Current Research in Environmental Sustainability 2 (2020) 100013

Contents lists available at ScienceDirect

Current Research in Environmental Sustainability

journal homepage: www.elsevier.com/locate/crsust

Data-driven sustainable supply chain through centralized logistics network: Case study in a Finnish pharmaceutical distributor company

Ahm Shamsuzzoha [a,*], Emmanuel Ndzibah [a], Kasperi Kettunen [b]

[a] School of Technology and Innovation, University of Vaasa, PO Box 700, FI-65101, Finland
[b] KONE, Finland

ARTICLE INFO

Article history:
Received 12 July 2020
Received in revised form 19 September 2020
Accepted 23 September 2020

Keywords:
Data-driven supply chain
Centralized logistics network
Information system
Pharmaceutical logistics
Lean distribution system
Environment friendly and sustainable supply chain

ABSTRACT

Logistics processes are in the core of transportation, providing a structure for distributing products on an international scale. This research was conducted as a commissioned research for a Finnish pharmaceutical wholesaler. In wholesale, logistics process is an important part of the core competencies and optimizing this process can provide significant competitive advantages. The objective of this research study was to investigate the causes of supply chain fragmentations and the ways to mitigate these effects. The central concepts are used as sustainable logistics process that minimizes carbon dioxide (CO2) emission, offers supply chain visibility, lean distribution channel, offers discrete event simulation and supply chain modelling. The empirical research employs a mixed research method consisting of both qualitative and quantitative data. Quantitative data is collected from the inbound deliveries of a Finnish pharmaceutical case company and qualitative data is gathered from a questionnaire survey within the case company. This study investigated the current inbound processes of the case company and compared to the developed model of the centralized pipeline system. The objective of this study was to investigate how a centralized logistic system minimizes travel cost to support environmental damage and can provide benefits to the inbound process of the case company. The research results indicated that a centralized pipeline system can provide improved information flow, higher freight capacity and reduced CO_2 emissions to support environmental friendly and sustainable supply chain and logistics processes.

1. Introduction

Data-driven supply chain becomes a critical part of modern business to move goods from one location to another. This form of supply chain helps to improve the visibility of the commodity from raw materials to consumption. Such visibility ensures modern supply chains to improved operational performance and real-time insight across the delivery chain (Lorenzo et al., 2017; Helo and Shamsuzzoha, 2020). This visibility also offers higher competitive advantage of the goods delivered across multiple countries before reaching to the consumer (Samson, 2010; Alkhatib et al., 2015; Salam et al., 2016; Feng and Shanthikumar, 2018; Meireles et al., 2020).

The core of this research is to better coordination and information flow between supply chain members, which can also help to increase operational efficiency. This concept is explored using a case study of a publicly traded Finnish pharmaceutical wholesale company. The case company receives pharmaceutical products most notably from Europe and then distributes these goods to licensed retailers within Finland. This research examines the level of fragmentation in the case company's supply chain that can be utilized to increase visibility.

In Finland, it has been the custom of the pharmaceutical industry to organize freight shipments to the wholesaler (Pharma Industry Finland, 2018). This means that for every delivery, the organizer must convey the information about the shipment separately. Operating this way has revealed to have issues related to visibility and management of incoming goods for the case company. Pharmaceutical logistics differ from many other industries due to the nature of the pharmaceutical products. Pharmaceutical products can be predisposed to contamination, theft or counterfeit, which in turn can cause a threat to public safety (Bansal et al., 2013; Burns, 2018; Ahmadi et al., 2020). For these reasons, traceability and documentations of pharmaceutical shipments are heavily legislated. Governments have applied additional legislations, safeguards and guidelines on how to handle pharmaceutical goods to avoid and minimize these issues. If a company wishes to sell or distribute a pharmaceutical product in a certain market, the company must comply with the regional legislation (Chung and Kwon, 2016). Pharmaceutical industry has stricter regulations and quality standards than many other industries and only licensed actors can handle pharmaceutical goods (European Commission, 2020). The availability of pharmaceutical products is crucial for the well-being of individuals and that results as pressure on the distributors and wholesalers to keep sufficient stocks (Alibabei and Yousefi, 2015; Heiskanen et al., 2017; Aceto et al., 2020). It is also critical to protect environmental degradation during pharmaceutical distribution channel (Weraikat et al., 2016; Kumar et al., 2019).

* Corresponding author.
E-mail addresses: ahsh@uva.fi, (A. Shamsuzzoha), emmanuel.ndzibah@uwasa.fi. (E. Ndzibah).

http://dx.doi.org/10.1016/j.crsust.2020.100013

This research examines pharmaceutical wholesale logistics in Finland, along with the operating countries of the principal companies. The regulations constructed by the European Union dictate the operating protocols, in addition to the regional legislations. Logistics processes with large volumes and multiple distributors are susceptible to fragmentation. To mitigate fragmentation, this research study explores the possibilities of centralizing and standardizing the incoming shipments to the case company.

The basic contribution of this research study is to understand and analyze the inbound goods delivery system of a case pharmaceutical company from existing distributed logistics system to centralized pipeline system. From the analysis, it is investigated that centralized logistic system can provide added benefits to the inbound process of the case company. The research results indicated that a centralized pipeline system can provide improved information flow, higher used freight capacity and reduced CO_2 emissions of the logistic processes. In order to investigate the current logistics system of the case company, this study is chosen a single research question which is as followed:

'*How to optimize a fragmented supply chain with centralized transportation in pharmaceutical wholesale?*'

Four sub-objectives are derived from this research question, which are as follows:

a) to identify key points of inefficiency
b) to utilize shipments at higher capacity to improve efficiency
c) to increase visibility and oversight for the incoming goods
d) to evaluate the achieved benefits for reducing waste and CO_2 emissions of the supply chain

The rest of the Sections are distributed as follows: Section 2 outlines related works on data-driven supply chain, lean supply chain, sustainable and environmental friendly supply chain and logistics management with identified research gaps and contributions. Section 3 illustrates the logistics network system highlighting centralized logistics systems and transportation pipeline system. Case company's profile is highlighted in Section 4, while methodology of this research study is introduced in Section 5. Various collected data from the case company is explained and analyzed in Section 6. Overall study conclusions are highlighted in Section 7, along with research limitations and future research direction.

2. Literature review

Hassini et al. (2012) define a supply chain as "all parties involved in fulfilling a customer order." Managing a supply chain can be complicated due to the fact that it is involved to multiple organizations and many decision makers. Supply chain management (SCM) can be defined as the management of resources, information and processes related to the supply chain. The goal of SCM is to improve supply chain performance in order to achieve higher efficiency and competitive advantages in a competitive market (Ballou, 2007). Supply chain performance and efficiency are subjective concepts that are defined by the strategic objectives and performance indicators. Utilizing different SCM methodologies, companies thrive to achieve sustainable competitive advantages (Bailey, 2015).

In health care system, supply chain needs to be worked in a risk-free environment. This healthcare sector has the involvement of different risks. In case of pharmaceutical supply chain, uninterrupted supply of medicines is critical (Vishwakarma et al., 2016). Sharma and Modgil (2019) studied the impact of total quality management, operational performance and supply chain on pharmaceutical industry. Kumar et al. (2019) discussed the study on green supply chain management in pharmaceutical industry, where they suggested how organizational managers need to achieve sustainability in operational perspectives. Bocek et al. (2017) addressed how blockchain can be applied to the pharmaceutical industry to ensure quality control and regulatory compliance over the transportation of medical products, where sensor devices are used to ascertain data immutability and public accessibility of temperature records. Vishwakarma et al. (2019) have discussed elaborately various challenges or barriers in the pharmaceutical supply chain.

2.1. Data-driven supply chain

Data-driven approach has the potential to enable new ways of organizing and analyzing supply chain processes and to drive supply chain performance (Hazen, 2014). In the context of supply chain, data can be used as the basis for quantitative and qualitative techniques aiming to improve the supply chain competitiveness. Data works as a driver of better decision-making and improved business performance for those firms able to leverage it (Yu et al., 2018). Analysis of useful data provides higher-quality outputs and increases the value-added content of supply chain and logistics systems.

In order to ensure supply chain sustainability, it is necessary to better design and management of supply chain and logistics modes. Organizations can use data or big data to communicate with various supply chain functions, e.g., purchasing, production and operations, distribution, marketing and sales, and after-sale service (Sanders, 2014). Organizations can efficiently manage global supply chains by using real-time data, while reducing defects and reworks within the production plants (Waller and Fawcett, 2013). To achieve maximum benefits from data driven approach, the necessary information must be shared across the supply chain processes not only within the organization, but also outside the organization, thus providing a real end-to-end process view to all supply chain partners (Yu et al., 2018).

In case of a data-driven supply chain process, collected data or information is shared across the entire supply chain with the objective to connect supply chain partners and provide end-to-end supply chain data access (Sanders, 2014). With the objective to continuously improving supply chain effectiveness, organizations need to leverage large supply chain datasets. From such datasets, organizations could improve demand forecasting and can do their supply planning by using their own data and supplement with customer and supplier data such as raw material data, delivery data, promotion data, and inventory data (Yu et al., 2018).

2.2. Lean supply chain

Bortolotti et al. (2016) defined lean as an operating strategy that aims to systematically reduce waste and maximize value creation of a manufacturing process. A Supply chain can be susceptible due to lack of visibility, miscommunication between members of the chain due to multilingual operations or other bottlenecks. These factors can result in a fragmented supply chain (FCS). FCS is the result of information not flowing efficiently enough between the members of the chain (Oracle, 2010). A major contributor to fragmentation is the lack of visibility in the supply chain. An example of information fragmentation would be a shipment arriving without documentation to the receiver, resulting in a bottleneck for the process.

Initially, lean was created for optimizing manufacturing processes. Since its conception, applications of lean methodology have evolved to consider non-manufacturing processes. For instance, supply networks adapted lean manufacturing in the form of lean distribution. Lean has become close to synonyms with increasing efficiency in SCM literature, illustrating the broadness of the concept (Reichhart and Holweg, 2007). This is largely due to the easily adaptable and condensed concept of "efficiency means creating maximum value while minimizing waste" (Bortolotti et al., 2016). According to lean methodology, the mission of a company is to create the highest possible value while minimizing waste. A key factor in increasing efficiency is to find the ways to increase performance of operations constantly. This methodology of continuous improvement means a constant process of identifying, fixing and analyzing activities that create waste or add no value. Lean methodology states that having no perceived problems in a supply chain is a problem in itself. This means that the activities of a supply chain should be monitored and measured constantly (Bailey, 2015).

2.3. Sustainable and environmental friendly supply chain and logistics management

Sustainability of an activity can be defined as the ability to maintain a desired level of function without depleting required natural resources in the process (Oxford Dictionaries, 2019). Hassini et al. (2012) define business sustainability as "the ability to conduct business with a long-term goal of maintaining the well-being of the economy, environment and society." Sustainable supply chain is playing a significant role in global business environment. It has attracted a significant attention to fulfill customer wishes and environmental needs (Wu et al., 2017b). Due to complexity in the global supply chain network that aroused from multi-channel goods distribution, the socio-environmental-economic issues have considered as major attributes to measure supply chain performance (Tseng et al., 2019). Data-driven supply chain is used efficiently to measure the sustainability in supply chain management (Jiao et al., 2018; Gawankar et al., 2019). Chavez et al. (2017) investigated the relationship between data-driven supply chains, manufacturing capability and customer satisfaction. Data-driven supply chain offers visibility and capability to achieve sustainable performance (Kamble et al., 2020; Jabbour et al., 2020; Kumar and Anbanandam, 2020).

Traditionally, supply and logistics chain aims at cost reduction and service improvement but there is less concern about the environment and societal dimensions (Mota et al., 2015). However, in today's business domains, environmental issues are becoming more and more critical. To monitor and manage the environment and also to ensure organizational long-term sustainability along with profit creation, there needs to deploy strict laws and regulations of the government (Agi and Nishant, 2017; Singla et al., 2018). Therefore, a methodological framework for incorporating environmental concerns in supply chain and logistics operations is required. Such framework can be defined as the embodiment of green practices at every possible step of the supply chain (Choudhary et al., 2020). Due to the added benefits from environmental sustainable supply chain such as reduction in operational cost as well as better environmental performance, a large number of companies are replacing their conventional supply chain model with greener supply chain management (Ahmad et al., 2017).

The impact of different carbon-emission-related policies on the design of the supply chain network brings benefit towards cost efficient productivity. Such green supply chain promotes improved and sustainable production capacities for production plants by exploring the trade-offs between transportation costs, facility investments costs, and emissions (Marufuzzaman et al., 2014; Khan, 2020). During execution of the supply chain and transportation, it is necessary to analyze the behavior of the chain under different regulatory policies such as carbon cap, carbon tax, carbon cap and trade and carbon offset mechanisms. Such analysis enhances the impact of each policy on the supply chain performance. In order to improve environment friendly sustainable supply chain, it is required a more comprehensive and integrated transportation and environmental policy approaches that combines essential legislation and economic instruments in a transparent way and across all transportation modes (Aronsson and Huge Brodin, 2006).

In logistics, the processes can be conducted, innovated, and improved in a way that is not harmful to the environment (Lockman, 1994; Nandi and Kumar, 2016). The focus of this research is to minimize waste and emissions that are created in the transportation process of pharmaceutical products. Sustainable logistics processes can be divided into three different dimensions such as economic, society and environment (Hassini et al., 2012; Anderson, 2012; Narimissa et al., 2020). In terms of economic perspective, sustainable logistics offer reduced cost by maintaining quality during transportation and ensuring the availability of the goods and optimizing the delivery routes (Bravo et al., 2019; Gruchmann et al., 2019; Arsić et al., 2020). With respect to societal aspects, sustainabile logistics promote reduced level of CO_2 emission, creation of more employment and ensuring safety and health during delivery of items (Lambrechts et al., 2019; Govindan et al., 2019; Scaburi et al., 2020). In case of environment consideration, sustainable logistics offer emission free transportation, energy efficient fuel consumption during transportation and use of multi-modal transportations to reduce cost (Bottani et al., 2019; Ren et al., 2020). Guerlain et al. (2019) proposed a data-driven decision-making system to achieve improved measures for logistics network. Data analytics can be used successfully to provide necessary guidelines towards logistics data and to mitigate logistics risks (Wu et al., 2017b).

2.4. Research gaps and contributions

In any form of supply chain and logistics management, it is essential to manage data and to use them ensuring supply chain success. This data driven supply chain needs to explore for obtaining competitive business advantage. Data driven supply chain also contributes towards lean and sustainable supply chain management. Both lean and environmental friendly and sustainable supply chain are critical for the companies to fulfilling business goals. In supply and logistics chain, lean, environmental and sustainable transportation systems can be designed in such a way to minimize resources and reduce costs. For companies, special focuses are necessary on their supply networks to measure their efficiencies with respect to waste minimization and environmental protection. In order to minimize the waste and environmental degradation, extensive researches are necessary to find out the factors, which are responsible to enhance such performance factors. This research therefore, tries to find out the causes and minimize the waste of resources in transportation pipeline system in a pharmaceutical company in Finland.

3. Logistics network systems

3.1. Centralized logistics systems

Logistics network centralization is a strategic method used in logistics to increase the efficiency of the supply chain. Centralized logistics systems are based on consolidating and standardizing the flow of outgoing and incoming shipments. Centralized logistics contribute to decrease variable costs of the supply chain that are related receiving of goods, longer freight distance or lack of visibility to incoming goods. In the context of this research, centralization can be employed in combining multiple small deliveries from multiple distribution points into singular larger shipments (Azzi et al., 2013).

Centralized logistics can provide increased efficiency when there are multiple distribution points with relatively small volumes of goods. Centralizing requires standardizing the shipment process to operate in a more predictable manner. However, with longer distances, organizing a centralized logistic system can require more planning and integration between the supply chain members. Benefits for a pharmaceutical wholesaler are optimizing the visibility and used capacity of incoming shipments, resulting in fewer trucks arriving. Fig. 1 shows the flow of deliveries to wholesaler in traditional distribution system and a hub-based centralized system. (See Fig. 2.)

3.2. Transportation pipeline system

Transportation pipeline is a standardized route that includes deliveries from multiple distribution points. A standardized and calculated route combines smaller deliveries into a one larger shipment. In the pipeline system, the wholesaler, pharmaceutical company and a 3PL (third party logistics) organizes a truck that picks up deliveries from multiple distribution points and usually send small shipments. The pipeline system utilizes the centralized nature of the transfer hub system, while keeping the system agile. Furthermore, the pipeline system does not demand large investments to an additional transfer hub, but it does require close cooperation between the involved supply chain members.

The transportation pipeline system has three distinct advantages in comparison to the traditional distribution system. Firstly, having fewer trucks arriving to the wholesaler's warehouse can operate more efficiently. Secondly, there is improved supply chain visibility (SCV), since the receiver organizes the trucks and the freight information is forwarded when the trucks are loaded. This could be done by a shared interface, where the data is instantly available to the supply chain members without being fragmented between the processes. For instance, the interface can be a

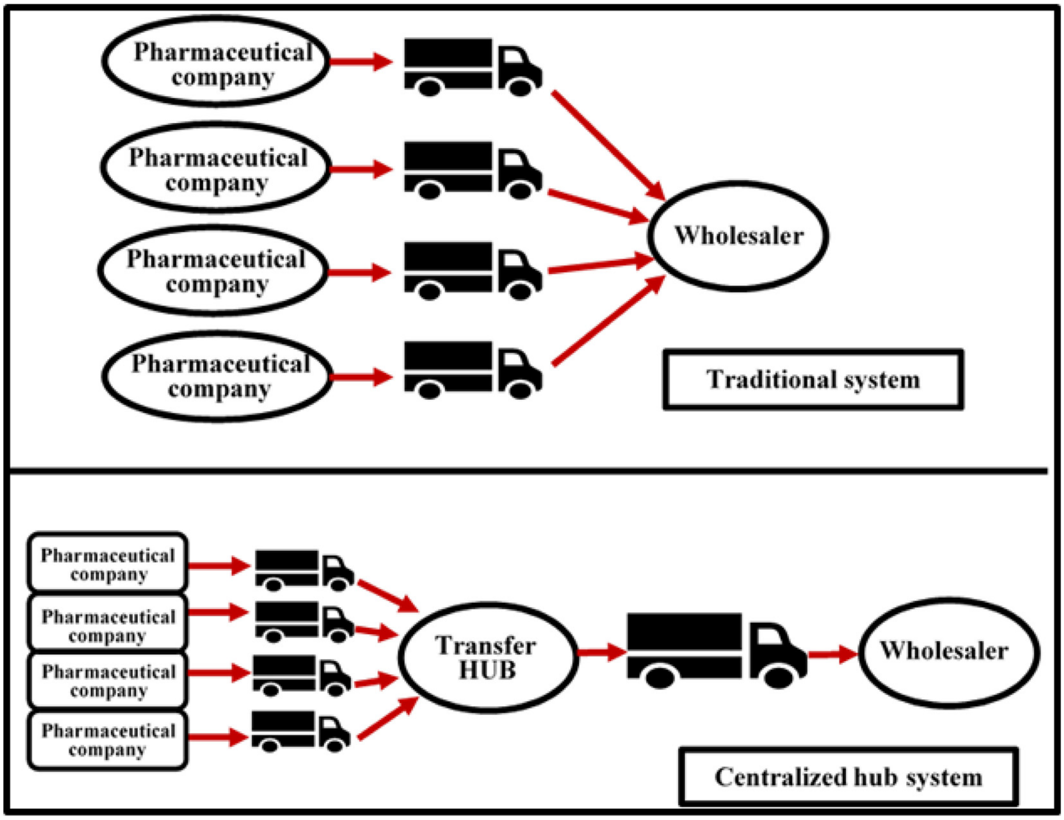


Fig. 1. Traditional logistic system and centralized hub system (Adapted from Azzi et al., 2013).

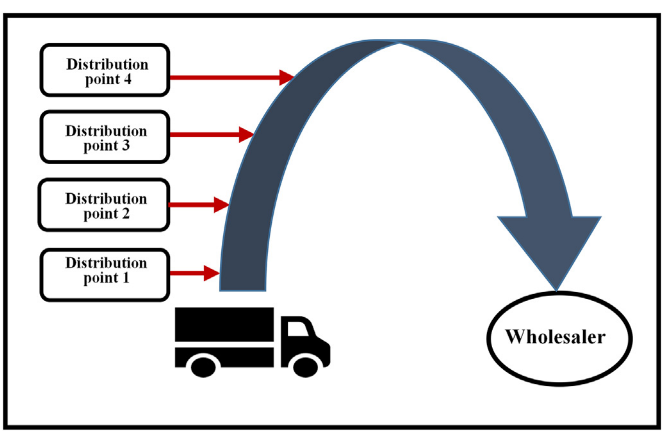


Fig. 2. Transportation pipeline system.

cloud-based, where the members can logged in to relevant information. Thirdly, the operating trucks can have higher used capacity than individual shipments from pharmaceutical company to the wholesaler. This results in fewer resources used in loading and unloading the shipments in addition to fewer vehicle kilometers driven.

Implementing a pipeline system can present significant challenges. Determining the distribution points used, calculating the routes and scheduling deliveries are aspects that should be considered. The implementation of the system requires cooperation between the wholesaler, principal company and the chosen 3PL partner. Personnel require sufficient training to be able to comply by the new operation methods. Preparations are necessary to avoid possible complications in the rolling out of the new system. The key performance indicators should be set up to measure the fulfillment of the strategic goals (Teker, 2017).

4. Case company profile

The studied case company is a Finnish publicly listed company with a strong position in the Finnish healthcare and wellbeing markets. The company promotes the wellbeing of people and animals by ensuring that medicines as well as health and wellbeing products are delivered in a safe and customer-friendly manner – whether through pharmacies, veterinarians, retailers, online channels or dose dispensing. It provides pharmaceutical companies an effective access to markets and improves consumers' wellbeing by ensuring that pharmaceuticals, health products and services are delivered in a safe and customer-friendly manner. The aim of the case company is to be more than regional wholesaler by providing additional services for pharmaceutical companies. These services are available to help companies to operate within the regulations and rules of the Finnish system. These services include medicine import, market access and regulatory affairs.

The operations under review are connected to the scope of this research study. These operations are coordinating to send, transporting and arrival of pharmaceutical goods to the wholesaler warehouse. The processes attached to receiving goods are known in the case company as inbound processes. Two departments of the case company are most involed in daily inbound processess such as supply chain coordination (SCC) and the incoming goods warehousing team. The SCC team functions as the customer services for the pharmaceutical companies and act as an intermediate between pharmaceutical companies and the case company's other departments. The responsibilities of the SCC team include but are not limited to:

- Ensuring safety and availability of medicinal products
- Questions associated with logistics and additional services
- Handling of orders and invoices

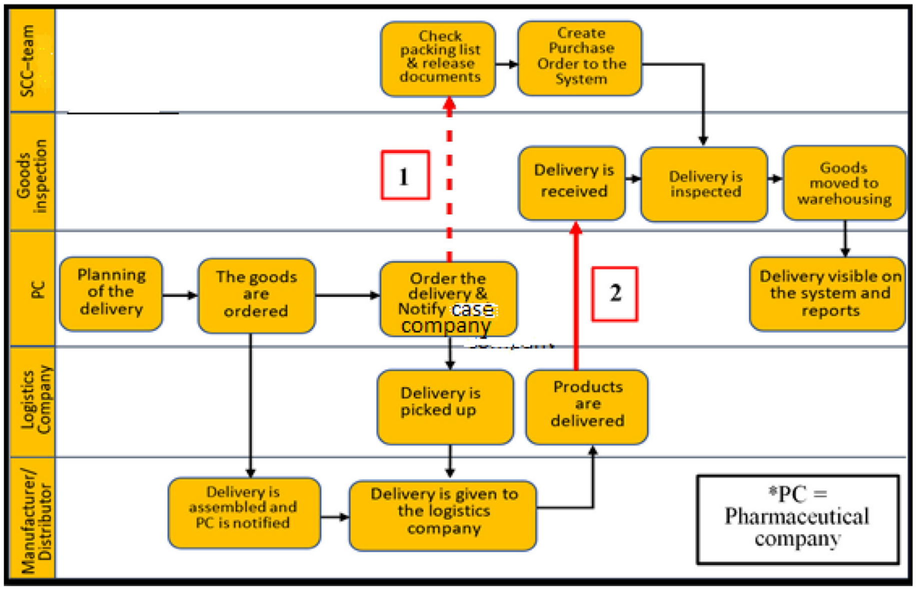


Fig. 3. Inbound processes for arriving goods.

- Tracking and saving of batch certificates
- Quarantine warehousing
- Narcotics importing
- Management of obligatory stock

Fig. 3 presents the planned processes of inbound deliveries to the case company. In the Fig. 3, arrow marked with 1 illustrates incoming information to the case company about deliveries, while arrow 2 represents the products arriving to the case company from manufacturers or distributors. In an optimal situation, the information and deliveries arrive in the order presented in the Fig. 3. However, this is not always the case. This is especially true with small and intermediate pharmaceutical companies with irregular delivery schedules.

The transfer of information in relation to the incoming deliveries is not always timely and accurate, resulting in divergences from the process presented in Fig. 3. These divergences proceed to cause delays and additional works that can described as waste. Pharmaceutical companies need to coordinate with the logistics companies, the manufacturer and the case company about the content, schedule and release documents of the arriving deliveries. All three parties should have a coherent understanding of their roles and responsibilities in the process.

The shortcomings of this process could be improved by centralizing the shipping and delivery processes. For example, if the information were available to all members of the delivery chain at the same time, there would be no fragmentation in the flow of information in relation to the flow of the products.

5. Research methodology

The empirical research focuses on analyzing and comparing two different scenarios of the inbound processes of the case company. Empirical research examines the current logistics system and compares it to a centralized transportation system. The empirical research employs a mixed research strategy (Williams, 2007). This means that both the quantitative and qualitative methods are combined in this research study. Quantitative methods provide a large sample size and general result. In contrast, qualitative methods provide a smaller sample size and more detailed information. Mixing the quantitative and qualitative methods provides a more comprehensive understanding of the research, as the two methods complement one another.

Fig. 4 presents the progression of the empirical research. The empirical research is divided into five phases. First phase is consisted of data collection, which is divided into primary data and secondary data. The literature review is secondary data, providing a theoretical framework for the study. Primary data are the gathered inbound delivery data and questionnaire answers. In the second phase, the data is analyzed to provide a description of the present state of the inbound process. In the following phase "modelling and analysis of the logistic systems", the collected data is used to model the logistics systems. In the third phase, the comparison analysis is conducted to explore the benefits and trade-offs between the current inbound process and the modelled centralized inbound process. In the fourth and final phase, the results of the empirical research are discussed and concluded.

The gathered quantitative data comprised of inbound data collected from the case company between 1.10.2018 and 30.09.2019. The qualitative data is primarily gathered from a questionnaire survey conducted within the members of the case company's personnel and presented in the appendix 1. The empirical research was conducted internally, as the quantitative and qualitative data was gathered from the case company.

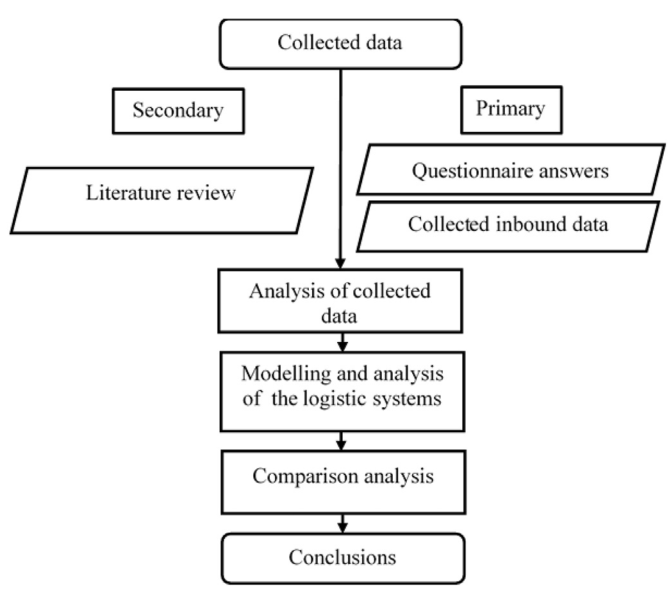


Fig. 4. The structure of the empirical research.

Table 1
The selection criteria of the inbound data.

1. Pharmaceutical company selection	16 pharmaceutical companies
2. Geographical location of the distribution points	Suitable for a centralized pipeline system
3. Logistic practices	Products arriving with inconsistent intervals and with poor visibility
4. Availability of the data	The data was available for extraction form the ERP and was found from the physical delivery document archive.

Table 2
The selected distribution points.

Pharmaceutical company	Pallets	Location
Company 1	262.04	France
Company 2	10.71	France
Company 3	33.29	France
Company 4	3.16	Belgium
Company 5	17.28	Netherlands
Company 6	9.36	Netherlands
Company 7	161.54	Denmark
Company 8	64.83	Denmark
Overall	562.20	

5.1. Qualitative data

A questionnaire survey was conducted to the case company's inbound processes in order to gather qualitative information. The questionnaire was constructed to serve the research objectives. The respondents answered the online questionnaire through an electronic form. All of the respondents were personnel from the case company involved in the inbound process. There were 16 respondents to the questionnaire. Nine out of 16 respondents were from the supply chain coordinators and rest seven respondents were from inbound warehouse workers. Both the supply chain coordinators and inbound warehouse workers are highly involved in the daily operative functions of the inbound processes. The questionnaire consists of four multiple-choice questions and four statements that the respondents rated on the Likert scale from 1 (completely agree) to 7 (completely disagree). Moreover, the respondents had a choice to suggest their own answers in the multiple-choice section, if the given alternatives did not correspond with their views on the matter. The objective of the questionnaire was to extract contextual and observational information of the inbound processes.

5.2. Quantitative data

Quantitative data is gathered from the arrived shipments from chosen distribution points in the timeframe 1.10.2017–30.9.2018. The inbound data is collected from inbound deliveries to the case company. A spreadsheet consisting of 66,980 rows of received products was extracted from the company's ERP system. This data consisted of all the products arrivals, including non-pharmaceutical products and various other products, not relevant to this study. Each row consisted of a single product and the arrived quantity. Thus, a single delivery had a spreadsheet row for each product that arrived on it. All of the product quantities were converted into pallets, meaning different sized packets could be comparable with each other. For instance, if 100 packets arrived and the pallet size was 300, it was converted to 0.33 pallets. Due to the immense number of inbound products, limitations to the considered data were necessary.

First phase of the inbound data gathering was to limit the scope of the data for closer examination. Approximately, 100 pharmaceutical companies sell products through the case company in Finland, from which 16 companies were selected to study. Focus was given on pharmaceutical companies that could benefit from the centralized pipeline system by increasing information flow and improved transportation efficiency. The selection

Fig. 5. The locations of chosen distribution points.

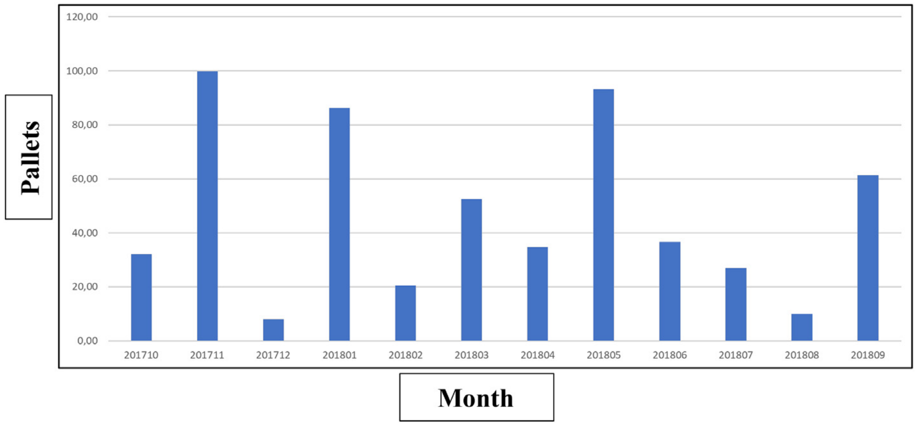


Fig. 6. The flow of monthly incoming products in pallets from the selected distribution points.

criteria of the inbound data are shown in Table 1. The sending locations of these products were then searched and matched to the physical arrival documents of the deliveries, since this information is not stored in an electronic form. 66 unique distribution points in Europe were identified for closer inspection. The distribution points were chosen using the criterion shown in the Table 1. The focus was on selecting distribution points that were projected as having insufficient supply chain visibility (SCV) that hindered inbound processes.

Overall, in the empirical research, eight distribution points that were chosen. The distribution points are located in France, Belgium, Netherlands and Denmark. The points are numbered from 1 to 8, based on the order of the points would be located on a centralized pipeline route. The chosen quantitative data consisted of 562.20 pallets of pharmaceutical products that arrived from the distribution points. The construction of the arrived pallets is presented in the Table 2.

6. Data collection from the case company and analysis

6.1. Location of the distribution points

Fig. 5 illustrates the geographical locations of the chosen distribution points. Geographical location was a selection criterion, as mentioned in the Table 1. The distribution points form a logical route from point 1 (France) to point 8 (Finland) at the case company's location that can be utilized in the centralized pipeline. This route is assumed as the optimum and standard route with respect to deliver items that minimizes transportation cost. The numbers in the map correspond to the numbers of the distribution points in the Table 1. Notably, the geographical locations of the distribution points are the framework for a centralized transportation route.

Fig. 6 illustrates the monthly flow of products from the chosen eight distribution points. From Fig. 6, it is noticed that before and after Christmas and summer holidays there is a visible increase in incoming flows. This variation is due to stock management for the winter and summer holidays. Inconsistent product flow presents challenges for standardizing the delivery processes, as the processes requires the agility to adapt for different volumes.

Table 3
The basic DES components (Adapted from Brailsford et al., 2014).

Entities	Trucks moving through the logistics system.
Queues	Warehouses, loading docks, unloading trucks.
Activities	Picking of deliveries, transportation of goods, inspecting documents, receiving deliveries.
Resources	Warehouse workers, SCC operators, transportation equipment, equipment operators.
Trigger	Required stock level or a special need of the products.

6.2. Proposed modelling processes

This research utilizes AnyLogic Simulation Software (version 8.3.3) to help to create a model of the centralized pipeline system. AnyLogic is a simulation software that is built for discrete event simulation (DES) modelling. AnyLogic provides methods to apply DES and geographic information system (GIS) aspects to a model within the software (Dawsen, 2011; Unwin et al., 2012; Weimer et al., 2016). It is important to note, that the AnyLogic simulation software is utilized in this research study with elementary components. Building a comprehensive model would require a research with a larger scope and resources.

The model is primary constructed from the collected inbound data, with the knowledge from the real-world functions. For the modelled systems, a less complex approach is taken for calculating the variability of activities. Attempting to simulate the variables can accurately produce trivial information.

There are five basic DES components, which are introduced in Table 3. Using these components, a basic a DES queuing system can be built. An example of a DES model is shown in Fig. 7. (See Fig. 8.)

Fig. 7 illustrates how a queuing system is adapted to a model. Entities enter the system to "queue 1" and then are directed to an activity. The chosen activity can depend on the entities requirements or it can be completely random. Resources are required to execute activities. If there are insufficient resources, the activities are blocked. The entities proceed to the following activities and finally exit the system. It is important that the model gather data as it runs. This data is called system statistics and it is used to evaluate the performance of the system (Brailsford et al., 2014).

6.3. Model analysis

This part of the study presents and analyses the constructed logistics models. The models are kept straightforward and functional, as constructing a complex model would require substantially more time for data gathering and mapping processes all across the supply chain. The focus of the

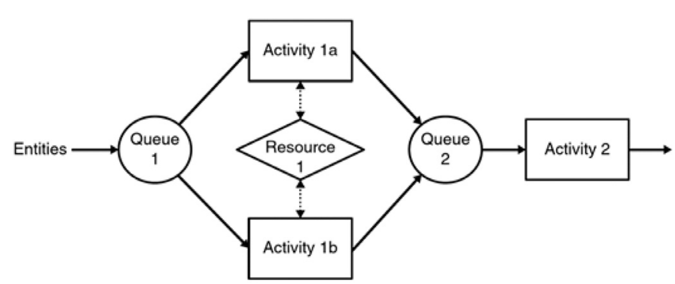


Fig. 7. Example of DES model flow (Brailsford et al., 2014).

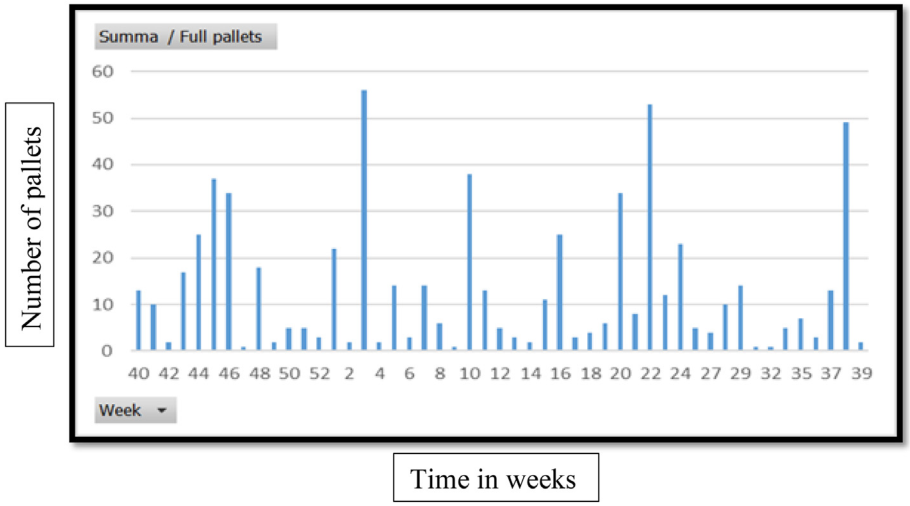


Fig. 8. The weekly inbound flow in the current system in full pallets.

models is the significant differences between the two logistics systems. These differences include the level of visibility of incoming shipments and required work in receiving deliveries. Thus, the models are not considered authentic replicas of the real-world processes. More specifically, the models provide a framework of the processes for calculations and comparative analysis. One model is built of the existing inbound logistics system and another is constructed for the centralized pipeline system. The constructed models and the data calculations are explained. The selected time-step in modelling was one week. The modelling was conducted primary based on the gathered inbound delivery data of the chosen distribution points.

6.4. The current transportation system

The current inbound process can be described as unstandardized and modelling the system proved to be a challenging task. Due to the lack of visibility to arriving shipments, there is partly insufficient information about the inbound flow of products to the case company. The constructed model of the current transportation system is primarily presented to establish a comparison to the centralized pipeline model and relies heavily on estimations.

During the 1.10.2018–30.9.2019 timeframe, there was 164 unique dates where a good receipt (GR) was created. These dates were corrected for delays in GR formations from same and similar locations. After the corrections, it was determined that 136 different received deliveries from the chosen eight distribution points had arrived. The deliveries from the pharmaceutical companies arrived to the case company with significant variability. Companies contracted logistics companies to transport the products. The logistics companies then hauled the products to the case company, delivering products from other companies at the same time if there were corresponding deliveries.

The case company's role in the current system can be determined as passive. The planning, delivering and providing sufficient information of the deliveries are mostly the responsibility of the pharmaceutical companies. The case company receives the goods and contacts the pharmaceutical companies if there are contaminations, other deviations or missing documents in the shipments. As the focus of this study is on the logistics systems of the inbound process, the inner warehouse resources are not considered in the modelling process. The focus of the current inbound process is the required labor hours in reception.

Fig. 9 illustrates the arrival process of the current logistics system. The model projects the lack of visibility in the inbound process. Thus, Fig. 9 is simple, mainly focusing on the arrival of the deliveries. Since every reception requires an hour and every delay two hours, it can be concluded that 192 h was required for the reception of these products.

6.5. Centralized pipeline model

For this research study, the pipeline system was chosen as the centralized logistics system under review. With aspects of GIS and DES and the inbound delivery data, a pipeline model was built. The purpose of the model is to provide an illustration on how the pipeline could be implemented for the chosen distribution points.

Fig. 10 presents the process flow of the pipeline built for this research. A significant difference to the current model is the involvement of the case company in the planning stages. The delivery is planned in cooperation with the logistics companies and distribution points. Thus, the information is not fragmented between processes. The case company has the knowledge what the arriving shipment contains, where it is located and what are the necessary documents. The result is increased SCV between the supply chain members. As it was discovered in from the questionnaire results, improving communication is an important part of optimizing the inbound processes.

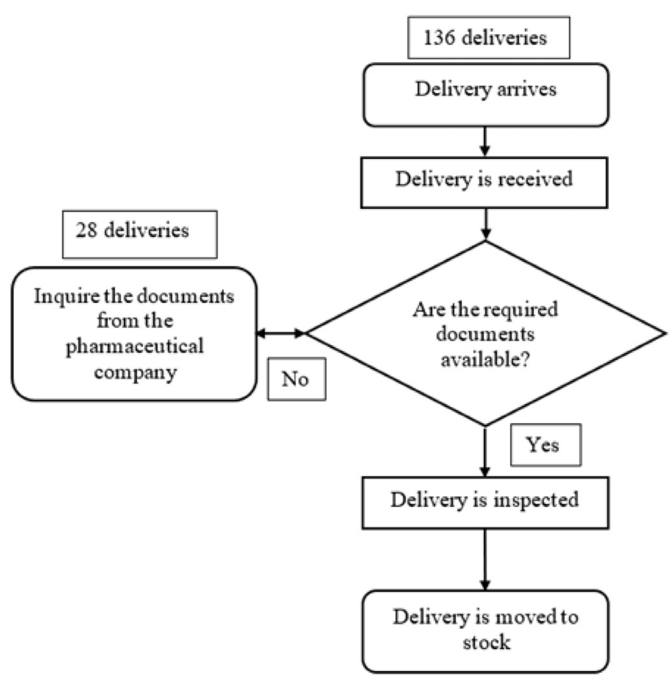


Fig. 9. The modelled arrival processes.

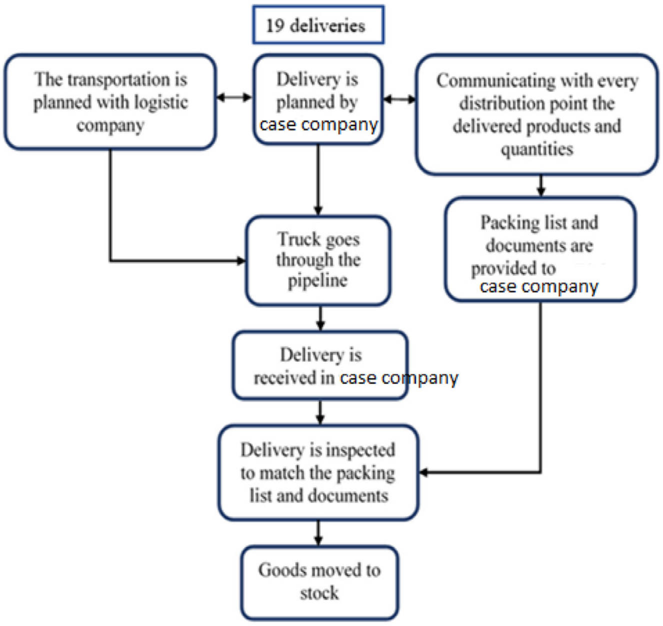


Fig. 10. The proposed process flow for the logistic pipeline system.

Fig. 11 shows calculated optimal route for the pipeline system using GIS. The overall length of the pipeline system passing through every distribution point is approximately 3270 km. First step in the pipeline system modelling is determining the values for key activities. Values were defined as estimated averages. The determined values can be adjusted later to modify the model, where necessary. The variation in the travelling, loading and unloading uses a randomized variation between a predetermined intervals. The entities moving in the model are the trucks, and for each truck, certain number of products is assigned in the distribution points. For this model, the operating truck capacity is defined between 18 and 65 pallets, depending on the size of the planned delivery. This provides the model with agility to the variations in the incoming product volume. Due to the fluctuation in the trip durations, the variation for each trip is assigned specifically. For every two hours travelled a variation of 15 min is added. This means that if a journey takes on average two-hours, it is assigned a randomized value between 105 and 135 min.

The model is constructed as a linear sequence of activities. This is presented in the Fig. 12. In the “source” block the truck delivery is created. “Start1” starts measuring time and “end1” stops the measurement. This measures the time it takes for a truck to travel through the pipeline. “Trip” blocks represent the activity of moving between the distribution points and the duration is determined by the trip variability. “Stops” are the queues spent in the distribution point loading the products and are assigned a value between 45 and 75 min at random.

The different quantities of incoming products required the pipeline to be adaptable to the distribution points sending the largest quantities of products. To fulfill this requirement, a truck can be deployed when there is sufficient number of products waiting for delivery. There were five truck capacities used; 18, 33, 48 and 65 pallets. The variation in the truck capacity provided the pipeline system with agility concerning the differences volumes of the deliveries. The pipeline deliveries were constructed from the historical inbound data. When dividing the arrived products into deliveries, selection criteria were applied. The objective was to deploy a truck with consistent intervals, to avoid excessive backlogs. However, the

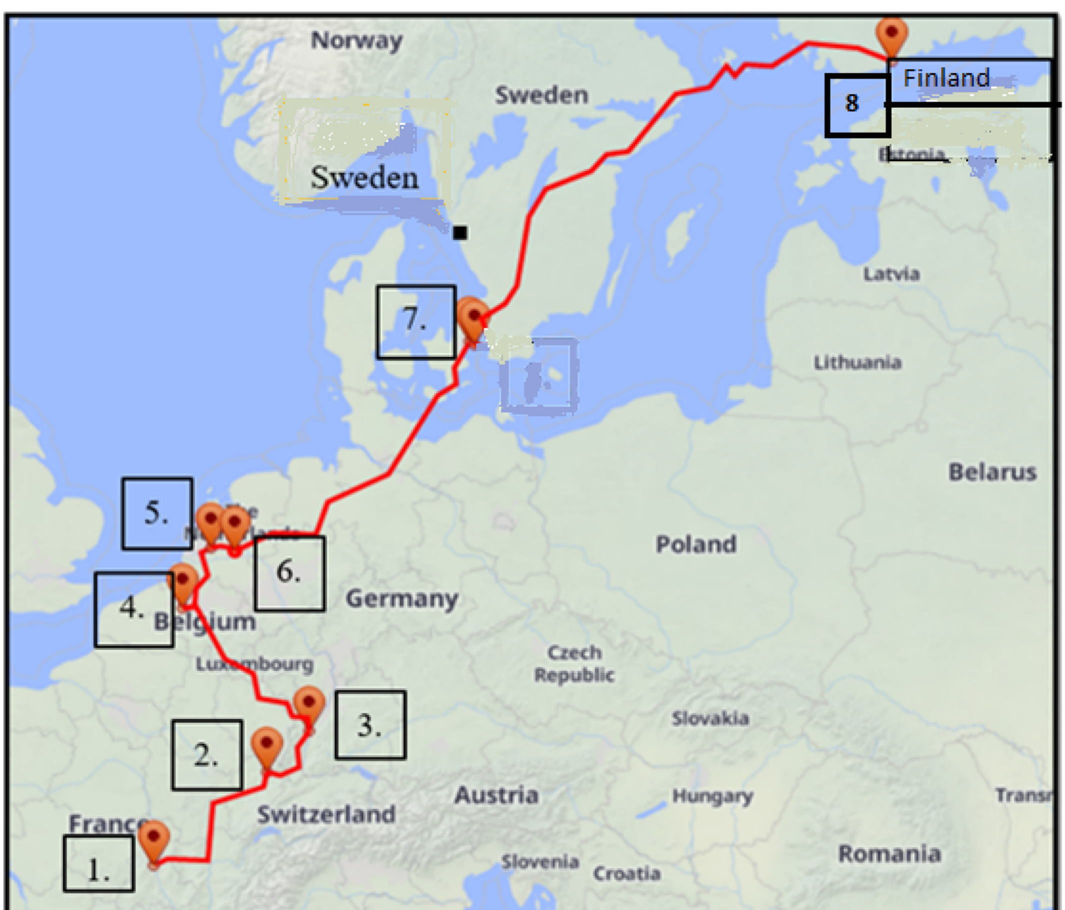


Fig. 11. The complete pipeline flow to the case company.

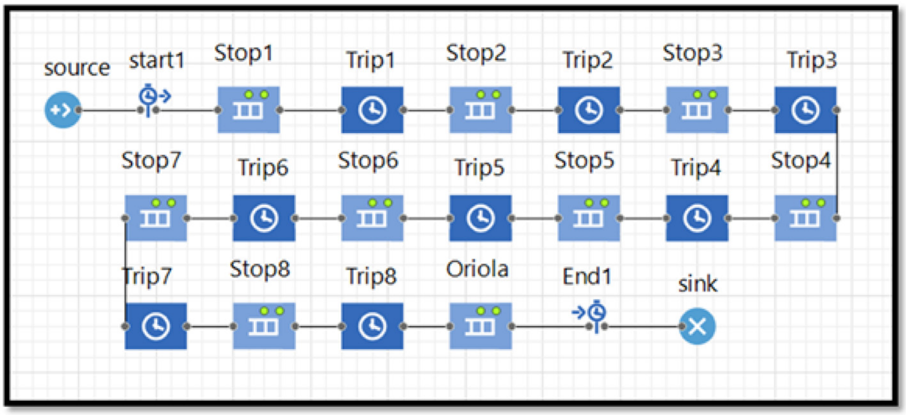


Fig. 12. The block flow of the pipeline.

Table 4
Delivery statistics for the pipeline.

Arrived pallets	Required pallet spaces	Arrived deliveries	Overall available truck capacity in pallets	Used truck capacity
563.51	663	19	723	663/723 = 91.7%

fluctuating inbound volumes posed challenges in achieving consistency. Furthermore, deliveries from the same distribution points were included to the same delivery as often as feasible.

The basic statistics used in the pipeline modelling are presented in the Table 4. Based on the inbound data, the pipeline can complete the deliveries in 19 truckloads. Furthermore, the used capacity can be calculated by dividing the required pallet space with overall truck capacity. From this it can be concluded that the arrived trucks are used with 91.7% capacity. Only one of 19 deliveries required a stop in eight distribution points. The other 18 trucks were a variation of the eight distribution points. The route starts from the first distribution point that has products for the specific delivery. Then the route progresses to the next distribution point on the delivery using the best possible route. With only 19 deliveries, it is feasible to estimate that all of these deliveries arrive with sufficient documentation. Thus, the model functions with the assumption there were no delays due to missing documents.

The scheduling and size of the deliveries is presented in the Fig. 13. Combined there were 19 deliveries. The used truck capacity is marked in the Fig. 13 with red lines. There were four different sizes used and the deliveries were distributed as:

- Truck capacity 18 – five deliveries
- Truck capacity 33 – six deliveries
- Truck capacity 48 – five deliveries
- Truck capacity 65 – three deliveries

The sum of these delivery capacities equals the available truck capacity, 723 pallet spaces. The products required 663 pallet spaces. Overall, the completed routes cumulated 56,510 vehicle kilometers with truck capacity of 91.7%.

Table 5 shows the output data from the modelled pipeline. The times illustrated in Table 5 include all the travelling and loading and unloading times, with the determined variation. Furthermore, the number of distribution points in each route is presented in the Table 5. Based on this model, it is plausible to distribute the products from the selected distribution points by utilizing a centralized pipeline.

6.6. Comparative analysis

This section of the article focuses on analyzing the significant differences between the current and pipeline system. The analysis is based on models presented on the previous section of this article. Table 6 condenses key statistics used in the comparison analysis.

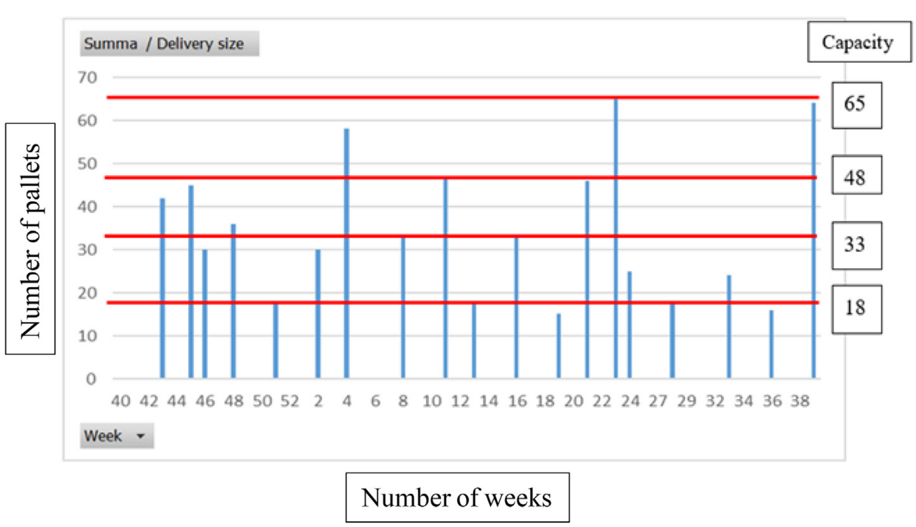


Fig. 13. The weekly inbound flow of the pipeline system in full pallets.

Table 5
System statistics of the pipeline model.

Delivery number	Hours in the pipeline	Driven kilometers	Distribution points in the route
1	45.12	3190	5
2	44.62	3180	5
3	41.27	2800	4
4	44.53	3180	4
5	49.48	3270	6
6	46.40	3190	6
7	44.82	3065	6
8	48.67	3270	7
9	43.15	3040	5
10	38.62	2540	3
11	38.20	2425	4
12	48.28	3270	5
13	43.95	3180	4
14	45.35	3180	6
15	18.52	1140	2
16	51.13	3270	8
17	49.20	3190	6
18	41.65	3065	4
19	45.53	3065	6
Total	**828.48**	**56,510**	**96**

Table 6
Model comparison statistics.

	Current system	Pipeline system
Number of received deliveries	136	19
Number of deliveries with missing documentation	28	0
Caused labour in reception	56 h	19 h
Used truck capacity -%	60%	92%

Increased knowledge: The pipeline system was constructed with the objective to provide increased visibility to the supply chain. Missing documents provide a significant source of inefficiency in the inbound processes. The pipeline system aims to optimize the information transfer by implementing cooperation from the start of the logistics flow. The increased SCV enables the case company to better prepare and schedule resources for the arriving processes. A significant problem in the current system is the passive role of the case company, only having the information that is provided to them. In contrast, in the pipeline system the case company gains the delivery information in the planning stage.

In the pipeline system, the tracking of the shipments using GIS is possible. This results in knowledge of the shipments location, content and scheduled arrival in advance. With a real-time interface, the three supply chain members can communicate and gain information about the shipments.

Capacity of the vehicles: A central objective of the pipeline system was to optimize the used capacity of the arriving trucks. According to the calculations, the pipeline system achieved used capacity of 92%. In comparison, the estimated average of used capacity was 60% d in the current logistic system. Increasing the used capacity is a straightforward method in decreasing used labor hours and the required shipments.

CO_2 emissions: The most significant sources of CO_2 emissions in the logistics processes are the driven vehicle kilometers. The pipeline system aims to reduce the number of arriving deliveries and increase the used capacity of the vehicles, thus reducing driven vehicle kilometers. The current system is not centralized and deploys trucks when needed, whereas the pipeline system deploys truck only when it is deemed to be as efficient as possible. This efficiency methodology is a key factor in reducing vehicle kilometers, and by proxy, the CO_2 emissions created. The approximate CO_2 emissions of this movement can be calculated by using the formulation:

*Travelled kilometers * CO_2 emissions per kilometer * specific emissions factor = CO_2 emissions.*

The vehicle kilometers in the pipeline system were 56,510. The selected CO_2 emission per kilometer is 100 g/km, and the average truck weight is 20,000 kg per truck. The specific emissions factor is the used capacity ratio of the shipments. The calculation is divided by 1,000,000 to convert it to metric tons.

The calculation can be presented as:

$$\frac{510\text{km} * (20\ 000\text{kg} * 100\text{g/km})}{1\ 000\ 000} * 0.917 = 2,220,400,000 \text{ metric tons of } CO_2$$

The emission for the current transportation system cannot be calculated, since the information about the vehicle movement is not available to the same extend. However, as the used vehicle capacity and the number of deliveries arrived is significantly higher, it can be argued that the CO_2 emissions are higher.

The flexibility of the pipeline is relatively poor. The planning stage requires more time to accumulate the products for a full delivery, which results in lower flexibility. The lack of agility was mitigated to a degree with

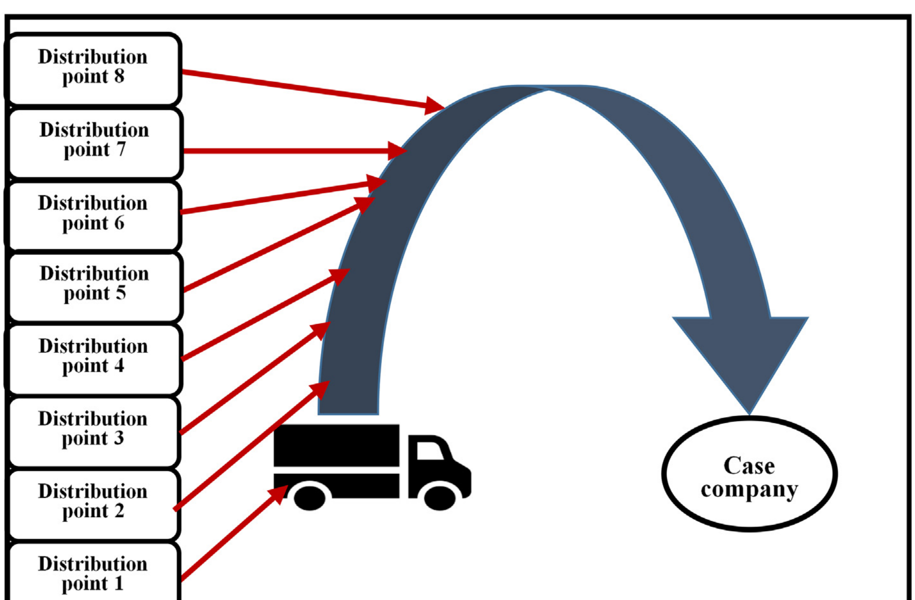


Fig. 14. Modified transportation pipeline system.

tailoring the truck capacity to the planned delivery, providing higher used capacity. A benefit of the current transportation system is the agility and the deliveries can be planned and executed in a shorter timeframe. However, the trade-off to agility is higher expenses of the logistics processes.

7. Conclusions, limitations and future research

The findings from this study are explored in the context of the research question and the four sub-objectives. The first research objective refers to find bottlenecks that hinder the performance of the inbound processes. The most significant point of inefficiency was the information transfer of the inbound deliveries to the case company. Second research objective refers to find out inefficiency in the shipments was addressed by using a centralized transportation system. The empirical research results indicated that the pipeline system could utilize 91.7% of the pallet spaces. Third research objective to increase the visibility and oversight for the incoming goods was addressed by proposing a centralized pipeline system framework for sharing information. The fourth and final research objective refers to evaluate the achieved benefits for reducing waste and CO_2 emissions of the supply chain was addressed by improving the overall efficiency and by reducing CO_2 emissions in the logistics processes.

The main purpose of this research was to provide a comprehensive analysis of the contemporary state of pharmaceutical logistics from a perspective of the case company operating in the Finnish market. Although previous studies conducted on the pharmaceutical logistics are extensive, the specific regulations and circumstances in Finland require special attention. Especially the single-channel distribution distorts the industry dynamic, making the results of studies conducted in different countries partly incompatible. The pipeline system was modified to fit the empirical research. This modified model is presented in Fig. 14.

Overall, the chosen methodology was valid for the selected research question and sub-objectives. However, there are several factors that limits to conduct this study are discussed too. The supply chain modelling calculations do not represent the real systems with complete accuracy. As the data gathering process advanced, the lack of information from arrived deliveries became apparent. Thus, the empirical research was constructed in parts on evaluations. The used data behind presented calculations is explained and it is disclosed when the used data is based on evaluations. AnyLogic simulation software is an advanced tool that takes years to master. The simulation models constructed for this research can be categorized as simplistic. Furthermore, the available data of the inbound processes made modelling difficult.

The number of respondents was lower than was expected. Having more respondents would have provided more validity to the gathered quantitative data. Furthermore, a significant portion of the conclusions is based on the answers from the questionnaire and this address objectivity and validity to research results. The unavailable data from the inbound processes did produce issues considering presenting detailed improvement suggestions. Thus, acquiring more detailed inbound in the future would allow more accurate suggestions for improvements.

This research study can be considered as the first step towards establishing a centralized pipeline system in the case company's inbound processes. In addition, this research study also considered environmental aspect of supply chain with the objective to maintain sustainability. This sustainable and environmental friendly supply chain is ensured in this study through reducing the routes and durations from distributed pipeline system to centralize pipeline system of items delivery. It is studied that centralized pipeline system increases vehicle uses from 60% to 92%, which supports overall performance improvement and sustainability. Moreover, due to the reduced travel distance through centralized distribution channel also contributed towards minimizing CO2 emission that supports to maintain environmental substantially in general.

Future research should be conducted on the matter for a more comprehensive analysis of the inbound shipments and the communications with other members of the supply chain. Implementing a centralized pipeline would require a deep partnership with a third party logistics (3PL). In finding a suitable 3PL partner, the case company could utilize AHP and identify a 3PL that corresponds with their valued attributes.

Appendix: 1

Questionnaires

The following is a questionnaire regarding the current state of the Case Company's inbound process. The focus is on the pharmaceutical products of the case company's in Finland receives from pharmaceutical companies. All of the answers are confidential.

Inbound process: the operations attached to arriving pharmaceutical deliveries to the case company in Finland.

Visibility: The transformation of information between the supply chain members (case pharmaceutical company and logistic companies).

Respondent profile

Name of the organization:
Years in the organization:
Currently held position:

1. In our opinion, what is the most prominent point of inefficiency (bottleneck) in the current inbound process?

☐ The current level of communication between the supply chain members.
☐ Inflexible legislation in place in Finland.
☐ Freight shipments are not utilized to full capacity.
☐ Lack of data from relevant operations.
☐ Undecided
☐ Other:

2. In your opinion, that type of deliveries create the most waste as a part of the inbound process

☐ Deliveries arriving without proper documentation or with insufficient information.
☐ The high volume of small shipments. (e.g. under 4 pallets)
☐ Contaminated shipments. (e.g. temperature deviations)
☐ Undecided
☐ Other:

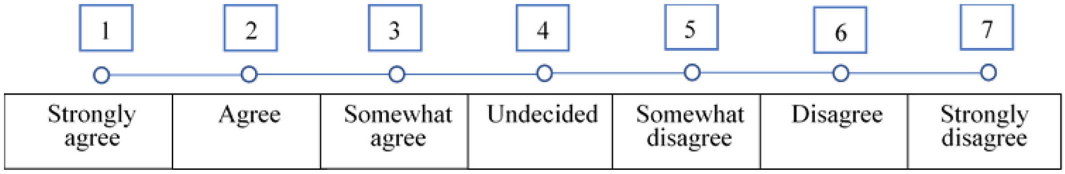
3. In our opinion, what would be a suitable indicator for measuring this waste?

☐ Lead time in the case company. (From arrival to stock).
☐ The percentage of contaminated shipments.
☐ The share of small deliveries from the overall arrivals.
☐ Undecided.
☐ Other:

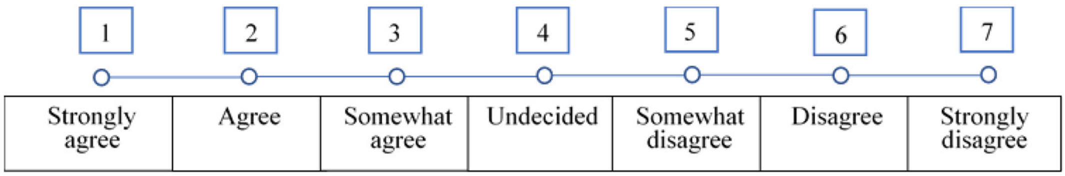
4. In your opinion, what is the most significant challenge in optimizing the inbound process?

☐ The high level of investments with uncertain results.
☐ Integrating operating systems is difficult and requires resources.
☐ Cooperation between supply chain members is challenging.
☐ Undecided.
☐ Other:

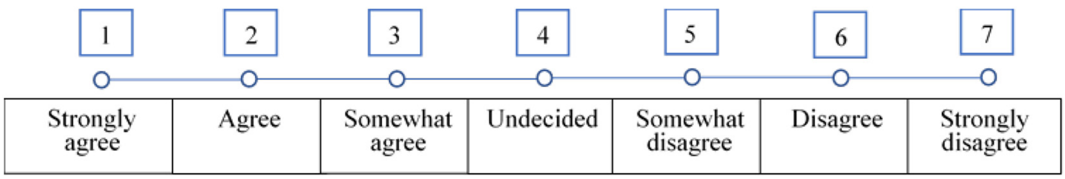
5. Visibility to inbound shipments could be significantly improved between case company and pharmaceutical companies.



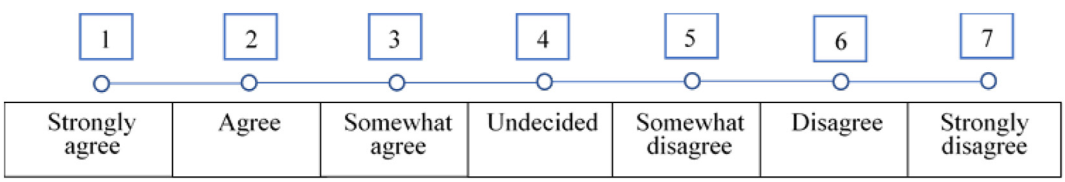
6. The focus on CO_2 emission control of the logistic processes is disproportionate in comparison to the benefits of lower CO_2 emissions.



7. Case company should proactively, either on its own or in collaboration, develop logistic services for pharmaceutical companies.



8. Communication between the case company, the logistic companies and pharmaceutical companies is excellent considering the inbound process of pharmaceutical goods.



Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Aceto, G., Persico, V., Pescapé, A., 2020. Industry 4.0 and health: internet of things, big data, and cloud computing for healthcare 4.0. J. Ind. Inf. Integr. 18, 100129.
Agi, M.A., Nishant, R., 2017. Understanding influential factors on implementing green supply chain management practices: an interpretive structural modelling analysis. J. Environ. Manag. 188, 351–363.
Ahmad, W.N.K.W., Rezaei, J., Sadaghiani, S., Tavasszy, L.A., 2017. Evaluation of the external forces affecting the sustainability of oil and gas supply chain using best worst method. J. Clean. Prod. 153, 242–252.
Ahmadi, V., Benjelloun, S., El Kik, M., Sharma, T., Chi, H., Zhou, W., 2020. Drug Governance: IoT-based Blockchain Implementation in the Pharmaceutical Supply Chain, Sixth International Conference on Mobile And Secure Services (MobiSecServ), 22–23 Feb. 2020, Miami Beach, FL, USA.
Alibabei, A., Yousefi, N., 2015. Information flow in the pharmaceutical supply chain. Iran. J. Pharm. Res. 14 (4), 1299–1303.
Alkhatib, S.F., Darlington, R., Yang, Z., Nguyen, T.T., 2015. A novel technique for evaluating and selecting logistics service providers based on the logistics resource view. Expert Syst. Appl. 42 (20), 6976–6989.
Anderson, J., 2012. Sustainable logistics. World Trade, WT 100 25 (2), 12.
Aronsson, H., Huge Brodin, M., 2006. The environmental impact of changing logistics structures. Int. J. Logist. Manag. 17 (3), 394–415.
Arsić, M., Jovanović, Z., Tomić, R., Tomović, N., Arsić, S., Bodolo, I., 2020. Impact of logistics capacity on economic sustainability of SMEs. Sustainability 12, 1911.
Azzi, A., Persona, A., Sgarbossa, F., Bonin, M., 2013. Drug inventory management and distribution: outsourcing logistics to third-party providers. Strat. Outsour. Int. J. 6 (1), 48–64.
Bailey, A., 2015. Lean supply chain. ASQ Six Sigma Forum Magaz. 14 (4), 31–32.
Ballou, R.H., 2007. The evolution and future of logistics and supply chain management. Eur. Bus. Rev. 19 (4), 332–348.
Bansal, D., Malla, S., Gudala, K., Tiwari, P., 2013. Anti–counterfeit technologies: a pharmaceutical industry perspective. Sci. Pharm. 81 (1).
Bocek, T., Rodrigues, B.B., Strasser, T., Stiller, B., B., 2017. Blockchains everywhere – A use-case of blockchains in the pharma supply-chain. 2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM), Lisbon, 2017, pp. 772–777.
Bortolotti, T., Romano, P., Martinez–Jurado, P. J. and Moyano–Fuentes, J., 2016. Towards a theory for lean implementation in supply networks. Int. J. Prod. Econ. 175 (C), 182–196.
Bottani, E., GiuseppeVignali, G., DavidMosna, G., RobertoMontanari, R., 2019. Economic and environmental assessment of different reverse logistics scenarios for food waste recovery. Sustain. Prod. Consump. 20, 289–303.
Brailsford, S.C., Brailsford, S., Churilov, L., Dangerfield, B.T., 2014. Discrete-Event Simulation and System Dynamics for Management Decision Making. 348. Wiley.
Bravo, M., Pradenas, L., Parada, V., 2019. An evolutionary algorithm for the multi-objective pick-up and delivery pollution-routing problem. Int. Trans. Oper. Res. 26 (1), 302–317.
Burns, C., 2018. FMD anti–tampering device can be verified at any time while in the pharmacy. Pharm. J. Available from Internet. https://www.pharmaceutical-journal.com/news-and-analysis/news-in-brief/fmd-anti-tampering-device-can-be-verified-at-any-time-while-in-the-pharmacy-european-commission-says/20205523.article?firstPass=false (Accessed on 16.01.2019).
Chavez, R., Yu, W., Jacobs, M.A. and Feng, M. (2017), "Data-driven supply chains, manufacturing capability and customer satisfaction", Prod. Plan. Control, Vol. 28, No. (11 – 12), pp. 906–918.
Choudhary, S., Kumar, A., Luthra, S., Garza-Reyes, J.A., Nadeem, S.P., 2020. The adoption of environmentally sustainable supply chain management: measuring the relative effectiveness of hard dimensions. Business Strat. Environ. https://doi.org/10.1002/bse.2560 Published online 28 July 2020.
Chung, S.H., Kwon, C., 2016. Integrated supply chain management for perishable products: dynamics and oligopolistic competition perspectives with application to pharmaceuticals. Int. J. Prod. Econ. 179 (C), 117–129.
Dawsen, C.J., 2011. Geographic Information Systems. 1st ed. Nova Science Publishers Inc, p. 153.
European Commission, 2020. Falsified Medicines. Available from Internet:. https://ec.europa.eu/health/human-use/falsified_medicines_en.
Feng, Q., Shanthikumar, J.G., 2018. How research in production and operations management may evolve in the era of big data. Prod. Oper. Manag. 27 (9), 1670–1684.

Gawankar, Shradha A., Angappa Gunasekaran, A., Sachin Kamble, S., 2019. A study on investments in the big data-driven supply chain, performance measures and organisational performance in Indian retail 4.0 context. Int. J. Prod. Res. 58 (5), 1574–1593.

Govindan, K., Kadziński, M., Ehling, R., Miebs, G., 2019. Selection of a sustainable third-party reverse logistics provider based on the robustness analysis of an outranking graph kernel conducted with ELECTRE I and SMAA. Omega 85, 1–15.

Gruchmann, T., Schmidt, I., Lubjuhn, S., Seuring, S., Bouman, M., 2019. Informing logistics social responsibility from a consumer-choice-centered perspective. Int. J. Logist. Manag. 30 (1), 96–116.

Guerlain, C., Renault, S., Ferrero, F., Faye, S., 2019. Decision support systems for smarter and sustainable logistics of construction sites. Sustainability 11 (10), 2762.

Hassini, E., Surti, C., Searcy, C., 2012. A literature review and a case study of sustainable supply chains with a focus on metrics. Int. J. Prod. Econ. 140 (1), 69–82.

Hazen, R.M. (2014), Data-driven abductive discovery in mineralogy, Am. Mineral., Vol. 99 No. (11–12), pp. 2165–2170.

Heiskanen, K., Ahonen, R., Kanerva, R., Karttunen, P., Timonen, J., 2017. The reasons behind medicine shortages from the perspective of pharmaceutical companies and pharmaceutical wholesalers. PLoS One 12 (6), e0179479. https://doi.org/10.1371/journal.pone.0179479 Available from Internet:. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5489167/.

Helo, P., Shamsuzzoha, A., 2020. Real-time supply chain—A blockchain architecture for project deliveries. Rob. Comput. Integr. Manufact. 63, 101909 June 2020.

Jabbour, C.J.C., Fiorini, P.D.C., Ndubisi, N.O., Queiroz, M.M., Piato, E.L., 2020. Digitally-enabled sustainable supply chains in the 21st century: a review and a research agenda. Sci. Total Environ. 725, 138177.

Jiao, Z., Ran, L., Zhang, Y., Li, Z., Zhang, W., 2018. Data-driven approaches to integrated closed-loop sustainable supply chain design under multi-uncertainties. J. Clean. Prod. 185, 105–127.

Kamble, S.S., Gunasekaran, A., Gawankar, S.A., 2020. Achieving sustainable performance in a data-driven agriculture supply chain: a review for research and applications. Int. J. Prod. Econ. 219, 179–194.

Khan, S.A.R., 2020. Introduction to the green supply chain management. The Critical Success Factors of Green Supply Chain Management in Emerging Economies, EAI/Springer Innovations in Communication and Computing. Springer, Cham.

Kumar, A., Anbanandam, R., 2020. Environmentally responsible freight transport service providers' assessment under data-driven information uncertainty. J. Enterp. Inf. Manag. Vol. ahead-of-print No. ahead-of-print.

Kumar, A., Zavadskas, E.K., Mangla, S.K., Agrawal, V., Sharma, K., Gupta, D., 2019. When risks need attention: adoption of green supply chain initiatives in the pharmaceutical industry. Int. J. Prod. Res. 57 (11), 3554–3576.

Lambrechts, W., Son-Turan, S., Reis, L., Semeijn, J., 2019. Lean, green and clean? Sustainability reporting in the logistics sector. Logistics 3 (3).

Lockman, L.M., 1994. Outsourcing logistics. Glob. Trade Transport. 114 (2), 45.

Lorenzo, Oswaldo, Claes, Björn, Oksana, Koryak, Angel, Diaz, 2017. Integration through orchestration: the interplay between enterprise systems & inventory management capabilities. J. Enterp. Inf. Manag. 30 (4), 555–583.

Marufuzzaman, M., Ekşioğlu, S.D., Hernandez, R., 2014. Environmentally friendly supply chain planning and design for biodiesel production via wastewater sludge. Transp. Sci. 48 (4), 555–574.

Meireles, M., Enzo, P., Frazzon, M., 2020. A data-driven approach to adaptive synchronization of demand and supply in omni-channel retail supply chains. Int. J. Inf. Manag. 102165 Available online 15 June 2020.

Mota, B., Gomes, M.I., Carvalho, A., Barbosa-Povoa, A.P., 2015. Towards supply chain sustainability: economicenvironmental and social design and planning. J. Clean. Prod. 105, 14–27.

Nandi, M., Kumar, A., 2016. Centralization and the success of ERP implementation. J. Enterp. Inf. Manag. 29 (5), 728–750.

Narimissa, O., Kangarani-Farahani, A., Molla-Alizadeh-Zavardehi, S., 2020. Evaluation of sustainable supply chain management performance: dimensions and aspects. Sustain. Dev. 28 (1), 1–12.

Oracle, 2010. Chain Reaction – The Fragmented Supply Chain. Available from Internet:. https://www.themanufacturer.com/mdc2011/pdf/ChainReaction-The-Fragmented-Supply-Chain.pdf.

Oxford Dictionaries, 2019. Definition of Sustainability in English. Available from Internet:. https://en.oxforddictionaries.com/definition/sustainability.

Pharma Industry Finland, 2018. Many Channels of Medicine Distribution. Available from Internet:. https://www.pif.fi/en/medicine/medicine-distribution.

Reichhart, A., Holweg, M., 2007. Lean distribution: concepts, contributions, conflicts. Int. J. Prod. Res. 45 (16), 3699–3722.

Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., Chen, Z., 2020. A systematic literature review of green and sustainable logistics: bibliometric analysis, research trend and knowledge taxonomy. Int. J. Environ. Res. Public Health 17 (261).

Salam, A., Panahifar, F., Byrne, P., 2016. Retail supply chain service levels: the role of inventory storage. J. Enterp. Inf. Manag. 29 (6), 887–902.

Samson, R.M., 2010. Supply–chain management. Nova Science Publishers ISBN 1-61668-284-1.

Sanders, N.R., 2014. Big Data Driven Supply Chain Management: A Framework for Implementing Analytics and Turning Information into Intelligence. Pearson Financial Times.

Scaburi A., Ferreira J.C. and Steiner M.T.A. (2020), “Sustainable logistics: a case study of vehicle routing with environmental considerations”, In: Leal Filho W., Borges de Brito P., Frankenberger F. (eds) International Business, Trade and Institutional Sustainability, World Sustainability Series. Springer, Cham.

Sharma, S., Modgil, S., 2019. TQM, SCM and operational performance: an empirical study of Indian pharmaceutical industry. Bus. Process. Manag. J. 26 (1), 331–370.

Singla, A., Ahuja, I.S., Sethi, A.S., 2018. An examination of effectiveness of technology push strategies for achieving sustainable development in manufacturing industries. J. Sci. Technol. Policy Manag. 10 (1), 73–101.

Teker, S.C., 2017. The implementation of analytic hierarchy process in pharmaceutical industry for selection process of 3rd party logistics service provider. Öneri 12 (48), 107–124.

Tseng, M.-L., Wu, K.-J., Lim, M.K., Wong, W.-P., 2019. Data-driven sustainable supply chain management performance: A hierarchical structure assessment under uncertainties. J. Clean. Prod. 227, 760–771.

Unwin, D.T., Tate, N., Unwin, D.J., 2012. Teaching Geographic Information Science and Technology in Higher Education. John Wiley & Sons, Chicester, p. 478.

Vishwakarma, V., Chandra, P.C., Barua, M.K., 2016. A fuzzy-based multi criteria decision making approach for supply chain risk assessment in Indian pharmaceutical industry. Int. J. Logist. Syst. Manag. 25 (2), 245–265.

Vishwakarma, V., Garg, C.P., Barua, M.K., 2019. Modelling the barriers of Indian pharmaceutical supply chain using fuzzy AHP. Int. J. Oper. Res. 34 (2), 240–268.

Waller, M., Fawcett, S., 2013. Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management. J. Bus. Logist. 34, 77–84.

Weimer, C.W., Miller, J.O., Hill, R.R., 2016. Agent-based modeling: An introduction and primer. 2016 Winter Simulation Conference (WSC), 11–14 Dec. 2016, Washington, DC, USA.

Weraikat, D., Zanjani, M.K., Lehoux, N., 2016. Coordinating a green reverse supply chain in pharmaceutical sector by negotiation. Comput. Ind. Eng. 93, 67–77.

Williams, C., 2007. Research methods. J. Bus. Econ. Res. 5 (3), 65–72.

Wu, P.-J., Chen, M.-C., Tsau, C.-K., 2017b. The data-driven analytics for investigating cargo loss in logistics systems. Int. J. Phys. Distrib. Logist. Manag. 47 (1), 68–83.

Yu, W., Chavez, R., Jacobs, M.A., Feng, M., 2018. Data-driven supply chain capabilities and performance: a resource-based view. Transport. Res. Part E: Logist. Transport. Rev. 114, 371–385.