, the information systems that connect those processes together and enable better flow of information and the technologies that accompany those information systems, leading in improved efficiency in warehouse and transportation operations. Finally, we will bring forth the issues that have emerged in the last decade, specifically the ones above, and explain how they increase the need for companies and organizations to incorporate Logistics 4.0 technologies and practices.

2.2 Supply Chain and Logistics Management

Logistics, as a term, was first used in military operations. "Strategy is art of handling troops in the theatre of war; tactics that of handling them on the field of battle… The French have a third process, which they call logistics, the art of moving and quartering troops…" (Lummus, Vokurka and Krumwiede, 2001). Today we use that term in a different sense. We define logistics as the management of the flow of goods from the point of origin to the point of consumption, given that the requirements of the consumer are met, with the involvement of information processing being a lot more prominent these days.

Supply chain management (SCM) is a much broader term including all the logistics processes mentioned above and is used to define all inbound and outbound logistics processes, linking all the different departments of the company and external partners (e.g. 3PLs), information systems providers, suppliers and carriers. It is a network of organizations and companies, dependent on each other, utilizing their combined expertise in order to manage and monitor the flow of goods and information from the supplier to the end user (Christopher, 2011), coordinating processes across finance, marketing, sales, production and information technology (IT) (CSCMP, 2018).

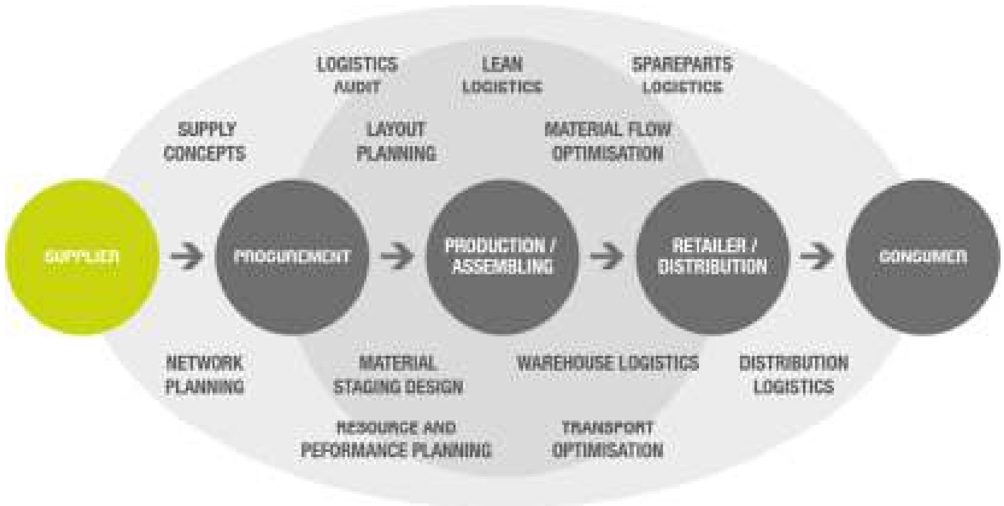

Figure 2.1 Logistics Management as a crucial part of Supply Chain Management. (IIBM LMS, 2018).

For industries, logistics support the optimization of production and distribution processes based on a variety of resources through management techniques for promoting the efficiency and competitiveness of enterprises (Tseng, Yue, & Taylor, 2005). Logistics can be described as a two-parter channel as follows:

1. The physical channel

Logistics services support the movement of materials and products from the point of production to the point of consuming, as well as associated waste disposal and reverse flows. These services are comprised of physical activities (e.g. receiving, storing, order picking, transportation etc.) (Galindo, 2016).

2. The information channel

The uninterrupted flow of goods is naturally dependent on the correct flow of information, ranging from the procurement procedures to last-mile delivery processes (Galindo, 2016). The physical and the information channels are interdependent and that is why physical activities would be unable to be completed without information processing, which showcases the connection between the two and their importance in today’s digital world.

2.3 Warehousing and Storage

The warehouse has evolved from the perception of being a repository to forming an integral part of the supply chain, as it is involved in numerous stages of sourcing and production, all the way up to distribution and delivery, ranging from the handling of raw materials to the distribution of finished products to the end customer (Rushton et al., 2014).

Warehouses can be grouped by type, depending on their importance and nature within the supply chain (Christopher, 2011) as seen below:

1- Their Function
2- Segmentation
3- Stage in the Supply Chain

4- Product Type
5- 3PL owned or Private owned
6- Covering Area
7- Whether they are Manual or Automated in Nature
8- By Height

2.3.1 The role of a Warehouse

The prime objective of a warehouse is to support the uninterrupted movement of goods through the supply chain to the end customer (Rushton et al., 2014). In past decades, warehouses were viewed as stockholding points in an attempt to match supply and demand, while also acting as a buffer between manufacturers and wholesalers, resulting in limited stock visibility and a slow flow of information (Richards, 2018). This resulted in companies and organizations keeping excess amounts of stock in warehouses, with a negative effect on operational, holding and logistic costs.

Holding inventory is a crucial role of the warehouse as it affects a number of operations and activities, such as better customer service and prevention of the fluctuation of demand affecting production and sales, while also being of great importance to the costs written above. This leads us to another role a warehouse performs, which is the role of the consolidation center, bringing together several product lines which customers would rather have delivered together than separate (Richards, 2018). Warehouses also perform as distribution centers, which can be defined as specialized buildings stocked with products which are to be distributed to retailers, costumers etc. (Supply & Demand Chain Executive, 2008).

Another vital role a warehouse performs is to serve as a trans-shipment point, basically used for serving outlying regions of a country. Small warehouses are used for sortation into small vehicle loads, which are then ready for delivery (Ballou, 2014).

Finally, the role of the returned goods center is vital to reverse logistics operations and processes, handling returned goods in an efficient and environment-friendly way. Reverse logistics have been of a continuously increasing importance due to the rise of e-commerce, along with a drive for environmental legislation (Bentz, 2015), in which product lines, single products or a batch of goods sometimes are retrieved from a point within the supply chain as damaged, expired, or to be re-manufactured (Rosier and Janzen, 2008).

2.3.2 Warehouse Operations

For a warehouse to perform efficiently, nine principles should be followed (Malindretos, 2015):

1- Automation
2- Customer Service
3- Ergonomics
4- Flexibility
5- Identification of Demand
6- Space Utilization
7- Systems Control

8- Unit Load
9- Work Productivity

Typical functions, seen among manual and automated warehouses are as follows:

1- Receiving: Incoming transported goods are received and identified, with the support of an information system.
2- Put-Away: Goods are then transferred to pre-defined, or not, reserve storage areas, which normally hold the largest amount of inventory.
3- Order Picking: The process of extracting goods from picking slots.
4- Sorting: When multiple orders are received, it is beneficiary to pick them all at once and have them sorted out later, before dispatching.
5- Packing: Goods need to be assembled or packed together after picking. This process may involve added value services, such as kitting and labelling (Malindretos, 2015).
6- Dispatching: Goods are marshalled together to form vehicle loads which are then loaded to outbound vehicles in order to move onto the next node in the supply chain (Rushton et al., 2014).

Figure 2.2 The functions listed above sorted by chronology (Rightwarehouse.com, 2018).

2.3.3 Receiving and Storing

Warehouse operations can be paralleled to a chain. This means that if all subsequent activities are successful, then processes are carried out more efficiently. Receiving processes is the first piece of that chain of processes and should be carefully planned out, as several tasks need to be done with precision and agility (Ballou, 2014). The prime objective of a correctly designed receiving process is to proceed to the put-away process with minimum effort and time spent, which is why logistics companies are so keen on constantly innovating and optimizing their practices and methods.

Upon unloading, goods are checked for their condition (e.g. temperature), quantity and quality. Poor quality (e.g. for loose packages) is dealt with by re-palletizing. A common method used is the transmitting of an advance shipping notice (ASN) by electronic data interchange (EDI) in order to be linked to the corresponding purchase order. The goods are then cross-checked against the ASN for that vehicle (Rushton et al., 2014). It should be noted that most warehouses book incoming vehicle loads in advance in order to support the correct allocation of resources to the activity and optimize receiving processes.

Storing is the next step after goods have been received and sorted. Unit loads must be checked before put-away (e.g. Palletized products are weighed, and dimension checked) to exclude pallets that don't fill the requirements and send them for manual rectification (Rushton et al., 2014).

2.3.4 Replenishment and Order Picking

The process that succeeds receiving and put-away processes is the replenishment of the picking face. This process's effect on accuracy and efficiency is of great importance, as an order depends on the replenishment of the picking slots for the operations to proceed as they would (Rushton et al., 2014). Should the replenishment process not occur, the order requiring the stock keeping unit (SKU) cannot be completed (Rushton et al., 2014). Various methods of checking the quantities left can be used for replenishment to take place, although defining an exact amount of quantity of goods left as a trigger point increases the risk of either replenishing too soon, or too late. That is the kind of situation in which a real-time computer system aids in replenishing at the right time with the right amount of quantity.

Storage is followed by order picking, a key warehouse operation that accounts for about 55% of the labor costs (Aalhysterforklifts.com.au., 2013). Its main objective is the extraction of specific goods from inventory to form a shipment with three key principles in mind: accuracy, good or higher quality and punctuality (Rushton et al., 2014). In very specific cases (e.g. an order of pallet quantities), the goods are directly pulled from the reserve storage areas and moved directly to the marshalling area.

In terms of what percentage each operation is still manual, order picking comes first by far, as it has the higher percentage of manual effort out of all the warehouse operations. That is why many technological advancements have been centered around aiding in the order picking processes, such as voice-picking and light-picking, technologies which are utilized alongside a warehouse management system and other information systems in an attempt to boost productivity and accuracy.

Picking productivity is mostly relying on four main factors (Rushton et al., 2014):

1- Information Technology
    a. -Information Systems in the Warehouse
    b. -Technological Aids such as Voice Picking or RF-scanner
2- Equipment
    a. -Type of Trucks
    b. -Whether there is Ground-Level or high-Level Picking
    c. -Category of Picking Process (e.g. picker-to-goods or goods-to-picker).
3- Management
    a. -Replenishment and Storage
    b. -Industrial Relations

c. -Workload Balance
d. -Leadership

4- Operational Requirements
a. -Scale of Operation
b. -Size of Items
c. -Product Range
d. -Specific Requirements (e.g. barcodes)
e. -Items per Order

Various picking methodologies have been applied through the years, each being suitable for specific order requirements such as size, volume and product characteristics (Ballou, 2014). Discrete order picking is the most common for its simplicity mostly, where the picker pulls one order, one line at a time. Orders are not scheduled and may be picked anytime during a shift on a particular day. Although simple and easy to understand, this method has a serious disadvantage when it comes to travel time, deeming it inefficient in most cases (Wheeler, 2018).

Zone picking is a methodology in which the warehouse is split in zones, where order pickers are dedicated to their respective zone. Typically, a warehouse management system (WMS) examines each order line and identifies where the picking the face for that specific SKU is located (Rushton et al., 2014). A serious disadvantage of this method is the possibility of one zone being overwhelmed with a great amount of orders received, which creates work imbalances among the different zones (Rushton et al., 2014).

Close control management of warehouse operations such as marshalling is enabled by the wave picking method (Myerson, 2015). Wave picking is very similar to discrete picking in that one picker picks one order, one SKU at a time. The main difference between the two is the scheduling window. In wave picking, orders may be scheduled to be picked at specific times of the day, which is usually done to coordinate and maximize the picking and shipping operations.

Batch picking is when the picker picks multiple orders at the same time, one SKU at a time. The advantage in the method is the fact that when multiple orders include the same SKU, the picker only needs to travel to the location of that specific SKU once. This results in a boost in productivity and efficiency (Myerson, 2015).

Cluster picking is a methodology of picking into multiple order containers at a time. The containers could be either totes containing order batches, discrete order shippers, or discrete order totes (Myerson, 2015).

Combinations of the different methodologies such as zone-batch picking and zone-batch-wave picking are less commonly used. Following is a table which summarizes the eight most commonly used picking methodologies.

Table 2.1 A summary of the picking methodologies seen in this chapter (Rushton et al., 2014).

Picking Methodologies			
	Picking Characteristics		
Picking Strategy	**Pickers per Order**	**Lines per Pick**	**Periods per Shift**
Discrete Picking	One	One	One
Batch Picking	One	Multiple	One
Zone Picking	Multiple	One	One
Wave Picking	One	One	Multiple
Cluster Picking	One	One	One
Zone-Batch	Multiple	Multiple	One
Zone-Wave	Multiple	One	Multiple
Zone-Batch-Wave	Multiple	Multiple	Multiple

Order picking equipment, suitable for the methodologies above, can be classified under three main categories, which are picker-to-goods, goods-to-picker and automated systems.

Picker to goods has the picker travel to the goods in order to pick them. Three factors come into play here (Rushton et al., 2014):

1- Storage Equipment (e.g. shelves, flow racks or push back racks)
2- Equipment the picker picks to (e.g. trolleys)
3- Equipment the picker picks on to (e.g. wooden pallet)

For ground-level picking, trolleys and roll-cage[1] pallets are usually utilized and, although manual in nature, tend to achieve high pick rates under the appropriate circumstances. Higher level picking is achieved through the use of free-path high-level picking trucks, which with the use of an elevating cab position, lift the picker to the ideal height for picking (Rushton et al., 2014). The disadvantage of high-level picking is that they achieve lower picking rates when compared to ground-level picking effectiveness. An upgrade to free-path high-level picking trucks are the fixed-path trucks, which run on a bottom rail and are guided by a top rail, thus allowing for faster processes. Pick cars are one step ahead, essentially being special fixed-path high-level picking trucks that straddles a horizontal conveyor[2] running the length of the aisle (Rushton et al., 2014).

Picker to goods is the standard working concept, but costs a lot of time and resources, which means that a significant reduction of time and money spent could potentially lead to greater efficiency and profit.

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[1] A trolley, or a pick-cart, usually has a shelf or shelves upon which the picker places the goods. Roll-cage pallets are normally taller and have wire mesh on three sides with an optional mesh door on the fourth side. Low-level order picking trucks (LLOPs) are electrically powered trucks usually used for picking from ground floor pallet locations (Rushton et al., 2014).

[2] A conveyor is a mechanical system that aids workers in goods handling, moving them from location to location. It is ideal for the handling of heavy/large items.

Moving goods to picker is a picking methodology that allows for greater efficiency because it enables automation and warehouse control systems to be fully utilized. Goods to picker systems are always best approached holistically, with process driving equipment selection or automation, not the other way around (Stone, 2015).

These solutions rarely work for every area of a facility, or for every SKU in the distribution center. It's all about blending the right solutions. Automated systems have proved to be a catalyst for logistics companies, as it greatly increases potential productivity, efficiency and accuracy in warehouse operations (Rushton et al., 2014).

Carousels include a range of types including horizontal, vertical, and vertical lift modules. They can be tied into enterprise resource planning (ERP) systems, WMS and warehouse control systems whether the carousel is in a large integrated system or a point of automation within a larger operation. They are usually deployed for component or item level picking. Manual picking can't match carousels for speed (about 600 lines per hour), but they come at a cost, as they are expensive, but less costly than comparable automation. They are best paired with voice or light directed picking systems (Stone, 2014).

An automated storage and retrieval system (AS/AR) tie the entire facility together, usually connected to an ERP system or a WMS, with a big range of capabilities like tying into conveyor systems and the control of sorting transfer and automated guiding vehicles (Voortman, 2004).

In the last decade or so, the industry has been changed by the proliferation of goods-to-picker robots such as Kiva Systems or automated sorters like A-frame Sorter. These systems tend to deliver storage units along complex paths, to stationary pickers (Stone, 2015). They usually operate without human intervention.

The systems reviewed above are typically equipped with technological supporting technologies. New order picking technological aids have been introduced since the third industrial revolution. Paperless picking is making things easy in terms of labor work and cost and comes without the increased possibility of errors due to the lack of paper. The cheapest solution, as seen in Table 2.2, is the Ring/Finger scanner, a gadget that can be used in conjunction with a smartphone or a terminal, offering completely hands-free capabilities. RF systems eliminate the data entry and all paper-handling tasks (Lucasware.com, 2018). Pick by light is a picker-to-goods technological aid that leads the picker with the use of led panels mounted on the shelves, displaying the exact quantity that needs to be picked. Pick by voice technology is using voice recognition, allowing the pickers to communicate with the WMS and as a result get all the details they need with the use of a microphone and earphones (Zeimpekis, 2018). A portable terminal which is always connected to the WMS through a W-LAN is necessary for pick-by-voice technology to be utilized. However, since scanning may add an additional verification step in every task, some warehouses actually lose in productivity when moving from paper-based picking to a scan-based process, especially among top performing pickers (Lucasware.com, 2018).

Table 2.2 A comparative table for Voice, Light and RF scanner picking technologies currently used (bcpsoftware.com, 2018).

	Voice Picking	**Light Picking**	**RF Scanner**
Accuracy	Very High	High	High
Productivity gained over paper-based picking	25%	40%	15%
Replenishment	YES	NO	YES
Stock count	YES	NO	YES
Heavy or Large items picking	YES	NO	NO
Dealing with frozen products	YES	YES	NO
Cost	Medium	High	Low

2.3.5 Packing

After order picking is completed, goods are packed and added-value services like labelling, kitting and assembly take place. Goods are picked simultaneously and then get sorted, in order to bring them together for packing (e.g. Items picked are conveyed to a sorter that brings various goods together for a specific order and then conveyed to an individual packing station) (Saghir, 2004).

Packing stations are specifically designed to boost the worker's efficiency, due to packing taking a lot of time to be completed. The table on which the work is done is adjusted to the appropriate ergonomics, while mechanical equipment, like conveyors, and computer systems provide details through a monitor aid in the process (Rushton et al., 2014). Automated equipment, usually integrated into the conveyors, such as labelers, sealers and closing machines are enabling immediate follow-up processes like sealing and labelling. Another technological aid which helps lower transport costs, is the specialist packing machines. These machines construct cartons to perfectly fit different customer orders. When packing is done, goods are sent to yet another sorter in order to sort postcodes, carriers, regions or vehicle loads (WERC, 2007).

2.3.6 Dispatching

What follows is the dispatching of the goods, which have been placed in or onto unit loads. This is an operation that can be completed with a manual, or an automated way. Goods are moved to the marshalling areas which are allocated based on the outgoing vehicle schedule (Rushton et al., 2014).

Vehicles mostly leave at the same time of day, according to the schedule, which means that loading is an activity that needs to be completed with speed, reliability and accuracy. Pre-loading drop trailers and swap bodies help workers catch up with less hurry, resulting in a smaller possibility of errors to occur (Malindretos, 2015). Another quite important factor to take under consideration is coordination, where good coordination results in better area usage, so that the load doesn't take up extra marshalling space.

Equipment necessary for dispatch processes to proceed range from boom conveyors to automated loading systems. Below is a list of handling equipment (Malindretos, 2015):

1- A boom conveyor, which extends into the vehicle or the container, where warehouse staff is tasked with lifting the goods off the conveyor.
2- Pallet trucks, which are best utilized for rear loading.
3- Fork-lift trucks ideally used for side unloading (e.g. curtain-sided vehicles).
4- Automated loading and unloading systems that can load and unload all pallets on the vehicle at the same time.
5- Automated tote bin loaders are only applicable when goods are dispatched in tote bins (e.g. A telecommunications company being supplied with smartphone accessories).

Loading bays equipment usually used (Loading Bay Equipment, 2018):

1- Dock levelers are permanently fitted at each bay, forming a minor inclination slope to match the height of each vehicle. Dock levelers need to be as long as the biggest vehicle expected to arrive at any given time.
2- Doors retracted above the opening when in use and normally fitted with windows so that they enable workers to see if there is a vehicle in the bay or not.
3- Dock shelters and seals offer weather protection in order to prevent any goods damaging, like getting full of dust or wet, depending on the situation.
4- Bumpers are almost always used to minimize the shock load to the building structure when a vehicle reverses up to the bay.
5- Lights are commonly used to give the driver indications as to the readiness of a vehicle to drive away, which results in a reduction of accidents, and provide illumination at night.
6- Vehicle restraints are used to restrain the wheels of a vehicle until it is safe to drive away.
7- Bollards are used to assist the driver in parking as centrally in the bay as possible.

The warehouse's layout plays a huge part in how successful receiving and dispatching processes are. Parameters that need to be taken into account are all external areas within the perimeter fence, such as vehicle roadways, parking areas and ancillary areas (Zeimpekis, 2018). There are three possible ways the loading/unloading bays can be laid out (Ballou, 2014):

1- A through flow can allow for better flow of goods within the warehouse, with goods sequentially moved from receiving to storage, then to picking, then to sortation, packing and dispatch. A through flow is commonly used when the number of bays is too great to fit on one side. It's best suitable for live storage[3] racking.

2- U-flow is ideal for cross-docking and drive-in racking[4], as it minimizes the distance goods need to travel. This major advantage U-flow of goods is best seen in an inventory-holding warehouse where receiving and dispatching happens at different times of the day.
3- Finally, the L-flow allows for receiving and dispatching areas to be forming an L-shape layout among them, suitable mostly for back to back[5] and very narrow aisle (VNA) racking[6].

Vehicle bays must be designed in a way that facilitates loading and unloading, so that they can optimize warehouse receiving and dispatching processes. When a vehicle bay is level intake, it enables better unloading for side-unloading vehicles. This process may take place inside the building, with a precaution for fumes and rising temperature, or outside (e.g. under a canopy). Another design that is commonly seen is the raised dock. With it, the floor is at the same level as the bed of the vehicle, allowing for direct access of a truck (e.g. a lift truck) (Rushton et al., 2014). This design is suitable for end-unloading, while a minor adjustment to the degrees between raised docks and the building is needed to enable side-unloading too. Receiving and dispatching areas in total, need to be designed in a way that it perfectly communicates with both suppliers and customers, as it represents a direct physical interface.

2.3.7 Warehouse Management System

Managing large warehouses with a very complex network of activities and processes is quite challenging. Information technology's role throughout the supply chain has proved to be one of the most important ones and its involvement in warehouse management is as crucial nowadays as ever. All different processes and tasks completed day-in and day-out are becoming more challenging as years pass, and information systems in the warehouse are able to fully support warehouse operations, enabling workers to complete tasks and activities with greater efficiency.

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[3] In live storage racking goods are handled according to the FiFo principle (First in-First out). The goods are loaded into the rack on one side and unloaded at the other side. This provides a very satisfactory flow of goods (e.g. for handling goods with a limited storage life). The live storage racking is fitted with brake rollers at regular intervals so that goods can be safely transported (Eab.info, 2018).

[4] This system is based on the storage by accumulation principle, which enables the highest use of available space in terms of both area and height. Drive-in racking is designed for the storage of homogenous products. It accommodates a large number of pallets for each SKU (Mecalux.com, 2018).

[5] Back-back Racking Systems are built by putting two modules back-to-back and interconnecting them together. Each pallet can easily be placed and transported independently. It allows operating a forklift. Bay height and beam length adjusted Back-to-Back Racking System's satisfy customer's need and expectations, which has the widest range of use from the smallest warehouses to the largest up to complex logistics centers (Temesist® Endüstriyel Depo Ve Raf Sistemleri, 2018).

[6] Very Narrow Aisle racking commonly referred to as VNA is an effective method of increasing pallet storage with in a given area with the advantages of selective racking. This system requires a special fork lift which reduces the aisle space by a minimum of 40% compared to traditional fork lifts. This system still provides 100 % product selectivity and utilizes the vertical space for pallet storage (Konstant.com, 2018).

A WMS interfaces with the company's ERP or legacy system in order to access valuable information, such as purchase orders, thus increasing the efficiency of warehouse operations, by storing all kinds of information (e.g. goods received or dispatched) and giving access to warehouse staff at any given time (Rushton et al., 2014). Another capability of the system is to give instructions to subsidiary systems like voice picking equipment or an AS/AR control system (Malindretos, 2015).

Figure 2.3 WMS adds the element of automation to warehouse operations, thus increasing productivity and efficiency (Schmidthk.com, 2018).

Warehouse management systems have a wide range of functionality with the added benefit of enabling users to turn on or off for specific applications (e.g. In electronics, batch traceability of components is providing workers valuable information). Warehouse activities are covered by WMS's capabilities and functionality as shown in the examples below (Rushton et al., 2014):

1- Receiving: Advanced shipping notes (ASNs), quality sampling, dimension and weight checking
2- Put-away: Best storage location algorithms
3- Replenishment: Trigger points, order-based replenishment
4- Picking: Picking route optimization
5- Added value services: Kitting, labelling, assembling
6- Packing: Correct carton size identification
7- Cross-docking: Planning, labelling
8- Sortation: Grouped by order, vehicle, geographic destination
9- Dispatching: Marshalling lane control, documentation, ASNs transmitting
10- Stock counting: Full count

Data capturing is another quite important factor for greater efficiency in warehouse operations and bar codes are the most common way of doing that. A bar comprises of a number of vertical or horizontal bars of varying thickness and each combination of bars represents a number or a letter. These codes are specifically designed, so that the first few bars indicate the symbology, a term commonly used among organizations for various purposes (Ballou, 2014). The next few bars indicate the national coding authority, the manufacturer, the product number and finally a check digit. Scanners are used to read bar codes for direct input of information in computer systems. Common applications of bar codes are bar code checking when picking and reading labels when sorting.

Radio frequency identification (RFID) is seeing a growth in popularity, despite being available for decades. Its main purpose is the identification of items with the use of radio waves (Rushton et al., 2014). Some common applications for RFID are the tracking of unit loads, and other item level purposes. The four components of an RFID system are:

1- Tags affixed to the goods or containers, comprised of the combination of microchips and an antenna with a battery most of the times.
2- Antennas receives the data from the tag.
3- Readers read the data transmitted by the antenna.
4- Host stations contain the application software and relays the data to the server.

Without information technology in the warehouse, logistics and supply chain management would not have evolved at all. In order to have an uninterrupted flow of goods, data capturing and processing play a vital role.

2.4 Transportation

Transportation is the next step in supply chain operations and one of the main reasons for civilization evolution and commerce growth through the years, as the transportation of goods isn't just a service to be taken lightly. Many different processes and activities need to be perfectly coordinated in order for transportation to be successful.

2.4.1 Transport Modes

There are 5 transport modes currently used for freight transportation:

- Maritime Transportation
- Air Transportation
- Pipeline Transportation
- Rail Transportation
- Road Transportation

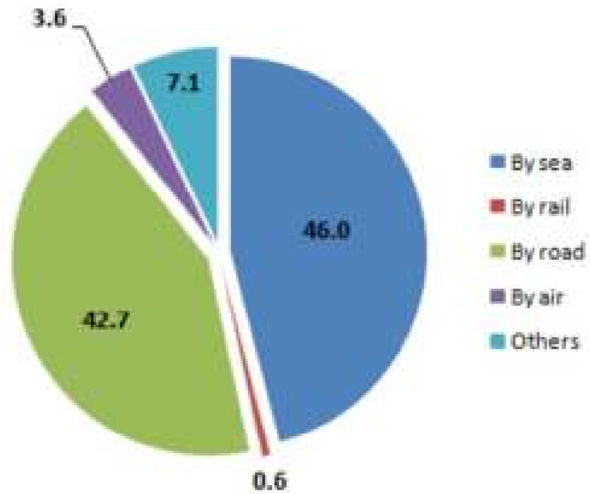

Figure 2.4 Freight transport mode of choice by percentage worldwide (SAFETY4SEA., 2018).

1- Sea-freight has been around for thousands of years and is the oldest mode of transportation, while still retaining the number one spot for the mode of choice internationally. In this mode of transport both the conventional load and the unit load (container) are relevant. Sea-freight has its advantages, but they come along with some disadvantages that other transport modes have resolved, as listed below (Rushton et al., 2014):
   a. Cost. Sea-freight is the cheapest way of transporting goods, as cargo ships can carry quite large packaged consignments that are going long distances.
   b. Availability. Services are widely available.
   c. Speed. Maritime transport is the slowest mode of freight transport.
   d. Delay problems. Unexpected delays due to bad weather, pre-shipment delays and delays at discharge ports are the three major delay factors to be seen.
   e. Damage. This mode is more prone to damage for products and packaging.
2- Pipeline transportation is the mode of choice when it comes to oil and gas transportation as 70% of domestically produced petroleum products in the U.S. are transported by pipeline (Hansen and Dursteler, 2017). Pipelines are large projects and have high upfront costs while it can also take significant time to obtain necessary permits. Even after construction is completed, pipelines can be costly to maintain (Smith and Christopher, 2014). The characteristics of pipeline transportation are as follows:
   a. Cost. Quite costly.
   b. Availability. Services not widely available.
   c. Speed. One of its strongest points.
   d. Delay problems. Usually none.
   e. Damage. Pipeline transportation is the safest transport mode.

3- Air freight has grown rapidly in recent years. Improved handling systems, greater cargo space, integrated unit loads, and scheduling have skyrocketed air freight as the mode of choice. Still, its high costs have kept it low at 3.6% when compared to sea-freight's 46.0%, as seen in figure 2.3 (SAFETY4SEA, 2018). A list of the characteristics of air freight can be seen below:
   a. Cost. The most expensive mode of transport and air freight's greatest disadvantage.
   b. Availability. Air freighting of products allows for great market flexibility as any number of countries and markets can be easily reached.
   c. Speed. Air transport is the quickest mode of transport, but that advantage can be lost due to delays. Ideal for short-life products and emergency supplies.
   d. Delay Problems. Airport congestion, paperwork delays, customs delays and bad weather (e.g. fog) can be delay factors.
   e. Damage. Over the years air-freight has grown into one of the safest modes of transport.
4- Rail transport is the most conventional form of transport. International trade trains cross Europe at relatively low speeds, while having the advantages of safety and being a non-polluting means of transport. The railway infrastructure covers a large part of the European union (EU) and that is why the EU did take an important initiative in March 2003, enabling private operators to exploit the existing infrastructure and to compete with state-owned railway companies for freight services transport (Malindretos, 2015). Its characteristics are listed below:
   a. Cost. Costs are relatively high due to the need for more than one transport mode.
   b. Availability. One of its greatest disadvantages due to lower flexibility of its itinerary.
   c. Speed. Quite slow, but relatively faster than sea-freight.
   d. Delay problems. One of its strongest advantages, because of very low chances of a scheduling department getting delayed.
   e. Damage. A safe transport mode.
5- 42.7% of freight transport happens via road freight transportation (SAFETY4SEA, 2018). One of the most important transport modes for national movements within individual countries. Road freight is always the mediator when it comes to intermodal transport due to its flexibility and adaptability to land transportation and a fully-grown road network. Roll-on roll-off services (RORO) enable road freight in the UK for example (Rushton et al., 2014). Its characteristics are as follows:
   a. Cost. Low costs with a caution for fuel management and empty-body movement.
   b. Availability. As previously stated, road transport is the mode of choice when it comes to nationwide freight transportation, but it shows its limitations when it comes to international freight transportation, where it needs to be combined with one or more different modes.
   c. Speed. This variable is quite complex to determine, as the factors having a role in road freight's speed of transportation are numerous.

d. Delay problems. With the use of fleet management systems which will be examined later in the chapter, and routing algorithms, drivers can now avoid delay problems created (e.g. road congestion).
e. Damage. Another variable that can clearly be said to have been dealt with due to more efficient packaging processes.

Below is a comparative table of the transport modes (excluding Pipeline transport):

Table 2.3 Comparing modes of transport across four crucial variables.

	Road	**Rail**	**Air**	**Sea**
Cost	Low	Medium	High	Low
Security	Medium	High	High	Medium
Availability	High	High	High	High
Type of Cargo	All	Heavy and Large loads	Small to medium loads, Emergency Supplies	All but more suitable for heavy and large loads

2.4.2 Line Haul Transportation

Line haul transportation is the transportation of goods from one location to the next, which typically happens via semi-trailer trucks or rail cars. There is a great variety of line haul vehicle types, as seen below, depending on the cargo (wewilltransportit.com, 2015):

1- Refrigerated Freight – Used for moving goods that need to be refrigerated.
2- General Freight – A basic container used to ship anything.
3- Livestock Hauler – Used to transport live animals from one location to another with safety.
4- Grain Hauler – Grain haulers are used to transport grain from a farm to a processing facility.
5- Tankers – Used to transport anything in liquid or gas form.
6- Doubles – A semi-trailer truck hauling two freight containers.
7- Triples – A semi-trailer truck hauling three freight containers.
8- Turnpike Duty or Double – Another method of pulling two containers with a single semi-trailer truck.
9- Bulk Hauler – Used to transport milk or smaller dry foodstuffs in bulk.
10- Auto Hauler – A carrier used to transport multiple automobiles.
11- Flat-bed – A flat shipping surface use to ship cargo that cannot fit in a container.

In order for line-haul transportation and transportation in general to be performed successfully, end-to-end visibility is to be considered as one of the most crucial factors for monitoring transportation and distribution. Monitoring shipments enables visibility through the supply chain and the only way this was happening through the years was due to data capturing from multiple systems and sectors of the supply chain (Savi, 2013). As a result, companies were unable to monitor and control costs relative to inventory, manufacturing, transportation etc.

Monitoring the location and the movement of containers is the way to obtain visibility into each distinct logistics process (Savi, 2013). Three areas benefitting from container management are inventory, replenishment and cost monitoring. Companies carry inventory in the form of raw materials, work-in-progress (WIP) and finished goods (Rushton et al., 2014). With real-time visibility into the location and condition of the containers, as well as the inventory they hold, companies can achieve greater confidence in supplier delivery schedules, inventory consumption and finished goods production schedules. (Ballou, 2014).

Another benefit of end-to-end supply chain visibility is in the management and control of the reusable containers themselves. Let's use an automotive manufacturing company as an example. Manufacturers use specialty racks for shipping automotive parts. Not only are these racks expensive, but they are also essential for moving parts and finished goods (Savi, 2013). If the right container is not available at the right location at the right time, it can lead to expensive last-minute transportation (relocation) costs and in extreme circumstances, not having these specialty racks available can even stop the assembly line (Savi, 2013).

Unfortunately, these assets are also prone to misuse and loss. Some industry estimates state that between 15-20% of the total container stock is stolen and/or lost each year (Savi, 2013). With better visibility of the container stock and their locations, companies can better utilize these assets through faster relocation and fulfillment. This improved asset utilization will help companies optimize their processes, meaning fewer total assets are required to maintain and run their operations (Antich, 2013).

2.4.3 City Logistics/Last Mile Delivery

The interest in transportation and distribution services in non-urban areas is a given, but an increase in these services in urban areas has been declared in the last decades due to a massive shift towards urbanization (Taniguchi, 2012). City logistics is a term first defined by Taniguchi in 1999, as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy".

The transport mode of choice in urban areas and cities is dominantly road freight, while other alternative methods have been utilized through the years, such as rail, underground systems and rivers (Tadic et al., 2015). The issues and challenges here are many and there has been an impressive amount of research and development in the city logistics area of research. Environmental awareness and road congestion have been the most difficult obstacles to overcome (Cardenas Barbosa, 2017).

Facility location for example, is a crucial factor, as many different variables depend on it (e.g. distance to be covered and accessibility) (Savelsbergh and Woensel, 2016). The better the network, the better the performance, meaning better distribution and delivery times, reduced carbon footprint and smaller probability for road congestions (Cardenas Barbosa, 2017).

The intra-city transport of goods is performed with the use of lighter and smaller vehicles in order to reduce the carbon footprint and increase agility within the city structures, while bigger and heavier vehicles are used outside the city limits (Visser and Binsberger, 2018). Distribution centers strategically located around the city enable for this method of transportation to be utilized. The larger vehicles arrive at the distribution centers, goods are then marshalled and sorted, with the next step being loading them in the smaller vehicles in order to distribute the goods within the city (Trebilcock, 2015).

Last-Mile Delivery is the final step in city logistics. It is a term derived from "last mile", which is borrowed from telecommunications network, and delivery, the act of delivering something (e.g. goods, letters etc.). The importance of the term comes from the multi-hub-and-spoke networks topology which can be compared to the structure of a tree (Faccio and Gamberi, 2015). As the network advances to the final customer, it becomes more populated and inefficiencies are easier to occur. There are indications that as much as 28% of the transport costs can be related to the last mile delivery or first mile pickup (Cardenas Barbosa, 2017). As a result, we define last mile delivery as the final leg of transporting the goods to the point of consuming.

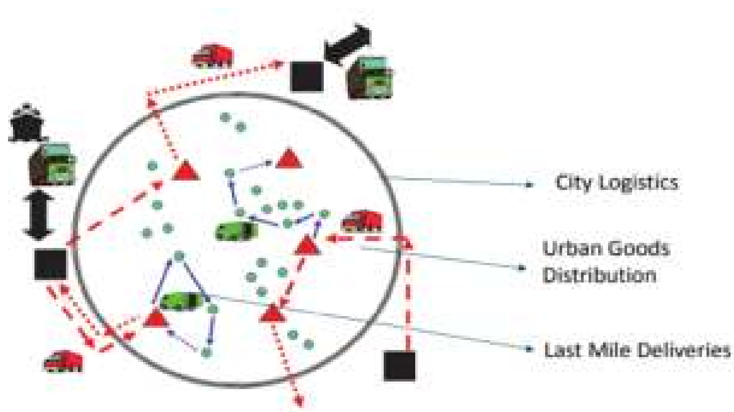

Figure 2.5 A geographical view of urban logistics, comprised of city logistics, urban goods distribution and last mile delivery (Malindretos, 2015).

As previously stated, research and development on city logistics and urban distribution is continuously getting traction. Fleet management systems currently used for these operations enable better distribution and delivery, not just for urban areas, but also for inter-urban and international transportation.

2.4.4 Fleet Management

Fleet management is the function that coordinates and facilitates various transport related activities with the aim of reducing operational costs through the management of assets used in each of the transport modes (White, 2015):

1- Ships
2- Aircrafts

3- Vehicles for work purposes
4- Rail Cars
5- Commercial Motor Vehicles

Through the years fleet management information systems have been developed in order to enable managers to efficiently monitor, control and administer transport operations. Specialized database packages have also been developed with the goal of optimizing fleet management processes and related activities (Rushton et al., 2014). Functions that depend on those databases and extract information from the data are:

1- Maintenance Scheduling. Monitoring the condition of mechanical parts of a vehicle, managing its carbon footprint, scheduling repairs and maintenance checks based on service history and analyzing costs based on maintenance or repair routines (Rushton et al., 2014).
2- Vehicle Parts Control. Enabling the oversight of stock quantity for various spare parts requirements, including the stock location and stock reports.
3- Fleet Administration. This function is always included in packages in order to ensure the legality and worthiness of vehicles (White, 2015).
4- Fleet Costing. A function that provides information related to fleet and vehicle costs.
5- Tachographs. These are used for monitoring the driver's hours of driving and resting, the distances travelled by individual vehicles, speed ranges throughout travels and fuel consumption (Guide to Digital Tachographs, 2006).

Digital tachographs are fitted on goods vehicles that are subject to tachograph rules and have been brought into service since 1 May 2006. It is a digital version of the analogue tachograph system. The digital system records information on a range of vehicle and driver activities. Data is stored in the vehicle unit memory and on driver cards (Guide to Digital Tachographs, 2006). Information extracted are used to produce key performance indicators (KPIs) for the vehicle fleet (e.g. tonnes per mile, fuel costs, miles/kilometers per gallon etc.).

Another way of monitoring and controlling fleets is through telematics, which can be defined as the combination of telecommunications systems and information technology. A very well-known application of telematics is the global positioning system (GPS), which aids in navigation of commercial vehicles while also boosting security due to enabling administrators to know the exact location of the vehicle (Rushton et al., 2014). Instructions may be given to remote assets regarding the vehicle's temperature, fuel consumption and parts performance, thus allowing drivers to avoid damages and reduce vehicle emissions as well as improving efficiency (The Ultimate Guide to Fleet Telematics, 2018).

2.4.5 Routing and Scheduling

Vehicle routing and scheduling are fleet management capabilities, which have been a topic worth of research and discussion. Through the years a huge number of algorithms have been developed to offer solutions but the number of parameters one must consider are far too great in number.

Usual routing and scheduling problems are:

1- Resource Planning. Refers to requirements regarding the transport fleet.
2- "What if" Planning. Identification and measurement of the effects of change on logistics operations (Rushton et al., 2014).
3- Planning fixed-route Schedules. Involves the longer-term aspects of routing and scheduling for regular deliveries of products (e.g. retail delivery operations and milk delivery) (Rushton et al., 2014).

Various methods are used for routing and scheduling problems, depending on the nature and complexity of each individual problem. Such methods include algorithms used to optimize transport operations by providing smallest-distance solutions for cost efficiency and maximum profits.

In order for said algorithms and information systems to be able to provide the best possible solutions for routing and scheduling problems, data have to be extracted from multiple areas such as distance factors, driver constraints, vehicle restriction, route factors, average speed on a variety of roads, unit loads and demand data (Rushton et al., 2014).

2.4.6 Information Systems in Freight Transportation

As previously stated, fleet management information systems assist managers in monitoring, controlling and administering vehicle fleets effectively. Other information systems and applications utilized for freight transportation are:

1- International Trade Management Systems. Specialist software packages available to control the international movement of goods, including features to assist with documentation requirements, finance and monitoring of progress (Ballou, 2014).
2- Supply Chain Event Management Systems. Systems monitoring the progress of orders and warning managers for possible potential issues (Rushton et al., 2014).
3- Electronic Point of Sale (EPOS). A common application used in retail stores around the world, used to facilitate easier payment processes (Rushton et al., 2014). Goods marked with bar codes are scanned and then the system tallies the price and records the transaction.
4- Proof of Delivery (POD). It is an essential component of the delivery process as it serves as an important acknowledgement to mark that the delivery has been completed (CarPal Fleet, 2018). By using the POD feature, not only do companies have the assurance that packages were successfully delivered, but also track the progress of the delivery. This aids companies in identifying potential issues before they become major liabilities (CarPal Fleet, 2018). Recipients must sign for receipt of the mail indicating the date when the mail item was delivered to them. A copy of the Proof of Delivery receipt is provided to the sender.

2.5 Reverse Logistics

Up until now we have seen current logistics operations and information systems utilized regarding forward logistics, meaning the transportation of goods from the point of origin to the consumer. Reverse logistics refers to the process of planning, implementing and controlling flows of raw materials, work-in-progress and final products from a manufacturing, consuming or distribution point, to the point of recovery or disposal (Rosier and Janzen, 2008). The different categories of returns are (Malindretos, 2015):

1- Commercial Returns. Returns for which there is an immediate demand at another market location or segment (e.g. customer dissatisfaction, catalogue sales, and overstocks etc.).
2- Repairable Returns. Defects and suspect components from field repair activities or products under warranty. Customer is usually entitled to a replacement product.
3- End-of-use Returns. Returned products/components which are no longer of use to the original owner, but for which new customers can be found.
4- End-of-life Returns. Items of no remaining use, which are processed due to contractual or legislative obligations.
5- Recalls. Products recalled by the manufacturer due to a condition or defect that could affect its safe operation.

2.5.1 Reverse Logistics Process

Returned goods go through the following activities based on the return type (Rosier and Janzen, 2008):

1- Product is retrieved from the market. Factors that should be monitored are quality, timing, quantity and composition of the returned goods.
2- Transportation, consolidation, transshipment and storage are examples of processes that need to be followed backwards and transport the goods to the point where the repair or disposal shall take place (Malindretos, 2015). Quality and composition are the two factors that indicate the route the returned goods will take within the supply chain network.
3- The type of recovery will be decided (e.g. re-use, repair, recycling etc.) (Bentz, 2015).
4- The materials, work-in-progress items or goods return into a forward supply chain.

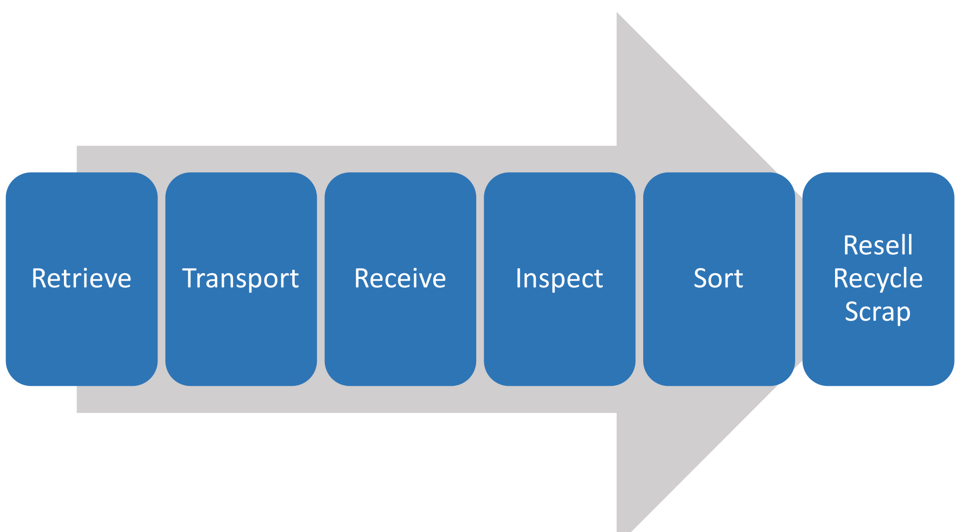

Figure 2.6 The reverse logistics process (Bentz, 2015).

2.5.2 Priorities and Issues

Recently, reasons for the process of re-processing are piling up, which essentially include the actions of recycling, reselling and scrapping (Bentz, 2015). Because of various investigations having shown that various products, such as electrical appliances, are of economic and environmental interest, reprocessing and recycling routes should be followed. The natural priority is to reduce waste. Then the goal is to exhaust all possibilities for reprocessing and re-using, and finally for recycling, as raw material or WIP products in order to re-manufacture the goods and put them back in the forward supply chain (Malindretos, 2015).

Some major issues that have arisen lately are summarized below:

1- The electricity consumed during the recycling process is important. Renewable energy can be a solution for energy spent in the recycling process.
2- The water spent to clean the materials at recycling centers can reach several tons daily.
3- Fuel consumption is required to transport the materials to the Recycling Centers. This issue is a major field of research for Reverse Logistics.

Therefore, the question of recycling should be approached holistically, as the final process of organization management of returned goods, because recycling is not an end-to-end goal.

2.6 Issues and Challenges

The logistics industry has been growing rapidly for quite some time now and technology, while having a high growth rate, has always been an integral part of logistics operations (Scriosteanu and Popescu, 2018). Nowadays various issues and challenges have emerged, that push logistics companies to re-organize how they do business. Issues may be external to logistics, such as deregulation, or derive from changes within logistics, such as the integration of information technology (Rushton et al., 2014). Higher customer demands, the rise of e-commerce, globalization and urbanization, cybersecurity and new business models driven by startups are just some of the issues that need to be addressed. Warehouse and transportation operations reviewed earlier in this chapter, need to be evolved in order to resolve these issues and drive the logistics industry forward.

2.6.1 Higher Customer Demands

Customer service is one of the most important factors in a company's growth and prosperity. Competitive success is greatly influenced by customer satisfaction and companies that fail to recognize that are in danger of being unsuccessful. Service is a factor of differentiation that has proved to be the key to a customer's decision to choose one brand over the other (Rushton et al., 2014). The ability to satisfy customer requirements is a challenge that all companies must face (Rushton et al., 2014). Major factors contributing to the rise of this challenge are listed below:

1- A rapid growth in customer expectations through the years.
2- Buyers recognize the importance of customer service.
3- Markets have become service-sensitive.
4- Immediate product availability has become vital.

5- Customer relationships have become a priority for most companies.

2.6.2 Organizational Structures

For many years logistics was not recognized as a discrete function within organizational structures, resulting in problems surfacing through processes such as distribution and storage. In addition to that, many companies could not re-organize their structure in order to integrate logistics as a discrete function, leading to major problems within (Jan, 2016). Companies and organizations which successfully recognized the logistics sector, did so in a way that was rendering the communication lines unclear (Rushton et al., 2014). This issue resulted in inefficiency and higher operational costs, while proving to be damaging for their reputation.

Incorporating new business models within their business strategies and recognizing the importance of logistics is the first step towards a successful supply chain (Galindo, 2016). The way logistics operations are organized has to be process-oriented and not structure-oriented, with key changes like emphasizing on the customer and the internal processes needed to be optimized in order to achieve customer satisfaction, while a reduction in operational costs will be immediately felt within company walls (Jan, 2016).

2.6.3 Globalization

Logistics will be greatly influenced by a global shift in the economic power of the emerging seven countries over the next years as well as regional changes, especially in Asia-Pacific which has quickly grown to now account for 50% of international trade (Noronha et al., 2016). Key developments worth highlighting are the major investments being made by the Chinese government in trade lanes to Europe.

Logistics will also experience a systemic change in terms of workforce and technology adoption, as it will be challenged by increasing competition as well as a growing shortage of skilled workers. Macroeconomic volatility and shifts in trade patterns will result in the rebalancing of global logistics and trade. In addition, structural changes in terms of workforce demographics and technological innovation will determine the shape and the rate of evolution within logistics (Grapht, 2018).

2.6.4 Startups and Logistics Industry Disruption

Logistics can be confidently said to be the backbone of international trade, but at the same time has been a fragmented industry with a slow adoption rate of new technologies. The underdeveloped market potential along with the potential of harnessing technology advancements makes this industry a target for disruption (Utterback and Acee, 2003). Established companies are often left with legacy IT systems that make globally streamlined IT services quite difficult to achieve.

In summary, whether startups are able to disrupt established industry giants or not, remains to be seen. It has already been felt in some service segments, but logistics providers do not have to take a reactive approach to startups (Noronha et al., 2016). Some are already partnering with startups, while others are acquiring startups or are even breeding their own startups in in-house incubators (Grapht, 2018). Thus, they themselves can drive rapid innovation and disrupt the logistics industry.

2.6.5 The Rise of E-Commerce

E-commerce presents a fundamental shift in how business is done. Instead of the traditional way of companies pushing goods to physical stores, e-commerce allows customers and consumers to customize their baskets according to their needs and have it delivered to their favored destination (Monahan and Hu, 2018). In bottom line, customers need companies to be quick and increase their logistics performance more than ever before, evidenced by the continuous rise of e-commerce, as seen in figure 2.8 (Robinson, 2018). This has created a structural forced change in underlying logistics operations and processes, forcing logistics companies and organizations to consider the integration of technologies that will bring them towards digitalization and automation, such as the Internet of Things and Advanced Robotics, technologies which will be reviewed in a later chapter.

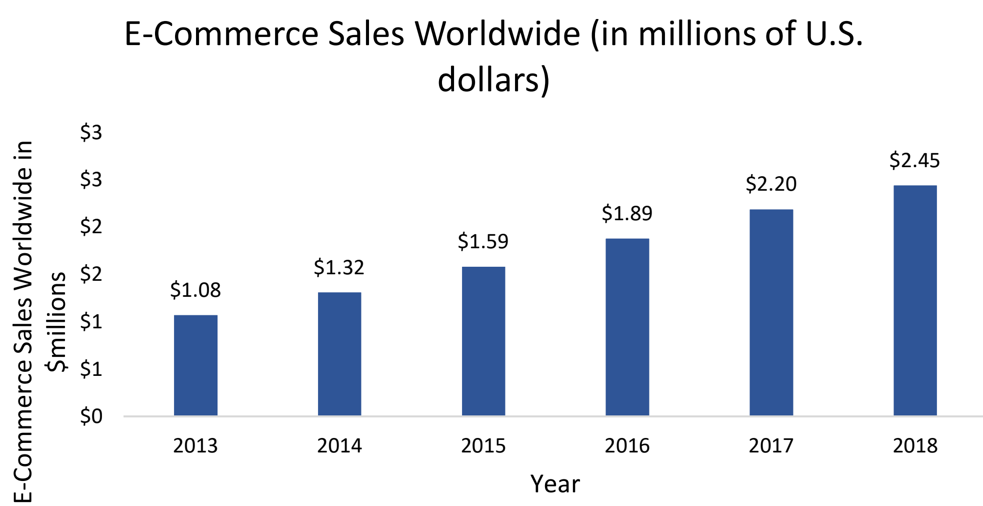

Figure 2.7 Global Retail E-commerce sales growth through the years (Vupune.ac.in., 2018).

2.6.6 Cybersecurity

Another unresolved issue are cyberthreats. High-profile data breaches and hacking of data systems as well as even physical objects (such as cameras and self-driving cars) are a worrying reminder of the continuously growing security vulnerabilities of the digital world (Noronha et al., 2016). In increasingly IT-rich supply chain networks, eliminating security threats and dangers has become a top priority in order to avoid harmful cyber-attacks that could result in entire operations being in a standstill. In parallel, continued global market volatility and regional instability have led to tightened security regulations that require higher levels of supply chain transparency and integrity more than ever (PwC, 2016).

A step towards protecting customer data is the general data protecting regulation (GDPR), which replaced the Data Protection Directive 95/46/EC and was designed to harmonize data privacy laws across Europe, to protect all EU citizens data privacy in order to reshape the way organizations approach data privacy (EU GDPR Portal, 2018).

2.7 Summary

In chapter 2, we delved into how current logistics operations are performed. Logistics operations consist of many processes and activities, all interlinked, resulting in the need for transparency and integrity. Higher customer demands and e-commerce are forcing companies and organizations to rethink their strategies and consider integrating logistics 4.0 technologies in order to be able to cope with the requirements. Cybersecurity has become a trend due to digitalization that is brought forward as the topic of the decade. These issues have brought forward the ever-existing problem of organizations and companies not completely integrating logistics as a discrete function within their structures.

In the next chapter, we will see how industrial revolutions have always driven the industry forward by revising Industry 1.0 through Industry 3.0. Finally, we will examine how Industry 4.0 is signaling the uprising of technologies and practices such as the Internet of Things, Big Data, UAVs etc., technologies that drive the logistics industry towards digitalization and automation.

Chapter 3 Industry 4.0

An industrial revolution can be defined as a series of events and facts that have a significant impact on both the society and the economy, while changing the industrial landscape with a transition to more efficient tools and practices (West, 2017; Deganutti, 2017). Such revolutions have taken place throughout the last four centuries, with the events of Industry 1.0 taking place during the 18^{th} and 19^{th} century. Each of those periods were marked by the widening of the economic scales, the birth of new social classes and the invention of tools and practices that were revolutionizing industries (Mokyr, 1998).

3.1 Background

Now we have reached the period in time where we can talk about a fourth industrial revolution, or Industry 4.0. The events and changes that are bound to arrive will digitalize the industrial world and alter the industrial landscape in ways that previous events did not. This chapter describes how things have changed throughout these industrial revolutions and how Industry 4.0 affects today's world. Finally, certain technologies that arrive with Industry 4.0 are reviewed, while analyzing the alterations that need to take place in the organizational structuring of corporations.

Three periods in time have been described as industrial revolutions, either due to a disruption in industrial production or an evolution in processes and operations (Galindo, 2016). Mechanization, steam and water power were the facilitators for Industry 1.0, mass production for Industry 2.0 and the introduction of automation and information technology (West, 2017; Schrauf and Bertram, 2016), as seen in table 3.1.

Table 3.1 History of Industrial Revolutions (Collins, 2017; Hammel Scale, 2018).

Industry 1.0 **(1760-1870)**	**Industry 2.0** **(1870-1970)**	**Industry 3.0** **(1965-Today)**	**Industry 4.0** **(Today-.)**
The introduction of mechanical production enabled by steam and water power	Mass production and creation of new jobs enabled by the introduction of electrical power	The introduction of IT and electrical systems contributed to further automation of production	IoT and more disruptive technologies and applications driving industries towards digitalization and further automation

3.1.1 Industry 1.0

It was between 1750 and 1840 when a transformation in manufacturing and production took place (Schrauf and Bertram, 2016). The transition from hand production methods to machines, the improved water efficiency and the birth of new industrial manufacturing and iron production processes (Deganutti, 2017) were the main pillars of the first industrial revolution.

Thousands of factories and textile mills were built, which were relying on large numbers of workers and machinery in order to manufacture large amounts of goods (Easton and Saldais, 2013), while the development of ships and rail networks further enhanced the commerce industry. New sources of power were established, such as steam power and electricity, which resulted in a total transformation of the manufacturing, agricultural and communications industries (Galindo, 2016).

All of those advancements and improvements led to the mechanization of transportation (Hobsbawm and Wringley, 1999; Galindo, 2016). In addition, telegraphs and telephone systems supported greater efficiency and speed in the transportation of goods (Hobsbawm and Wringly, 1999).

3.1.2 Industry 2.0

Following the events and breakthroughs made throughout the period of the first industrial revolution, technological advancements and pathbreaking inventions took place in energy, materials, chemicals and medicine (Mokyr, 1998) around 1870, resulting in huge shifts in production effectiveness, due to a boom of innovation in research and development. The second industrial revolution can be said to be more of a continuation of Industry 1.0, rather than a revolution on its own, characterized by the effect electrification had on production and automation (Schrauf and Bertram, 2016) and the beginning of mass production (West, 2017).

The main difference between Industry 2.0 and Industry 1.0 was that the advancements leaned a lot more on science (Mokyr, 1998). Scientific base was the key to determining the plan or the tasks needed in order to utilize energy and materials correctly and get the results, while reducing the waste of materials and energy. For example, with the concepts of engineering and thermodynamics, advancements in manufacturing industries were much more possible to occur (Mokyr, 1998).

Production changes mostly occurred in the technology sector. Electrical power and telephone networks were added to a group of systems already used before 1870, consisted of railroad and telegraph networks, as well as gas, water supply and sewage systems (Mokyr, 1998).

Industry 2.0 also had a significant impact on the transportation industry, as railroads became faster and more comfortable. A truly groundbreaking change to railroads was the application of new power sources, most notably the Diesel engine (Mokyr, 1998), invented by Rudolf Diesel. The central feature of said engines is the well-known compression-induced combustion. In maritime transport, the invention of the steam turbine by Gustav de Laval and Charles Parson in 1884 led to a revolution at sea (Mokyr, 1998), which led to more efficient, faster and quieter travels.

3.1.3 Industry 3.0

Following Industry 2.0 and the advancements it brought in production and automation, the third industrial revolution was characterized by the development of digital fabrication devices and the democratization of production (Naboni and Paoletti, 2015) and was based on the convergence of communication and energy (Rifkin, 2011). Its two greatest technological breakthroughs were the digital computer and the industrial robots (Schrauf and Bertram, 2016; Galindo, 2016; West, 2017).

The unification of the internet and renewable energy enabled the integration of new production systems, with communication technology being greatly influenced by the 20^{th} centuries' innovators, such as Steve Jobs (Rifkin, 2011).

These advancements led to an increased automation in production, with automotive industries being the first to experiment with the use of information technology systems and robotics (West, 2017). As a direct result of Industry 3.0, new job positions and an increased gap in wages range were only natural to come. The first programming jobs appeared and the information and communications technology (ICT) sector started to form (Rifkin, 2011).

To sum it up, each industrial revolution appears to be either an evolution to the previous revolution, or a revolution bringing abrupt changes to the industrial world.

3.2 Industry 4.0

Industry 4.0 can be defined as the current trend towards automation and digitalization with emerging technologies such as the Internet of Things, Big Data, Advanced Robotics, Augmented Reality and Unmanned Aerial Vehicles, which will be reviewed later in the chapter (West, 2017; Vaidya et al., 2018). The constant evolution of production systems, transportation processes and the designing of advanced software solutions, along with issues such as the higher customer demands, cyberthreats, globalization, the continuous rise of e-commerce and the emergence of new business models disrupting the industries were pushing for what is now called the fourth industrial revolution (Baretto et al., 2017).

3.2.1 Necessity for Industry 4.0 Technologies

Industry 4.0's main objective is the fulfillment of individual customer requirements with accuracy and efficiency (Vaidya et al., 2018). Its main characteristics are digitalization and automation with Internet of Things (IoT) and Big Data leading the way for technologies which enable a transparent and uninterrupted flow of information, which is vital for today's companies and organizations (West, 2017).

The focus in Industry 4.0 is on cyber-physical systems. Such systems are able to optimize the receiving and transmitting data processes, due to the utilization of sensors and the internet. By doing so, communication between human and machine or physical items is achieved (West, 2017), and real-time decision-making can be supported. Such sensors are embedded in equipment.

In order to support such great loads of data, Big Data technologies are incorporated, with new software solutions being able to process such great amounts of raw data (Vaidya et al., 2018). Then comes the simplification of the user's interfaces, which increases a worker's mobility and productivity (West, 2017). Advanced Robotics and augmented reality (AR) revolutionize security, warehousing, transportation and manufacturing. These technologies will be introduced in subchapter 3.3.

Industry 4.0 and the technologies mentioned break plateaus and set new limits for corporations (Vaidya et al., 2018). It also allows for startups to disrupt industries and triggers changes in existing companies' business strategies and models (Ibarra et al., 2018) by providing the perfect platform for innovation. As competition intensifies and globalization keeps on affecting international companies, innovation becomes a necessity in order to keep on creating competitive advantages (Vaidya et al., 2018).

Aside from innovation in automation, digitalization is the other major aspect of Industry 4.0 (West, 2017). As of today, 80% of information and communications companies have digitalized their processes, while companies in the electronics and electrical systems industry lead the way with a digitalization[7] of rate of 89% (Geissbauer et al., 2014). The manufacturing and engineering industry follow with an 85% digitalization rate, while the automotive industry is just as close with an 84% respectively (Geissbauer et al., 2014). Digitalization rate, as seen in figure 3.1, has a direct impact on cost reduction for industries.

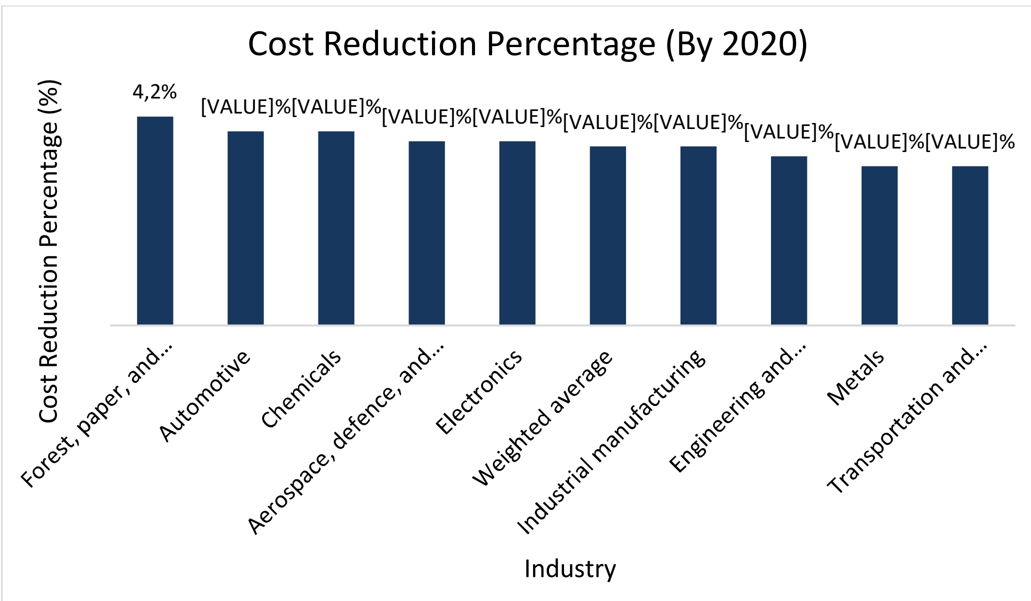

Figure 3.1 Cost reduction percentage expected for companies investing in digitalization by 2020, grouped by industry (PwC, 2016).

3.2.2 Issues raised from Industry 4.0 Adoption

Table 3.2 Issues raised from Industry 4.0 adoption (Renjen, 2018).

Issues				
Cyberthreats	Talent Acquisition	Labor	Organizational Structures	Cost
Exposure of	Need for	Fear of job	The need for	High investment costs

[7] Digitalization is consisted of customer-oriented processes, such as e-commerce, digital marketing, social media managing and customer experience improvement through personified and customized offers (Schrauf and Bertram, 2016).

personal or corporate information	skillful employees	positions lost	reformed organizational structures	

The rapid digitalization and the rate at which the business landscape is changing makes cyberthreats an issue, but according to Dr. Kurt Altenegger, “The cyber risk is not necessarily higher in an Industry 4.0 environment, as new cyber security will be introduced at the same pace as Industry 4.0 applications”. The priority for most companies isn’t just preventing cyber-attacks, but also learning how to deal with them (Schlaepfer et al., 2014).

Another issue is about the readiness of any company’s IT infrastructure (Schlaepfer et al., 2014). The necessity of talented and skillful employees was mentioned earlier and as evidenced, rapid digitalization will challenge that. The biggest issue, as it stands, is the impact Industry 4.0 will have on HR and labor and organizational structures (Ermolaeva, 2017).

3.2.3 Issues arising in HR Sectors

It is a common belief that IoT and Advanced Robotics will lead to mass unemployment, but that is not the case (Franklin, 2018). We are led to a time when hybrid jobs will dominate the job landscape. For example, someone working in the healthcare industry will need to be re-skilled and as a result his job will be more accurately described as being in the IT-Healthcare industry (Franklin, 2018). Of course, low skills jobs will be the first to be replaced according to a report by consulting firm Zinnov, although it is noted that it will be matched by job creation in other areas (Franklin, 2018).

On the other hand, a study conducted by the World Economic Forum stated that the transition to Industry 4.0 will result in a loss of at least 5.1[8] million jobs of non-technical nature in 15 major developed and emerging countries (World Economic Forum, 2016). The skills that are mostly sought after are mathematical and analytical skills in a combination with a familiarity with computers (Coutinho, 2017).

The shifts in labor and industry are coming at a rapid pace and HR is very important in managing the changes and aiding in a smooth transition for employees (Shamim et al., 2016). HR should reform some traditional practices and emphasize on a flexible job design, an engaging and swift training curriculum, and finally, boost the employee’s morale with the utilization of performance appraisal and personal development consulting sessions (Shamim et al., 2016; Franklin, 2018).

3.2.4 New Organizational Structures

Besides the issues in HR sectors, the changes that are about to arrive due to industries entering the Industry 4.0 era, push corporations into new ways of doing business (Jakes, 2016). The necessary steps a corporation should follow in order to cope with the rapid

[8] 7.1 million jobs, mostly of administrative and white-collar office nature, will be lost and 2.1 million jobs will be created related to science and mathematics (DW.com, 2016).

digitalization of the business landscape and achieve innovation are as follows (Ibarra et al., 2018; Baretto et al., 2017; Mrugalska and Wyrwicka, 2017):

1- Standardization of systems and connections.
2- An investment in research and human resources. Employers carefully and accurately trained to use and navigate through the plethora of systems and processes provide a huge advantage to companies.
3- Understanding and respecting legal frameworks.
4- New business models, due to the increasing customer demands, leading from the mass production phase to the mass customization one.

By summarizing the features mentioned above, three approaches are identified as to the direction of a new business model that enables a company to adapt to the rapid digitalization (Ibarra et al., 2018):

1- A service-oriented approach. A product-service system (PSS) concept that describes the development, realization and offering of product-service bundles to the customer.
2- A network-oriented approach. Horizontal and vertical integration of the value chain, as a way to expand a company's boundaries.
3- A user-driven approach. More responsive manufacturing processes resulting in a better alignation of user-driven design and customer value creation.

Industry 4.0 enables startups and small-size companies to try such new business models with a tendency towards disruption of the industrial landscape (Noronha et al., 2016). But traditional organizational structures appear to be inflexible and that is because they are usually multilayered in nature, deeming them unsuitable for a company with the goal of achieving full digitalization (Ermolaeva, 2017). Corporate organizational structure should be designed in a way that helps companies achieve their objectives (Jakes, 2016), while also adapting to the circumstances at hand.

Companies and organizations need to be more flexible and adaptive to change, as today's fast changing environment requires innovations in all sectors (Ermolaeva, 2017). A priority has to be given to decreasing management stages to two or three (Jakes, 2016). The following organizational structures seem to be the most suitable for the new era of industry, in order to help companies go full digital (Jakes, 2016; Ibarra et al., 2018; West, 2017):

1- Lean Organizations. Characterized by a flat structure with suppressed hierarchical levels and teams that work with many tasks, often utilizing the Kaizen methods[9].
2- Fractalization. Essentially a company broken into many pieces performing independently.

[9] The Kaizen method is a management concept conceived in Japan. Its main mantra is the continuous development and the founding elements of it are team work, discipline, improved morale, quality circles and suggestions for improvement (Valuebasedmanagement.net, 2016).

3- Amoebas. A loosely bounded organizational network without hierarchical arrangements. They function independently with full responsibility to the corresponding entrepreneur.
4- Network Organizations. Formed by agreements between small and middle-size companies with participants being connected to each other.
5- Virtual Organizations. A combined effort of a number of smaller companies that agree on the use of shared information channels. There is no leadership and no hierarchy, just separated companies responsible for their actions.

Those organizational structures are quite suitable for the new era of Industry 4.0. They benefit the companies in cutting time intervals, reducing operational and transactory costs, while optimizing productivity (Ermolaeva, 2017). But more actions are required for a company to build a digital profile, able to cope with the higher demands (PwC, 2016). Said actions are as follows (PwC, 2016; Ermolaeva, 2017; Jakes, 2016):

1- An investment in data analytics and utilization of Big Data technologies.
2- A regional segmentation, in order to simultaneously adapt to globalization, but also satisfy distinct demands.
3- Build digital trust based on transparency, legitimacy and effectiveness.
4- Companies need to educate staff about digital technologies and applications of Industry 4.0 and build the digital culture within the company infrastructure.
5- Investment in Industry 4.0 technologies.

Industry 4.0 and its technologies offer solutions to issues and challenges that companies were previously having trouble with. Issues pointed out by skeptics are manageable considering that companies have realized that necessary steps need to be taken in order to adapt to the changes, as currently used practices and technologies have their disadvantages. An industry heavily affected by Industry 4.0 is the logistics one. Logistics 4.0 boosts end-to-end visibility and traceability through the supply chain, optimizes production and streamlines processes (Mrugalska and Wyrwicka, 2017; PwC, 2016).

3.3 Logistics 4.0 and Emerging Technologies

Logistics 4.0 is a term derived from the combination of Industry 4.0 technologies and innovations and their application on inbound and outbound logistics (Barreto et al., 2017). A narrower concept than Industry 4.0, Logistics 4.0 focuses on typical features, such as automation and digitalization (Szymanska et al., 2017). The technologies most commonly utilized are the Internet of Things, Big Data analytics, Augmented Reality (AR), Unmanned Aerial Vehicles and Advanced Robotics.

Logistics 4.0 technologies and systems implementation has several advantages, which are the following (Szymanska et al., 2017; Galindo, 2016; West, 2017; Gesing et al., 2018):

1- Standardization of several Logistics Functions
2- Streamlining of Processes
3- Greater Flow of Information
4- Cybersecurity
5- Optimization of Production
6- Lower Operational Costs

The disadvantages that come with Logistics 4.0 implementations are as follows (Szymanska et al., 2017; Barreto et al., 2017; Gialos and Zeimpekis, 2018):

1- High Investment Costs
2- Cumbersome Organizational Structures
3- Fear of Cyber Threats
4- HR Implications
5- Resistance to Change
6- IT Supply Network Possession Requirement
7- Requirement for Highly Skilled Workers

The technologies analyzed next aim at replacing processes which do not need operational or decision-making processes from workers (Galindo, 2016). The following subchapter provides a deeper explanation of said technologies.

Emerging technologies support logistics operations in ways that currently utilized technologies cannot. As a result, the technologies explained here are key to companies and organizations growing past the issues and challenges that have occurred and move towards digitalization and automation. The following table presents a summary of the technologies analyzed in this chapter.

Table 3.3 Emerging technologies of Logistics 4.0 (DHL, 2015; Oracle, 2018; Malek et al., 2017).

Technologies	Description	Impact
IoT	Connecting physical objects and machinery to a central control system, usually monitored through a device such as a smartphone.	IoT totally changes the business landscape by increasing digitalization and automation in operations and processes.
Big Data Analytics	Access to amounts of data far greater than what was previously available, which enable more accurate analytics-insights.	Increased accuracy in decision-making, greater operational transparency, optimized customer service, greater efficiency in resource planning and better precision at scheduling.
Advanced Robotics	Robots and machinery which learn on their own through machine learning and deep learning algorithms, monitored through devices such as laptops and smartphones. Designed to replace processes and tasks demanding precious amounts of time and effort from workers.	Huge impact on warehousing and operations management in general.
Augmented Reality	Information accessible through a device worn on the head and displayed through an interface.	Optimizing and achieving greater efficiency in everyday processes and activities.

UAVs	Unmanned aerial vehicles designed to receive and deliver items, aid in intralogistics activities and patrol remote facilities.	Huge impact on distribution and delivery, while also elevating security levels for facilities and warehouses.

3.3.1 Internet of Things (IoT)

The internet has grown large so rapidly that it has become a household term and according to the latest report from Global Digital, internet users have surpassed the 4 billion line. The Internet is centered around the concept of connection, with smartphones, laptops, PCs, smartwatches etc. all connected to it in order to send, receive, process and store data.

IoT is the next step for the concept of connection, allowing for devices previously unthought of, such as lights, doors, refrigerators, drones etc. to be controlled by the user with one central device to monitor their action, which is usually a smartphone or a computer (Macaulay et al., 2015), allowing for a machine-to-person (M2P) or a machine-to-machine (M2M) link. The connection to physical objects through the internet allows users to enjoy its full potential for the support of their business, transparency in operational processes and better monitoring and controlling of devices and objects at work etc. (Macaulay et al., 2015).

As a result, IoT can be defined as the convergence of information technology (IT) operational technology (OT) (Macaulay et al., 2015). It presents a technology transition that will have huge implications on everything, ranging from daily activities (e.g. sortation of items) to business level operations. Taking advantage of sensor technology and Big Data analytics, IoT offers several advantages for companies, such as operations visibility and production efficiency, thus creating new sources of value (Macaulay et al., 2015; Deloitte, 2018). According to a DHL & Cisco report, the logistics industry is estimated to provide $1.9 trillion dollars of value by the end of the decade showcasing the impact IoT will have on the business landscape (Macaulay et al., 2015).

Another advantage IoT offers to business and logistics companies is the impact it has on decision making. By connecting assets and objects, vast amounts of digital information now become available, enabling for faster and more accurate decision making (Macaulay et al., 2015; Malek et al., 2017). As a result, that allows for more adaptive customer experience, optimized operations and processes, faster cycle times and reduced costs (Liu, Zhang and Wang, 2018; Malek et al., 2017). But in order to obtain these vast amounts of new data and intelligence, IoT utilizes many different technologies including wireless local (e.g., Bluetooth, RFID, Zigbee, Wi-Fi), mesh network and wide area connections, such as 4G, as well as wired connections (Zhong, Xu and Wang, 2017).

Of course, IoT also includes more consumer-oriented devices[10], embedded technologies, and apps (e.g. the thermostat monitor). An important element of this is the incorporation of controllers and actuators (Arduino is a well-known example), so that an action taken in the

[10] These devices are usually programmed with the use of the C programming language, which is preferred due to it not requiring a lot of processing power (Curry, 2016). Other languages used for developing IoT applications for more complex tasks, such as a thermostat monitor, are C++ and Java.

digital world, such as a user clicking a link in an application (IoT Agenda, 2018), can result in a corresponding action in the physical world (e.g. an alarm sounds, a lever flips, an assembly line comes to a halt etc.).

All those features of IoT mentioned above and the advancements that it can bring in industries are still in pubertal stage. Roughly 1% of the world's physical objects have been connected to the internet, which means that in the following years IoT is going to play a huge part in the shaping of the industrial and non-industrial world (Macaulay et al., 2015).

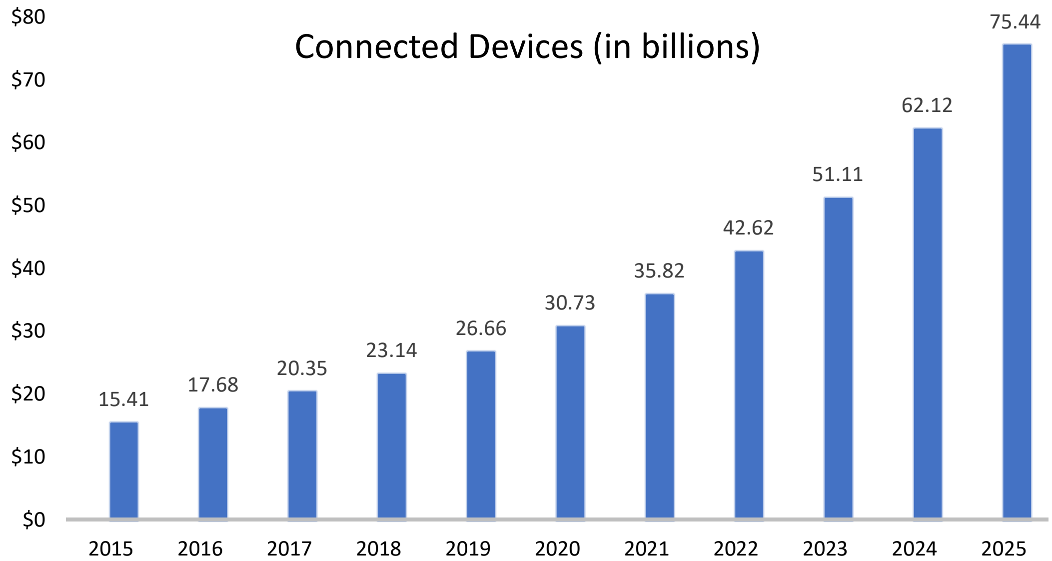

Figure 3.2 Graph showing the amount connected devices, showcasing the fact that there is still a lot more to be seen (Bicheno, 2015).

3.3.2 Big Data

As already seen, IoT enables the creation of new sources of data and intelligence. This leads us to an obstacle of sorts, in the fact that data have become way too large to be handled by common software solutions and its impact on the way companies do business will not have the same effect without the utilization of Big Data analytics (Jeske et al., 2013; Lachhab et al., 2018). That is due to a change in two very important data characteristics. The first is the fact that with more devices being connected and sensor technology continuously on the rise, more data streams are being generated and as a result, there is an increase in the velocity of data aggregation and processing (Jeske et al., 2013). Secondly, data has become greatly varied, with newly generated data originating from various distinct sources, such as e-commerce catalogs, surveillance cameras, internet surfing, forums etc. (Jeske et al., 2013). These unstructured data sources result in a much higher data type variety, further implicating matters. Conclusively, Big Data can be defined as data containing greater variety along with increasing volume and velocity (Oracle.com, 2018).

The advantage of these massive volumes of data is that they can be used to address business problems which companies wouldn't have been able to tackle before (Lachhab et al., 2018). As already seen, companies and organizations around the world are focusing on minimizing risks and taking accurate decisions (Jeske et al., 2013; Oracle, 2018). Data-driven insights and

Big Data influenced decision-making are longed for in an industry such as the logistics one, in order to increase the profits and decrease the risks (Jeske et al., 2013). Big Data's worldwide revenue can be seen in the figure below.

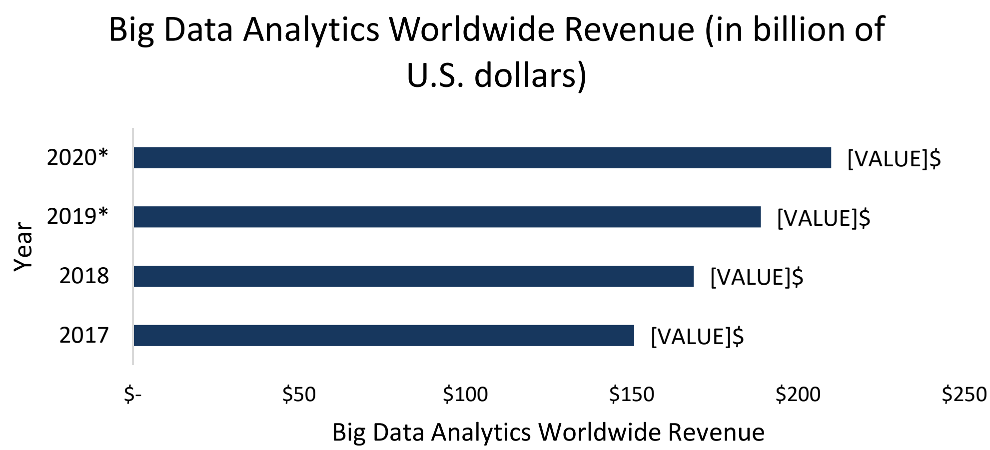

Figure 3.3 Big Data analytics' worldwide revenue based on a survey by IDC (Shirer and Goepfert, 2017).

But achieving the desired results through the processing of large datasets containing important intel is one thing. Finding value in big data is equally crucial. It is an entire discovery process that requires experienced analysts, business managers and executives who ask the right questions, recognize patterns, make informed assumptions, and predict behavior (Oracle.com, 2018). These functions are enabled by Business Intelligence (BI) technologies which support in extracting, wrangling and analyzing data in order to produce insightful reports (AWSmarketplace, 2017). The advantages brought by Big Data can be felt in operations and production efficiency, customer service, maintenance and work schedules, real-time routing optimization, machine preparations, finance and many more sectors and departments within a company structure (Lachhab et al., 2018).

3.3.3 Advanced Robotics

Robotics have been a topic of discussion for decades. Starting from sci-fi films and pure imagination, advanced robotics have reached the point where they have become reality. Surgeries aided by robot arms, robot kitchens, fully walking robots aiding nurses in bringing food to patients, robots in factories supporting the workers in heavy-items activities and many more applications have been seen in this decade.

Investment in robotics research has been at its highest point from the beginning of this decade with the U.S. government having invested more than $96 million in it (Bonkenburg, 2016). In April, Japan's prime minister announced the creation of the Robot Revolution Initiative Council with a plan to quadruple robotics sale from $5 to $20 billion by 2020 (Bonkenburg, 2016). Other sources of funding for a new era of robotics have been corporation giants Amazon and Google. Amazon bought Kiva in 2013 with a total cost of $775 million (Bonkenburg, 2016), but according to Amazon exec Dave Clark, in the first two years of their deployment Kiva robots had cut operating expenses by 20%, which translated in $22 million of cost savings for each fulfillment center (Kim, 2015). Google on the other hand, bought eight robotics startup companies with a focus on a branch of artificial intelligence, called deep learning (Bonkenburg, 2016; Gesing et al., 2018).

3.3.4 Augmented Reality (AR)

Augmented Reality, a relative to Virtual Reality (VR), enables the virtual appearance of digital information onto the physical world, providing information usually on a screen or a remote monitor (Müller, 2018; DHL, 2015).

In a report by SAP, AR and VR are expected to reach adoption levels of 20% by 2019, while 15% of all field-technicians will be utilizing AR technologies by 2020 (Müller, 2018). AR's projected market size in 2022 is expected to be 7,75 times bigger than in 2018, as seen in figure 3.6 (Murray, 2018).

Its use in business operations is of great importance, despite it being adopted at a slow rate (Müller, 2018). It can provide new ways in data-handling, increase activity-related efficiency by interacting with the physical world and simplify work-related tasks (DHL, 2015). Given a window of 3-5 years, AR is expected to be integrated in any assisting device and data exporation processes (Müller, 2018). Its efficiency when used in warehouse operations will be explained in the next chapter.

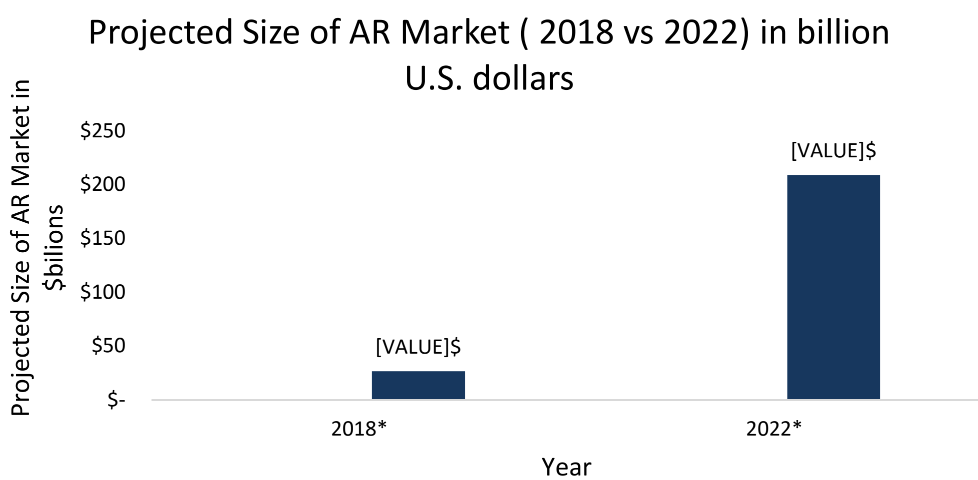

Figure 3.4 Projected size of AR market in 2022 compared to 2018 based on a survey conducted by IDC (Murray, 2018).

3.3.5 Unmanned Aerial Vehicles

UAVs have been used for years in military and non-military operations. The main types of engine used today in non-military UAVs are the electric engine and the internal-combustion engine (DHL, 2014). The electric engine is environmentally friendly and makes no noise compared to the internal-combustion engine, making it a better choice in densely populated areas. It is relatively inexpensive to charge the battery, but battery weight is a drawback and UAV range can be limited by the battery's capacity (DHL, 2014). Hybrid systems have been developed, combining the best of both worlds. The internal-combustion engine is used for longer distance flights, and the electric engine is used for take-off and landing in areas requiring quiet operation.

There are numerous advantages coming with the use of UAVs. They are great for security around facilities and delivery of items in remote locations or in a city center, while they can aid in intralogistics activities. A disadvantage is that UAVs regulation is a difficult matter to resolve, as public concerns about security (DHL, 2014) and their integration in a controlled airspace is a pressing matter, as more and more logistics companies and other organizations start utilizing UAVs for their activities. As a result, their adoption rate is not increasing at the expected rate, as evidenced in the figure concerning the expected worldwide drone spending for 2017 to 2021 (Dukowitz, 2018).

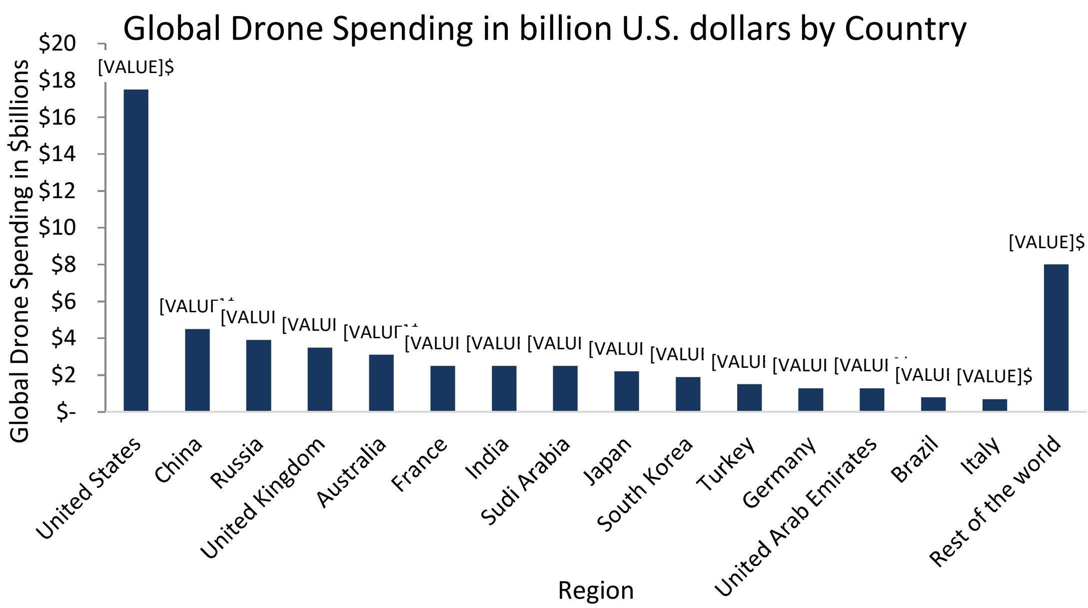

Figure 3.5 Expected Global Drone Spending for 2017-2021 based on a survey conducted by Goldman Sachs, grouped by Country (Goldman Sachs, 2018).

3.4 Summary

This chapter described how the world has evolved from Industry 1.0 up to the era of Industry 4.0. The issues that some skeptics have raised were pointed out and evidence says that these issues are resolvable. Then, Logistics 4.0 was introduced and its technologies were examined in general.

In the next chapter, we will see how Logistics 4.0 technologies revolutionize the logistics industry, with an analysis on how they affect warehouse and transportation operations and processes performed, thus driving it towards digitalization and automation. Then, a Logistics 4.0 technologies implementation framework will be introduced with an example presented regarding UAVs implementation for inventory management and facility patrolling.

Chapter 4 Industry 4.0 on Logistics Operations

4.1 Introduction

The impact Industry 4.0 will have on the business world was analyzed in chapter 3, as well as the emerging issues and the requirements for an organization to adopt digitalization and automation strategies. Finally, Logistics 4.0 was introduced along with its emerging technologies.

This chapter describes how Logistics 4.0 technologies will affect logistics operations, with emphasis on warehousing, freight transportation and distribution. Current technologies, systems and logistics operations are not able to cope with the challenges at hand (Schrauf and Bertram, 2016), such as the increased customer demands, the rise of e-commerce, cyber threats and globalization.

As for today's logistics operations, plenty of the processes performed remain manual or semi-automated in nature (Gregor et al., 2017). Integrating Logistics 4.0 concepts and transforming the organizational structure enables corporations to constantly evolve and keep up with the ever-changing industrial environment (Noronha et al., 2016).

The Logistics 4.0 concepts and technologies that will be described, as presented in chapter 3, are as follows:

- Internet of Things and its subsidiary technologies (e.g. RFID, sensors etc.)
- Big Data
- Advanced Robotics
- Unmanned Aerial Vehicles
- Augmented Reality

4.2 IoT and its Applications on Logistics Operations

The Internet of Things is expected to transform the logistics industry due to its capability of allowing the connection of objects to the internet with the use of RFID tags, wireless networks and information systems, as seen in figure 4.1. IoT's prospects for logistics operators and business customers are beyond significant (Macauley et al., 2015). Its positive effects can be witnessed across the supply chain, including warehouse operations, freight transportation and distribution and delivery (Macaulay et al., 2015; Gregor et al., 2017).

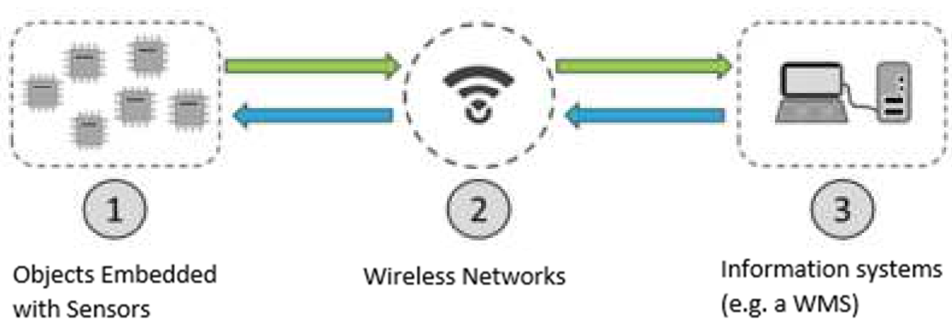

Figure 4.1 The IoT "ecosystem", comprised of three main components, which are sensor-embedded objects, wireless networks and information systems.

IoT aids in real-time monitoring of assets, maintenance time-intervals, boosting precision and speed in warehouse operations (e.g. picking), optimizing last-mile delivery processes, lowering operational costs, optimizing productivity and providing intel in order to make greater use of data analytics (Macaulay et al, 2015; Galindo, 2016; Karakostas, 2016). Operations for which IoT's impact will be thoroughly analyzed are as follows:

- Picking
- Inventory Management
- Receiving
- Dispatching

These warehouse operations are still mostly manual or semi-automated in nature (Field, 2015). At average, logistics costs of activities involving human action are estimated to be \$25-35 per hour, while the same activities based on IoT operating concepts showed a cost saving of 80-90% and a performance growth of 20-30% (Gregor et al, 2017). Another important result was the reduction of risk of fault, a factor playing a noteworthy role in manually performed activities (Gregor et al., 2017).

Such activities are ones performed for picking processes. In the traditional way a list of items would be given to the picker and then he would walk around the warehouse in order to pick said items with either the support of a WMS, picking aiding technologies (e.g. voice picking) or completely not (Field, 2015; Rushton et al., 2014). But with the implementation of IoT, such processes are transformed by getting completely digitized and partially automated (Field, 2015). Now, the list of items would be automatically sent to cart-like robots, which would perform the picking activities and deliver the items to the workers (Macaulay et al., 2015).

Another major value proposition of IoT is the monitoring of items, equipment and workers in order to increase safety and efficiency (Macaulay et al., 2015). For example, after the dispatching processes are completed, sensor technology can be utilized to monitor the pallet's movement and exact location, enabling real-time monitoring and the transmission of information previously unavailable (Field, 2015).

So, as evidenced in the previous example, by connecting different assets across the entire supply chain in a way that has a meaningful impact, IoT offers logistics companies greater automation and generates data by said connections, which provide the stepping stone to reach greater levels of operational efficiency and more accurate insights (Macaulay et al., 2015).

4.2.1 IoT in Warehouse Operations

Warehouses have always been the "heart" within a supply chain, being vital to the flow of goods and information (Zeimpekis, 2018). Nowadays, it can become a key to achieving a competitive advantage for logistics companies and IoT applications are ideal for that continuously changing technological environment that warehouses are defined by (Shields, 2017). The following figure depicts an IoT-enabled warehouse:

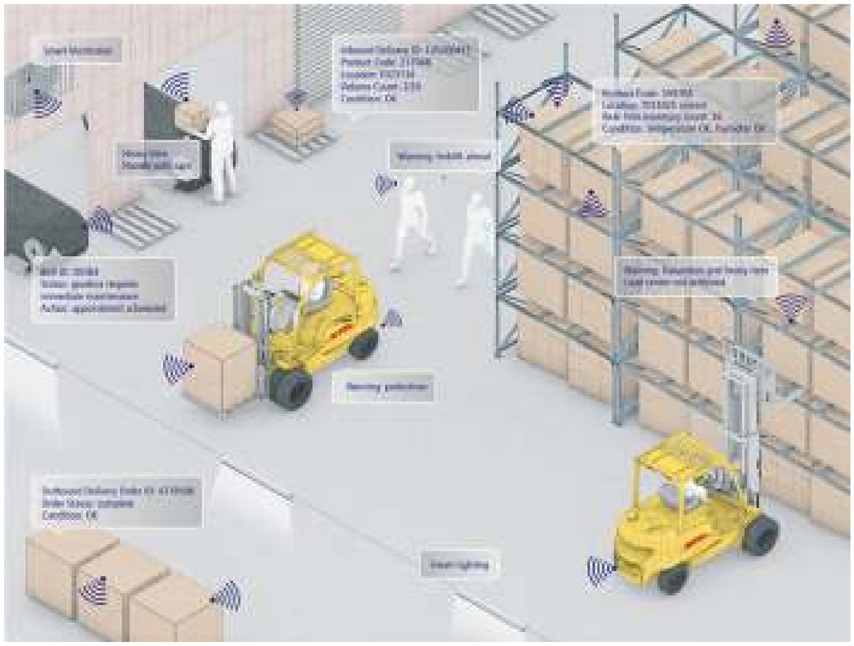

Figure 4.2 The IoT-enabled warehouse, with multiple applications, such as condition monitoring, smart inventory management, smart ventilation etc. (Hector, 2018).

The factors that make a warehouse the perfect environment for implementing an IoT framework are of equal importance and value (Macaulay et al., 2015). On average, thousands of variable types and goods are stored in a warehouse, while their placement must be specifically picked in order to enable the highest efficiency levels in extracting, processing and delivering processes (Macaulay et al., 2015). In addition, a modern-day warehouse contains many physical objects and machinery that, once connected and optimized through IoT technologies, can offer significant new data streams, as seen in figure 4.2. Such objects can be pallets, forklifts etc., or even the warehouse infrastructure itself (Zhong et al., 2017).

The following table describes the IoT subsidiary technologies utilized.

Table 4.1 IoT subsidiary technologies and their uses in Logistics Operations (Macaulay et al., 2015; Zhong et al., 2017).

Technologies	Uses
Sensors	Monitoring of different assets and generating data streams that enable real-time decision making and more accurate insights.
Microprocessors	Tailored to allow optimal performance and efficiency of various systems.
Actuators	Components responsible for controlling a mechanism.
Wireless Connection	Enabling the connection between machines and workers. Now, with the arrival of 5G networks, IoT-based solutions are even more accessible.
Semiconductors	Materials with an electrical conductivity value falling between that of a conductor and that of an insulator.
Wireless Readers	RFID readers attached to a machine. Logistics operators carry mobile readers, because of constant movement. Wireless communication devices strategically installed ensure signal coverage and greater transparency.

The adoption of pallet and item-level universal tagging with the utilization of low-cost identification devices, such as RFID[11], shown in figure 4.2, strengthens the path towards an IoT-driven smart-inventory management (Macaulay et al., 2015). It provides real-time visibility for a more efficient inventory management, preventing situations, such as an out-of-stock one, that would otherwise prove to be quite costly for companies (Macaulay et al., 2015).

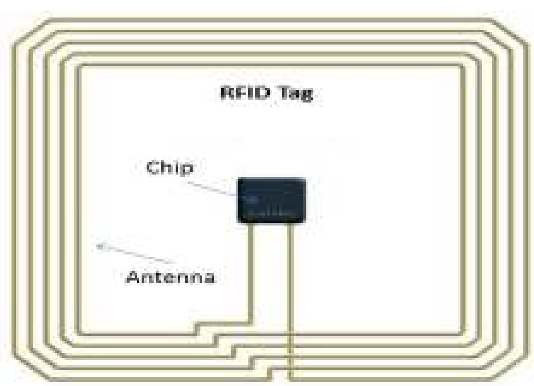

Figure 4.3 An RFID tag stores data regarding the object it is embedded to electronically. The wireless reader tracks and identifies the tag with the use of electromagnetic fields (West, 2017).

[11] RFID has been around for decades, but it has gone through a huge rise in popularity recently, due to Industry 4.0 (West, 2017).

Another cost and time-saving advantage is the data captured during the receiving processes, with the wireless RFID readers capturing data related to volume and dimensions (Zhong et al., 2017). During the dispatching processes, these readers eliminate the possibility of error due to a thorough scanning of the pallets (Macaulay et al., 2015). Finally, stock levels are automatically updated (Field, 2015). The following table compares RFID to barcode utilization.

Table 4.2 Compares RFID tags to Barcodes utilization in the warehouse.

	Barcode	**RFID**
Read Range	Ranging from several inches to several feet	Up to 100+ feet, depending on the tags used
Read Rate	One at a time	Up to 1000s simultaneously
Read Speed	Seconds	Milliseconds
Reliability	◓	◕
Data Capacity	◔	●
Legend	◔ : Low ◓ : Medium ◕ : Medium to High ● : High	

Throughout the duration of these processes, sensor technology allows for optimal asset monitoring and controlling (Deloitte, 2018). By connecting all assets to a central system, IoT allows for a full utilization of sensor technology's capabilities (Deloitte, 2018). A variety of sensors can be deployed to monitor the movement and location of items and pallets, while other sensors can be used for controlling and monitoring sorting systems and warehouse vehicles (Deloitte, 2018), thus facilitating predictive maintenance and resulting in the prevention of failures and extended damages (Macaulay et al,2015) by warning managers for any necessary preventive actions. Another major advantage gained by the utilization of sensor technology is the monitoring of a pallet's or a package's condition (e.g. temperature and humidity), thus enabling greater quality and customer service (Deloitte, 2018).

Connecting all assets to a central system and optimizing the transmission and receiving of data is based on wireless networks and stable connectivity (Shields, 2017). The standard mobile networks utilized are the 4G LTE (Ericsson, 2017). But the fifth-generation mobile network, shortly named 5G, will be able to send data ten times faster (Shields, 2017). This overlaps with the revolution IoT is bringing to warehouse operations and creates significant prospects for the future, as it is expected that 5G usage will have reached 15% of the world population by 2022 (Ericsson, 2017; Shields, 2017).

By summing it all up, the following table describes the impact IoT and its logistics applications have on warehouse operations.

Table 4.3 The impact and the results of implementing IoT-based solutions (Newcastle Systems, 2017; Datex, 2018; Zhong et al., 2017; Gregor et al., 2017; Macaulay et al., 2015).

IoT Applications on Warehouse Operations		
Operations	**Impact**	**Results**
Receiving	• Accurate Inspection • Thorough Accountability • Real-time Visibility and Traceability • Compliance with Labelling Standards	• Lowered Time Intervals • Reduced Operational Costs • Increased Labor Performance • Optimization of Processes and Activities
Putting Away	• Real-time Monitoring of Location and Condition	• Reduced Operational Costs • Efficient Space Utilization • Optimizing Productivity
Picking	• Performance Monitoring • Warehouse Navigation • Knowledge of Exact Location for Items and Goods	• Reduced Operational Costs • Reduced Time spent walking and searching • Automation
Packing	• Knowledge of Item's Conditions at any given Time	• Compliance with Regulations • Quality Assurance
Dispatching	• Real-time Monitoring • Accurate Scheduling • Thorough Accountability • Reduced Risks	• Compliance with Regulations • Efficient Truck Space Utilization when Loading • Prevented Damages to Goods • Reduced Operational Costs • Optimized Productivity

4.2.2 IoT Applications on Freight Transportation

Logistics providers transport goods by air, sea, rail, road and pipeline, through widely distributed networks that depend on an uninterrupted flow of information (Deloitte, 2018). IoT and its subsidiary technologies aid in streamlining several processes and achieving greater efficiency through automation and digitalization (Macaulay et al., 2015). The transportation operations to be analyzed are as follows:

- Fleet Management
- Asset Management

- Loading/Unloading of Goods
- Last-Mile Delivery

IoT is set to expand the track and trace concept by making it more accurate, predictive and secure (Macaulay et al., 2015). Monitoring the location and the condition of a shipment provides further real-time visibility and traceability during transportation, preventing thefts and damages (Deloitte, 2018). This is made possible through the use of telematic sensors in trucks and sensor-embedded tags on goods which are then transmitting data about the location and the condition (Deloitte, 2018).

Sensors are already utilized for fleet management by many logistics providers with great success (Macaulay et al., 2015). IoT can expand their use by collecting the information, extracted from every truck, for example, into a central system which then identifies the most suitable routes for each truck, thus reducing deadhead kilometers, cutting fuel costs and optimizing fleet efficiency (Zhong et al., 2017; Macaulay et al., 2015).

Another significant advantage of IoT and the use of sensor technology is the predictive nature it adds to asset management (Zhong et al., 2017). The most common reasons a truck needs maintenance are material degradation and various mechanical damages (Nearsay.com, 2018). A truck with embedded sensors placed around the most regularly problematic areas and a telematic unit connected to a central system is enabled to autonomously decide the circumstances of a required maintenance by alerting the driver and the maintenance crew, as seen in figure 4.5 (Macaulay et al., 2015).

IoT is also improving work conditions for drivers, specifically long-distance ones who are susceptible to sleep deprivation, dehydration and exhaustion (Crizzle et al., 2017). Cameras in the vehicle are able to detect signs of said implications and alert the driver in order to warn him (Macaulay et al., 2015). Figure 4.5 sums the above IoT-enabled features with the example of a line-haul transportation operation.

Figure 4.4 Displays how IoT revolutionizes transportation operations by featuring all of the advantages and capabilities discussed above: Monitoring of vehicle condition status, the driver's vitals, shipment ID reporting etc. (Macaulay et al., 2015).

To sum it all up, freight transportation is a continuously evolving and expanding area of the supply chain with numerous amounts of factors affecting its efficiency (Kappauf, Lauterbach and Koch, 2012). The following table describes the impact of IoT technologies on freight transportation.

Table 4.4 Describing the impact of IoT technologies on freight transportation (Deloitte, 2018; Macaulay et al., 2015; Malek et al., 2017; Zhong et al., 2017).

IoT's impact on Freight Transportation	
Freight Transportation Areas	**Impact**
Fleet Management	• Optimized Routing • Fuel Management • Reduced Deadhead Kilometers
Asset Management	• Optimized Asset Utilization • Predictive and Autonomous Maintenance • Vehicle Up Time Increased by ~30%[12]
Transportation of Goods	• Real-time Visibility and Traceability preventing Thefts and Damages • Increased Accuracy and Speed
Health and Safety	• Prevention of Collisions and Delays • Optimized Processes

4.2.3 IoT-enabled Last-Mile Delivery

Last-mile delivery is the last part of the supply chain, thus making it a crucial one. In the latest years, urbanization, e-commerce and increased consumer demands have resulted in a rise of complexity levels of last-mile delivery (Pronello et al., 2017). IoT offers solutions which serve both the end customer and logistics providers, by creating new streams of communication between the two and enabling the birth of new business models (Macaulay et al., 2015). Such an example can be seen in figure 4.6, featuring the capabilities of an IoT-based last-mile delivery operational framework.

Figure 4.5 Shows how IoT redefines last-mile delivery. Features displayed: a) Automatic order placement, b) flexible address, c) delivery notification, d) returned goods request, e) collection route optimization (Macaulay et al., 2015).

[12] Results backed by a project ran by Volvo, DHL and others (Macaulay et al., 2015).

One IoT-enabled solution is about optimizing the collection routes for workers picking mails and items from mail boxes by the placement of sensors inside as seen in figure (Macaulay et al., 2015). Enabled by the global system for mobile communication (GSM) technology, sensors transmit a signal, alerting workers in case that the mail box is empty (Newatlas.com, 2018). Proximity sensors are then used to alert the consumer for any mail or item placed in the mail box, or simply report condition status (e.g. humidity) inside it, as seen in figure 4.6 (Macaulay et al., 2015).

Another revolutionary solution IoT is deeming possible is the anticipatory delivery services (Macaulay et al., 2015). The most commonly used example is that of the smart fridge, which tracks and predicts low stock of goods and then automatically replenishes with an online delivery (Macaulay et al., 2015). An algorithm developed by Amazon enables logistics providers to predict an order by a consumer and as a result, they move the predicted order at a location close to the consumer's address, thus reducing lead time on delivery (Supplychain247.com, 2018). In addition to that, through IoT-enabled smart-devices and the advancements in delivery methods and practices, consumers can now alter the designated address and time slots, even when the parcel is on its way (The Communications Logistics, 2018). In order to allow consumers to have real-time visibility and traceability, RFID or similar sensory tags and printed NAC smart labels are used (Deloitte, 2018; Supplychain247.com, 2018).

Finally, IoT has a positive impact on reverse logistics (Liu et al., 2018). Consumers can track the movement of delivery people and vehicles in order to return an item (Macaulay et al., 2015), although this advancement comes with a disadvantage. The fact that returning goods is facilitated allows consumers to return them more often, which is costly for logistics companies (Supplychain247.com, 2018). Specifically, 11% of sales took the reverse trip in 2017 (Supplychain247.com, 2018). Amazon took an initiative by banning shoppers who returned items too often (Supplychain247.com, 2018).

A summary of the advantages brought by IoT implementations are as follows (Macaulay et al., 2015; Supplychain247.com, 2018; Deloitte, 2018):

1- Real-time Visibility and Traceability for Consumers
2- Flexible Delivery Address and Time Slot
3- Easily Returned Goods
4- Optimized Collection Routes

4.3 Big Data in Logistics

The logistics industry is one in which Big Data analytics has numerous applications (Marr, 2016). Analytics have been a part of logistics management for a long time, but Big Data applications can provide real-time analytics by the extraction and processing of huge and constantly growing non-structured datasets as seen in figures 4.7 and 4.8 (Garcia Marquez and Lev, 2017).

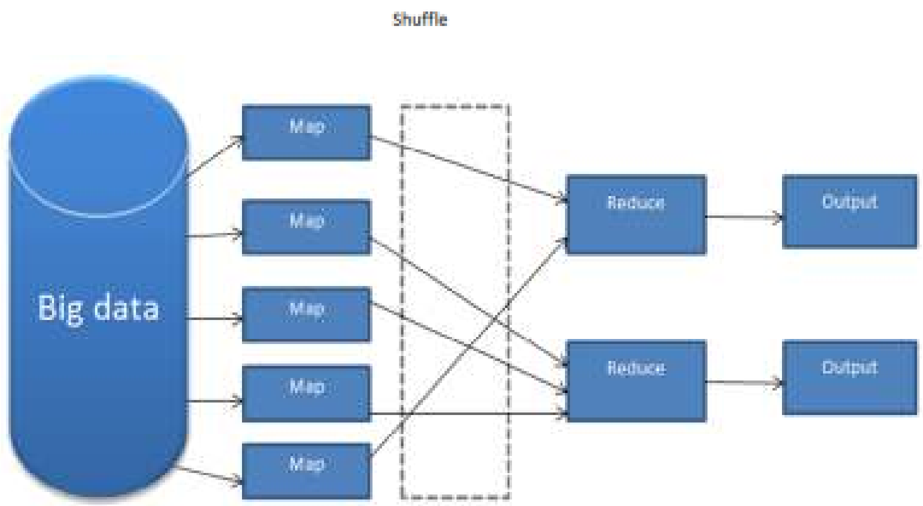

Figure 4.6 The large datasets are decomposed and broken down into smaller datasets in order to be properly processed, which is the mapping process. Mapping is followed by the Reduce phase, where results are combined to produce powerful insights (Ali et al., 2016).

The following figure maps the Big Data technological ecosystem.

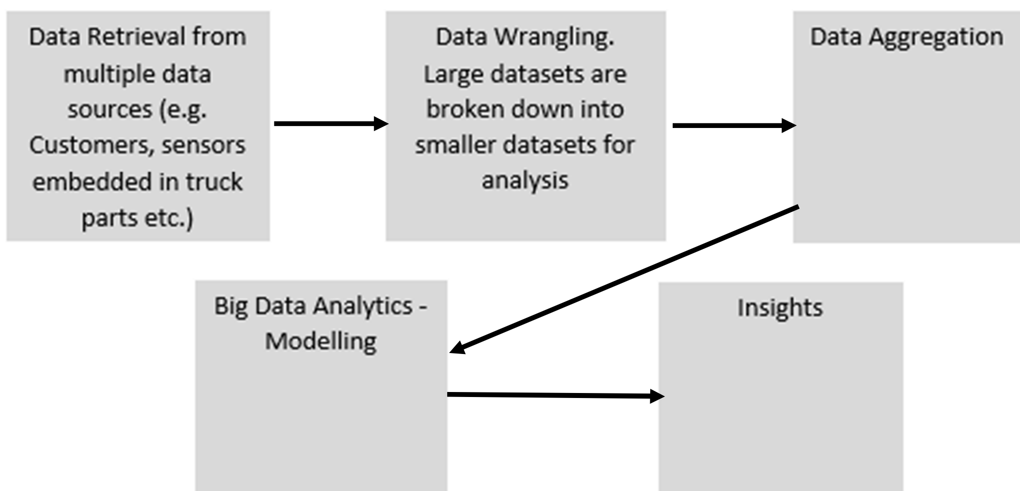

Figure 4.7 The Big Data ecosystem, starting from the retrieval of data from multiple data sources and reaching to powerful insights.

The advantages of Big Data analytics for the logistics and transportation industry are listed below (Garcia Marquez and Lev, 2017; Ben Ayed et al., 2015; Pyne and Rao, 2016):

1- Real-time analytics from data generated by a wide network of sensors and GPS devices
2- Big Data-enabled storing and processing of very large and unstructured datasets
3- Advancements in routing and scheduling
4- Greater insights
5- Greater customer service

4.3.1 Data-Driven Business

With IoT applications and the constant increase in connected devices, more data are being generated by the second (Serrato and Ramirez, 2017). Big Data analytics can provide a competitive advantage for logistics companies utilizing Big Data applications for their businesses (Jeske et al., 2013).

Increasing operational efficiency is the first objective of Big Data analytics implementation (Kirkos, 2015). A key competitive advantage for logistics providers lies in the way resources are handled (Jeske et al., 2013). For example, a shortage translates into poor customer service and a surplus into reduced profitability (Malindretos, 2015). In order to optimize resources utilization, logistics providers should make use of Big Data analytics. By incorporating such technologies, companies are enabled to improve the reliability of their strategic and operational resource planning (Jeske et al., 2013), while being flexible enough to differentiate their plan according to the circumstances at hand (Ben Ayed et al., 2015).

At the strategic level, results by the utilization of Big Data analytics lead to decisions regarding the long-term future of the company, such as an investment in warehouse equipment, distribution centers, information systems etc. (Jeske et al., 2013). In addition to that, Big Data's predictive character, driven by advanced regression and modelling algorithms, enables companies to reduce risk and achieve a more dynamic approach to their resource planning (Ben Ayed et al., 2015). For example, Big Data-enabled forecasting may predict a future state of over-capacity, thus allowing companies to make any corrective decision (Jeske et al., 2013; Malek et al., 2017).

At operational level, small-scale daily tasks and activities are managed (Jeske et al., 2013). By IoT-enabled real-time monitoring and the utilization of Big Data analytics, resource utilization is optimized (Jeske et al., 2013) and supply chain management becomes more responsive, adaptive and flexible (Seratto and Ramirez, 2017; Malek et al., 2017). For example, the prediction of upcoming congesting on routes allows for an optimized routing process which increases operational efficiency (Jeske et al., 2013).

Another key area in which Big Data's impact is felt is market intelligence (Jeske et al., 2013). By using regression analysis, logistics providers can generate forecasts based on large shipment records datasets, thus predicting demand (Anshari et al., 2018).

Big Data's effect also extends to supply chain forecast (Ben Ayed et al., 2015). By tracking the type and volume of goods transported worldwide grouped by region and country, logistics providers are enabled to forecast regional demand and adapt accordingly (Jeske et al., 2013).

When comparing traditionally utilized data warehousing to Big Data solutions, as seen in table 4.5 (e.g. data lakes, data swamps, etc.), the advantages are clear, although companies should consider utilizing both ways of storing and processing data as both short-term and long-term decision making is equally important (Craig, 2016).

Table 4.5 Comparison between Data Warehouse and Big Data.

	Data Warehouse	**Big Data**
Readiness	●	◓
Greater Insights	◓	●
Security	●	◕
Cost	$$$	$$
Legend	◓: Medium ◕: Medium to High ●: High	
	$$: Medium $$$: High	

To sum it all up, the following table describes how Big Data affects different areas of business operations.

Table 4.6 How Big Data affect the way logistics companies do business (Anshari et al., 2018; Kirkos, 2015; Malek et al., 2017).

Big Data Driven Business	
Area	**Impact**
Resource Planning	• Optimized Risk Management • Greater Insights and Long-Term Decision Making • Optimized Resource Utilization • Responsive, Adaptive and Flexible SCM
Market Intelligence	• Greater Insights • Forecasts based on Big Data analytics • More accurate Demand Forecasting
Supply Chain Forecast	• Adaptability • Accurate Regional and Country Demand Forecasting

4.3.2 Big Data for Greater Customer Service

Big Data applications and technologies revolutionize strategies related to customer service (Anshari et al., 2018) by enabling mass customization and personalization of sales (Jeske et al., 2013). Customer relationship management (CRM) strategies tend to be more successful when supplied with large amounts of data (Anshari et al., 2018). Listed below are ways in which Big Data analytics are revolutionizing CRM strategies, thus enabling companies to cope with the greater customer demands (AWSmarketplace, 2017; Jeske et al., 2013):

1- Personalization and mass customization
2- Aggressive marketing through push notifications enabled by Big Data insights
3- Real-time decision making for greater customer experience
4- Anticipatory delivery services

According to a survey conducted by Deloitte, 62% of corporations consider customer service to be a crucial factor in achieving a competitive advantage (Deloitte.com, 2018). This is evidence that more than half logistics companies realize that customer relations are quite valuable and that customer value is enhanced by the use of Big Data analytics (Anshari et al., 2018). For logistics providers such value can be created by data extracted from distribution networks and data mining of shipment records (Jeske et al., 2013).

Another issue that Big Data applications can resolve is retaining existing customers (Jeske et al., 2013). The reason why retaining customers is challenging lies in the fact that there are more than a few indirect touch points for them (e.g. website visits, mobile applications, call centers etc.) (Malindretos, 2015). Big Data analytics enable logistics providers to merge different data sources together and extract valuable insights about customer satisfaction, service quality, customers on the brink of leaving and identifying elements that keep a customer loyal (Jeske et al., 2013). For example, when a customer lowers his shipment volumes but keeps his sales records positive or at least stable, then that is a sign of his dissatisfaction and the situation requires the coordination of a retention program customized around that customer's needs (Jeske et al., 2013).

In order to achieve valuable customer insights, the multiple data sources that logistics providers should extract information from are as follows (Jeske et al., 2013):

1- Service Quality Levels Records (e.g. the net promoter score (NPS))
2- Public Customer Information
3- Shipment Records (e.g. type of goods, volume, frequency, time to arrival etc.)
4- Complaints Management

Another key way in which Big Data creates value for logistics companies is through customer profiling (Anshari et al., 2018). Customer profiling can be defined as a way of picturing individual customers by grouping them by goals, characteristics and market size (Anshari et al., 2018).

By creating customer profiles, companies can adjust all the parameters of customer service according to the individual customer (Anshari et al., 2018), thus achieving a competitive advantage through leveraging personalization (Jeske et al., 2013).

One example of successful customer profiling is the application of Big Data analytics by Rolls Royce (Anshari et al., 2018). By sensor installation and Big Data analytics, they could predict an aircraft engine breakdown with great precision. By doing that, they were able to sell a combined bundle of the engines and the monitoring services which were generating profit based on the utilization of said engines by the customers (Anshari et al., 2018). The result was that more than 70% of the annual revenue was generated by this service (Anshari et al., 2018), showcasing Big Data's impact.

To sum it all up, the following table describes the impact Big Data has on customer service.

Table 4.7 Describing Big Data's impact on customer service (Jeske et al., 2013; Anshari et al., 2018).

Big Data's Impact on Customer Service	
How?	**Impact**
Revolutionizing CRM Strategies	• Overcoming previously unresolved customer service issues • Brand name strengthening
Focus on extracting valuable Insights by analyzing Data from multiple Data Sources	• Personalization and mass customization • Real-time decision making resulting in greater customer service
Customized and Personalized Customer Retention Programs	• Increased customer satisfaction • Real-time decision making resulting in greater customer service
Customer Profiling	• Greater customer service • Increase in revenue • Anticipatory delivery services

4.3.3 Big Data Analytics and Fleet Management

The facilitation of real-time monitoring and decision-making presents a huge benefit for fleet management (Merchant Fleet Management, 2015). Such factors are enabled by Big Data analytics. With the use of sensor technology, telematics and Big Data analytics, drivers and managers can now monitor fuel consumption, check vehicle condition status of mechanical parts and have a more direct oversight of the vehicle's movement (Ben Ayed et al., 2015). As a result, fuel management is optimized, predictive maintenance is enabled and the driver's vitals can be monitored throughout the travels (Jeske et al., 2013).

Another advantage of Big Data analytic is its contribution to the classic travelling salesman problem (Jeske et al., 2013). Big Data enables rapid data processing, thus creating a dynamic approach towards routing and re-routing issues (Jeske et al., 2013). By tapping into multiple data sources and through swift data processing, re-routing, in case of blocks, congested roads or natural disasters, and the optimization of delivery based on the vehicle load are enabled (Ben Ayed et al., 2015).

To sum it all up, the following table presents how Big Data enables features and capabilities that were previously unavailable using Logistics 3.0 technologies.

Table 4.8 How Big Data Analytics affect fleet management and enables new features and capabilities (Jeske et al., 2013; Ben Ayed et al., 2015).

Big Data Analytics in Fleet Management	
Areas of Impact	**Impact**
Fuel Management	• Reduced Operational Costs
Predictive Maintenance	• Reduced Operational Costs • Optimization of Vehicle Utilization
Driver's Vitals and Vehicle Movement and Condition Monitoring	• Optimization of Performance • Optimization of Vehicle Utilization • Reduced Operational Costs
Rapid Data Processing and Data Mining through Multiple Data Sources Leading to more Dynamic Routing and Scheduling	• Dynamic Re-Routing in case of congestion, natural disasters etc. • Optimization of Routing and Scheduling according to Multiple Factors

4.4 Advanced Robotics in Logistics Operations

Another core Logistics 4.0 technology that was generically presented in chapter 3 is Advanced Robotics, which, in conjunction with IoT, opens up a wide array of possibilities for the future of logistics operations, due to them driving the logistics industry towards automation, as many day-to-day warehouse and transportation processes and activities can be fully or partially automated in order to achieve optimization and greater efficiency (Romeo, 2017). The operations and activities to be discussed are summarized at the following table:

Table 4.9 The logistics operations to be discussed, revolutionized by advanced robotics.

Warehouse Operations	**Freight Transportation**
Picking	Unloading/Loading Goods
Packing	Last-Mile Delivery
Receiving and Dispatching	

4.4.1 Robotics in Warehouse Operations

According to a 2016 survey conducted by St. Onge Company, around 75-80% of warehouse operations are manually performed, while 15% of them are mechanically assisted (Michel, 2016). That leaves a considerably small ~5% of completely automated operations and processes (Bonkenburg, 2016; Michel, 2016).

There are numerous day-to-day standard activities and processes which, once automated, can offer multiple benefits, such as smaller time intervals, reduced operational costs and enhanced productivity (Romeo, 2017).

For picking and packing, most processes and activities are repetitive and are most suitable for automation (Bonkenburg, 2016). Robotics such as Kiva, seen in figure 4.9, are able to move collections of items or an entire shelf from picking slots to sortation areas, thus saving huge amounts of time and worker's effort (Kim, 2015). Then, robotic arms, such as Robo-Pick, can automatically identify items brought from the picking slots and sort them out (Bonkenburg, 2016).

Figure 4.8 Goods to picker technology: Kiva moving a collection of items (Kim, 2015).

Another system for picking items, an opposite to the goods-to-picker systems described above, is the mobile picking robots, with cameras and sensors mounted on it in order to facilitate a more direct picking process (Bonkenburg, 2016). Such an example is Fetch and Freight, two robots developed by Fetch Company, which can collaboratively pick items from picking slots and directly place them in tote bins, as seen in figure 4.10 (IEEE Spectrum, 2015).

Figure 4.9 Fetch and Freight enabling full automation of the picking operation and offering a picker-to-goods solution (IEEE Spectrum, 2015).

Another advantage advanced robotics have when utilized in warehouse operations is adding the element of customization to packing processes (Michel, 2016). For example, when a consumer visits a super market and sees an offer of a 50% discount for beef, the activity of changing stickers and packages is one that comes with operational and time-related costs (Bonkenburg, 2016).

With advanced robotics such as Baxter, shown in figure 4.11, a robot developed by Rethink Robotics Company to aid workers in simple tasks (Balinski, 2014), packing processes are partially automated, increasing efficiency and speed, thus reducing operational costs and time spent (Fitzgerald and Quasney, 2018).

Figure 4.10 Baxter, designed by Rethink Robotics Company, assists in packing and sorting activities and tasks (Balinski, 2014).

Further and more expanded applications of advanced robotics are expected to be utilized in the future, with fully automated distribution and sorting centers totally transforming warehouse operations (Balinski, 2014). Such centers are expected to be equipped with all the applications described above, with the addition of UAVs, exoskeleton support for workers, seen in figure 4.12, and swarm robots, all connected to one IoT-enabled central system (Bonkenburg, 2016). Such facilities will be totally digitalized and automated, bringing operational efficiency, flexibility and productivity to a new level (Fitzgerald and Quasney, 2018).

Figure 4.11 Based on electric power to function, exoskeleton support for workers aids them in day-to-day tasks or heavy and large item carrying. Such exoskeleton support is developed by Panasonic (Burgess, 2016).

4.4.2 Robotics revolutionizing Distribution and Delivery

Robotics applications are also suitable for logistics operations outside the warehouse. One thing most imported goods have in common is that they are made in Asia, which means that shipments arrive to their destination in a standard shipping method (Bonkenburg, 2016). This means that upon arrival, unloading the goods, sorting them to and stacking them on pallets are processes that require a lot of time and effort (Bonkenburg, 2016). Robotics enable speed and efficiency by automating these processes. For example, a robot such as the Parcel Robot, shown in figure 4.12, can identify the optimal sequence in which to unload the goods and then place them on a conveyor to transport them to the sorting center (I-scoop.eu, 2018).

Figure 4.12 The DHL parcel Robot is a prototype developed by DHL and associates (Bonkenburg, 2016), which assists in unloading and loading of goods (I-scoop.eu, 2018).

Finally, another significant advancement advanced robotics initiated is in delivery (Bonkenburg, 2016). Starship Technologies have developed small robots which can carry up to two average weight shopping bags and deliver parcels to an address picked by the consumer, who can also track the robot's movement through an app on any smart device (Burgess, 2018). These self-driving robots utilize sensor technology, GPS tracking, radar and mounted cameras in order to move autonomously (Burgess, 2018). Table 4.10 compares delivery robots to more ready-to-deploy delivery solutions, such as e-cargo bikes and the common delivery cars.

Table 4.10 Comparative table of three last-mile delivery methods, delivery cars, e-cargo bikes and delivery robots.

	Delivery Cars	**E-Cargo Bikes**	**Delivery Robots**
Readiness	●	◕	◑
Eco-Friendliness	◔	●	●
Avoidance of Congestion	◔	◕	●
Weight Capacity	●	◕	◔
Cost	$	$$	$$$
Legend	◔ : Low ◑ : Medium ◕ : Medium to High ● : High		
	$: Low $$: Medium $$$: High		

The following table summarizes the advancements advanced robotics offer to logistics operations.

Table 4.11 How advanced robotics revolutionize Logistics operations (Burgess, 2018; Romeo, 2017).

Advanced Robotics and their Impact on Logistics Operations			
Warehouse Operations		**Transportation and Delivery**	
How?	**Impact**	**How?**	**Impact**
Automation in Picking	• Speed and Efficiency in Individual Processes • Reduces Rate of Errors • Increased Labor Productivity	**Automation in Loading and Unloading Goods**	• Reduced Operational costs • Optimized Processes • Reduced effort by Workers • Optimized Stacking and Unloading/Loading Sequence
Collaborative Effort in Packing	• Reduced Time spent • Reduced Operational Costs	**Self-Driving Robots**	• Faster and more agile Delivery • Flexible Address • Real-Time monitoring of Parcel's location
Development of Fully Automated Distribution and Sorting Centers	• Revolutionizing Warehouse Operations by turning them fully Digital and Automated		

4.5 Unmanned Aerial Vehicles in Logistics Operations

UAVs, empowered by the IoT framework, offer logistics operations significant benefits for plant security, warehouse processes facilitation, inventory monitoring and remote and very populated areas delivery (DHL, 2014). The following applications will be discussed:

- Intralogistics Applications
    1- Inventory Management
    2- Processes and Activities Facilitation
    3- Large-Scale Facilities Security and Safety
- Urban Delivery
- Rural Delivery

4.5.1 UAVs Intralogistics Applications

UAVs in the warehouse facilitate processes efficiency by delivering items or tools fast without a worker having to leave his post and pause his task (H.ESSERS, 2018). Another advantage is the inventory check, with the drone taking a picture of the inventory which is then digitally processed for counting (Trebilcock, 2018). A comparison to traditional inventory management practices is shown in table 4.11. This prevents any human mistakes or mismatches, adding operational efficiency and increased productivity to the wide array of benefits that logistics operations get from the use of UAVs (Sandle, 2017).

Table 4.12 Compares conventional inventory management to smart inventory management with the utilization of UAVs.

Inventory Management: Conventional Warehouse (Semi-Automated) vs Smart Warehouse (Automated)		
	Reach Trucks, Pallet Stackers, etc.	**UAVs**
Readiness	●	◓
Real-Time Visibility	-	●
RFID Compatibility	-	●
Cost	$$	$$$
Legend	◓ : Low ● : High	
	$$: Medium $$$: High	

Figure 4.13 UAVs developed by MIT researchers can read RFID tags using existing RFID-reading systems in the warehouse, meaning that there is no need for them to carry a reader (Lumb, 2017).

4.5.2 UAVs for Security in Large-Scale Facilities

Security and safety are valuable UAVs applications which are most suitable for large warehouses, enabling the monitoring of a number of building sites at the same time, while also offering safety services to customers (Bonkenburg, 2016). Results from UAVs patrolling the warehouse premise are a reduction in theft, intrusion prevention, gatekeeping, value-added-services for customers, on-site repairs for difficult to reach areas and guidance for incoming vehicles (H.ESSERS, 2018; DHL, 2014).

4.5.3 UAVs in Urban Delivery

UAVs offer a solution to many implications urbanization creates for the logistics industry (Bonkenburg, 2016). The rise of e-commerce, congested roads, pollution etc. are issues that cause major problems to ground-level delivery (Savelsbergh and Woensel, 2016). By taking delivery to sky-level, UAVs by-pass the issues mentioned above and allow faster and more efficient delivery.

An example of UAVs delivering an item can be the delivery of a book. After calculating all parameters (e.g. road congestion, weather conditions etc.) a UAV picks up a designated shipment automatically and takes off to the point of delivery (DHL, 2014). At the same time, consumers can track their shipment through a smart device via GPS (DHL, 2014).

4.5.4 UAVs in Rural Delivery

UAVs offer several capabilities for rural delivery (DHL, 2014). Reaching remote areas such as mountains, islands etc., which lack the properly functioning infrastructure of a city enables logistics companies to reduce costs and become more flexible when it comes to delivery (Bonkenburg, 2016).

Numerous possibilities can be exploited. For example, during an emergency situation, UAVs can deliver pharmaceuticals at any given time (DHL, 2014). UAVs can also be considered as an extra service for any customer that requires a fast and unscheduled delivery (DHL, 2014). The following table summarizes how UAVs revolutionize warehouse and transportation and delivery operations and processes.

Table 4.13 Displaying UAVs' impact on Logistics operations (DHL, 2014; Sandle, 2017; Trebilcock, 2018).

UAVs Impact on Logistics Operations							
Intralogistics Applications		Facility Security and Safety		Urban Delivery		Rural Delivery	
Applications	Impact	Applications	Impact	Applications	Impact	Applications	Impact
Moving small Items and Tools in the warehouse	Increased Labor Productivity And Efficiency	**Simultaneous Building Site monitoring**	Increased Security and Safety	**Avoidance of Congested Roads**	Faster and more Efficient Delivery	**Delivery to Remote Areas**	More Efficient and Flexible Delivery
Inventory Management	Real-Time Monitoring of Inventory Levels	**Value-added-service for Customers**	Added Security for Customers and New Value Streams Created	**Eco-Friendly**	Less Air Pollution	**Emergency Delivery**	Delivery of Pharmaceuticals and other Emergency Supplies
Error Prevention	Reduced Errors and Mismatches Frequency	**On-Site Repairs**	Increased Efficiency Increased Productivity	**Automated and fast Delivery**	Greater Customer Service	**Unscheduled Customer Delivery**	Greater Customer Service
-	-	**Guidance for Incoming Vehicles**	Greater Customer Service Faster and Optimized Processes	**-**	-	**-**	-

4.6 Augmented Reality in Logistics Operations

AR is a revolutionary enabler for supply chain and logistics management, as it supports numerous operations and offers several benefits (Merlino and Sproge, 2015). Those benefits can be seen in warehouse operations, freight transportation and goods delivery (Glockner et al., 2014). The operations and processes to be discussed are as follows:

Table 4.14 The logistics operations to be discussed, revolutionized by AR.

Warehouse Operations	**Freight Transportation**
Picking	Asset Management
Inventory Management	Fleet Management
Receiving	Loading/Unloading of Goods
Dispatching	Last-Mile Delivery

4.6.1 Augmented Reality in Warehouse Operations

One of the most studied warehouse operations that accounts for more than 50% of warehousing costs is picking, deeming it an ideal operation for AR implementation, due to the plethora of information that can be digitized (e.g. Count of inventory, item location, aisle navigation etc.) (Stoltz et al., 2017). For example, vision picking has the picker wearing the necessary equipment and helps guide him to the exact location of an item as seen in figure 4.15, which once retrieved is checked by the WMS for successful retrieval and automatically updates inventory (Merlino and Sproge, 2015).

Figure 4.14 An example of the AR headset displaying information regarding shelf number, barcode, aisle, stock numbers etc. (Hci.vt.edu, 2018).

Such systems have been developed by big companies, such as SAP and Intel. The following figures show how the smart glasses function.

Figure 4.15 Displays the AR headset worn by workers and shows its features, such as the display and the camera (Intel, 2015).

The benefits for picking operations are as follows (Glockner et al., 2014):

1- Object Recognition
2- Scanning
3- Navigation
4- Connection with the WMS
5- Hands-free Integration
6- Error Reduction

Results showed a 40% reduction in errors when AR was utilized (Glockner et al., 2014). Table 4.14 displays a comparison between four picking methodologies and technologies. It is worth noting that AR has the potential to showcase similar benefits for other operations, such as storing, receiving and dispatching (Stoltz et al., 2017).

Table 4.15 Compares picking technologies and showcases how AR-based vision picking is superior.

	Pick-by-Voice	Pick-by-Light	Pick-by-RF Scan	Pick-by-Vision
Usefulness	High	High	Medium to High	High
Error Rate	Low to Medium	Low to Medium	Medium to High	Virtually Zero
Ergonomics	Medium to High	High	Medium	High
Navigation	Medium to High	High	Medium to High	High
Safety	High	High	Medium	High
Cost	$$	$$$	$	$$
Legend	○ : Virtually Zero ◓ : Medium ◕ : Medium to High ● : High			
	$: Low $$: Medium $$$: High			

Aside from the aforementioned operations, a warehouse also functions in a similar way to a city (Stoltz et al., 2017), evidenced by its unique and complex structure and the variety of processes and operations, thus making AR a perfect technological aid in order to increase digitalization and streamline processes and tasks (Merlino and Sproge, 2015). As a result, a reduction in time needed for individual processes to be performed occurs, which sequentially brings operational costs down (Stoltz et al., 2017).

One more advantage of AR is predictive maintenance. In previous subchapters, IoT's and Big Data's impact on maintenance and optimization of resource utilization was analyzed, but AR is similar to an interface, displaying critical information to the user about the individual robotic and mechanical equipment (e.g. conditions such as temperature and humidity) (Mourtzis et al., 2017; Stoltz et al., 2017).

In the following table, a summary of AR's applications on warehouse operations is presented, along with the benefits of integrating AR technology.

Table 4.16 Describing the benefits for integrating AR in warehouse operations (Glockner et al., 2014; Stoltz et al., 2017; Merlino and Sproge, 2015).

AR Applications on Warehouse Operations		
Operations	**Applications**	**Benefits**
Receiving	• Checking Incoming Goods • Directions for Arrangement of Unloading Sequence • Guiding Drivers	• Reduced Operational Costs • Reduced Time Intervals • Optimization of Receiving Processes
Storing	• Guiding to Exact Locations • Check for Replenishment Requirements • Displaying Item Details	• Reduced Time spent • Optimization of Put-Away Processes
Picking and Packing	• Displaying Route and Location for Specific Items • Indication of Optimal Retrieval Sequence • Displaying Item Details and Conditions	• Optimization of Picking Processes • Cut Time Intervals • Avoidance of Congested Aisles • Operational Efficiency and Reduced Costs
Dispatching	• Displaying Workers own Vitals and Performance Indexes • Indication of Optimal Positioning for Goods to be Distributed • Indication of Cardboard Type to be Used • Showing how to place Orders in a Vehicle depending on Order Type, Size, Destination and Sensitivity	• Reduced Operational Costs • Optimization of Space Utilization in the Vehicle • Increased Safety for Sensitive Packages

4.6.2 AR in Freight Transportation

AR's applications extend to freight transportation with various benefits, including the optimization of several operations and processes (Glockner et al., 2014).

Until recently, most collectors would manually count pallets and parcels or individually scan the barcode on each one with a handheld device (Glockner et al., 2014), leading to unnecessarily long and costly processes. With AR, the worker can perform a throughout 3D scan of items and pallets, saving a lot of labor time, resulting in an optimization of said processes (Glockner et al., 2014). In addition, any damages or loose packages can be detected early enough to prevent any disadvantageous incidents (Glockner et al., 2014).

Moreover, AR can inform drivers about the whereabouts and condition of goods in the truck, display their own physical condition, alert them for any possible vehicle damage and show them fuel levels at any given time without requiring any head or hand movement (Merlino and Sproge, 2015).

Another area in which AR implementation can have very advantageous effects for logistics companies is dynamic traffic support (Glockner et al., 2014). Having already showcased IoT and Big Data applications on freight transportation and how they enable real-time decision making and dynamic scheduling and routing, AR systems have the potential to be the most ideal driver assistance technological aid (Merlino and Sproge, 2015). By drawing information regarding traffic, congestion in roads, unexpected events, route to a destination and exact locations on the windshield of the vehicle or on specially modified glasses, such as the Google Glasses (Glockner et al., 2014). Aside from the real-time information processing, an additional advantage of AR in contrast to the conventional navigation systems is that the driver doesn't lose his focus by looking at a screen outside his field of vision (Glockner et al., 2014).

To sum it all up, the following table describes how AR digitalizes transportation operations.

Table 4.17 Describing how AR revolutionizes freight transportation operations and what are the benefits (Glockner et al., 2014; Merlino and Sproge, 2015).

AR revolutionizing Freight Transportation Operations	
How?	**Benefits**
Throughout 3D Scanning of Items	• Reduced Time spent • Optimization of Loading and Unloading Processes
Prevention of Damages, Vehicle and Personal Health Monitoring	• Reduced Errors • Damage Prevention • Optimized Labor Productivity
Enabling Real-Time Decision Making and Dynamic Transport Support	• Dynamic Re-routing • Avoidance of Congested Roads • Focus on Driving • Alerts in Case of Unexpected Events (e.g. avalanche)

4.6.3 AR in Delivery

Last-mile delivery services and the rise of e-commerce have been growing at a parallel rate (Glockner et al., 2014). Logistics companies aim at lowering last-mile delivery costs and AR is ideal for achieving that (Glockner et al., 2014).

By enabling intelligent vehicle loading, AR significantly reduces the time a driver spends locating a specific parcel, thus decreasing the time he/she spends not-driving (Glockner et al., 2014). In addition, intelligent loading and unloading reduces the risk of parcel to item damage (DHL, 2015).

Another main delivery problem that AR can solve is navigation. Missing street numbers, misspelled addresses, entrances not easy to find and towns or villages with no naming plan for addresses are posing quite a challenge to the delivery man (Glockner et al., 2014). AR can access details from databases by pointing the device towards a building or a location or simply create new entries in existing databases for said buildings and locations that no information is available for (Glockner et al., 2014). By doing that, more information shall be available in the next delivery.

However, traditionally used GPS applications are not capable of being used in perfect coherence with AR technology, as the measurements of longitude, longitude and altitude are not enough (Huang, 2018). The following table compares GPS to a more AR friendly technology, VPS (Virtual Positioning System).

Table 4.18 Compares GPS to VPS.

	GPS	**VPS**
Readiness	●	○
Real-Time Data Processing	-	●
Instant Localization	-	●
Scalability	-	●
User's Orientation	○	●
Geometry Detection	◒	●
Legend	○ : Low ◒ : Medium to High	● : High

The following table summarizes AR's benefits for last-mile delivery.

Table 4.19 Presenting AR's application for last-mile delivery (Glockner et al., 2014).

AR Applications in Last-Mile Delivery	
Applications	**Benefits**
Intelligent Loading/Unloading	• Package Safety • Less Time Not Driving • Reduced Operational Costs
Last-Mile Navigation	• Reduced Operational Costs • Optimized Delivery Processes
New Address Entries and An Ever-Improving Database leveraged by IoT and Big Data	• Optimization of Processes • An Ever-Expanding Address Network

4.7 Logistics 4.0 Implementation Framework

At this point, a framework is introduced to display the necessary steps a company should follow in order to implement any of the emerging Logistics 4.0 technologies presented and examined in this chapter. Emerging issues, such as social acceptance, workers' doubting and being afraid of being fired, high investment costs, standardization of operations, IT infrastructure requirements, regulations and cybersecurity are obstacles that need to be overwhelmed in order to successfully implement any emerging Logistics 4.0 technologies. These issues and challenges will be explained in detail. Finally, an example of Logistics 4.0 technologies implementation will be displayed, based on the framework that is presented in this chapter.

4.7.1 The Framework

The framework is split in five (5) phases of equal importance for a successful implementation. Decide, Prepare, Execute, Improve and Maintain are the five phases of the framework and are displayed in the following figure.

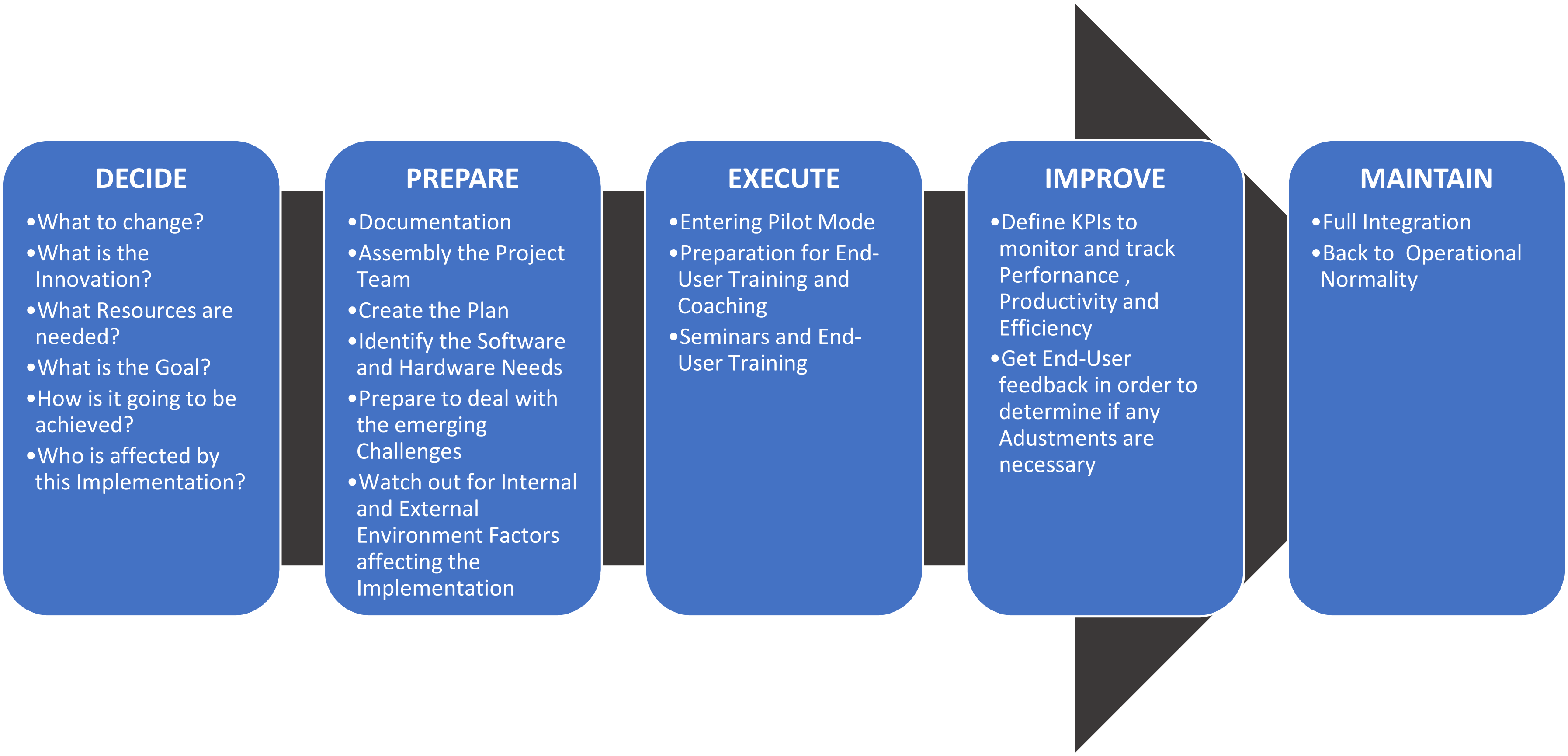

Figure 4.16 The Framework a company should follow in order to successfully implement Logistics 4.0 technologies.

Each phase of the framework depends on some corresponding components, which are critical to the success of the implementation and are described below:

1- Decide. In this phase, the company needs to determine the a) purpose of the implementation (e.g. Higher operational efficiency), b) the innovation (e.g. digitalization and automation) and, c) define the resources which are necessary for the implementation project to proceed (WENDY HIRSCH CONSULTING, 2018).
2- Prepare. During the preparation stage, both components and roles need to be determined. Critical components are a) documentation, b) assembling of the project team, c) creating the plan, d) defining the needs in software and hardware, e) preparing a data transfer plan and, f) prepare to deal with the challenges and issues that emerge by correctly determining the stakeholders, which form the roles that have an immediate impact on the framework's phases. Stakeholders are as follows:
    a. Governments
    b. Society and Organizations
    c. Management
    d. Employees
    e. Project Team
    f. Competition
    g. Partners
3- Execute. During this phase, the implementation project enters pilot mode, in order to optimize any software or hardware performance and most importantly, train and coach the end-users.
4- Improve. After completing the end-users training and coaching and determining whether piloting was successful or not, the implementation framework enters its fourth phase. During that period, end-users provide valuable feedback. Another crucial component of this phase is determining the KPIs to be utilized for monitoring and tracking system's performance, efficiency, productivity, etc.
5- Maintain. In the final phase of the implementation framework, full integration of the newly implemented technologies is expected. At that stage, all operations and activities should proceed normally.

4.7.2 The Emerging Challenges

Implementing Logistics 4.0 technologies is associated with emerging challenges of social, technological, economic, HR-related and operational nature (Barreto et al., 2017). Social challenges are consisted of regulations (e.g. UAVs flight area), environmental organizations, acceptance of revolutionary technologies by the public and cybersecurity (Noronha et al., 2016). Technological challenges are originating from the company's internal environment and are consisted of the needs in software and hardware, which have a direct impact on the economic challenge of high investment costs for Logistics 4.0 technologies implementation. HR issues are formed by the concern of employees and the fear of losing their job, or watching their salaries reduced (Ermolaeva, 2017). Finally, operational issues emerge due to the need for standardization and the need for reformed organizational structures, an issue thoroughly explained and analyzed in chapter 3. The following figure summarizes the aforementioned challenges and splits them into their respective environments, external and internal.

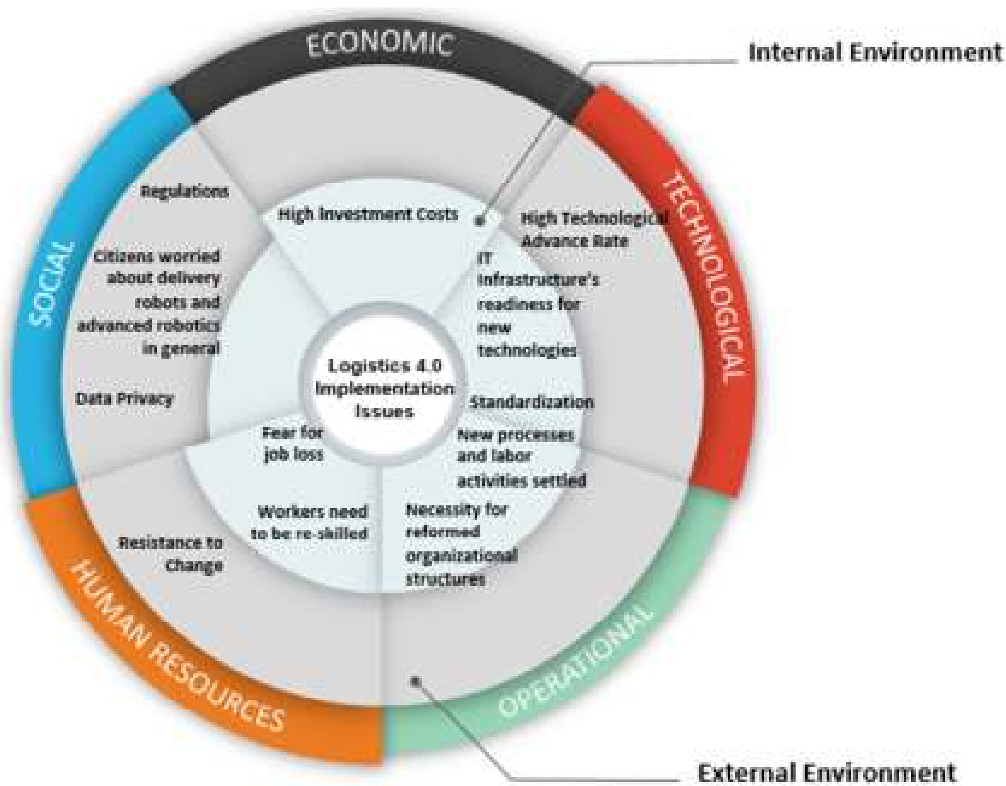

Figure 4.17 Displaying the issues and challenges of the Logistics 4.0 implementation (Gialos and Zeimpekis, 2018; Barreto et al., 2017).

Dealing with these challenges is key for a successful Logistics 4.0 implementation. Companies should comply with regulations and make efforts towards displaying an eco-friendlier profile, as well as dedicate time and effort into conducting educative seminars and releasing informational leaflets that educate the public about the revolutionary technology and its safety.

On the technological frontier, a company should have full knowledge of the necessary upgrades that are required for a Logistics 4.0 technology implementation in order to avoid any increase in total implementation costs, thus decreasing payback time and increasing return on investment. Dealing with this issue is crucial, as the investment costs are high (Gialos and Zeimpekis, 2018).

Standardizing operations is another challenge a company should deal with in order to properly integrate the emerging technology to be implemented, as it will enable the maximizing of operational efficiency and productivity. Standardizing operations leads to another challenge, which is the necessity for reformed organizational structures. Decreasing management levels allows for a more flexible and adaptive approach (Jakes, 2016), something achieved through the adoption of organizational structures such as fractalization, lean organizations, network organizations, virtual organizations and amoebas, explained in chapter 3.

Finally, dealing with HR issues is vital to a company's function as employees and workers need to be reassured that a Logistics 4.0 implementation leading to digitalization and automation is not a threat to their jobs or salaries, but the way forward for the company to achieve higher operational efficiency, productivity and innovation (Ermolaeva, 2017).

Company leaders and managers should reassure the employees that their skillset will be improved through training and coaching in order to allow them to utilize their skillset in more technical areas and that jobs are not threatened but empowered by this implementation.

4.7.3 Implementing UAVs for Inventory Management

The benefits of an implementation of UAVs for inventory management was described earlier during this chapter. An example of the framework's use for implementing UAVs in the warehouse is as follows:

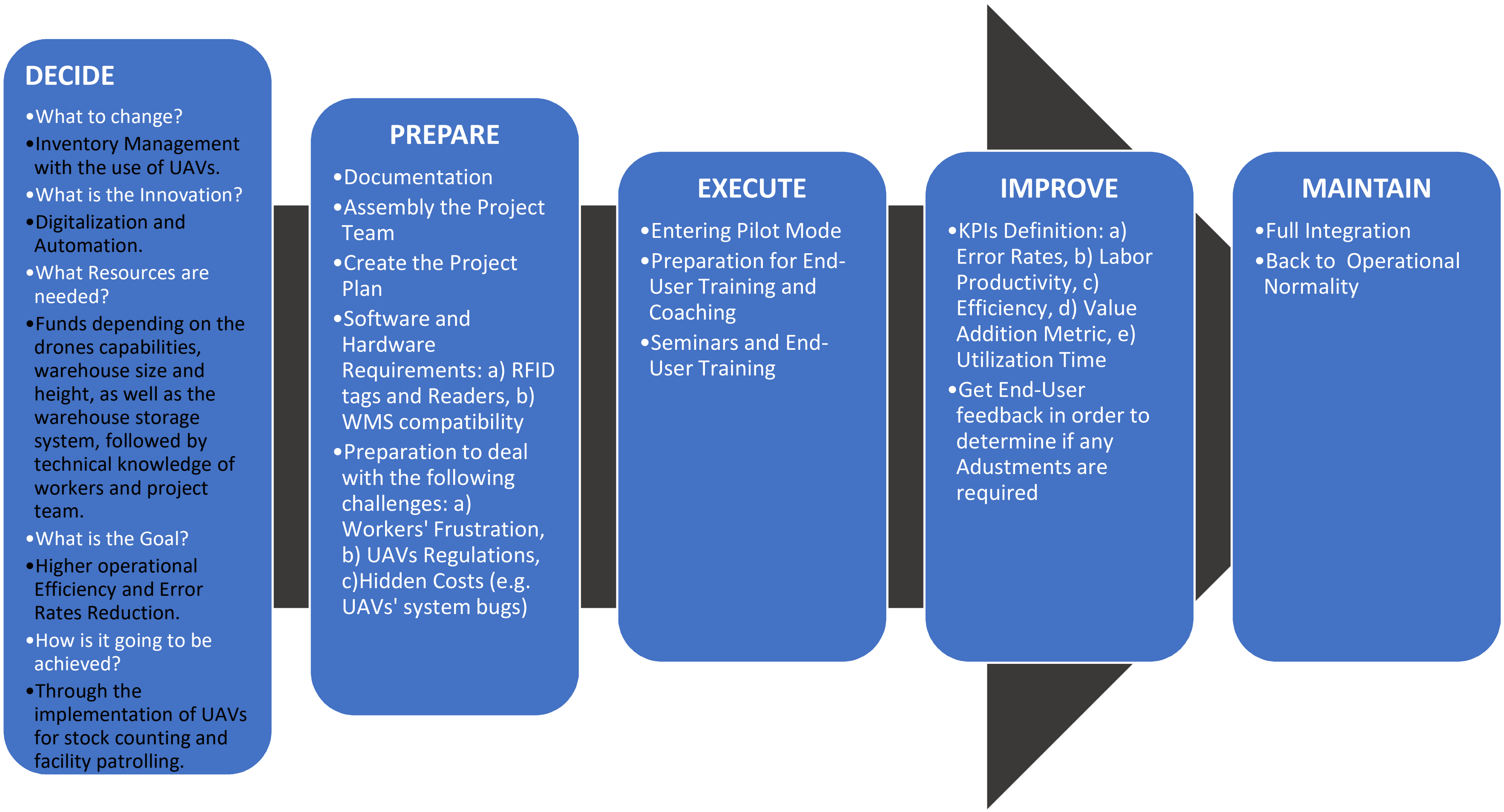

Figure 4.18 Framework about UAVs implementation for Inventory Management.

During the Decide phase, the company decides to automate several processes and tasks regarding inventory management and facility patrolling, with the goal of achieving higher operational efficiency and decreasing error rates. The economic resources needed are based on a number of factors, more specifically the warehouse size and height, the warehouse storage system, the infrastructure and the drone capabilities needed for performing the chosen processes and tasks.

At the Prepare phase, documentation and assembling the project team are completed. Then, software and hardware requirements are recognized. For example, an up-to-date WMS and the RFID compatibility with the UAVs are needed. At this stage, issues raised need to be dealt with, as regulations regarding UAVs are still being formed and companies need to track those changes and comply accordingly, while workers need to be assured that their expertise will be utilized in more areas and tasks by having them thoroughly trained in the new operational processes and systems (e.g. the UAVs handling equipment).

After the Execute phase, where the pilot mode is entered, several KPIs are defined during Improve for monitoring and tracking end-user feedback, UAVs performance and results provided. The KPIs are as follows (WENDY HIRSCH CONSULTING, 2018):

1- Error Rate
2- Labor Productivity
3- Efficiency
4- Value Addition Metric
5- Utilization Time

Finally, during the Maintain phase, operations are back to normality and the UAVs have been fully integrated.

4.8 Summary

In this chapter, logistics 4.0 technologies and their applications on warehouse, transportation, distribution and delivery operations were examined, with an implementation framework proposed for companies that may aim at implementing said technologies. Finally, a framework regarding the implementation of UAVs for inventory management was presented. The following table presents which logistics 4.0 and logistics 3.0 technologies apply to each individual operation and which of them transforms manual operations to automated.

Table 4.20 Summarizing the technologies that drive logistics operations towards automation and digitalization (Gialos and Zeimpekis, 2018; Noronha et al., 2016).

Logistics 4.0 vs Logistics 3.0 Technologies										
Operations	Logistics 3.0 (Semi-Automation/Manual)					Logistics 4.0 (Automated)				
	Pallet Stacker	RF, and Voice Picking	Manual Handling (e.g. Picking)	Barcode Tags	Hand Pallet Truck	IoT (RFID, Sensors etc.)	Big Data Analytics	Advanced Robotics (AGVs, Self-Driving Vehicles etc.)	UAVs	AR
	Warehousing									
Receiving	✔		✔	✔	✔	✔		✔		✔
Put-Away	✔		✔			✔	✔	✔		✔
Inventory Management	✔	✔		✔		✔	✔		✔	
Picking			✔	✔		✔		✔	✔	✔
Packing			✔			✔		✔		✔
Dispatching	✔		✔	✔	✔	✔	✔	✔		✔
	Freight Transportation									
Loading/Unloading	✔	✔	✔		✔	✔	✔	✔		
Fleet Management						✔	✔			
Scheduling and Routing						✔	✔			✔
Package Handling		✔	✔					✔	✔	✔
Navigation						✔	✔			✔
Last-Mile Delivery				✔		✔	✔	✔	✔	✔

In the following chapter ten case studies of Logistics 4.0 technologies implementation will be reviewed in order to showcase several outcomes of how these technologies revolutionize the logistics industry.

Chapter 5 Case Studies in Logistics Operations

5.1 Introduction

In previous chapters, a review of the current status of logistics operations was conducted followed by the introduction of Logistics 4.0 and how its revolutionary technologies can potentially reshape the logistics industry and drive it towards digitalization and automation. This chapter's goal is to display the advantages of implementing logistics 4.0 technologies in warehouse and transportation operations by reviewing several case studies.

The following table shows a list of ten case studies that have been reviewed and show how logistics 4.0 technologies have been adopted successfully by organizations and companies.

Table 5.1 Displaying the case studies to be reviewed and which technologies are present in each situation

Company	Case Study	Technologies				
		IoT	Big Data	Advanced Robotics	AR	UAVs
Bobcat	SmartLIFT Technology	✓	✓			
DHL	Weighing Pallet Shipments	✓		✓		
Intel	Vision Picking				✓	
DHL	Dynamic Inventory Control	✓	✓			
Fraunhofer IML	InventAIRY Project	✓				✓
Mercedes, DHL & Volvo	Maintenance on Demand	✓	✓			
DHL	DHL's SmartTruck	✓	✓			
UPS	Project ORION for Routing	✓	✓			
Jack in the Box	Delivery Robots			✓		
Amazon	Drone Delivery		✓			✓

5.2 Case Study 1: Bobcat and SmartLIFT Technology

Bobcat is a company supplying construction machinery and equipment (Wormer, 2014). Loaders, excavators and various types of construction and industrial equipment are originating from Bobcat Co.'s main production facilities which consist of three warehouses in the 25.000 to 50.000 square feet range (Bradley, 2014).

5.2.1 The Challenge

Production materials of various kinds (e.g. large steel coils) pass through those warehouses in order to get to manufacturing. It was reported that more than 40 truckloads of inbound material are arriving each day resulting in deeming inventory control challenging and increasing error rates revolving around location of goods and packaging (Bradley, 2014).

Errors included faulty location reporting and inaccurate quantities which were human errors in nature (Bradley, 2014). Bobcat used gatekeepers and forklift drivers in order to check inventory in a standard frequency and report to their superiors, but the human factor played a crucial role in the high error rate resulting in the company seeking out for a solution to rule out human errors (Bradley, 2014; Wormer, 2014). The company aimed for a system which could support real-time data processing and take out the human factor.

RFID tags were considered, but the great amount of steel in the facilities would end up in lost signals and inaccuracy (Bradley, 2014), which would only aggravate the problem. As a result, Bobcat leaders opted for a visually-based solution (Bradley, 2014).

5.2.2 The Solution

IoT and Big Data analytics offered the solution. SmartLIFT, short for Smart Labor, Inventory and Forklift Tracking, is a business intelligence software solution based on the utilization of GPS and sensor technology, which combined with Big Data analytics offers real-time data processing of data generated by the WMS and new data originating from the use of sensors (Bradley, 2014).

With SmartLIFT, which is essentially an indoor GPS, information regarding truck location, speed and condition, pallet location and condition (e.g. size and weight) and a precision to the inch are enabled (Bradley, 2014). As for how it works, 11 by 11-inch barcodes are fixed on the warehouse ceiling and optical SmartLIFT sensors are mounted on top of the lift trucks in order to establish an uninterrupted visual connection resulting in a continuous real-time location tracking (Bradley, 2014). As for the label scanning a label reader is placed between the lift masts, resulting in an automatic label scanning (Bradley, 2014). Furthermore, a lift height sensor and a pallet detector are placed on the lift forks (Bradley, 2014). As a result, the WMS and the ERP are continuously being “fed” with real-time information transmitted through a terminal mounted on the lift truck (Bradley, 2014). These supporting technological aids can be seen in figure 5.1.

Figure 5.1 Showing the locations of the individual supporting technologies on a TELEHANDLER BOBCAT V417 (onestoprentalsales.com, 2018).

In the beginning, one fourth of the trucks were supplemented with SmartLIFT sensors in order to monitor the output and test the results (Bradley, 2014). Drivers had no problem getting used to the new ways of performing operations according to Donnie Herbst, Bobcat's strategic materials manager at the time (Bradley, 2014).

5.2.3 The Results

SmartLIFT proved to be quite beneficial to Bobcat, evidenced by the 25 to 30% increase in driver's productivity and the ~0% of errors revolving around the placing of pallets. Inventory accuracy was seeing significant increases and Bobcat leaders decided to expand the use of the SmartLIFT sensors even further. According to Donnie Herbst, an 18-month return on investment was expected (Bradley, 2014).

5.3 Case Study 2: DHL's Weighing Forks on a Forklift Truck

Logistics companies depend on accuracy when it comes to weighing goods, as miscalculations result in missing out on turnover and that is something providers desire to avoid (Ravas, 2018).

5.3.1 The Challenge

DHL Poland was facing such a problem to a great extend as managers could not find an efficient way to weigh pallet shipments and as a result were missing out on turnover (Ravas, 2018). The reason was due to a logistic implication, simply the fact that weighing pallets was too time-consuming (Ravas, 2018). One unfruitful solution was processing pallets by hand because of their various sizes deeming sorting and weighing on automated belts impossible (Ravas, 2018).

5.3.2 The Solution

Using specially designed weighing forks on a forklift truck was the first step (Ravas, 2018). The RWV weighing forks seen in figure 5.2 are connected to a display in the truck cabin which transmits the pallet data to a truck terminal which sequentially sends these data to the WMS through a W-Lan wireless network (Ravas, 2018). It is worth mentioning that the revolutionary feature of the RWV weighing forks is the capability for real-time data processing.

Figure 5.2 The RWV weighing forks (Ravas, 2018).

After lifting the pallet, the driver scans the barcode and information regarding the postal code, the sender's profile, the shipment details and the declared weight get sent to the WMS, which in turn matches the declared weight to the weight measured by the RWV forks, making any necessary alterations to the invoice (Ravas, 2018).

Finally, the WMS informs the driver about the internal destination of the pallet (Ravas, 2018). The driver then takes the pallet to the corresponding dock for loading and either leaves it for further shipment or immediately loads it to the truck (Ravas, 2018).

5.3.3 The Results

The following table compares the operations before and after installing the RWV forks.

Table 5.2 Comparing warehouse operations pre and post smart weighing forks installation (Ravas, 2018).

Before	After
Weighing was taking a lot of time to be completed	Weighing pallets is only adding <10 seconds to the procedures
Miscalculations were a direct result of the inability to correctly weigh pallets	Accurate calculations lead to a match between the declared and the measured weight
The drivers needed to know where to drive the pallet	The driver is directly informed by the WMS about the pallet's destination
Higher operational costs due to the above factors	Reduced operational costs
Impaired labor productivity	Higher efficiency in labor productivity

5.4 Case Study 3: Vision Picking at the Inter Arizona Distribution Center

The importance of picking in warehouse operations has been highlighted throughout all previous chapters and since it is costly and labor-intensive it is only logical for companies to try to reduce related costs and increase efficiency levels (Intel, 2015).

The advantages of vision picking are many when compared to pick-by-voice, pick-by-light, RF-scanning and paper-picking as seen below (Intel, 2015):

1- Hands free at all time

2- Information and details accessible through AR technology and appearing in front of the worker's optical field
3- Perfect for worker's ergonomics and natural motions

5.4.1 Vision Picking vs RF Picking at the Intel Arizona Distribution Center

Intel is one of the largest and most well-known technology corporations. They decided to implement Ubimax's Jet Pro Smart glasses, supported by AR technology, and pit it against RF scanners in their facilities (Intel, 2015). Pick lists were provided to both sides (Intel, 2015).

Figure 5.3 The differences between the two picking methods were reported by workers with the flexibility and efficiency that the smart glasses offer being unanimously applauded (Intel, 2015).

The following disadvantages were reported by those using RF-scanners (Intel, 2015):

1- Too much information
2- Information not displayed in a coherent way
3- Manual data entry
4- The handheld scanner increasing risk of injury (e.g. when on a ladder)
5- Stopping to look at the handheld display and picking back up was increasing time spent

On the other hand, users using the head-wearable glasses reported that the information presented was much more coherent, as shown in figure 5.4, and did not interfere with their activities since both hands were free and information were shown in front of the glasses (Intel, 2015), not requiring them to stop and check a screen. In addition, having both arms free increased the feeling of safety for workers, let alone the production efficiency increase (Intel, 2015).

Figure 5.4 The information on the right concerns the aisle and the shelf for locating the item, while the information on the left concerns the item code, the quantity to be retrieved and the delivery note to be put on the box (Intel, 2015).

5.4.2 The Results

In total, 120 test picks took place with the Intel Recon Jet Pro leading to a 29% increase in pick rate with a reduced error rate (Intel, 2015). To highlight the difference, the fact that the first pick performed with the utilization of the smart glasses resulted in a 15% decrease in picking time per box is evidence about the efficiency that AR technology facilitates (Intel, 2015).

5.5 Case Study 4: DHL's Dynamic Inventory Control

Inventory management is one of the most important elements of supply chain management and integral to the operational efficiency of a warehouse (Rushton et al., 2014).

5.5.1 The Challenge

Throughout visibility and traceability through the supply chain are key for the automotive industry, as the collaboration between manufacturers, parts suppliers, logistics providers and transportation companies are crucial to total performance (DHL, 2018).

But DHL faced a major challenge when in partnership with an automaker company with a plant in Mexico. It was reported that three different production processes, 22 suppliers and 300-part numbers were involved (DHL, 2018). The company was in a great need for effective and dynamic inventory control, as unused materials and high operational and transactional costs were ordinary (DHL, 2018).

5.5.2 The Solution

DHL's IoT-enabled solution was based on a supplier IT system developed to support basic manufacturing operations, such as replenishment of supplies and deliveries with the goal od improving the efficiency of inbound-to-manufacturing material flow (DHL, 2018). This system connected all the customer suppliers into a central platform allowing for real-time inventory management and production scheduling while increasing flexibility and streamlining processes (DHL, 2018).

5.5.3 The Results

Direct results were evidenced by a 30% reduction in inventory and a 50% reduction in unused materials (DHL, 2018). Error rate was significantly reduced and operational and transactional costs were decreased, while time intervals for supplier response were optimized (DHL, 2018).

5.6 Case Study 5: The InventAIRy Project by Fraunhofer IML

The InventAIRY research project was based on the use of UAVs in indoor and outdoor warehouse operations, specifically inventory management and picking (Federal Ministry for Economic Affairs and Energy, 2015). Inventory control, goods locating and retrieving and aisle routing are targeted for automation and digitalization through the use of UAVs, as drones are able to detect the necessary goods, systematically check for replenishment, retrieve needed objects and navigate through the warehouse, while staying constantly connected to the WMS (Federal Ministry for Economic Affairs and Energy, 2015). These drones generate maps for the area they cover by utilizing smart algorithms and IoT-enabled sensors with the addition of 3D cameras and scanners. This case study examines how the use of UAVs for intralogistics applications can aid in automating inventory management by facing the challenges stated below.

Figure 5.5 The InventAIRy Bonn Test Copter (Ais.uni-bonn.de, 2016).

Figure 5.6 The InventAIRy copter in a Panopa Logistik warehouse (Ais.uni-bonn.de, 2016).

5.6.1 The Challenge

Stock-taking, checking for replenishment needs, navigating through the warehouse searching for specific goods or items and picking are mostly manual in nature, if not completely, which results in many periods during a working day when a warehouse's operation remains still (Federal Ministry for Economic Affairs and Energy, 2015), as such activities require a lot of labor time and effort to be performed.

The use of barcodes and RFID tags facilitates easier and less time-consuming processes during receiving, picking and dispatching, but during stock-taking and stock levels checking the task of scanning is still manual, thus allowing no benefits (Federal Ministry for Economic Affairs and Energy, 2015) and also increasing the risk of errors.

5.6.2 The Solution

The UAVs utilized in the warehouse are able to automatically check inventory levels without any human interference, thus reducing operational costs, increasing reliability and boosting labor productivity due to workers focusing on their tasks instead of being invested in time-consuming activities regarding inventory management (Federal Ministry for Economic Affairs and Energy, 2015). When a deviation in inventory levels is detected, the WMS is immediately informed for any corrective moves needed to be taken (Federal Ministry for Economic Affairs and Energy, 2015).

Finally, the UAVs can easily be connected to the WMS with no need for customizations in software development allowing for a greater information flow (Federal Ministry for Economic Affairs and Energy, 2015).

5.6.3 The Benefits

The following table compares how the InventAIRy project's UAVs altered the way warehouse operations are conducted, highlighting the benefits.

Table 5.3 Displaying how UAVs transform inventory management (Federal Ministry for Economic Affairs and Energy, 2015).

The Utilization of InventAIRy Project's UAVs in an Automotive Company's Warehouse		
Before InventAIRy	**Post-InventAIRy**	**Benefits**
Manual inventory levels checking and stock-taking	Automated activities and tasks regarding inventory management	• Less time-consuming activities and tasks • Reduced operational costs • Increased labor productivity • Decreased error rate
Time-consuming aisle navigating for locating an object or goods	Automated object or goods locating with an integrated warehouse map	• Automated navigating and locating tasks and activities • Increased labor productivity
Interrupted flow of information	Uninterrupted flow of information as UAVs are connected directly to the WMS	• No need for software development customizations and patches • Uninterrupted flow of information
Unspecified regulatory frameworks and guidelines	Specified regulatory frameworks and guidelines	• Greater productivity and efficiency

5.7 Case Study 6: Maintenance on Demand (MODE)

MODE is a research project conducted by the combined forces of DHL, Volvo and others regarding IoT and Big Data-enabled real-time monitoring of a vehicle's health statistics and condition with very advantageous applications for the logistics industry, as predictive maintenance can boost vehicle uptime by ~30% and reduce dead mileage (CORDIS| European Commission, 2013; Macaulay et al., 2015).

5.7.1 The Logistics Challenge

Transportation of goods is a huge part of the supply chain road transportation accounts for 42,7% of goods transportation mode of choice (SAFETY4SEA, 2018). Predicting failures of materials, parts or other vehicle systems is crucial to a more efficient and sustainable transportation of goods, leading to increased revenues and greater customer satisfaction in the process (Macaulay et al., 2015).

Many logistics providers struggle with efficiently monitoring their fleet's vitals etc., leading to increased operational costs, more deadhead miles due to a possible vehicle's failure, decreased productivity and sequentially lesser customer service (Macaulay et al., 2015).

5.7.2 The Solution

MODE offers a solution based on leveraging IoT and subsidiary technologies (e.g. sensors) and Big Data analytics (Macaulay et al., 2015). By strategically placing sensors in various mechanical or non-mechanical parts of the vehicle (e.g. the damper systems) and by having a telematic unit inside the driver's cabin, a remote user, such as the manager, can monitor the vehicle's vitals and condition (e.g. Temperature, humidity, material degradation etc.) and fuel consumption, with real-time data processing based on a wireless 4G connection and with Big Data analytics allowing for a much greater volume of data to be processed, thus offering much more immediate and crucial information (Macaulay et al., 2015). It is worth mentioning that Big Data analytics is the key to real-time decision making, as it boosts profitability and generates more revenue in the long-term.

Figure 5.7 Many collaborating partners offered their expertise in developing the MODE project. As seen in this figure, the damper system, the fuel injector and the oil system have been embedded with sensors which send the data to the central system, which sequentially transmits them to a remote user (Avonwood, 2013).

The data are transmitted to a central system for processing and then onto the maintenance system for analysis (Macaulay et al., 2015). In case of a maintenance requirement or an emergency such as a system or a mechanization failure the driver is alerted to either pull over or head to the closest station (CORDIS| European Commission, 2013).

5.7.3 The Benefits

MODE was first tried on a commercial vehicle, Mercedes Benz C-Class, with great success. The advantages for the logistics industry are as follows (CORDIS| European Commission, 2013; Macaulay et al., 2015):

1- Accurate maintenance intervals based on Big Data analytics
2- Vehicle uptime increased by 30%
3- Predictive maintenance based on vehicle usage profile and materials condition enables service packages to be offered for added value
4- Saved maintenance costs of up to 25%
5- Greater customer service due to increased flexibility and fleet efficiency

6- Big Data aids in increasing profitability and customer satisfaction in the long-term
7- Dynamic fuel management

5.8 Case Study 7: DHL and the SmartTruck

Last-mile delivery has always been a costly logistics operation with lots of potential for efficiency and cost reduction (Jeske et al., 2013). In this case study, the challenge of reducing operational costs while increasing operational efficiency is stated, followed by analyzing how DHL's SmartTruck makes use of IoT and Big Data analytics in order to achieve those goals and revolutionize the way logistics providers approach delivery operations (Laetsch et al., 2016).

5.8.1 The Challenge

Delivering a parcel is a complex and demanding task with the factors of the continuously uprising e-commerce and the greater customer demands deeming it even more difficult today (Noronha et al., 2016).

Environmental factors also demand attention, with many logistics companies and governments agreeing upon searching for solutions for reducing CO_2 emissions (Noronha et al., 2016). Empty-running miles addresses not easily found, congested roads, are all factors for more CO_2 emissions (Jeske et al., 2013). Apart from that, those factors also negatively affect operational efficiency, as they increase costs and possibly have a negative impact on customer satisfaction too (Jeske et al., 2013).

5.8.2 The Solution

In order to effectively face those challenges, DHL launched the SmartTruck in 2010, a truck supported by the combined technological forces of IoT and Big Data (Laetsch et al., 2016). The SmartTruck is allowing for real-time data processing, regarding road congestion and navigation, by utilizing a telematic unit and being in constant contact with a manager through the GPS (Laetsch et al., 2016). This enables the manager to have more control over the fleet, which augments overall performance (Laetsch et al., 2016).

These technological advancements generate another big advantage of the IoT and Big Data enabled SmartTruck, as they allow real-time route optimization which leads to a more dynamic approach towards routing and last-mile delivery (Laetsch et al., 2016). In addition, the system immediately informs managers and drivers for any changes or problems, such as a misplaced package, thus increasing flexibility and adaptability (Laetsch et al., 2016).

Finally, the SmartTruck constantly feeds the manager data regarding fuel consumption, miles travelled, the driver's vitals, goods and items condition and the vehicle's health (e.g. temperature, pressure etc.) (Laetsch et al., 2016).

5.8.3 The Benefits

By using the DHL SmartTruck, the benefits are as follows (Laetch et al., 2016):

1- 15% less miles travelled
2- Decreased CO_2 emissions
3- Predictive maintenance leading to greater operational efficiency
4- Greater customer service due to routing optimization
5- Reduced operational costs

5.9 Case Study 8: UPS Leveraging Big Data Analytics

Big Data analytics offer great value to logistics providers, as already mentioned before. Companies investing in Big Data applications and projects are seeing reduction in costs, greater insights and increased efficiency among many more benefits (Jeske et al., 2013).

5.9.1 UPS Big Data Projects

UPS, a leading logistics company, has been investing in Big Data centered projects for a while now, having realized the value analytics can offer (Samuels, 2017). The company's aim is to leverage automation and innovation in a way to optimize their delivery operations and processes globally (Samuels, 2017).

Such a project is known as Network Planning Tools (NPT), which utilizes Big Data, operations research and Artificial Intelligence in order to enable real-time data processing and decision making for better decisions (Samuels, 2017). These tools are expected to optimize the distribution of more than 60 million packages in the U.S. per day, alone (UPS, 2018).

Another Big Data focused project playing a huge part in the smart logistics network that UPS is planning, is the ORION (On-road Integrated Optimization Network) project (Samuels, 2017; UPS, 2018).

ORION is a fleet management system developed to fundamentally turn away from the way standard systems operate (Samuels, 2017). ORION utilizes advanced algorithms in order to allow real-time decision making for drivers and managers, thus optimizing routing and delivery, by processing data regarding pickup time, package deliveries scheduling, route performance and vehicle condition (UPS, 2018).

The system leverages Big Data analytics in order to dynamically optimize routes with the goal being a reduction in overall miles and greater customer service (Samuels, 2017).

5.9.2 Results and Goals

UPS has already launched ORION with great success, as 85 million of miles have been saved per day and fuel consumption is lower, thus saving $84 million per year and a total of $30 million per year is being cut from operational costs (Mclean, 2014).

These numbers are expected to grow even further with ORION continuously evolving with advanced algorithms and Big Data analytics tools, supported by the rise of IoT-enabled technologies (Samuels, 2017).

5.10 Case Study 9: Jack in the Box investing in Delivery Robots

Quick service restaurants (QSR) depend on great customer satisfaction, which is formed based on factors such as speed, quality and service (Miles, 2017). This case study focuses on a QSR chain, Jack in the Box, which is constantly striving for innovation in a very competitive market (Miles, 2017).

5.10.1 Investment in Autonomous Delivery Robots

Jack in the Box is spread across 21 states with 2,200 and more restaurants (Miles, 2017). Realizing the impact great customer satisfaction can have on revenue and brand-name strength, the restaurant chain's leaders decided to invest in a partnership with technology company DoorDash and logistics company Marble with the goal of expanding the delivery window by partly automating their delivery operations (Miles, 2017).

They started by having delivery robots carrying food up to the customer's door in San Francisco, which proved successful due to the fact that autonomous delivery robots enabled late-night deliveries and increased operational efficiency and flexibility (Miles, 2017). These robots are about 90 cm tall and look like a smaller Mars Rover (Mashable, 2017). Their advantage over delivery vehicles (mini-cars, motorcycles, bicycles etc.) is their quicker navigation capabilities enabled by a continuous 4G connection (Miles, 2017; Mashable, 2017).

The delivery robot is equipped with a software which allows it to act autonomously, with light detection and ranging technology enabling an all-around "vision", thus adding safety and efficiency to its navigation through the city (Mashable, 2017). In addition, high-resolution cameras, ultrasonic sensors and 3D maps provide the delivery robot all the necessary tools for a perfectly performed delivery (Mashable, 2017).

Figure 5.8 The delivery robot, called Happy, developed by DoorDash and Marble (Mashable, 2017).

The success ignited an extension of the partnership to include more restaurant locations in different states, with the QSR chain aiming at a continuously increased customer satisfactory level (Miles, 2017).

5.10.2 Future Investments

The QSR chain is aiming at integrating other technological aids and platforms in order to achieve greater levels of customer satisfaction, such as on-demand delivery, again enabled by the use of delivery robots (Miles, 2017). Adapting early is risky, but in the food industry technologies derived from logistics 4.0 can potentially revolutionize the current status (Miles, 2017).

5.11 Case Study 10: Amazon's Drone Deliveries

Amazon is one of the most well-known and largest online retail companies worldwide, so it is natural for the company's CEO, Jeff Bezos, and his partners to continuously look for ways to innovate and revolutionize the industry (BBC News, 2013).

5.11.1 Investing in UAVs

Delivering goods is an operation depending on multiple factors and Amazon wants to optimize it in order to increase customer satisfaction levels, while reducing operational costs (BBC News, 2013).

In 2013, Amazon decided to invest in the Octocopters, as seen in figure 5.9, drones which could carry goods up to 2,3 kgs (BBC News, 2013). These drones enabled immediate delivery below the hour mark, a revolutionary feature (BBC News, 2013).

The service was later named Amazon Prime Air and was designed with the goal of optimizing delivery processes (BBC News, 2013). Airspace regulations were putting the project at a halt though, but in late 2016 the civilian air space was opened to drones (BBC News, 2013).

Figure 5.9 The octocopter utilized for the Prime Air service by Amazon (Spary, 2015).

5.11.2 Advantages

After the regulations issue was surpassed, Amazon fully utilized UAVs for delivering goods (Business Insider, 2018). It is now estimated to result in savings of up to $50 million, due to enabling rural delivery at much lower operational costs, while its shipment cost is at a low $1 per trip (Business Insider, 2018). In addition, UAVs can deliver goods in as low as 30 minutes at a speed of 100 mph, which results in greater customer satisfaction levels and even lower operational costs (Business Insider, 2018).

5.12 Summary

In this chapter, five warehousing-related and five freight transportation-related case studies were analyzed, with the objective being the highlighting of Logistics 4.0 technologies' benefits and advantages. Each case study was revolving around a challenge or a point to be proven, with emerging technologies offering solutions that currently utilized technologies cannot provide. Then, the benefits and the advantages of utilizing the Logistics 4.0 emerging technologies were laid out and explained thoroughly.

Chapter 6 Conclusions

The purpose of this Master thesis was to determine how Logistics 4.0 technologies revolutionize logistics operations, develop a framework for adoption and showcase examples of said technologies implementations in order to display their impact.

6.1 Main Findings

Reviewing current information systems and practices in warehouse operations was the first step in this thesis. It has been found that individual operations are still semi-automated at a percentage of 75-80% (Michel, 2016). However, warehouse management systems, automated storage and retrieval equipment, pallet trucks, picking technological aids (e.g. RF-picking) etc. are facilitating an easier approach to most processes and activities (Rushton et al., 2016).

The challenges that emerged have been exploiting the limits of currently utilized warehouse technologies and practices, highlighting the inefficiencies that exist within their capabilities (Barreto et al., 2017), as analyzed in chapter 2. The rise of e-commerce has led to a continuous need for faster and more accurate operations due to the exponential growth of online sales, while the goods making the reverse trip have been on the rise showcasing the necessity of efficient reverse logistics processes (Malindretos, 2015; Monahan and Hu, 2018). Globalization’s uninterrupted rise shows why logistics providers and companies are required to optimize their inbound and outbound logistics operations (Grapht, 2018). The aforementioned challenges are related to the higher customer demands, as orders are placed at a higher frequency and customers demand precision, accuracy and efficiency when it comes to having their goods delivered, which results in a greater need for optimizing packing and dispatching operations (Jeske et al., 2013). In addition, companies and logistics operators are required to adjust to environmental and social regulations (e.g. lowering CO_2 emissions and reducing waste) (Noronha et al., 2016).

When it comes to freight transportation, fleet management systems and routing software solutions are utilized at a great extend and success already, but one thing highlighted, through the case studies analysis which was performed in chapter 5, was the necessity for real-time monitoring and visibility throughout the goods’ journey from dispatching to the customer (Malek et al., 2017). Approximately 42,7% of the distributors choose road transportation of goods over other transportation modes, but although road vehicles facilitate a not so expensive and adaptable distribution, a number of serious implications have been difficult for logistics providers to overcome (SAFETY4SEA, 2018; Barreto et al., 2017). For example, some of the most common implications that were analyzed are fuel consumption as a factor of great uncertainty, the condition of sensitive products as it demands continuous monitoring and the mechanical, or no mechanical, parts of the vehicle that need to be monitored in order to prevent material degradation and increase vehicle up time (Nearsay.com, 2018). In addition, reducing vehicle empty-running miles was highlighted as key to reducing CO_2 emissions (Jeske et al., 2013). As for urban distribution, research on city logistics and last-mile delivery has been going strong for the last decade and more, as challenges and implications emerging in that sector of freight transportation are quite complex in nature and require close attention when one considers solutions (Cardenas Barbosa and Vanelslander, 2017). Congested roads, air pollution, vehicle empty-running miles and fuel consumption are issues which are significantly heightened in these kinds of situations.

Then, after thoroughly reviewing current warehouse and freight transportation operations and the challenges and issues that have emerged along the way, chapter 3 introduced Industry 4.0 and how companies should proceed in digitalizing their operations, as building a flexible organizational structure is a challenge that needs to be addressed and adopting the digital enterprise model is a crucial step before implementing the new age technologies, as companies must add the elements of flexibility and adaptability (PwC, 2016; Jakes, 2016) Finally, it was stated that companies worldwide should be careful during adopting those technologies and embracing increased automation and digitalization, as HR issues such as workers being afraid of losing their job need to be prevented (DW.COM, 2016).

Then, the Logistics 4.0 concept was introduced and analyzed, followed by a general description of the key technologies that are examined in the thesis. IoT is the pinnacle of those technologies, as it enables new data streams creation from sources previously being non-exploitable and allows companies to monitor and control mechanizations, fleets etc. by a central system. As a result, real-time monitoring and controlling produce greater and more precise insights and real-time visibility and traceability is enabled by sensors and stable wireless connection, while it adds preventiveness to the manager’s toolkit (Malek et al., 2017; Karakostas, 2016).

Big Data analytics provide a powerful tool to companies, as the new data streams generated by IoT produce much greater amounts of data which common software cannot process. Key advantages of Big Data analytics produced by its ability to process huge datasets by normally breaking them down into smaller ones and piecing them back together after processing is done, are real-time data processing and real-time decision making (Jeske et al., 2013).

Advanced Robotics revolutionize logistics operations due to increasing automation. As seen in several case studies in chapter 5, many repetitive day-to-day activities and tasks are streamlined, while further flexibility is added due to robotics assisting workers (e.g. in case study 9 where delivery robots assisted with the delivery of food during non-working or rush hours) (Miles, 2017; Bonkenburg, 2016).

Augmented Reality offers numerous advantages for warehouse workers, as it presents information in an easy and coherent way, without having the worker stop and stare at a screen full of excess information (DHL, 2015). As it was reported by workers using the AR wearable in the trials conducted by Intel and examined in the third case study, all the information presented are related to the condition, location and route to specific products or objects (DHL, 2015; Intel, 2015). AR’s advantages extend to distribution and last-mile delivery, as it can display critical information regarding packages carried and the condition of the vehicle, while navigating and looking out for not-easy to find addresses are facilitated by its use (DHL, 2015).

UAVs present a revolutionary technology in many different ways. It was thoroughly analyzed, that UAVs possess a wide array of applications, such as facilities patrolling, warehouse assistance as seen in the case study referring to the InventAIRY project, distribution to remote areas or to areas where ground-level distribution is difficult (e.g. congested roads) and fast-time delivery as seen in the tenth case study which is about Amazon’s drone deliveries and its Prime Air feature (DHL, 2014; Business Insider, 2018).

In the framework that was developed and displayed in chapter 4, five distinct phases were considered as the key steps towards a Logistics 4.0 technology implementation with an example being showcased regarding the implementation of UAVs for inventory management and warehouse patrolling. It was thoroughly explained that in order for the implementation to be successful, several issues and challenges of technological, social, economic, operational and HR-related had to be overcome. The framework was developed in a way that it deals with said challenges.

The case studies examined in chapter 5 showcased how the aforementioned Logistics 4.0 technologies revolutionize logistics operations and drive companies towards greater automation and digitalization, thus enabling an upward trend for innovation.

6.2 Conclusions

The upcoming changes to the technological landscape and the social, economic, environmental and more practical issues and challenges that have emerged are pushing companies and logistics providers into making a shift in their organizational structures in order to adopt Logistics 4.0 technologies and optimize logistics operations. However, embracing a digital profile is challenging for existing companies which have been operating under a more traditional organizational structure (PwC, 2016), while startups can disrupt the industry due to the new trend towards Logistics 4.0 technologies.

These technologies, as stated in chapter 4 and shown in the case studies analysis, allow logistics operators to take advantage of numerous features which currently utilized technologies cannot offer, thus allowing companies to enter the digital age of the business and logistics landscape (Jakes, 2016). The combination of IoT and Big Data analytics is revolutionizing how the supply chain network operates and allows managers to have knowledge of situations across the supply chain at any given time. Advanced Robotics boosts automation levels and increases production and operational efficiency. AR significantly enhances labor productiveness and operational efficiency in freight transportation. Finally, UAVs offer new capabilities for warehouse management and distribution and last-mile delivery (Müller, 2018).

However, implications and issues that have emerged regarding Logistics 4.0 technologies adoption are slowing things down. These are summed up below (Barreto et al., 2017; Gialos and Zeimpekis, 2018):

1- Cumbersome Organizational Structures
2- High Investment Costs
3- Resistance to Change
4- Human Resources Implications (e.g. a worker being afraid of losing his job)
5- Lack of Necessary IT Expertise
6- IT Supply Network Possession Requirement
7- Fear of Cyber Threats

So, as it stands right now the most probable worldwide trends to continue driving the logistics industry forward are globalization, urbanization, technology's constant evolution, digitalization and climate changes (e.g. greenhouse effect) (Kunze, 2016).

The constant technological and digitalization-focused evolution, due to increased focus on innovation, and the adoption of Logistics 4.0 technologies, depending on how fast the aforementioned implications and issues can be overcome, is expected to keep on powering the development of innovative applications e.g. (track and trace, labor assistance, information transportation for 3D printing etc.) (Kunze, 2016). In addition, these trends facilitate a smoother launch for startups seeking to disrupt the industry, a fact that will factor in furtherly shaping the industrial landscape in the near future (Kunze, 2016; Utterback and Acee, 2003).

On the other hand, the continuous rise of digitalization hides a risk in the form of cyber threats, as more and more critical amounts of data are in the "cloud" (Grapht, 2018). Companies should invest in cyber security, as the prevention of cyber-attacks increases reliability and credibility, which results in greater customer satisfaction levels and supply chain performance (Grapht, 2018; Deutsche Post AG, 2012).

Digitalization, supported by increased automation, also factors in the development of new ways of delivery, which is especially important for city logistics (Kunze, 2016; Deutsche Post AG, 2012). UAVs are expected to thrive in the coming years as air-level delivery is adopted by more and more companies with an expanded array of capabilities (Kunze, 2016).

Finally, globalization is a driving factor for establishing worldwide standard regulations and compliances, as e-commerce has increased the levels of complexity for last-mile delivery and customization (Kunze, 2016).

The framework that was developed and described in chapter 4 allows a company to proceed with a Logistics 4.0 technology implementation smoothly, without being negatively affected by the issues and challenges at hand. The five phases described are of equal importance and deal with those challenges accordingly. The five phases that were described are as follows:

1- Decide. During that phase, the company decides what is the change, the reason behind it and the way the project will proceed.
2- Prepare. During that phase the company is preparing for the implementation, as well as creating a plan to deal with the issues and challenges.
3- Execute. During this phase the project enters pilot mode.
4- Improve. In this phase, KPIs are defined and feedback is being given by end-users.
5- Maintain. In the final phase, operations turn back to normal with a full integration of the Logistics 4.0 technology at hand.

To sum it all up, companies and organizations should embrace the Logistics 4.0 concepts and adopt their revolutionary technologies by making any necessary adjustments and changes to their organizational structure, in order to drive them towards digitalization and automation with the goal of increased innovation, while carefully handling the issues and risks at hand.

6.3 The Way Forward

As a conclusion, it is evident that Logistics 4.0 applications and trends is a topic subject to continuous research and development. This Master thesis was focused on performing a literature review of current logistics operations and information systems utilized, followed by an introduction and a thorough explanation of Logistics 4.0 technologies and applications. Then, a framework was introduced, laying out the proper steps a company should follow in creating the necessary conditions for Logistics 4.0 adoption. Finally, a case studies analysis was conducted for warehousing and freight transportation operations, showcasing the advantages and benefits of Logistics 4.0 technologies' integration.

A future potential advancement of the research on Logistics 4.0 technologies would be the testing of the framework developed in this thesis in a real-world environment (e.g. a company) in order to monitor the integration process of the emerging technologies and the results yielded, as well as the implications that emerged. Additionally, a comparison between currently utilized technologies and Logistics 4.0 technologies could be performed in the form of benchmarking, thus highlighting the advantages of Logistics 4.0 technologies.

References

Aalhysterforklifts.com.au. (2013). Order Picking in the Warehouse - Logistics & Materials Handling. [online] Available at: http://www.aalhysterforklifts.com.au/index.php/about/blog-post/order_picking_in_the_warehouse [Accessed 8 Jul. 2018].

Ais.uni-bonn.de. (2016). University of Bonn, Computer Science VI, Autonomous Intelligent Systems. [online] Available at: http://www.ais.uni-bonn.de/videos/ICUAS_2016/ [Accessed 20 Oct. 2018].

Ali, H., Elmogy, M. and Barakat, S. (2016). A BIG DATA PROCESSING FRAMEWORK BASED ON MAPREDUCE WITH APPLICATION TO INTERNET OF THINGS. Ciência e Técnica Vitivinícola. 31.

Anshari, M., Almunawar, M., Lim, S. and Al-Mudimigh, A. (2018). Customer relationship management and big data enabled: Personalization & customization of services. Applied Computing and Informatics.

Antich, M. (2013). Top 10 Trends in Truck Fleet Management. [online] Worktruckonline.com. Available at: https://www.worktruckonline.com/152701/top-10-trends-in-truck-fleet-management [Accessed 14 Jul. 2018].

AUTONOMICS for Industry 4.0. (2015). Berlin: Federal Ministry for Economic Affairs and Energy.

Avonwood. (2013). MoDe Development Projects Case Study - Avonwood. [online] Available at: https://avonwood.co.uk/2013/10/05/development-projects-case-study/ [Accessed 20 Oct. 2018].

AWSmarketplace. (2017). Business Intelligence & Big Data on AWS.

Balinski, B. (2014). Automation: a challenge and an opportunity - Manufacturers' Monthly. [online] Manufacturers' Monthly. Available at: http://www.manmonthly.com.au/features/automation-a-challenge-and-an-opportunity/ [Accessed 25 Oct. 2018].

Ballou, R. (2004). Business logistics management. Upper Saddle River, N.J.: Prentice-Hall.

Ballou, R. (2007). The Evolution and Future of Logistics and Supply Chain Management. Researchgate.

Barreto, L., Amaral, A. and Pereira, T. (2017). Industry 4.0 implications in Logistics: An Overview. ScienceDirect.

BBC News. (2013). Amazon testing drones for deliveries. [online] Available at: https://www.bbc.com/news/technology-25180906 [Accessed 2 Oct. 2018].

Bcpsoftware.com. (2018). Warehouse Technologies | Voice WMS | RF Scanning | Pick to Light |. [online] Available at: http://www.bcpsoftware.com/solutions/voice-technology-solutions/warehouse-technologies-take-your-pick/ [Accessed 22 Jul. 2018].

Ben Ayed, A., Alimi, A. and Ben Halima, M. (2015). Big Data Analytics for Logistics and Transportation. ResearchGate.

Bentz, B. (2015). Managing Reverse Logistics to Improve Supply Chain Efficiency and Reduce Cost - Supply Chain 24/7. [online] Supplychain247.com. Available at: https://www.supplychain247.com/article/managing_reverse_logistics_to_improve_supply_chain_efficiency_reduce_costs [Accessed 15 Jul. 2018].

Bicheno, S. (2015). Ericsson forecasts LTE subscriptions to increase seven-fold by 2020. [online] Telecoms.com. Available at: http://telecoms.com/424181/ericsson-forecasts-lte-subscriptions-to-increase-seven-fold-by-2020/ [Accessed 2 Aug. 2018].

Bonkenburg, T. (2016). Robotics in Logistics. DHL.

Bradley, P. (2014). Bobcat excavates productivity, inventory improvements – DC Velocity. [online] Dcvelocity.com. Available at: http://www.dcvelocity.com/articles/20140917-bobcat-excavates-productivity-inventory-improvements/ [Accessed 26 Sep. 2018].

Bright Alliance Technology. (2018). 6 Frequently Asked Questions About Barcode Vs RFID Scanners - Bright Alliance Technology. [online] Available at: http://www.batlgroup.net/2016/07/6-frequently-asked-questions-barcode-vs-rfid-scanners/ [Accessed 29 Oct. 2018].

Business Insider. (2018). Amazon and UPS are betting big on drone delivery. [online] Available at: https://www.businessinsider.com/amazon-and-ups-are-betting-big-on-drone-delivery-2018-3 [Accessed 2 Oct. 2018].

Burgess, M. (2018). These tiny autonomous robots are ready to deliver lunch to your office. [online] Wired.co.uk. Available at: https://www.wired.co.uk/article/starship-technologies-robots-deliveries-intuit-compass-test [Accessed 12 Sep. 2018].

Burgess, M. (2016). Watch Panasonic's power-lifting exoskeletons in action. [online] Wired.co.uk. Available at: https://www.wired.co.uk/article/panasonic-robot-suit-exoskeleton [Accessed 26 Oct. 2018].

Camhi, J., (2018). http://www.businessinsider.com. [Online] Available at: https://www.businessinsider.com/ai-supply-chain-logistics-report-2018-1 [Accessed 12 May 2018].

Cardenas Barbosa, I. and Vanelslander, T. (2017). City logistics, urban goods distribution and last mile delivery and collection. ResearchGate.

CarPal Fleet. (2018). Proof of Delivery? What Are Its Benefits?. [online] Available at: https://carpalfleet.com/proof-of-delivery/ [Accessed 15 Jul. 2018].

Cheng, Y., Yue, W. and Taylor, M. (2005). THE ROLE OF TRANSPORTATION IN LOGISTICS CHAIN. [ebook] Researchgate. Available at: https://www.researchgate.net/publication/281230908 [Accessed 6 Jul. 2018].

Clegg, B. (2017). BIG DATA: How the information revolution is transforming our lives. Icon Books Ltd.

CollabNet VersionOne. (2018). Agile Transformation & Agile Implementation Consulting. [online] Available at: https://www.versionone.com/customer-success/consulting-services/ [Accessed 4 Nov. 2018].

Collins, M. (2017). The surprising future of manufacturing - Magellan Financial Group. [online] Magellan Financial Group. Available at: https://www.magellangroup.com.au/insights/the-surprising-future-of-manufacturing/ [Accessed 5 Sep. 2018].

CORDIS | European Commission. (2013). Final Report Summary - MODE (Maintenance on Demand). [online] Available at: https://cordis.europa.eu/result/rcn/58854_en.html [Accessed 30 Sep. 2018].

Coutinho, L. (2017). Industry 4.0, Jobs for the future vs. future with no jobs.

Craig, G. (2016). What Is The Difference Between Data Lakes, Data Marts, Data Swamps, And Data Cubes?. [online] Intersog. Available at: https://intersog.com/blog/what-is-the-difference-between-data-lakes-data-marts-data-swamps-and-data-cubes/ [Accessed 29 Oct. 2018].

Crainic, T. (2003). Long-Haul Freight Transportation. ResearchGate.

Crizzle, A., Bigelow, P., Adams, D., Gooderham, S., Myers, A. and Thiffault, P. (2017). Health and wellness of long-haul truck and bus drivers: A systematic literature review and directions for future research. Journal of Transport & Health, 7, pp.90-109.

Cscmp.org. (2018). Home. [online] Available at: https://cscmp.org/ [Accessed 21 Jul. 2018].

Curry, D. (2016). IoT and coding: The most important IoT programming languages – ReadWrite. [online] Readwrite.com. Available at: https://readwrite.com/2016/07/08/programming-languages-iot-pt2/ [Accessed 2 Aug. 2018].

Datex Corporation. (2018). IoT and the Smart Warehouse. [online] Available at: https://www.datexcorp.com/iot-and-the-smart-warehouse/ [Accessed 7 Sep. 2018].

Dedić N. & Stanier C. (2016). Measuring the Success of Changes to Existing Business Intelligence Solutions to Improve Business Intelligence Reporting. Springer.

Deganutti, J. (2017). The First Industrial Revolution: How manufacturing changed in XVII-XVIII centuries.

Delivering Tomorrow Logistics 2050 A Scenario Study. (2012). Bonn, Germany: Deutsche Post AG.

Deloitte.com. (2013). 2013 Global contact center survey Results and key insights. [online] Available at: https://www2.deloitte.com/us/en/pages/operations/articles/2013-global-contact-center-survey.html [Accessed 9 Sep. 2018].

Deloitte. (2018). Shipping smarter: IoT opportunities in transport and logistics. [online] Available at: https://www2.deloitte.com/tr/en/pages/technology-media-and-telecommunications/articles/internet-of-things-iot-in-shipping-industry.html [Accessed 7 Sep. 2018].

Deloitte. (2018). Using smart sensors to drive supply chain innovation.

DHL, (2015). Breakout session: Augmented Reality in Logistics. Dubai.

DHL. (2014). Unmanned Aerial Vehicles in Logistics.

Doz, J., (2017). The Future of E-commerce: 2020 and Beyond. [Online] Available at: http://www.doz.com/marketing-resources/marketing-resourcesthe-future-of-e-commerce-2020-and-beyond. [Accessed 20 May 2018].

Dua, A. (2018). Comparison of RFID Cost versus NFC and Barcode for Inventory Tracking | RFID4U. [online] RFID4U. Available at: https://rfid4u.com/comparison-of-rfid-nfc-and-barcode-for-inventory-tracking-part-1-rfid/ [Accessed 29 Oct. 2018].

Dua, A. (2018). Comparison of RFID Cost versus NFC and Barcode for Inventory Tracking | RFID4U. [online] RFID4U. Available at: https://rfid4u.com/comparison-of-rfid-nfc-and-barcode-for-inventory-tracking-part-2-rfid/ [Accessed 29 Oct. 2018].

Dukowitz, Z. (2018). Who's Working Where: Introducing Our In-Depth Guide to Jobs in the Drone Industry - UAV Coach. [online] UAV Coach. Available at: https://uavcoach.com/drone-jobs-guide/ [Accessed 29 Aug. 2018].

DW.COM. (2016). Industry 4.0 to be huge job killer | DW | 18.01.2016. [online] Available at: https://www.dw.com/en/industry-40-to-be-huge-job-killer/a-18987635 [Accessed 13 Aug. 2018].

Dynamic Inventory Control. (2018). DHL.

Eab.info. (2018). LIVE STORAGE RACKING. [online] Available at: http://www.eab.info/storage-equipment/live-storage-racking/ [Accessed 11 Jul. 2018].

Easton, M. and Saldais, M. (2013). Industrial Revolution. Oxford University.

Ehmke, J. (2012). Integration of Information and Optimization Models for Routing in City Logistics.

Ericsson. (2017). Ericsson Mobility Report. Ericsson Mobility Report. [online] Ericsson. Available at: https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf?utm_source=Triggermail&utm_medium=email&utm_campaign=Post%20Blast%20%28bii-iot%29:%20How%205G%20will%20revolutionize%20the%20IoT%20%E2%80%94%20Qualcomm%20eyes%20smart%20speakers%20for%20growth%20%E2%80%94%20Alphabet%20drone%20exec%20will%20head%20up%20industry%20alliance&utm_term=BII%20List%20IoT%20ALL [Accessed 2 Sep. 2018].

Ermolaeva, A. (2017). Industry 4.0 and HR in Logistics. Ph.D. UNIVERSITY OF ECONOMICS IN PRAGUE.

EU GDPR Portal. (2018). EU GDPR Information Portal. [online] Available at: https://www.eugdpr.org/ [Accessed 25 Jul. 2018].

Faccio, M. and Gamberi, M. (2015). New City Logistics Paradigm: From the "Last Mile" to the "Last 50 Miles" Sustainable Distribution.

Field, A. (2015). Enter the Smart (Internet of Things) Warehouse. [online] Supplychain247.com. Available at: http://www.supplychain247.com/article/enter_the_smart_internet_of_things_warehouse/warehousing [Accessed 1 Sep. 2018].

Fitzgerald, J. and Quasney, E. (2018). Using autonomous robots to drive supply chain innovation. Deloitte.

Franklin, M. (2018). Industry 4.0: How Automation and IoT Will Affect Jobs. [online] Datafloq.com. Available at: https://datafloq.com/read/industry-4-0-how-automation-iot-will-affect-jobs/4539 [Accessed 13 Aug. 2018].

Galindo, L. (2016). The Challenges of Logistic 4.0 for the Supply Chain and Information Technology. Norwegian University of Science and Technology.

García Márquez, F. and Lev, B. (2017). Big Data Management. Springer.

Geissbauer, R., Schrauf, S., Koch, V. and Kuge, S. (2014). Industry 4.0 - Opportunities and Challenges of the Industrial Internet. PwC.

Gesing, B., Peterson, S. and Michelsen, D. (2018). ARTIFICIAL INTELLIGENCE IN LOGISTICS. [Online] Available at: https://www.logistics.dhl/content/dam/dhl/global/core/documents/pdf/glo-ai-in-logistics-white-paper.pdf [Accessed 25 May 2018].

Glockner, H., Jannek, K., Mahn, J. and Theis, B. (2014). AUGMENTED REALITY IN LOGISTICS. DHL.

Gialos, A. and Zeimpekis, V. (2018). Current status and challenges on Logistics 4.0 technologies in warehouse operations. In: 4th ICSC.

Ginters, E. and Gutierrez, J. (2013). Low cost augmented reality and RFID application for logistics items visualization. Valmiera: ScienceDirect.

Goettler, S. (2014). Pick-by-Vision – Augmented Reality in logistics. [online] The blog of Logistics at MGEPS at UPV. Available at: https://logisticsmgepsupv.wordpress.com/2014/05/18/pick-by-vision-augmented-reality-in-logistics/comment-page-1/ [Accessed 31 May 2018].

Grapht, H. (2018). Transportation & Logistics 2030 Volume 4: Securing the supply chain. PwC.

Gregor, T., Krajcovic, M. and Wiecek, D. (2017). Smart Connected Logistics. ScienceDirect.

Greif, A. (2002). Handbook of Game Theory with Economic Applications. ScienceDirect.

Guide to Digital Tachographs. (2006). [ebook] RSA. Available at: http://www.rsa.ie/Documents/Tachograph_Enf/Tacho%20Cards/Tacho%20Guides/Guide_to_Digital_Tachographs.pdf [Accessed 15 Jul. 2018].

Gustavsson, P., Holm, M., Syberfeldt, A. and Wang, L. (2018). Human-robot collaboration – towards new metrics for selection of communication technologies. ScienceDirect.

Hammel Scale. (2018). Industry 4.0 Weighing Solutions | Hammel Scale. [online] Available at: https://www.hammelscale.com/industry-4-0/ [Accessed 26 Aug. 2018].

Hansen, M. and Dursteler, E. (2017). Pipeline, Rails and Trucks: Economic, environmental, and safety impacts of transporting oil and gas in the U.S.. [ebook] Available at: https://www.strata.org/pdf/2017/pipelines.pdf [Accessed 13 Jul. 2018].

Harnessing the Power of Big Data for Fleet Management. (2015). [ebook] Merchants Fleet Management. Available at: https://www.merchantsfleetmanagement.com/docs/default-source/whitepapers/6bc95808-6d97-6325-8c74-ff0000a054a5 [Accessed 9 Sep. 2018].

Hci.vt.edu. (2018). Augmented Reality in Transportation – Center for Human-Computer Interaction. [online] Available at: http://hci.vt.edu/projects/augmented-reality-in-transportation/ [Accessed 25 Oct. 2018].

Hector (2018). Essential Elements to Deploying IoT in the Warehouse. [online] Articles.cyzerg.com. Available at: https://articles.cyzerg.com/essential-elements-to-deploying-iot-in-the-warehouse [Accessed 24 Oct. 2018].

H.ESSERS. (2018). Drones for Logistics.

Hobsbawm, E. and Wrigley, C. (1999). Industry and empire. New York: New Press.

Hoey, B. (2018). What is Logistics 4.0?. [online] Blog.flexis.com. Available at: https://blog.flexis.com/what-is-logistics-4.0 [Accessed 6 Oct. 2018].

Horejsi, P. (2015). Augmented Reality System for Virtual Training of Parts Assembly. ScienceDirect.

Huang, S. (2018). Why GPS won't be enough for the AR era. [online] Medium. Available at: https://medium.com/sturfee/why-gps-wont-be-enough-for-the-ar-era-2c647b6f3352 [Accessed 29 Oct. 2018].

Hülsmann, T. (2015). LOGISTICS 4.0 AND THE INTERNET OF THINGS.

Ibarra, D., Ganzarain, J. and Igartua, J. (2018). Business Model Innovation through Industry 4.0: A Review. ScienceDirect.

IEEE Spectrum: Technology, Engineering, and Science News. (2015). Fetch Robotics Introduces Fetch and Freight: Your Warehouse Is Now Automated. [online] Available at: https://spectrum.ieee.org/automaton/robotics/industrial-robots/fetch-robotics-introduces-fetch-and-freight-your-warehouse-is-now-automated [Accessed 25 Oct. 2018].

IIBM LMS. (2018). Supply Chain Management and Logistics in Retail Management - IIBM Institute LMS. [online] Available at: http://www.iibmindialms.com/library/management-basic-subjects/retail-management/supply-chain-management-logistics/ [Accessed 19 Jul. 2018].

Industry 4.0: Building the digital enterprise. (2016). [ebook] PwC. Available at: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf [Accessed 26 Aug. 2018].

IoT Agenda. (2018). What is IoT devices (internet of things devices)? - Definition from WhatIs.com. [online] Available at: https://internetofthingsagenda.techtarget.com/definition/IoT-device [Accessed 2 Aug. 2018].

i-scoop.eu. (2018). Logistics 4.0 and smart supply chain management in Industry 4.0. [online] Available at: https://www.i-scoop.eu/industry-4-0/supply-chain-management-scm-logistics/ [Accessed 2 Aug. 2018].

I-scoop.eu. (2018). Robots and cobots in logistics - the next stage of growth - Industry 4.0. [online] Available at: https://www.i-scoop.eu/robots-cobots-logistics-4-0/ [Accessed 25 Oct. 2018].

Jakes, J. (2016). Position of Logistics in Organizational Structures - Trends. International Journal of Management Science and Business Administration, 2(7), pp.42-50.

Jeske, M., Gruner, M. and Weiss, F. (2013). Big Data in Logistics. DHL.

Kappauf, J., Lauterbach, B. and Koch, M. (2012). Logistic Core Operations with SAP: Inventory Management, Warehousing, Transportation, and Compliance. 8th ed. Springer.

Karakostas, B. (2016). Event prediction in an IoT environment using naïve Bayesian models. ScienceDirect.

Kayikci, Y. (2018). Sustainability impact of digitization in logistics. ScienceDirect.

Kim, E. (2015). Amazon's $775 million deal for robotics company Kiva is starting to look really smart. [online] Business Insider. Available at: https://www.businessinsider.com/kiva-robots-save-money-for-amazon-2016-6 [Accessed 29 Aug. 2018].

Kirkos, E. (2015). Business Intelligence and Data Mining. Kallipos.

Konstant.com. (2018). High Density - Very Narrow Aisle | VNA, Very Narrow Aisle Racks, Very Narrow Aisle Racking Systems. [online] Available at: http://www.konstant.com/HighDensityVeryNarrowAisle.php [Accessed 11 Jul. 2018].

Kunze, O. (2016). Replicators, Ground Drones and Crowd Logistics A Vision of Urban Logistics in the Year 2030. In: International Scientific Conference on Mobility and Transport Transforming Urban Mobility. ScienceDirect.

Lachhab, F., Bakhouya, M., Ouladsine, R. and Essaaidi, M. (2018). Towards an Intelligent Approach for Ventilation Systems Control using IoT and Big Data Technologies. ScienceDirect.

Laetsch, J., Knoche, L., Schalk, T. and Driskel, C. (2016). Big Data & The Truck Industry: How Logistics Firms Utilize and Analyze Big Data- A Case Study of DHL and the SmartTruck. [online] BigdataBigbrotherBigboon. Available at: https://bigdatabigbrotherbigboon.wordpress.com/2016/11/29/big-data-the-truck-industry-how-logistics-firms-utilize-and-analyze-big-data-a-case-study-of-dhl-and-the-smarttruck/ [Accessed 30 Sep. 2018].

Liu, S., Zhang, G. and Wang, L. (2018). IoT-enabled Dynamic Optimisation for Sustainable Reverse Logistics. ScienceDirect.

Loading Bay Equipment. (2018). [ebook] GANDHI. Available at: http://geapl.co.in/pdf/loading-bay-equipment-brochure.pdf [Accessed 22 Jul. 2018].

Lucasware.com. (2018). Compare Voice Picking to RF and PTL | Mobile Work Execution. [online] Available at: https://www.lucasware.com/how-voice-compares/ [Accessed 10 Jul. 2018].

Lumb, D. (2017). MIT researchers use drone fleets to track warehouse inventory. [online] Engadget. Available at: https://www.engadget.com/2017/08/25/mit-drone-fleets-track-warehouse-inventory/?guccounter=1 [Accessed 25 Oct. 2018].

Lummus, R., Vokurka, R. and Krumwiede, D. (2001). The relationship of logistics to supply chain management: developing a common industry definition. [ebook] MCB UP Ltd. Available at: https://www.emeraldinsight.com/doi/abs/10.1108/02635570110406730?src=recsys&fullSc=1&journalCode=imds [Accessed 6 Jul. 2018].

Macaulay, J., Buckalew, L. and Chung, G. (2015). Internet of Things in Logistics. DHL & Cisco.

Malek, Y., Kharbouch, A., Khoukhi, H., Bakhouya, M., De Florio, V., Ouadghiri, D., Latre, S. and Blondia, C. (2017). On the use of IoT and Big Data Technologies for Real-time Monitoring and Data Processing. ScienceDirect.

Malindretos, G., (2015). Supply Chain, Logistics and Customer Service.

Making the Smart Logistics Network a Reality. (2018). UPS.

Management Consulting Prep. (2018). Frameworks - Management Consulting Prep. [online] Available at: https://mconsultingprep.com/case-interview-frameworks/ [Accessed 4 Nov. 2018].

Marr, B. (2016). How Big Data and Analytics Are Transforming Supply Chain Management. [online] Forbes.com. Available at: https://www.forbes.com/sites/bernardmarr/2016/04/22/how-big-data-and-analytics-are-transforming-supply-chain-management/#7fcaab0b39ad [Accessed 8 Sep. 2018].

Mashable. (2017). You can now watch tech bring food to your door with a few taps of your smartphone (Paid Content by Jack in the Box). [online] Available at: https://mashable.com/2017/08/16/jack-in-the-box-delivery-robot/?europe=true [Accessed 20 Oct. 2018].

Mclean, L. (2014). Breaking Down Big Data & Why You Should Care -. [online] Sisdigital.agency. Available at: https://sisdigital.agency/2014/01/breaking-down-big-data-why-you-should-care/ [Accessed 2 Oct. 2018].

Mecalux.com. (2018). Drive-in pallet racking. [online] Available at: https://www.mecalux.com/pallet-racks/drive-in-pallet-racking [Accessed 11 Jul. 2018].

Merlino, M. and Sproge, I. (2017). The Augmented Supply Chain. ScienceDirect.

Michel, R. (2016). 2016 Warehouse/DC Operations Survey: Ready to Confront Complexity - Supply Chain 24/7. [online] Supplychain247.com. Available at: https://www.supplychain247.com/article/2016_warehouse_dc_operations_survey_ready_to_confront_complexity/erp [Accessed 12 Sep. 2018].

Miles, S. (2017). Case Study: Jack in the Box Explores Autonomous Delivery Robots | Street Fight. [online] Streetfightmag.com. Available at:

https://streetfightmag.com/2017/08/22/case-study-jack-in-the-box-explores-autonomous-delivery-robots/ [Accessed 2 Oct. 2018].

Mokyr, J. (1998). The Second Industrial Revolution, 1870-1914.

Monahan, S. and Hu, M. (2018). US E-Commerce Trends and the Impact on Logistics. CSCMP.

Moore, M. (2018). What is Industry 4.0? Everything you need to know. [online] https://www.facebook.com/TechRadar. Available at: https://www.techradar.com/news/what-is-industry-40-everything-you-need-to-know [Accessed 31 May 2018].

Mourtzis, D., Zogopoulos, V. and Vlachou, E. (2017). Augmented reality application to support remote maintenance as a service in the Robotics industry. ScienceDirect.

mprosys.in. (2018). Inventory Management System | Warehouse Management Software | Do You Really Need WMS ?. [online] Available at: http://www.improsys.in/warehouse_management_systems.htm [Accessed 16 Jul. 2018].

Mrugalska, B. and Wyrwicka, M. (2017). Towards Lean Production in Industry 4.0. ScienceDirect.

Müller, J. (2018). Emerging Technology Trends. SAP.

Murray, S. (2018). Worldwide Spending on Augmented and Virtual Reality to Achieve a Five-Year CAGR of 71.6% by 2022, According to IDC. [online] IDC: The premier global market intelligence company. Available at: https://www.idc.com/getdoc.jsp?containerId=prUS43860118 [Accessed 5 Sep. 2018].

Myerson, P. (2015). Supply Chain and Logistics Management Made Easy. New Jersey: Pearson Education, Inc.

Nearsay.com. (2018). Truck Mechanics Explain 3 Reasons to Keep up With Semi-Truck Maintenance - Hobbs Spring & Suspension Inc - Hobbs. [online] Available at: https://nearsay.com/c/371128/245028/truck-mechanics-explain-3-reasons-to-keep-up-with-semi-truck-maintenance [Accessed 7 Sep. 2018].

Newatlas.com. (2018). Postybell mailbox sensor conquers the tyranny of distance. [online] Available at: https://newatlas.com/postybell-gsm-mailbox-sensor/31687/ [Accessed 7 Sep. 2018].

Newcastlesys.com. (2018). How To Improve Warehouse Receiving Process. [online] Available at: https://www.newcastlesys.com/blog/how-to-improve-warehouse-receiving-process [Accessed 7 Sep. 2018].

Noronha, J., Bubner, N. and Bondebenner, P. (2016). Logistics Trend Radar. DHL Customer Solutions & Innovation.

Naboni, R. and Paoletti, I. (2015). Advanced Customization in Architectural Design and Construction.

Onestoprentalsales.com. (2018). TELEHANDLER BOBCAT V417 17 FOOT REACH 44 Rentals Airdrie AB, Where to Rent TELEHANDLER BOBCAT V417 17 FOOT REACH 44 in Calgary Alberta, Strathmore, Chestermere, Didsbury, and Airdrie AB. [online] Available at:

https://www.onestoprentalsales.com/equipment.asp?action=category&category=21&key=13-002 [Accessed 19 Oct. 2018].

Oracle.com. (n.d.). What is Big Data? | Oracle. [online] Available at: https://www.oracle.com/big-data/guide/what-is-big-data.html [Accessed 2 Aug. 2018].

Patel, N. (2017). Significance of fleet management in logistics Industry. [Blog] Peerbits. Available at: https://onmogul.com/stories/significance-of-fleet-management-in-logistics-industry [Accessed 23 Jun. 2018].

Peopledatalabs.com. (2018). How Big Data Is Bringing Humanity Back to Customer Service. [online] Available at: https://www.peopledatalabs.com/blog/customer-service-data [Accessed 9 Sep. 2018].

Picking and Packing Best Practices. (2007). [ebook] WERC. Available at: http://www.werc.org/assets/1/workflow_staging/Publications/696.PDF [Accessed 22 Jul. 2018].

Potenza, E. (n.d.). All That Glitters - What is industrialisation?.

Pronello, C., Camusso, C. and Valentina, R. (2017). Last mile freight distribution and transport operators' needs: which targets and challenges?. ScienceDirect.

Pyne, S. and Rao, P. (2016). Big Data Analytics Methods and Applications. Springer.

RAVAS. (2018). DHL weighs special shipments with RWV-weighing forks on a forklift truck. [online] Available at: https://www.ravas.com/en/cases/dhl-weighs-special-shipments-rwv-weighing-forks-forklift-truck [Accessed 27 Sep. 2018].

Renjen, P. (2018). Industry 4.0: Are you ready?. [online] Deloitte Insights. Available at: https://www2.deloitte.com/insights/us/en/deloitte-review/issue-22/industry-4-0-technology-manufacturing-revolution.html [Accessed 5 Sep. 2018].

Richards. (2018). The role of the Warehouse.

Rifkin, J. (2011). Third Industrial Revolution. Forbes.

Rightwarehouse.com. (2018). Warehousing & Storage | Right Warehouse, Delhi, NCR, India. [online] Available at: http://rightwarehouse.com/warehousing-storage/ [Accessed 21 Jul. 2018].

Robinson, A. (2018). Three Key Trends in Logistics E-Commerce. [online] Transportation Management Company | Cerasis. Available at: https://cerasis.com/2018/01/04/logistics-e-commerce/ [Accessed 15 Jul. 2018].

Romeo, J. (2017). Robots at the Warehouse: Changing the Face of Modern Logistics - Robotics Business Review. [online] Robotics Business Review. Available at: https://www.roboticsbusinessreview.com/manufacturing/robots-warehouse-changing-face-modern-logistics/ [Accessed 12 Sep. 2018].

Rosier, M. and Janzen, B. (2008). Reverse Logistics How to realise an agile and efficient reverse chain within the Consumer Electronics industry. PwC.

Rushton, A., Croucher, P. and Baker, P. (2014). The Handbook of Logistics and Distribution Management. 5th ed.

SAFETY4SEA. (2018). Maritime transport carried 63% of Albanian exports in 2017 - SAFETY4SEA. [online] Available at: https://safety4sea.com/maritime-transport-carried-63-of-albanian-exports-in-2017/ [Accessed 16 Jul. 2018].

Saghir, M. (2004). THE CONCEPT OF PACKAGING LOGISTICS. [ebook] Lund. Available at: https://www.pomsmeetings.org/ConfProceedings/002/POMS_CD/Browse%20This%20CD/PAPERS/002-0283.pdf [Accessed 10 Jul. 2018].

Samuels, M. (2017). Big data case study: How UPS is using analytics to improve performance | ZDNet. [online] ZDNet. Available at: https://www.zdnet.com/article/big-data-case-study-how-ups-is-using-analytics-to-improve-performance/ [Accessed 2 Oct. 2018].

Sandle, T. (2017). Using drones in large warehouses to prevent inventory mismatches. [online] Digitaljournal.com. Available at: http://www.digitaljournal.com/tech-and-science/technology/using-drones-in-large-warehouses-to-prevent-inventory-mismatches/article/504812 [Accessed 12 Sep. 2018].

Savelsbergh, M. and Woensel, T. (2016). City Logistics Challenges and Opportunities.

Savi. (2013). Best Practices in Improving Container Management and Increasing Supply Chain Efficiencies. [ebook] Available at: http://www.savi.com/wp-content/uploads/Savi_WhitePaper-final-1212130439PM.pdf [Accessed 14 Jul. 2018].

Schlaepfer, R., Koch, M. and Merkofer, P. (2014). Industry 4.0. Challenges and Solutions for the Digital Transformation and use of exponential Technologies. Deloitte.

Schmidthk.com. (2018). Warehouse Management System (WMS) | Schmidt. [online] Available at: http://www.schmidthk.com/industries-solutions/automation/warehouse-management-system/ [Accessed 4 Nov. 2018].

Schrauf, S. and Bertram, P. (2016). Industry 4.0: How digitization makes the supply chain more efficient, agile, and customer-focused. [ebook] PwC. Available at: https://www.strategyand.pwc.com/reports/digitization-more-efficient [Accessed 26 Aug. 2018].

Scriosteanu, A. and Popescu, D. (2018). Customer Service: The Important Goal of Logistics. Craiova: University of Craiova.

Segovia, D., Mendoza, M., Mendoza, E. and Gonzalez, E. (2015). Augmented Reality as a Tool for Production and Quality Monitoring. ScienceDirect.

Serrato, M. and Ramirez, J. (2017). The Strategic Business Value of Big Data. In: F. Garcia Marquez and B. Lev, ed., Big Data Management. Springer.

Shamim, S., Cang, S., Yu, H. and Li, Y. (2016). Management Approaches for Industry 4.0.

Shields, N. (2017). Here's how 5G will revolutionize the Internet of Things. [online] Business Insider. Available at: https://www.businessinsider.com/how-5g-will-revolutionize-the-internet-of-things-2017-6 [Accessed 2 Sep. 2018].

Shirer, M. and Goepfert, J. (2017). Big Data and Business Analytics Revenues Forecast to Reach $150.8 Billion This Year, Led by Banking and Manufacturing Investments, According to IDC. [online] IDC: The premier global market intelligence company. Available at: https://www.idc.com/getdoc.jsp?containerId=prUS42371417 [Accessed 5 Sep. 2018].

Smith, Christopher E. (2014). Crude Oil Pipeline Growth, Revenues Surge; Construction Costs Mount. Oil and Gas Journal. Available at: http://www.ogj.com/articles/print/volume-112/issue-9/special-report-pipeline-economics/crude-oil-pipeline-growth-revenuessurge-construction-costs-mount.html [Accessed 13 Jul. 2018].

Spary, S. (2015). FAA grounds Amazon drone delivery. [online] Campaignlive.co.uk. Available at: https://www.campaignlive.co.uk/article/faa-grounds-amazon-drone-delivery/1334152 [Accessed 20 Oct. 2018].

Sreedhar, D. (2016). Augmented Reality Transport Improving Daily Life. [online] Appearition. Available at: https://www.appearition.com/industryar-augmented-reality-transport-improving-daily-life/ [Accessed 25 Oct. 2018].

Staff, 2. (2018). “Vision Picking” in the Warehouse - Augmented Reality in Logistics - Supply Chain 24/7. [Online] Supplychain247.com. Available at: http://www.supplychain247.com/article/vision_picking_in_the_warehouse_augmented_reality_in_logistics [Accessed 24 May 2018].

Stoltz, M., Giannikas, V., McFarlane, D., Strachan, J., Um, J. and Srinivasan, R. (2017). Augmented Reality in Warehouse Operations: Opportunities and Barriers. ScienceDirect.

Stone, S. (2015). Order Picking: Goods-to-Person Alternatives and Techniques. [online] Cisco-eagle.com. Available at: http://www.cisco-eagle.com/blog/2015/10/29/goods-to-picker-methods-and-alternatives/ [Accessed 9 Jul. 2018].

Stone, S. (2014). Questions to Ask: Carousel Picking Systems. [online] Cisco-eagle.com. Available at: http://www.cisco-eagle.com/blog/2014/10/28/questions-to-ask-carousel-picking-systems/ [Accessed 9 Jul. 2018].

Supplychain247.com. (2016). Amazon’s Real-Time Map Tracking Package Delivery App Available to All US Customers - Supply Chain 24/7. [online] Available at: http://www.supplychain247.com/article/amazons_real_time_map_tracking_package_delivery [Accessed 7 Sep. 2018].

Supplychain247.com. (2018). Data Driven Logistics. [online] Available at: https://www.supplychain247.com/paper/presentation_data_driven_logistics [Accessed 8 Sep. 2018].

Supply & Demand Chain Executive. (2008). Guest Column: The Five Most Common Mistakes when Planning a Distribution Center. [online] Available at: https://www.sdcexec.com/sourcing-procurement/news/10327113/guest-column-the-five-most-common-mistakes-when-planning-a-distribution-center [Accessed 21 Jul. 2018].

Szymanska, O., Adamczak, M. and Cyplik, P. (2017). LOGISTICS 4.0 – A NEW PARADIGM OR SET OF KNOWN SOLUTIONS?.

Tadic, S., Zecevic, S. and Krstic, M. (2015). Status and Trends.

Taniguchi, E. (2012). Concept and Best Practices of City Logistics.

Taylor, R. (2017). Tesco makes UK's first delivery by ROBOT in test of technology which could change shopping forever. [online] The Sun. Available at: https://www.thesun.co.uk/tech/3691573/tesco-makes-uks-first-delivery-by-robot-during-test-of-pioneering-one-hour-delivery-service/ [Accessed 25 Oct. 2018].

Temesist® Endüstriyel Depo Ve Raf Sistemleri. (2018). BACK-TO-BACK RACKING SYSTEM | TEMESIST® INDUSTRIAL RACK AND STORAGE SYSTEM. [online] Available at: https://temesist.com/back-to-back-racking-system/?lang=en [Accessed 11 Jul. 2018].

The Communication Logistics Specialists. (2018). The Internet of Things Reinvents Parcel Delivery Services. [online] Available at: http://www.communication-logistics.com/parcel-delivery-services.html#.W5Liz-gzbIU [Accessed 7 Sep. 2018].

The Economist. (2012). The third industrial revolution. [online] Available at: https://www.economist.com/leaders/2012/04/21/the-third-industrial-revolution [Accessed 13 Aug. 2018].

The Ultimate Guide to Fleet Telematics. (2018). Fleetcarma.

Tipping, A. and Kauschke, P. (2016). Shifting patterns: The future of the logistics industry. [Online] pwc.com. Available at: https://www.pwc.com/sg/en/publications/assets/future-of-the-logistics-industry.pdf [Accessed 24 May 2018].

Tjahjono, B., Esplugues, C., Ares, E. and Pelaez, G. (2017). What does Industry 4.0 mean to Supply Chain?. ScienceDirect.

Transportation & Logistics 2030 Volume 4: Securing the supply chain. (2011). PwC.

Trebilcock, B. (2015). Distribution centers: It's all about the business. [ebook] Available at: https://www.logisticsmgmt.com/article/distribution_centers_its_all_about_the_business [Accessed 14 Jul. 2018].

Trebilcock, B. (2018). The Emerging Role for Warehouse Drones in the Supply Chain - Supply Chain 24/7. [online] Supplychain247.com. Available at: http://www.supplychain247.com/article/the_emerging_role_for_drones_in_the_supply_chain [Accessed 12 Sep. 2018].

Utterback, J. and Acee, H. (2003). Disruptive Technology.

Vaidya, S., Ambad, P. and Bhosle, S. (2018). Industry 4.0 - A Glimpse. ScienceDirect.

Valuebasedmanagement.net. (2016). Summary of the Kaizen philosophy and method. Abstract. [online] Available at: http://www.valuebasedmanagement.net/methods_kaizen.html [Accessed 16 Aug. 2018].

Vision Picking with Intel® Recon Jet™ Pro. (2015). [ebook] Intel. Available at: https://www.ubimax.com/cms/customer-projects-20170717-1-ODa0ZhM8.pdf [Accessed 23 Sep. 2018].

Visser, J. and Binsbergen, A. (2018). NEW URBAN GOODS DISTRIBUTION SYSTEMS. [ebook] Available at: http://www.tft.lth.se/fileadmin/tft/dok/KFBkonf/3binsbergenvisser.PDF [Accessed 14 Jul. 2018].

Voortman, C. (2004). Global Logistics Management.

Vupune.ac.in. (2018). [online] Available at: https://www.vupune.ac.in/blog/growth-of-e-commerce-fuels-need-for-skilled-management-graduates [Accessed 16 Jul. 2018].

WENDY HIRSCH CONSULTING. (2018). Implementation Framework. [online] Available at: http://wendyhirsch.com/implementation-framework/ [Accessed 4 Nov. 2018].

West, A. (2017). Industry 3.0 vs. 4.0 - Vision of the new manufacturing world.

Wewilltransportit.com. (2015). Line Haul Transportation. [online] Available at: https://www.wewilltransportit.com/line-haul-transportation/ [Accessed 14 Jul. 2018].

Wheeler, C. (2018). The 8 Best Order Picking Methods (Including Batch Picking). [online] Newcastlesys.com. Available at: https://www.newcastlesys.com/blog/bid/348476/order-picking-methods-and-the-simplest-ways-to-minimize-walking-infographic [Accessed 8 Jul. 2018].

White, J. (2015). Fleet Management - Logistics Operational Guide (LOG) - Digital Logistics Capacity Assessments. [online] Dlca.logcluster.org. Available at: http://dlca.logcluster.org/display/LOG/Fleet+Management [Accessed 15 Jul. 2018].

World Economic Forum. (2016). Industry 4.0. [online] Available at: https://www.weforum.org/agenda/2016/05/industry-4-0/ [Accessed 26 Aug. 2018].

Wormer, P. (2014). How Bobcat used SmartLIFT technology to boost warehouse performance. [online] Info.totaltraxinc.com. Available at: http://info.totaltraxinc.com/blog/how-bobcat-used-smartlift-technology-to-boost-warehouse-performance [Accessed 26 Sep. 2018].

Zeimpekis, V. (2018). Storage Areas: Designing and Organizing.

Zhong, R., Xu, X. and Wang, L. (2017). IoT-enabled Smart Factory Visibility and Traceability using Laserscanners. ScienceDirect.