A FRAMEWORK FOR RISK ASSESSMENT OF

LAST MILE DELIVERY

by

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Declaration of Authorship

I declare that this thesis is my own work and, to the best of my knowledge and belief, it does not contain material published or written by a third party, except where permission has been obtained and/or appropriately cited through full and accurate referencing.

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Dedication

To Shahem and Hannah…

Abstract

The remarkable explosion of e-commerce has marked the latest years of different industries around the world and put forward a higher requirement for the last mile delivery. The last mile delivery is one of the most complex, costly, and inefficient processes along the entire logistics fulfillment chain in an e-commerce context. Its corresponding risks are major contributors to delivery failure. This study proposes a comprehensive framework on risk identification and analysis in the last mile delivery to support the delivery planning. Risks will be deduced from available literature and others will be induced through semi-structured interviews with experts in the field. This study adopts Bayesian Belief Network (BBN) to identify the interdependency among risks and rank them, as the conventional ranking methods fail to take interdependency into account. The results of this study indicate that privacy concerns risk, IT risks, and natural disasters risk were ranked the top three with risk exposures of 0.1055, 0.1009, and 0.1002, respectively. This study will aid logistics service providers to ultimately decide the solutions of last mile delivery that need to be utilized by prioritizing last mile delivery possible risks to increase their competitiveness, increase their market share, and minimize delivery costs.

Keywords: E-commerce; *Last mile delivery; Risk; Risk assessment; Risk management; Bayesian Belief Network*.

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Chapter 1. Introduction

1.1 Overview

Final delivery, with a "last mile" metaphor, relates to the final movement of products from the last upstream distribution center, consolidation point, or local warehouse to the final location (e.g., doorsteps of recipients or designated pick-up address). Last mile delivery has been regarded as one of the most complex and inefficient processes through the supply chain [1]. It is rooted in the e-commerce logistics particularity [2], for example, the frequent and larger number of small parcels or packages, the large dispersion of recipients, the time limit for delivery, and the high potential for failure of delivery. Home delivery inefficiency leads to high last-mile delivery costs.

In response, e-retailers and logistics service suppliers' actors continually seek new delivery service solutions, often driven by technology advancements. Industrial reports show that organizations worldwide are testing new trends such as drones, parcel lockers, crowd-sourced deliveries, and autonomous vehicle deliveries, along with fulfillment models [3]. Since many e-retail giants believe that last-mile delivery capabilities are their core assets to gain competitive advantages, last-mile fulfillment is what the ongoing e-commerce battles are fighting for [4].

For competing and leading these battles, the service provider must have a clear knowledge of the risks that last mile delivery faces. Every business faces different types of risk, according to the corresponding sector(s) of the enterprise. Regarding that, each enterprise should focus on risk assessment for identifying the specific risks it faces and takes action according to a proper risk response strategy [5]. Stephenson [6] describes risk management in terms of two dependent variables: risk identification and risk analysis. In risk identification, all potential risks should be determined within the organization's boundaries, whereas in risk analysis, probable impact, cause, and control over those risks should be determined.

Therefore, this research aims to develop a framework to assess and rank risks in last mile delivery from a logistics provider point of view and it tries to answer the following sub-questions:

- What is last mile delivery?
- What are the available solutions of last mile delivery?
- What are the corresponding risks of last mile delivery?
- What is the probability of occurrence and impact for each identified risk?
- Are there any interdependencies among the risks?
- What is the ranking of the risks considering the interdependency?

1.2 E-commerce

The commerce and technology relationship has existed for a long time and still continues. In recent decades, various advancements and innovations in Information and Communication Technology (ICT) have led to numerous developments in many areas, including global commerce. Consequently, processes in many areas, such as commerce, economy, banking, and customs have evolved and changed [7]. Traditional commerce will no longer be able to meet modern demands as time goes by [8].

The internet has become an integral part of people's lives [9]. People around the world believe that the internet plays a major role in our lives and has led to the creation of job opportunities and improvements in business and commerce. Novel electronic technologies have resulted extensively in business patterns creating opportunities [10]. Information Technology (IT) is considered one of the greatest developments owing to its impressive and fruitful impacts on the economy, science, and culture. IT is known as one of the greatest inventions. The use of IT in business and economical operations has led to the creation of a modern interdisciplinary approach, known as e-commerce, that plays an important role in global economic relations [11]. E-commerce has many definitions; all are valid but differ according to the lens used to view it. Kalakota and Whinston [12] defined e-commerce as follow:

- E-commerce is the distribution of information, products/services, or payments through telephone lines, computer networks, or any other means, from a communication perspective.
- E-commerce, from the viewpoint of business processes, is the use of technology to automate business transactions and workflows.
- E-commerce is a tool from a service perspective that addresses the need of businesses, customers, and management to reduce service costs while enhancing the quality of goods and increasing the speed of delivery of services.

- From an online perspective, the ability to buy and sell products and information on the internet and other online services is provided by e-commerce.

In this research, the definition of e-commerce from an online perspective will be adopted.

E-commerce makes it much easier to access the global market for different types of goods and services with open contact between producers, suppliers, and consumers [13]. The organization can get benefits from e-commerce such as cost reduction, expanded potential market, and new business opportunities [14]. Almost any possible economic relationship such as B2B (business to business), B2C (business to customer), C2C (customer to customer), B2A (business to administration), and C2A (customer to administration) can be taken up through e-commerce [15]. In this study, the focus will be on B2C (business to customer) where products and services are directly sold to consumers via the internet by eliminating intermediaries; businesses can charge lower prices and achieve higher profits [16].

The main challenge for companies is how to bring this service to the customer. E-commerce comes with a range of advantages from the customer's point of view, such as a greater choice of service, the ability to obtain products not sold locally, better price control and convenience. Consumers ordering products online means delivering this item to them at home. However, the delivery solution is very demanding from the business point of view and requires complex planning. Businesses usually outsource the delivery aspect to third-party logistics companies (3PL) due to the complex planning and challenging nature of last-mile delivery.

1.3 Third-Party Logistics (3PL)

Many researchers have defined 3PL in different ways; there is no single or standard definition of 3PL [17]. Stank and Maltz [18] refer to 3PL as any company that provides a service not owned by it. Berglund et al. [19] described 3PL as a logistics service provider responsible for managing, transporting and warehousing goods on behalf of a shipper. Another definition is that 3PL is an external organization performing all or part of the logistics role of a supplier or consumer [20]. Per Bagchi and Virum [21], 3PL is said to be a shipper's long-term partner, which provides the shipper with a range of logistics activities. In this study, the definition by Hertz and

Alfredsson [22] will be adopted, which defines 3PL as an external provider managing, overseeing and distributing logistics services to customers on behalf of a business or supplier.

Due to the complex, dynamic and challenging nature of after-sales services, namely logistics, e-commerce companies outsource these services to 3PL companies, which are now playing a crucial role in many supply chains. With the growing trend of outsourcing, many organizations have outsourced their logistics activities to 3PL providers to focus on their core competencies, which reduces operating costs and improves service level [23]. By outsourcing e-commerce, businesses may focus on their primary mission: to sell products and gain a competitive advantage. Wilding and Juriado [24] argue that the main reasons for outsourcing logistics services to logistics companies are categorized into five sections, namely costs or revenue related, service-related, operational flexibility, business-related emphasis, and asset utilization or efficiency related.

Related costs and revenues are the main reason why e-commerce firms outsource [24]. Logistics activities require heavy investment in the support and hardware of information technology that third-party logistics companies can provide. Therefore, e-commerce companies may avoid heavy investment and operating costs in IT and hardware by outsourcing. Lacity and Hirscheim [25] conclude that it is possible to achieve a 10-20% reduction in cost by outsourcing.

1.4 Last Mile Delivery

The term Last Mile is used in the supply chain to describe the movement of goods from fulfillment centers or transport hubs to their final destinations. In other words, the last mile is the last leg of the product's trip before it reaches the consumers' doorstep , and it is considered as the moment that matters [26]. This last leg is often the supply chain's least effective link, accounting for up to 75% of the total cost of delivery [1]. The last mile is described as the final stage in the online retail distribution process and is one of the most challenging aspects of the supply chain [27]. That is, last mile delivery, is the only stage that has direct contact with the customers. The party delivering the goods is the representative not only of the organization for which they work for, but of all the organizations that have contributed along the supply chain, and this involves a professional and customer service-oriented delivery strategy. Consoli

[28] found that the customer's main drivers for e-commerce are: time savings, economic benefits, and various choices. These include the ability to obtain goods that are not sold locally, better comparison of prices and convenience.

Researchers have been trying for years to solve the last mile delivery's economic, social, and environmental pressures. Apart from economic and legal restrictions, the biggest problem today is "unattended home delivery," where the recipient is often not at home on the day of delivery [29]. For home deliveries, due to the "not - at-home" issue, the high degree of failed deliveries implies additional costs and extra kilometers and carbon emissions [1]. This is because the package may have to be delivered several times before delivering it successfully. Figure 1 shows the delivery process.

Figure 1: Last mile delivery operation [31].

A retail warehouse or an e-shop distribution center is the initial starting point for the last mile delivery. There are several ways by which goods reach the final customer. Either own vehicles or 3PL service providers are used from the e-shop distribution center. Goods are normally transported to a regional distribution center prior to the final delivery leg. Deliveries can also be made from either own vehicles or 3PL through a retail outlet store from a retail distribution center. If the delivery is to a locker bank or collection, the customer must travel to that place to collect the parcel.

The last-mile delivery poses a paradox between speed and cost; customers expect fast delivery on the same day or on-demand but remain highly sensitive to price and generally prefer the cheapest delivery options available. Above all, there are many other situations that raise last mile delivery problems like incorrect customer addresses, crowded customer locations, driver shortages, and some adverse economic conditions like rising fuel prices. The main factors that can adversely affect the efficiency of the last mile delivery are the following:

1.4.1. Absence of parcel recipient. This issue, referred to as unattended delivery, is of increasing concern to e-commerce stakeholders and is regarded to more than 20% of the first-time home delivery failure [30]. Failure to deliver orders to their intended recipients during the first distribution attempt causes consumers annoyance, increases the costs of delivering services, and results in high carbon emissions. Additional costs are incurred for logistics operators by returning items to distribution centers or transport hubs and rearranging these failed deliveries. For consumers, on the other hand, failed deliveries would reduce the ease and time savings of online shopping as customers may need to handle the last mile delivery and collect their returned orders from certain places or alternative addresses. In addition, a failure rate of 10% increases CO_2 emissions by 15% and with a failure rate of 50%, the percentage of emissions increase will reach 75% [31]. Parcel recipients are critical factors for home delivery performance, and failures in delivery can be negatively reflected in both companies and providers of delivery services.

1.4.2. Delivery windows. Organizations may need to offer their customers time frames options in which the customer will be available to receive the parcels in order to avoid the "not at home" problem. Increased delivery requests lower last mile delivery efficiency as customers prefer shorter delivery windows while companies prefer longer windows to better manage delivery routes. Customers tend to favor narrow time slots as wide ones keep them attached to their homes for hours waiting for their orders. On the other hand, the addition of delivery time restrictions imposes a high cost on delivery service providers, as delivery costs with time windows are significantly higher than those without time windows [31]. For example, a 3-hour delivery window is 30%–45% more costly than a typical 9-hour delivery window [32]. The paradox, in the end, is that tighter windows are more convenient for customers but more expensive for logistics operators. In order to achieve a balance, many companies offer specific delivery times but at an additional charge over the basic delivery service to minimize the increased cost of restricting delivery times through shorter windows [32].

1.4.3. Customers density. Customer density, which is the number of customers in a specific area, is also considered one of the main operational and logistical challenges when directly delivering orders to customers [32]. The distribution of a few orders to low-density areas where deliveries can contain only one package significantly exacerbates last mile delivery costs, especially the rising transport costs. There is a strong relationship between the density and efficiency of delivery routes for customers [32]. Deliveries in central urban areas lead to high efficiencies in the number of deliveries per mile traveled. On the other hand, suburban areas and rural settings reduce the efficiency of routes as they usually result in an increased distance per package, i.e., very few deliveries per mile traveled. The issue of suburban and rural density provides fewer opportunities for logistics companies to optimize their delivery routes leading to greater inefficiencies in routes. Companies can increase market density by limiting deliveries to certain days of the week, but this gives less choices to consumers and increases their inconvenience.

1.4.4. Environmental challenges. The steady increase in freight delivery vehicles leads to many environmental issues such as traffic congestion, noise nuisance, harmful emissions and public space problems. Freight vehicles account for around 15% of overall urban traffic and have a more significant impact than passenger vehicles because of their size and frequent stops [33]. Emissions from diesel-powered freight vehicles are harmful to the climate and public health, and therefore providers of delivery services should comply with emission standards. Therefore, e-retailers and logistics providers should not only focus on reducing last mile delivery costs but also lowering their freight vehicles ' carbon footprint. Providers should minimize the total number of their trucks in order to minimize these emissions and maximize the use of existing trucks. In addition, they can shift to greener delivery types, e.g., bikes, however, at the expense of delivery speed. The growing demands for environmentally friendly transport forces last-mile logistics providers to move into green logistics deals and think ecologically about the impact of last mile delivery.

The above-mentioned challenges and others dictate that companies should diligently manage the last mile of their deliveries to meet the expectations of customers in terms of delivery times and overall delivery experience and to operate at the lowest possible cost, online retailers and businesses should invest in new technological solutions. Companies have been tweaking around a lot of tactics and approaches for managing the last mile. Some approaches have been introduced, such as consolidation centers, pick-up points, delivery boxes, alternative addresses, near shops, and self-service parcel stations. Even though these solutions ensure that 100% of the parcels are delivered, customers are responsible for the final leg of the journey. As the value of the last mile delivery grows, some new innovative approaches are being introduced by e-commerce companies, including Walmart, Amazon, and Google. Amazon is testing delivery drones that carry parcels to consumers wherever they are at the moment of delivery and therefore think beyond home delivery [34]. With these drones, and with the option "Bring it to me" from the customer's mobile device, after placing the order, the customer does not have to stay in one location. While the idea for delivery drones' solution is promising, there are still strict operating rules and a way to go before regulators open the sky for commercial use. Amazon, Walmart and Google are currently piloting delivery projects on the same day in selected locations [34]. Despite the pressures and costs of accelerated transport, Amazon, Walmart, and Google are considering same-day delivery; intrigued by the newly emerging crowdsourcing concept.

1.5 Risk Management (RM)

Risk Management (RM) can be generally defined as a systematic process that a company follows in order to reduce the likelihood of unexpected events occurring in order to maximize profit. The most popular definition of RM is published by Association for Project Management (APM): "A process whereby decisions are made to accept known or assessed risks and/or the implementation of actions to reduce the consequences or probability of occurrence" [35]. Stranks [36] describes RM in terms of identification, evaluation and control of exposure to each risk that hinders project success. He formulated four basic principles of RM: (1) minimization of negative impacts of risk in a business; (2) recognition, evaluation and economic control of risks that hinder business success and profit; (3) determination of the most relevant way to tackle major and minor risks to a company's profit; and (4) a procedure for adapting to the impacts of progress. According to Chong [37], risk is a fundamental aspect of RM, the main aim of which is to minimize or maintain risk at a level that is acceptable for an enterprise. RM may be compared to drawing a map of hazards and the probable harm they may cause; the map can then be used to solve the challenges caused by risks, according to their sources [37].

RM is now being widely used in almost all projects and it is becoming a must-have tool nowadays. In order to handle the complex and increased uncertainty of projects, there are several steps to be followed in the context of RM. Project Management Institute (PMI) [35] divided RM steps into RM planning, risk identification, risk qualitative analysis, risk quantitative analysis, risk response development and risk monitoring and control. Various methods and tools are used throughout these steps, including brainstorming, Delphi technique, interviewing, root cause analysis, SWOT analysis probability and impact matrix, risk breakdown structure (RBS), Multi-Criteria Decision Making (MCDM), probability distributions, sensitivity analysis, expected monetary value analysis, modeling and simulation techniques. One weakness of the most common methods for analysis is that they assume independence of risks and ignore any interdependency among the risks. Therefore this study utilizes the Bayesian Belief Network in order to capture and analyze the interdependency among risks as well as the risk network effect.

1.6 Research Problem

The last mile delivery is regarded as the most expensive section of goods distribution, where it accounts for 13-75% of the total supply cost. It is considered the least efficient and most polluting section of the entire logistics chain. Although there are different solutions and researches that have been proposed to enhance the performance and solve challenges of last mile distribution, it is still considered as the bottleneck of e-commerce [38]. It is imperative to develop new and innovative delivery methods to reduce the cost, make the last mile more effective and efficient to realize greater customer value. All proposed solutions have corresponding risks that need to be counted for and considered. This can only be achieved by assessing these risks to ensure the best utilization of last mile solutions. To the best of our knowledge, there is no current literature that investigates risks nor study risk assessment in last mile delivery. This study proposes a comprehensive framework on risk identification and analysis in last mile delivery from logistics providers point of view, considering any possible interdependency among the risks.

1.7 Research Objectives

In this study, a framework that assesses risks in the last mile delivery will be developed. It will identify, categorize, and rank risks that impact last mile delivery efficiency.

The research will achieve the following main objectives:

- Facilitate the ultimate investigation of solutions and challenges of last mile delivery.
- Extract and identify all possible risks in the different last mile delivery solutions.
- Categorize the risks of the proposed framework and determine the relative probability and severity of each risk.
- Identify risks interdependency and prioritize risks.

1.8 Research Significance

The contribution of this research extends to both academia and logistics companies by investigating and analyzing all risks that impact the last mile delivery efficiency. A last mile delivery risk assessment framework will be developed. Moreover, this study will help logistics service providers to ultimately decide the solutions of last mile delivery that need to be utilized by considering last mile delivery risks to increase their competitiveness, increase their market share, and minimize delivery costs.

1.9 Thesis Organization

The rest of this thesis is organized as follows: Chapter 2 provides literature review discusses last mile delivery different solutions and risk management in supply chain and logistics. Moreover, some of the proposed frameworks and models in the previous literature are reviewed. The Methodology is presented in Chapter 3. Chapter 4 illustrates the final framework and discusses the analysis of the collected data and the results. Finally, Chapter 5 concludes the thesis.

Chapter 2. Literature Review

This chapter aims to investigate last mile delivery corresponding risks by reviewing related literature. In the first part of this research, an in-depth review of the literature concerning last mile delivery solutions and challenges is presented in order to deduce last mile delivery risks. Then, after deducing risks, risk management and supply chain risk assessment related work is discussed..

2.1 Last Mile Delivery Solutions

Logistics companies have designed different last mile delivery solutions to address the problem of failed deliveries and the rising costs associated with it. The unattended delivery solutions at the customer's home include the reception box, delivery box, and controlled access system, while away from the customer's home include collection points and locker banks [39].

2.1.1. Reception box. The reception box is permanently fixed to a wall outside the customer's home. Delivery person has access to that box by using a key or a code [39]. The reception box is useful for the delivery of nonperishable small parcel and post. However, the reception box can be vulnerable to theft or other damages such as rain or storm. Hence, the reception box may not be useful to deliver a highly valuable and important parcel or goods. In addition, if the customer requires to return goods/parcels, he/she has to drop the parcel at nearby collection points.

Pros and Cons

The reception box presents the advantages of fewer failed deliveries, lower vehicle operating cost, and more control over planning, routing, and scheduling of delivery rounds [39]. With the use of the reception box, third party logistics providers will not have to redeliver the products two or three times before it is successfully delivered due to the consumer not being at home. This has the potential to reduce the cost associated with attended home deliveries, hence leading to efficiency and less carbon emission. For customers, it is convenient to have their parcels delivered straight to a reception box in their home. The reception box lowers the delivery time used and reduces the expense of redelivery when customers do not attend the delivery time window [40]. Although reception box solutions enable the benefit of unattended reception, its main disadvantage is the cost associated with installing these boxes in customers' home. Up-front investments and installation cost needed for reception box solution are high and it may lead to huge losses if the customer does not use the services [41]. The reception box is not widely used and the main reason for this is the high cost, which is estimated to be between 1,000 and 2,300 euros [41]. Investing in reception boxes will have a negative effect on the finances of third party logistics providers due to the huge cost associated with each installment. However, if e-commerce business or customers are willing to finance their reception box, the burden of the financing boxes by 3PL will be eliminated.

2.1.2. Delivery boxes. A delivery box's functionality is almost similar to a reception box. Delivery boxes are usually owned by the retailer or delivery company. Delivery person transports the delivery boxes, filled with goods and places at a customer's home. Customers are given a key or a password to open the box. Later on, empty boxes/boxes containing returned items are retrieved in separate collection rounds by the delivery person. [39].

Pros and cons

The benefits of using a delivery box include fewer failed deliveries, lower vehicle operating costs, and more control over planning, routing, and scheduling of delivery rounds [39]. 3PL will not have to redeliver parcels when using a delivery box solution due to the problem of the customer not been at home. Delivery box solution shortens delivery time and eliminates redelivery costs [40]. The main advantage of using the delivery box is, it can be used for more than one customer (flexibility) as compared to the reception box, because of its mobility. The major burden on 3PL providers has to do with the cost involved in investing in these boxes. The investment required in a delivery box solution, however, is much lower than using customer-specific reception boxes and the boxes can be used to serve other customers if the customer does not start using the service, since only a new locking system will have to be installed for the customer [41].It will be prudent for 3PL providers to invest in delivery box solution due to its cost effectiveness as compared to the reception box solution. The payback period for the delivery box solution would be much shorter compared to the reception box solution. From the 3PL service provider viewpoint, the delivery box solution makes a faster acquisition of new customers and a higher growth rate possible. From the customer viewpoint, the reception box solution is preferable, offering total independence of the delivery time windows and logistics service provider [41].

2.1.3. Controlled home access. A controlled home access system provides the delivery person with a means such as a security code or keys to access a locked area to drop goods usually the garage, shed or other outhouse areas [39]. In a unit that is placed in a position where delivery personnel can reach, a key can be sealed; the driver inserts an access code into the sealed unit to release the key and open the specified delivery location to leave the goods [39]. A telephone-connected electronic keypad is used by the home access system to control the door's opening and closing. The keyboards interact with a central server that allows the company to change the pin codes after each shipment. The keypad automatically generates another code number which is used to confirm that the delivery has been made when the driver closes the door. A confirmation message would be sent to the customer's phone or email address when delivery is done [42].

Pros and Cons

A controlled home access system offers the same benefit as both reception and delivery box solutions in terms of shortening delivery and eliminating redelivery cost, leading to greater efficiency on the part of 3PL service providers. The home access system could reduce the average drop times from 10 minutes to 4 minutes and achieve an 84 percent higher productivity level than the home delivery attendance [42]. The main security concern with his system is, it could serve as a route into the home for burglars and goods delivered by one company could be stolen by a later delivery driver [42]. For instance, delivering parcels and being stolen by someone means the 3PL service provider will have to reimburse the customer which will come at a cost to the 3PL.

2.1.4. Collection points. Collection points are based on the use of locations other than customers' homes to which goods are delivered for pick up by customers. These goods can be delivered to the nearest Post Office, convenience store, supermarkets or a petrol station with long opening hours which can be close to the customers' residence. In this case, customers can choose where they want to pick up their parcels, e.g., if they want to pick up their parcels closer to work instead of home. If no choice is made by the customer, the carrier will choose the nearest location. Goods are delivered to the collection point by the retailer or its carrier and the customer is informed that their order is ready for collection. With regards to the collection point, a notification will be sent to the customer by either email, text, or letter that their parcel is in at the nearest pick up point or location. Collection points lead to fewer delivery locations and increased drop density [39]. For example, Kiala company provides a collection point service for e-commerce companies for non-food products in Europe, including countries like Belgium, France, the Netherlands and Luxembourg. The company has established a network of collection points (Kiala point) of about 4660 in Europe which customers can collect, pay for and return their parcel of [1].

Pros and cons

The benefit of using a collection point lead to a fewer delivery locations and better drop density [39]. That is a bulk of products can be dropped at one location to serve customers around that locality. As compared to reception box, delivery box and home access collection point leads to greater efficiency because 3PL service providers will not move from house to house to deliver products but would deliver customers' orders to a convenience store, hence cutting down transportation cost drastically. According to Ding [43], size and weight of parcels at collection point are not strict or not limited as compared to locker banks. Mcleod et al. [44] found that customer mileage could be reduced by 80% using a collection point for failed deliveries. Pick up can be done any time by the customer after delivery. This can result in a huge reduction in transportation costs and eliminate redelivery costs for 3PL service providers. Wang et al. [45] found that operation efficiency would improve drastically because the collection point could serve as several delivery points. The collection point is beneficial to the operating parties because when collecting their parcels, about 25 percent of collection point users will buy something [46]. However, on the part of consumers, going to a collection point to retrieve their parcels reduces the convenience of online shopping. That is, with the use of the collection point solution, the main benefit of online shopping (convenience) could be defeated. However, it was found that the inconvenience related to the collection point is reduced or solved if the collection is made in the course of a trip the consumer is already making [42],[46]. For instance, if a customer is going to the petrol station to buy fuel, the customer can collect their parcel thereby reducing or eliminating the problem of inconvenience.

2.1.5. Locker-banks. They are similar to collection points, are collections of reception box units. They are not sited at each customer's premises but can be sited in apartment blocks, workplaces, car parks, railway stations, convenience stores, shopping mall, etc. Customers are not typically given their own locker to optimize its use (lockers have electronic locks with a variable opening code and can be used for different customers on different days). They may be used by or used by many by one distribution company. When a client order arrives, he or she is informed of the box number and location and the code to open the box by a call. Locker-banks need the client to make the final leg of the journey. However, locker-banks are normally located in precise areas to make the deviation in customers' journeys as short as possible. Pack station by Inpost and DHL is an example of this type of solutions [39]. For example, Deutsche Post (DHL) in Germany provide PackStation as a system of locker bank solution. The system offers customers the opportunity of access to their parcels 7 days a week, 24 hours per day and can also be used for parcel returns. Registered customers are issued with a PIN, an internet password and a city plan showing all the PackStation locations. Parcels are normally held for nine calendar days.

In 2001 DHL introduced the PackStation in two cities in Germany, namely Berlin and Dortmund. By the end of 2005, they had introduced 600 machines in more than 90 cities, used by over 300,000 of its registered customers. They had plans of national coverage by the end of 2007 [39].

Pros and Cons

With the use of locker banks solution, it is possible for 3PL service providers to drop off many orders at one stop, thereby reducing transportation cost and delivery time per customer. Locker banks have the potential of eliminating unsuccessful deliveries and reducing delivery costs, city congestion, and greenhouse gas emissions [47]. Locker banks favor the reduction of traffic and improve the use of cargo compartment by consolidating deliveries and making them more independent from the available time slots [45]. Locker banks offer flexibility because the lockers can be used for different customers. Lockers have automatic locks and can be used on multiple days by different clients [39]. Nonetheless, implementation and efficient utilization of locker banks requires the support of local residents, logistics providers and the support of local authorities with regard to permission and selection of sites [47]. Also, from the consumers' point of view travelling to retrieve parcels defeats the main purpose of shopping online (convenience). But, the inconvenience related to locker banks is reduced or solved if the collection is made in the course of a trip the consumer is already making as in the case of collection points.

2.1.6. New forms of delivery: crowdsourcing approach. At this point in time, city logistics are primarily conducted with trucks and vans. In technologically advanced and developed countries, they are gradually being replaced with alternative technologically more advanced solutions, such as; electric vehicles, air drones, Cargo pipelines and tubes, 3D printers, and crowdsourcing [48]. However, in other less developed regions, most of these promising solutions still have strict operating rules and a way to go before regulators open the sky for commercial use by drones, or build an infrastructure from scratch to meet the cargo pipelines and tubes needs, as well as the high expenses of these technologies like 3D printers and requiring a license to print specific products [49]. On the other hand, crowdsourcing is the most applicable and feasible advanced solutions, it can be applied at this time and this level of advancement in the region.

Crowd logistics is a delivery approach where private individuals serve as carriers in return for payment by using their own means of transportation, e.g., car, bike or public transport. There is no need for additional transport resources and it is an environmentally friendly option [48]. Since delivery is achieved on scheduled routes with minor detours, a trip dedicated exclusively to a particular delivery is not carried out. Negative sides illustrate the fact that a large user network has to be established in order to make a crowd logistics solution profitable, which typically takes a long time. It is also difficult to guarantee the quality of service when private unknown persons and non-professionals serve as drivers [48].

It is a solution to meet rising consumer expectations in terms of speed, individualization and more cost-effective delivery services. In their research Buldeo Rai et al. [50] defined crowd logistics as "an information connectivity enabled marketplace concept that matches supply and demand for logistics services with an undefined and external crowd that has the free capacity with regards to time and/or space, participates on a voluntary basis and is compensated accordingly". In other words, an online platform plays a role as a marketplace where the sender posts a request for transportation to a receiver. Transportation request involves delivery details, such as weight and size of an item, delivery time, and location of delivery. The crowdsource or private individual willing to make a delivery is matched by the platform with a delivery request and in return receives certain compensation for the provided service.

Crowd delivery is a more environment-friendly option comparing with traditional delivery and has lower operating costs than conventional delivery. In their study, Wang et al. [45] point out this reduction in operating costs, CO2 emissions and traffic congestion which are results of a high level of parallelism and coordination in crowd delivery systems. A number of deliveries are therefore performed concurrently due to a large number of individual carriers carrying out deliveries with their own existing resources. Usually, a carrier is given one or a few tasks. Consequently, a possible delay in one plan has a slight effect on a successor. However, each carrier is linked via the platform to the relevant customer and can communicate and make adjustments, e.g., to alternate a delivery location or postpone it. Larger volumes of orders are assigned to a carrier in the traditional delivery and they need to be delivered successively. A potential delay during a route thus affects all the following tasks and can even lead to a failure of delivery due to lack of time.

2.2 Risk Management in Last Mile Delivery

Hillson [51] states that risk is mainly related to negative events that occur during a project or a process, whereas the Association for Project Management (APM) [52] and the Project Management Institute (PMI) [35] describe risk as sometimes having positive and sometimes negative impacts. "Risk can be defined as an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one objective, such as time, cost, scope, or quality" [35]. "Risk is an uncertain event or set of circumstances which, should it occur, will have an effect on the achievement of one or more objectives" [52]. From these two definitions, last mile delivery risks can be defined as an uncertain event that can influence the final leg effectiveness. Thus, in order to ensure that last mile delivery risk induces minimal negative impact, risk management is essential. However, available literature does not cover the possible risks in last mile delivery in specific but it covers risks in supply chain in general, thus this research builds on previous studies in risk management in supply chain and logistics, in order to invistigate the discussed risks and the methodolgies follwed in assessing these risks.

It is advised to follow certain guidelines when considering risk management in organizations and in the supply chains; they form to ensure that the process is thorough and effective. In all types of organizations, the ISO 31000 family of international standards provide a framework for risk management. Figure 2 shows the basic risk management process, as defined in ISO 31010 [53].

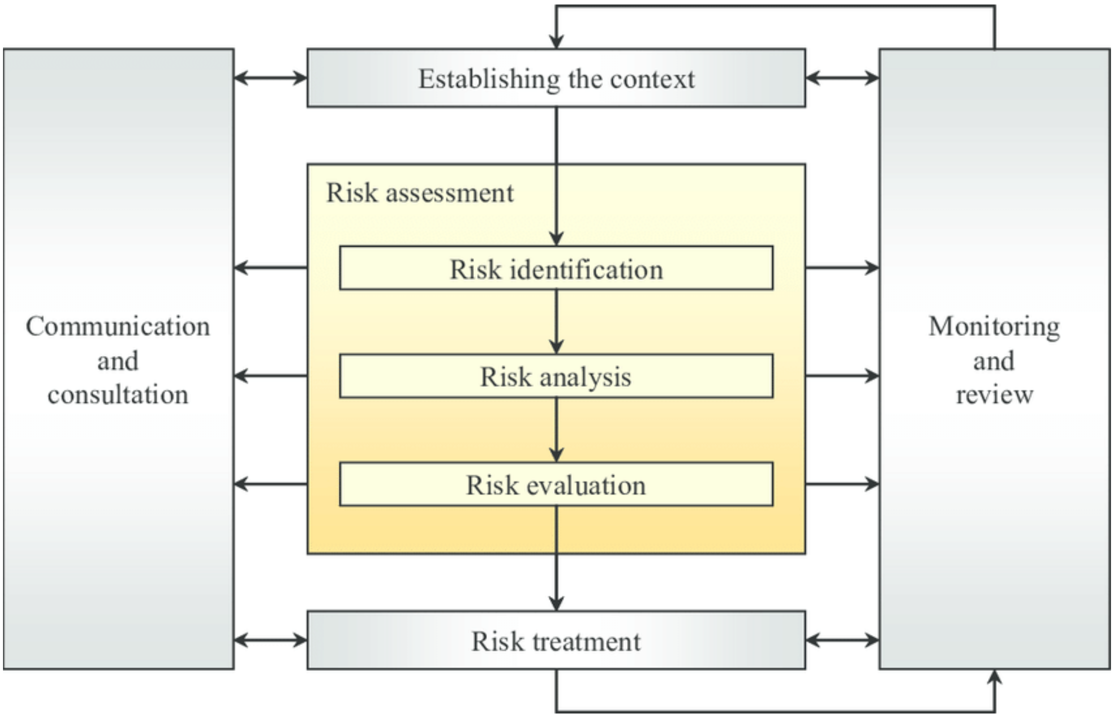

Figure 2: The risk management process as defined in ISO 31010 [53].

It is believed that the risk assessment process, particularly risk identification, is the most important one in the whole process of risk management. It must be noted that the risks that are not recognized and described in the first stages of risk management are not subsequently addressed and therefore go unnoticed and uncontrolled. Because of that, this study aims to construct a framework for risk assessment in last mile delivery. Therefore, in the first stage of this study, last mile delivery risks need to be identified and categorized. The next section 2.3, reviews previous literature on supply chain risks, in order to get an understanding of supply chain possible risks, its categorization, and proposed frameworks.

2.3 Supply Chain and Logistics Risks

In recent years, several incidences showed that global supply chains are exposed to unexpected events and accordant consequences. To derive mitigation strategies, managers require information about the risk their company is subject to.

To assess risks, they must be recognized in the first place. Therefore, the first step in the assessment framework Is risk identification. Risk identification is a fundamental step in the risk assessment framework. In this step, decision makers should identify each possible risk event to be able to assess it in the next step. Supply chain risks can be categorized in several ways. Christopher and Peck [54] suggested that supply chain risks can be grouped into three categories based on the source of risks, i.e., internal to the firm, external to the firm but internal to supply chain network, and external to the network. Chopra and Sodhi [55] divided risks into nine types such as disruption, delays, systems, forecast, intellectual property, procurement, receivables, inventory, and capacity; and then the corresponding drivers of the risks are also listed Kouvelisetal [56]. Risk varies from firm to firm. These classification approaches aim at providing a systematic identification framework and not at providing universal results in any case.

Stephan Wagner [57] divided supply chain risk sources into five distinct classes in their study," An empirical examination of supply chain performance along several dimensions of risks : (1) demand side; (2) supply side; (3) regulatory, legal and bureaucratic; (4) infrastructure; and (5) catastrophic. While the first two risk source categories deal with supply-demand coordination risks that are internal to the supply chain, the latter three focus on risk sources that are not necessarily internal to the chain.

While Ziegenbein and Baumgart [58] considered the top-level processes of the Supply Chain Operations Reference model (SCOR)[60] in their study of supply chain risk assessment. They introduced a quantitative approach for measuring the probability of occurrence and the financial impact of disruptions in the supply chain based on the concepts of fault tree analysis and business interruption value, as they defined risk as the product of the probability of occurrence of an undesirable event and the financial consequences. Ziegenbein and Baumgart have taken both parameters into account for assessing supply chain risk. Some of the listed risks are implied in last mile delivery and will be further investigated in this study, such as; quality problems, time delays, damage/loss of goods, disasters and legal liabilities.

In logistics, Lam et al. [59] have categorized risks faced by the logistics service providers into nine categories which are resource risk (1), managerial risk (2), physical environment risk (3), human risk (4), security risk (5), financial risk (6), market risk (7), regulatory/policy risk (8), and operations risk (9). In each category, the possible sub-risk factors that belong to the risk factors are also identified. The possible risks and their sub-risk factors were identified through the interviews.

After identifying risks, risks can be analyzed, evaluated, and managed. Faizal and Palaniappan [60] have taken up a case study to develop an effective method for managing supply chain risk in a manufacturing industry involving in casting by collecting the sample data and developing a strategy for risk mitigation. Firstly, risks were identified and categorized into four sources: Demand risk, supply risk, operational risk, and environmental risk. The method of assessment follows the Failure Mode Effect Analysis (FMEA) guidelines. It is used to prioritize the risk using Risk Priority Number (RPN), which can be calculated from the probability of occurrence, severity, and detection of risk and also using Risk Score Values (RSV) in which Severity and Occurrence of risk is calculated. High RPN values indicate a higher level of risk.

Tuncel and Alpan [61] criticized that the previous SCRM research because it always focuses on assigning specific values to the risk impact and probability, which is challenging to implement in the real world. Tuncle and Alpan used the OM-AHP method to make relative comparisons among the potential risks with respect to two criteria: probability and consequence severity. They proposed a framework to analyze a risky supply chain network by a failure mode, effects, and criticality analysis (FMECA) technique. Based on judgments from the engineers, historical data and subjective estimates, the severity index and occurrence rate can be obtained to classify the risks in this frame. Based upon the mix of expert judgment and experience, Fang and Marle [62] assess the risk impact and probability on a qualitative scale. In particular, qualitative scales of risk probability are corresponding to nonlinear probability measures. The risk assessment framework is applied using the Orders of Magnitude AHP (OM-AHP) which in the context of this problem provides many advantages over the traditional AHP and other methods. The mathematical justification that was provided as a guideline for organizing the criteria and alternatives into clusters can significantly reduce the decision makers' time and effort in risk assessment models as well as in general AHP models.

From OM-AHP to N-AHP in the supply chain, Abdel-Basset et al. [63] have quantified risks using an integrated neutrosophic analytical hierarchy process (N-AHP) and a neutrosophic technique has been demonstrated for this task. It is intended to match the similarity of order preference to the ideal solution (N-TOPSIS). In their study, neutrosophic principles can effectively and efficiently deal with ambiguous, unclear and incomplete information that has a major impact on risk management.Using triangular neutrosophic numbers in comparison matrices, the evaluation process of supply chain risk is presented. Researchers have used a score function to convert triangular neutrosophic numbers to their corresponding crisp value and have found the relative closeness of each risk in their study to the ideal solution, the values were; C_1 = 0.44, C_2 = 0.62, C_3 = 0.27, C_4 = 0.57, C_5 = 0.46, C_6 = 0.54, C_7 = 0.95, C_8 = 0.26, C_9 = 0.14 plotted in Figure 3, higher value indicates higher risk.

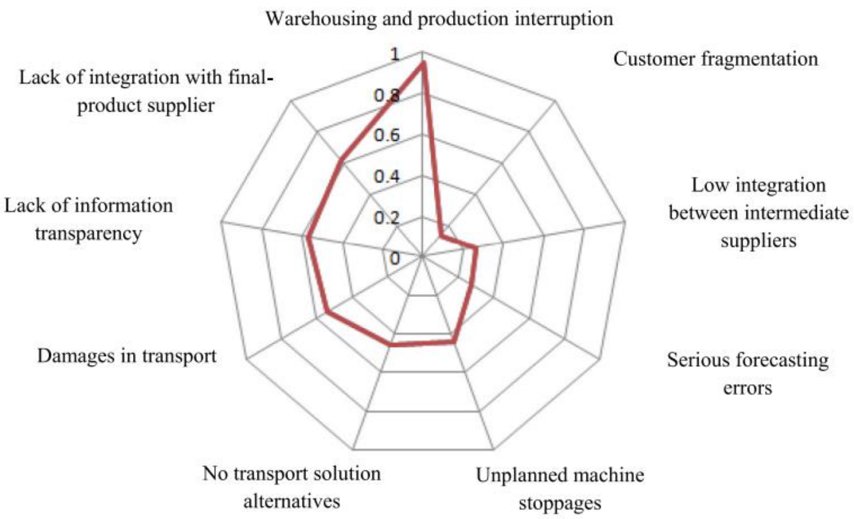

Figure 3: The ranking of risks that affect the achievement of company's goal [63].

So far, the traditional tools and different models used and developed in risk assessment in supply chain management ignore the complex interdependencies between risks and use point estimates for probability and impact values. On the other hand, in the construction industry, a study by Abroon Qazi and Irem Dikmen was conducted on construction projects [65], in which they proposed a novel methodology that is grounded in the theoretical framework of BBNs to prioritize risks, their methodology accounts for interdependent interactions of risks unlike the conventional risk matrix based tools. Qazi and Dikmen demonstrated their methodology through a real application. They successfully proved the importance of utilizing an interdependency- based risk management process, as the results of two ranking schemes, assuming independence and interdependence of risks were correlated negatively [65]. Therefore, for the purpose of this study, this research methodology will be based on the study conducted by Abroon and Irem.

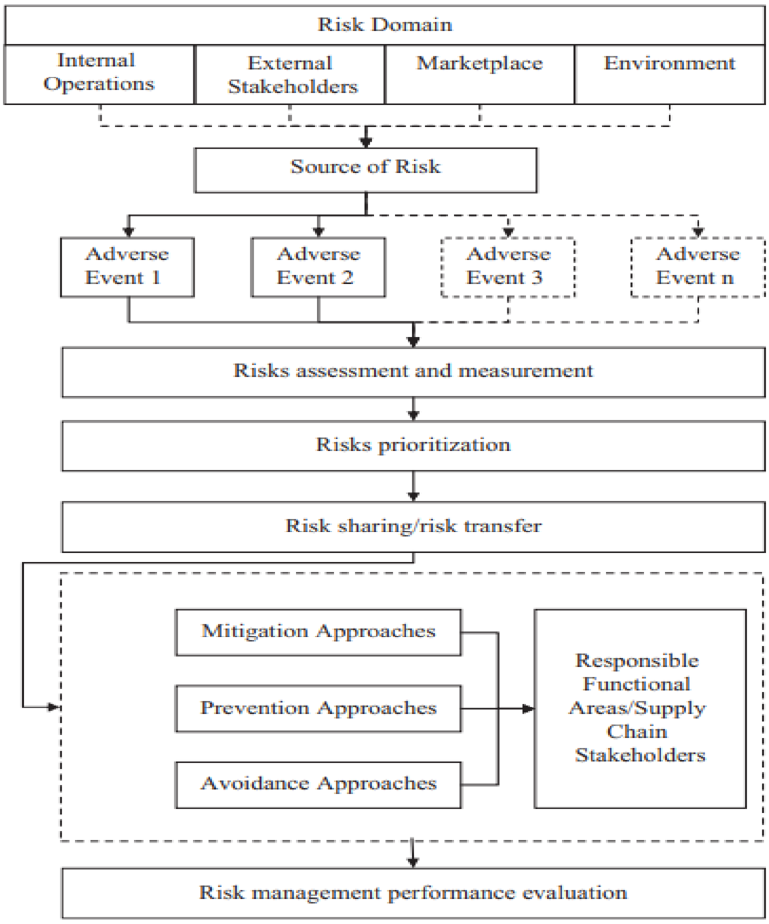

Figure 4: Supply chain risk management framework.

2.4 COVID-19 Pandemic and Supply Chain

While supply chains around the world have already suffered from epidemics and pandemics, an unprecedented, far-reaching disruptive epidemic, namely COVID-19, has recently seriously hit supply chains [66], COVID-19 is considered as a new type of extremely contagious coronavirus with destructive impacts [67].

The new pandemic of COVID-19, first spotted in Wuhan, China, has triggered the most extreme recession in nearly a century. According to the new Organisation for Economic Co-operation and Development (OECD) Economic Outlook [68], it has caused enormous harm to the health, employment, and well-being of people. COVID-19 has influenced almost every nation in the world and has virtually put the whole world on hold. The number of confirmed global cases up to date are more than 72.2 million; the number of deaths crossed 1.61 million [69]. Unfortunately, the number of cases and deaths is still exhibiting significant growth in many countries, with the Americas (most notably the USA and Brazil) been in the pandemic's epicenter [70]. Our generation has never met anything remotely similar to this pandemic, the speed with which COVID-19 can kill even perfectly healthy humans (sometimes within just a few days), and the unprecedented disruption in work and social life that it has brought (getting workers furloughed for months, and the vulnerable part of the population in strict isolation for 12 weeks), makes this pandemic unique. In addition, supply chains have faced major upstream disruptions due to this pandemic and the resulting global healthcare crisis, while hoarding and panic buying have caused similarly significant downstream disruptions. The balance of supply and demand was further impacted by the travel restrictions and lockdowns implemented by several countries worldwide.

The COVID-19 pandemic is already affecting large-scale supply chain management (OSCM) operations [71]. The extreme ripple effects of this challenge involve numerous strategies and steps, including comprehensive supply chain resilience strategies [67]. In addition, the response of the OSCM to such outbreaks should be to make global supply chains more interconnected and digitally ready [72]. In such circumstances, the digitalization of the supply chains may enhance the efficiency of the response to outbreak-related disturbances by increasing the flexibility of the OSCM [67].

The pre-disaster and post-disaster outcomes focused on flexibility and durability have been conceptualized as a supply chain model [73]. Ivanov and Dolgui [74] discovered a digital supply chain twin system for managing risks in pre, during and post disruption stages. Similarly, Olivares and Elmaraghy [75] suggested a dynamic model to evaluate the supply chain service level in separate situations by considering partial and total disruptions. A modular production system analytical model has been developed to analyze the sequence of loading or unloading operations using autonomous mobile robots to increase system productivity and flexibility. The study suggested a strategic planning for serious, medium and mild scenarios of logistics problems and revenue losses [76]. Dolgui et al. [74] have developed a smart contract framework for a logistics service provider in the light of emerging technologies. Using an event-driven dynamic approach, the model studies the tradeoff between supply chain lead time and contract costs.

All of these proposed solutions that aim to support the supply chain through this pandemic have possible risks, such as IT risks, which need to be considered in managing risks in the supply chain. Other risks resulting from the pandemic should be considered, such as capacity fluctuations and economic conditions.

Chapter 3. Methodology

This chapter will describe the research philosophy, approach, strategy, research methods, data collection method, and data analysis techniques that will be followed in this research to achieve the objectives presented in Chapter 1. The following sections will identify the process for exploring the last mile delivery risks to develop a framework that identifies last mile delivery risks and ranks them to support courier companies and improve their delivery process.

3.1. Research Philosophy

The last mile delivery risks are to be explored first by studying literature to get an understanding of these risks and if there is interdependency between them. New factors will be be induced by interviewing experts. This is the interpretative philosophy part where researchers see truth as socially constructed. In order to understand how people think, what they do, and how they solve the challenges they face, they interpret the elements of the analysis and incorporate human interests into a study. Interpretivist philosophy is based on the dissociation of reality and the human mind [77]. The problem under study involves adopting both interpretative and positivist philosophies and the use of qualitative and quantitative approaches to address research questions.

3.2. Research Approach

The philosophies followed in this study require a mixed approach between the inductive and deductive approaches. This mixed approach is labeled abductive reasoning. Choosing this approach will support the study by exploring all the possible risks that affect last mile delivery. In addition, each selected philosophy requires different approaches to solve the research problem issues [78].

3.3. Research Purpose

There are two purposes for this research: exploratory and explanatory. Exploratory studies explore research questions and identify the current understanding of studying them in order to search for new insights. While explanatory studies identify the causal relationships between variables of the study and determine the interdependency between the variables. The purpose of this study is to identify and quantify the last mile delivery risks to explore the interdependency between the risks and prioritize last mile delivery risks.

3.4. Research Strategy

Personal interview and internet survey strategies were followed to achieve these research objectives. Face-to-face interview with two experts was done to validate the risks of the study; while the online survey was constructed to collect and analyze individual responses through questions.

3.5. Research Choice or Methodology

Punch [79] stated that any research proposition can be tested using two main methods; either qualitative or quantitative. However, Creswell et al. highlighted that both methods have advantages and disadvantages [80]; so a combination of both approaches, called the triangulation method, is preferred. The triangulation method is about merging theories, methods observations, and experimental materials to avoid bias and weaknesses if a single method was adopted, and this will also increase the validity and reliability of the obtained results [81].

The quantitative method examines the occurrence level based on calculations and numbers. It also investigates the relationship between variables statistically. This method is based on structured data collection tools [82]. On the other hand, the qualitative method (non-numerical information) explores the ideas or concepts under study to gain perceptions and a comprehensive understanding about the topic and the variables related to it. In addition, this method will help to understand the human feelings and opinions towards the research question through subjective interpretations of experiences [77].

In light of this study, methodological triangulation was used for the data collection and validation stages. First, the qualitative method was used in mapping risks of last mile delivery from previous literature reviews; subsequently, face-to-face interviews with semi-structured questions were conducted with experts from the logistics and supply chain field. The face-to-face interview with semi-structured questions, using the inductive method, is suitable for an exploratory qualitative survey technique. Face-to face interview captures the interviewees' reactions and emotions towards the question. On the other hand, semi-structured questions will allow asking new questions to find new risks [77]. This interview method will verify the literature review findings on last mile delivery risks and identify new risks that are not mentioned in the literature. Then, a survey that targets project managers, E-commerce, logistics and supply chain professionals was developed by asking Likert scale questions on a scale from 1 to 5. Quantitative methods were used in quantifying the responses and ranking risks based on their impact and likelihood. Lastly, the Bayesian network method was used to check the interdependencies between the risks.

3.6. Survey

A good questionnaire is the main key to conduct a good survey as Chan and Chan stated [83]. To achieve this study goal, data of risks impact and the likelihood of occurrence were collected based on a structured online survey targeting project managers, E-commerce, logistics and supply chain professionals.

To confirm the survey ability to provide sound results regarding the risks of last mile delivery, this study considered both its validity and reliability as a data collection instrument. Specifically, this study analyzed its content, criterion, and construct validity by interviewing an expert from the field, and its reliability using Cronbach's alpha coefficient. In survey validity, Demerouti [84] defined the validity of an instrument as the determination of the extent to which the instrument reflects the abstract construct being examined and the degree in which a test or other measuring tool is truly assessing what it proposes to measure. Instrument validity can be assessed using different methods [84]. This study considered the survey's content and construct validity.

Content validity describes the extent to which test objects perform conceptually. The determination of content validity is a logical process that does not require statistical analysis.

In addition to the construct validity, one of the concerning aspects when a study is developed based on Likert Scale data is the internal reliability of the survey. Reliability of an instrument is defined as the degree of consistency with which it measures an attribute; it characterizes to what level a test, procedure, or tool is a repeatable attribute [85]

3.7. Statistical Analysis

Changing focus from the instrument to the survey responses, additional statistical analysis methods were used to quantitatively evaluate the collected responses. In addition to determining general descriptive statistics to characterize the survey responses, Bayesian Belief Network (BBN), was constructed.

Bayesian Networks (BNs), also known as Bayesian Belief Networks (BBNs) and Belief Networks, are probabilistic graphical models that represent a set of random variables and their conditional interdependencies via a directed acyclic graph (DAG) [86]. They can be used to explore and display causal relationships between key factors and the final outcomes of a system in a straightforward and understandable manner. A Bayesian network represents the causal probabilistic relationship among a set of random variables, their conditional dependencies, and it provides a compact representation of a joint probability distribution [87]. It consists of two major parts: a directed acyclic graph and a set of conditional probability distributions. The directed acyclic graph is a set of random variables represented by nodes. For risk measurement, a node may be a risk domain, and the states of the node would be the possible responses to that domain. If there exists a causal probabilistic dependence between two random variables in the graph, the corresponding two nodes are connected by a directed edge [87], while the directed edge from node A to node B indicates that the random variable A causes the random variable B. Since the directed edges represent a static causal probabilistic dependence, cycles are not allowed in the graph. A conditional probability distribution is defined for each node in the graph. In other words, the conditional probability distribution of a node (random variable) is determined for every possible outcome of the preceding causal node(s). Since a directed acyclic graph represents a hierarchical arrangement, it is unequivocal to use terms such as parent, child, ancestor, or descendant for certain nodes [88].

Bayesian networks apply Bayes' Theorem (also known as Bayes' rule or Bayes' law). In Bayes' theorem, a prior (unconditional) probability represents the likelihood that an input parameter will be in a particular state; the conditional probability calculates the likelihood of the state of a parameter given the states of input parameters affecting it; and the posterior probability is the likelihood that parameter will be in a particular state, given the input parameters, the conditional probabilities, and the rules governing how the probabilities combine. The network is solved when nodes have been updated using Bayes' Rule:

$$P(\mathrm{A}|\mathrm{B}) = \frac{P(\mathrm{B}|\mathrm{A})P(A)}{P(B)} \quad (1)$$

where P(A) is the prior distribution of parameter A; P(A|B) is the posterior distribution, the probability of A given new data B; and P(B|A) the likelihood function, the probability of B given existing data A. Bayes' theorem was derived by the Reverend Thomas Bayes, and was first published posthumously in the essay Towards Solving a Problem in the Doctrine of Chances [89]. BNs use Bayes' Theorem to update or revise the beliefs of the probabilities of system states taking certain values, in light of new evidence (referred to as a posteriori). Unlike many other modeling techniques used for different risk assessment, Bayesian networks use probabilistic, rather than deterministic, expressions to describe the relationships among variables [90]. Lack of knowledge is accounted for in the network through the application of Bayesian probability theory. This allows subjective assessments of the probability that a particular outcome will occur to be combined with more objective data quantifying the frequency of occurrence in determining conditional probabilistic relationships. Because uncertainty is accounted for in the model itself, Bayesian networks are a particularly appropriate method for dealing with systems where uncertainty is inherent, which tends to be a key issue in ecological systems. Communication of uncertainties is also essential when developing models for management.

Bayesian networks are particularly strong in their ability to capture causality and by their intuitively appealing interface, which helps to effective communication between statisticians and non-statisticians (e.g., physicians or policy-makers) [87]. Furthermore, Bayesian networks can be used for both qualitative and quantitative modeling since they can combine objective empirical probabilities (frequencies) with subjective estimates [91]. An important practical strength of Bayesian networks is that they can be constructed automatically from databases (so called "learning"). Finally, Bayesian networks are able to deal with issues like data over-dispersion (by adding another node representing an additional error term to mean of every observation), the relationship between coefficients (representing the coefficients as nodes in the graph), missing data (each missing observation is represented as a node in the graph), measurement errors on covariates, measurement errors on observables, or further sources of complexity [88].

The adopted methodology utilized a data-driven approach to capture the range of risk exposure specific to each risk rather than a point estimate. After collecting the data related to the likelihood of occurrence and level of impact of each risk from 3PL providers, the risk exposure of each risk was calculated using equation (2) [92]:

$$r_{ij} = \alpha_{ij}\beta_{ij} \qquad (2)$$

where

r_{ij} is the risk exposure assessed by respondent j for risk i;

i is the ordinal number of risk, $i \in (1, . . . , 23)$;

j is the ordinal number of valid feedback to risk i, $j \in (1, . . . , 25)$;

α_{ij} is the ordinal number representing the likelihood occurrence of risk i, assessed by respondent j, $\alpha ij \in (1, . . . , 5)$;

β_{ij} is the ordinal number representing the level of impact of risk i assessed by respondent j, $\beta_{ij} \in (1, . . . , 5)$.

Secondly, risks exposure were mapped to a risk matrix that was partitioned by the author into three zones; high, medium and low. This partitioning method represents the risk tolerance of a decision-maker in a project [93]. Therefore with regard to discretizing a risk matrix into risk exposure zones, decision makers will have a clear preference.

Thirdly, a data-driven Bayesian approach is used for developing models after discretizing the data inducing the model's network structure and estimating the model's parameters [94]. Bayes server software package was utilized and a PC algorithm was used for the modeling of the network. Based on an overall score reflecting the ability to predict the combination of values specific to various scenarios, these algorithms often select a particular network.

Knowing that each risk has the ability to propagate its impact across the entire network, risks can be prioritized. This is done by shifting each risk to both extremes (high, low) and recording the overall risk exposure impact on the network. This concept is operationalized by means of a new risk metric, namely network propagation impact (NPI) [65]; equation (3) shows how to calculate the NPI:

$$NPIRi = RE|(Ri = high) - RE|(Ri = low) \qquad (3)$$

Ranking is done depending on the NPI values. The higher the NPI reflects a higher effect of the risk on the network.

Chapter 4. Results and Analysis

In this chapter, the theoretical framework, which identifies all possible risks in last mile delivery, will be proposed along with risk mapping to different schemes. All risks identified will be analyzed and ranked based on the collected data and the methodology presented in chapter 3.

4.1. Last Mile Delivery Risk Framework

The last mile delivery risks were explored first by studying the literature to get an understanding of these risks from 3PL context. The framework identified and listed 19 risks associated with the last mile delivery,12 risks were compiled from 22 studies and 7 risks were added by the auther. The proposed framework categorized risks under five main criteria which are: (1) financial risk; (2) operation and technical risk; (3) environmental risk; (4) quality risk; (5) legal related risk.

Additionally, risks were mapped onto three different schemes. The first scheme used is based on the TBL (triple bottom line) parts; social, environmental, and financial. The TBL dimensions are also known as the three Ps: people, planet and profits. Minimum performance is to be achieved in the environmental, economic and social aspects, according to the TBL approach [95]. Suppliers play an important role in the overall value development and overall environmental impact of an enterprise, so sustainability concerns (environmental, social, and economic) have begun to be taken into account by academics and supply chain management professionals (SCM) [96]. Therefore, attention is paid to the integration of sustainable supply chain management (SSCM). Organizations are aware of the value of the sustainability responsibility of their suppliers in their own growth, and any organization's environmental sustainability is difficult without implementing SSCM practices [97]. In this study, risks were assigned to their associated sustainable bottom line to assess in managing risks considering the 3P's.

The second scheme is based on whether the risk is internal or external to the organization. The last scheme divided the risks based on their impact into financial, quality, and operational risks.

The content validity of the framework was determined by semi-structured face-to-face interviews with logistics and supply chain experts who have more than 15 years of experience. Experts agreed that the 19 identified risks have an impact on the last mile delivery process. Moreover, four risks were added by the experts—namely, shipment return, competition, natural disasters, and operations waste. Table 1 illustrates the proposed final framework of the study.

4.2. Survey Design and Results

4.2.1. Survey creation. A survey was conducted targeting project managers, E-commerce, logistics, and supply chain professionals. It was based on the presented theoretical framework developed based on the literature review and semi-structured face-to-face interview with two experts.

Fellows et al. recommended that all surveys be piloted and completed by a sample of respondents [81]. A pilot study offers a trial run for the survey, ensuring that the question wording is clear, pinpointing vague questions, testing data collection techniques, and assessing the effectiveness of respondent invitations [98]. After modifying the draft survey based on feedback from experts, a revised draft survey was distributed to five project managers. The purpose of this step was to ensure that the questions were clear and to detect any problems that might arise when completing the survey. Based on the pilot survey results, the questions were determined to be generally clear. Thus, the survey used in this study was finalized and published.

The survey was divided into two parts; Part one: Respondent's background. Part two: Relative importance index of last mile delivery risks in terms of occurrence and impact. The final survey was three pages in length, it included a supplemental cover letter. It was published as provided in Appendix A.

4.2.1.1. ***Part 1: respondent's background and project description.*** The first part of the survey right after the cover letter is questions related to the respondent's information; Name, industry, size of the organization, total years of experience, years of experience in the supply chain, years of experience in E-commerce, and years of experience in risk management.

The majority of the survey respondents are working in large size organizations in different industries related to the last mile delivery. The experience profiles for the respondents are shown in Figures 5 to 8.

Table 1: Last mile delivery framework.

Criteria	Risk	Reference	Scheme 1			Scheme 2		Scheme 3		
			Economical	Environmental	Social	Internal	External	Financial	Quality	Operational
Financial Risk	Customers unavailability	[48], [30], [31], [32]	X				X	X		
	Package damage/loss	[36], [39], [47], [49], [50]	X				X	X		
	Customers Density	[33, 49, 51]	X				X	X		
	Cash on delivery		X			X		X		
	Shipment return		X				X	X		
	Competition		X				X	X		
	Economic conditions		X				X	X		
Operational & Technical Risk	Traffic congestion	[34, 42, 44, 49]		X			X			X
	Size and weight limitation	[40]	X			X				X
	Capacity fluctuations		X			X				X
	IT risks		X			X				X
	Delivery location identification		X				X			X
Environmental Risk	Noise pollution	[34, 49]		X			X		X	
	Harmful emission	[34, 42, 44, 49]		X			X		X	
	Natural disaster			X			X	X		
	Operations waste			X		X				X
Quality Risk	Delivery inconvenience	[39, 43]	X			X			X	
	Delivery window	[33, 38]	X			X			X	
	Customer Service quality	[45, 49, 52]	X			X			X	
	Delivery time	[3, 52, 53]	X			X			X	
	Privacy concerns				X	X			X	
Legal related Risk	Workforce Protection	[37]			X		X		X	
	Laws and regulations				X		X		X	

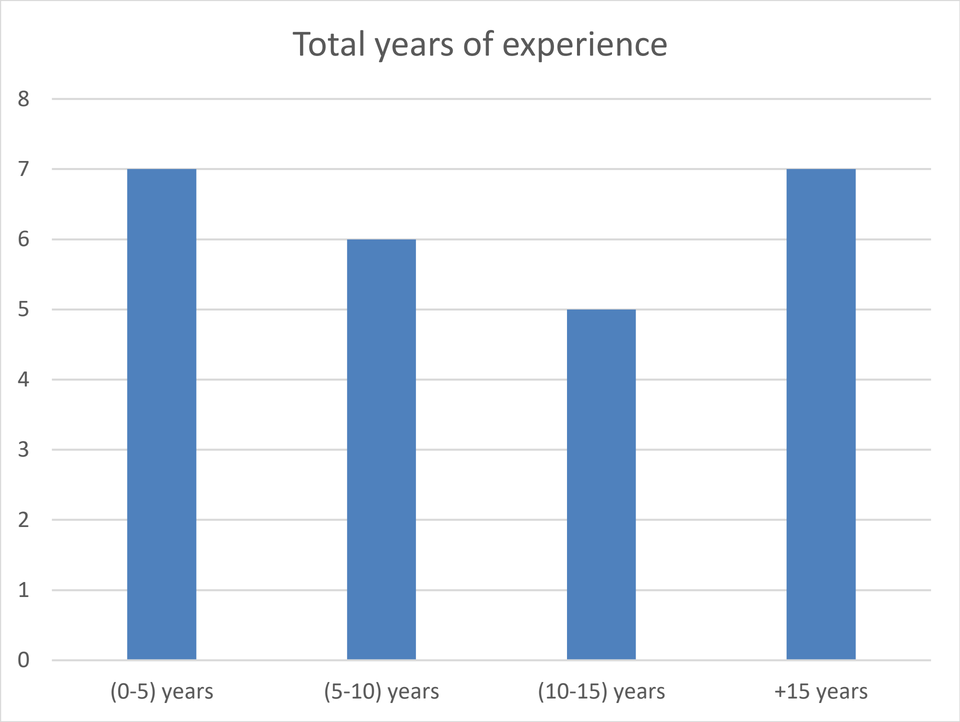

Figure 5: Respondents' total years of experience in the field.

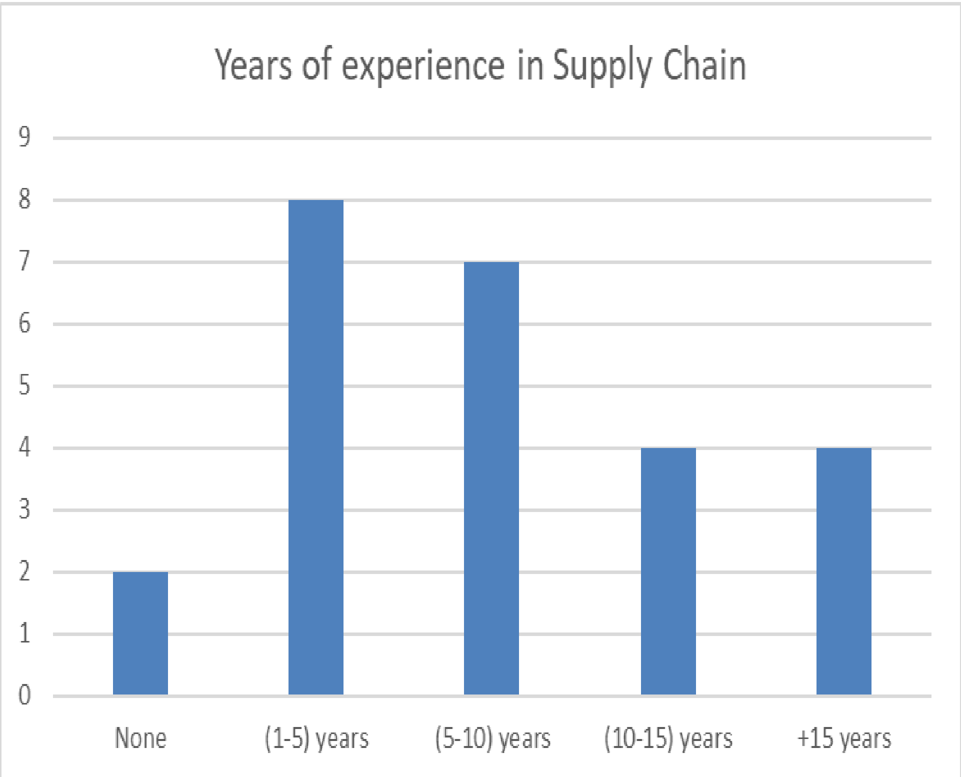

Figure 6: Respondents' years of experience in supply chain.

Figure 7: Respondents' years of experience in E-Commerce.

Figure 8: Respondents' years of experience in Risk management.

4.2.1.2. ***Part 2: Relative importance index of last mile delivery risks in terms of occurrence and impact.*** This part is divided into two sections, based on the risk exposure of each risk which is calculated by multiplying the likelihood of occurrence of a risk times the level of impact of that risk [92].

First section asks about the likelihood of the occurrence of each risk of the 23 risks, a five-point Likert scale was used in the survey by the respondents to show their opinion about the level of likelihood of the occurrence of each risk, where (1) indicates almost uncertain, while (5) indicates almost certain as shown in Table 2. This scale allows the qualitative data obtained from the survey to be transformed into quantitative data [99]. The second section asks about the level of the associated impact of each risk from 1 to 5 on a Likert scale: where 1 indicates negligible impact, while 5 indicates severe impact as shown in Table 3.

Table 2: Likert scale as used to measure risk likelihood of occurrence.

1	2	3	4	5
Almost uncertain	Unlikely	Neutral	Likely	Almost certain

Table 3: Likert scale as used to measure risks impact.

1	2	3	4	5
Negligible	Minor	Moderate	Significant	Severe

An online website tool was employed in the development and distribution of the survey, as well as in the collection of the responses. The survey link was sent out by emails to project managers, E-commerce, logistics, and supply chain professionals. Only the complete responses were used for further analysis, resulting in 25 completed surveys. Table 4 and Table 5 represent the responses to the likelihood and impact of each risk. There were some missing data that were not filled by some of the 25 respondents. However, as mentioned earlier Bayesian networks are able to deal with such issues.

The risk exposure of each risk was calculated using equation (2) in Section 3.7. The resulting exposure which varies from 1 to 25 is shown in Table 6. Risks exposure were mapped to the risk matrix shown in Figure 9. Risks with a value greater than or equal to 10 are considered critical (high exposure risk), while risks with a value less than or equal to 4 are categorized as a low exposure risk. Risks with exposures from 5 to 9 are classified as medium exposure risks.

Table 4: The likelihood of occurrence of the risks responses.

Srl.	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23
1	1	2	3	1	2	5	4	3	4	5	1	2	1	1	1	1	1	5	5	4	5	5	5
2	3	2	4	4	4	5	3	4	4	3	5	2	3	3	3	5	2	4	4	5	5	5	5
3	4	2	4		3	1	4	4	3	4	1	4	3		1	4	3	4	4	4	1	1	3
4	5	4	4		5	2	2	1	1	4	1	2	1	1	1	1	1	3	2	3	1	1	1
5	4	3	4	5	3	4	3	3	4	5	5	4	2	3	1	3	3	4	3	4	4	2	3
6	4	3	1	4	3	3	3	4	2	5	5	4	2	2	2	3	4	4	4	5	3	2	5
7	5	5	5	5	5	3	4	4	5	5	2	4	1	5	5	5	5	5	5	5	5	5	5
8	5	2	4	4	3	5	4	5	3	5	2	5	2	2	2	2	4	4	5	5	2	3	3
9	4	4	5	4	5	4	3	4	5		4	3	3	4	3		4	4	5	4	4	4	5
10	3	1	2	2	1	3	2	3	1	4	1	4	1	1	1	1	2	2	4	3	1	1	1
11	3	3	5	5	5	5	5	5	5	5	3	4	3	3	3	3	3	4	5	4	3	4	3
12	5	5	5	5	5	5	4	5	5	1	5	4	4	5	4	1	5	5	5	5	5	5	5
13	3	2	3	4	4	3	3	2	4	4	4	3	3	2	1	4	2	2	3	3	4	2	4
14	3	2	3	5	4	5	5	4	3	3	4	3	1	3	4	5	4	2	4	5	3	5	5
15	4	1	3	3	2	4	3	4	2	5	1	5	1	1	1	1	3	3	5	4	1	2	2
16	1	1	3	4	3	4	3	3	3	3	1	2	1	1	1	1	1	2	3	2	1	2	1
17	3	3	4	3	4	3	2	3	4	1	3	2	2	3	2	1	3	3	4	3	3	3	4
18	5	5	5	3	5	4	5	4	5	5	5	3	3	5	5	5	3	4	5	5	5	5	5
19	2	2	4	5	4	5	4	4	4	4	2	3	2	2	2	2	2	3	4	3	2	3	2
20	3	2	3	3	2	5	5	4	2	5	4	4	1	4	1	1	2	2	4	2	2	2	4
21	4	3	4	4	3	5	5	5	3	5	5	5	2	5	2	2	3	3	5	3	3	3	5
22	2	1	2	2	1	4	4	3	1	4	3	3	1	3	1	1	1	1	3	1	1	1	3
23	4	3	4	4	3	4	2	2	4	3	2	3	2	2	1	3	5	3	4	5	4	2	3
24	4	3	2	2	3	3	3	3	4	3	2	3	2	3	2	1	1	2	3	3	2	1	2
25	2	2	3	1	2	3	2	5	3	5	2	1	1	1	1	1	2	2	3	2	2	1	1

Table 5: The level of impact of the risks responses.

Srl.	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23
1	4	5	3	1	1	4	2	3	1	3	1	1	1	1	5	1	2	1	5	3	1	3	1
2	1	3	2	5	4	4	3	4	4	3	2	2	2	4	4	5	2	1	3	2	4	5	4
3	4	4	1	1	4	4	4	4	3	2	4	4	1	4	1	4	4	3	4	1	1	1	2
4	1	5	1	1	3	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1
5	5	5	3	5	4	3	3	4	4	3	4	5	2	2	3	3	4	4	5	5	4	2	4
6	5	5	2	5	4	3	3	3	2	4	5	4	2	2	2	3	5	5	5	5	4	4	4
7	3	5	2	5	3	4	4	4	5	5	3	5	1	5	5	3	3	4	4	4	4	4	4
8	5	5	5	5	5	4	4	5	3	5	5	5	3	5	5	3	5	5	5	5	4	4	4
9	4	5	5	4	4	5	4	3	4	4	4	5	4	3	4	4	5	4	4	5	4	4	4
10	3	4	3	4	4	2	2	3	1	3	3	3	1	3	3	1	3	3	4	3	2	2	2
11	5	5	5	5	5	5	5	4	4	4	3	4	3	3	3	3	3	4	4	4	5	3	3
12	5	5	5	5	5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5
13	3	2	1	2	3	2	2	4	3	4	5	5	5	3	4	5	4	1	5	4	3	3	4
14	5	5	3	2	4	4	5	5	3	3	4	2	3	3	5	5	5	3	4	5	5	3	5
15	4	5	4	5	5	3	3	4	2	4	4	4	2	4	4	2	4	4	5	4	3	3	3
16	4	4	3	3	3	3	3	2	2	2	1	2	1	1	1	1	1	2	2	2	3	1	1
17	3	4	4	3	3	4	3	2	3	3	3	4	3	2	3	3	4	3	3	4	3	3	3
18	5	5	1	1	5	3	4	3	5	5	5	4	2	2	5	5	5	5	5	5	5	5	5
19	5	5	4	4	4	4	4	3	3	3	2	3	2	2	2	2	2	3	3	3	4	2	2
20	3	2	2	2	2	4	4	3	2	5	5	4	1	1	1	1	2	2	4	3	2	2	4
21	4	3	3	3	3	5	5	4	3	5	5	5	2	2	2	2	3	3	5	4	3	3	5
22	2	1	1	1	1	3	3	2	1	4	4	3	1	1	1	1	1	1	3	2	1	1	3
23	4	4	4	3	4	5	5	1	3	3	4	4	1	1	5	2	4	3	4	3	5	3	3
24	1	5	3	1	1	5	5	3	1	1	5	1	1	1	5	1	1	2	1	1	1	5	5
25	5	5	2	2	3	3	2	5	4	3	4	4	2	2	5	2	3	2	3	2	5	5	5

Figure 9 shows the risk matrix used in this study, it illustrates the three zones of the identified risks depending on their exposure.

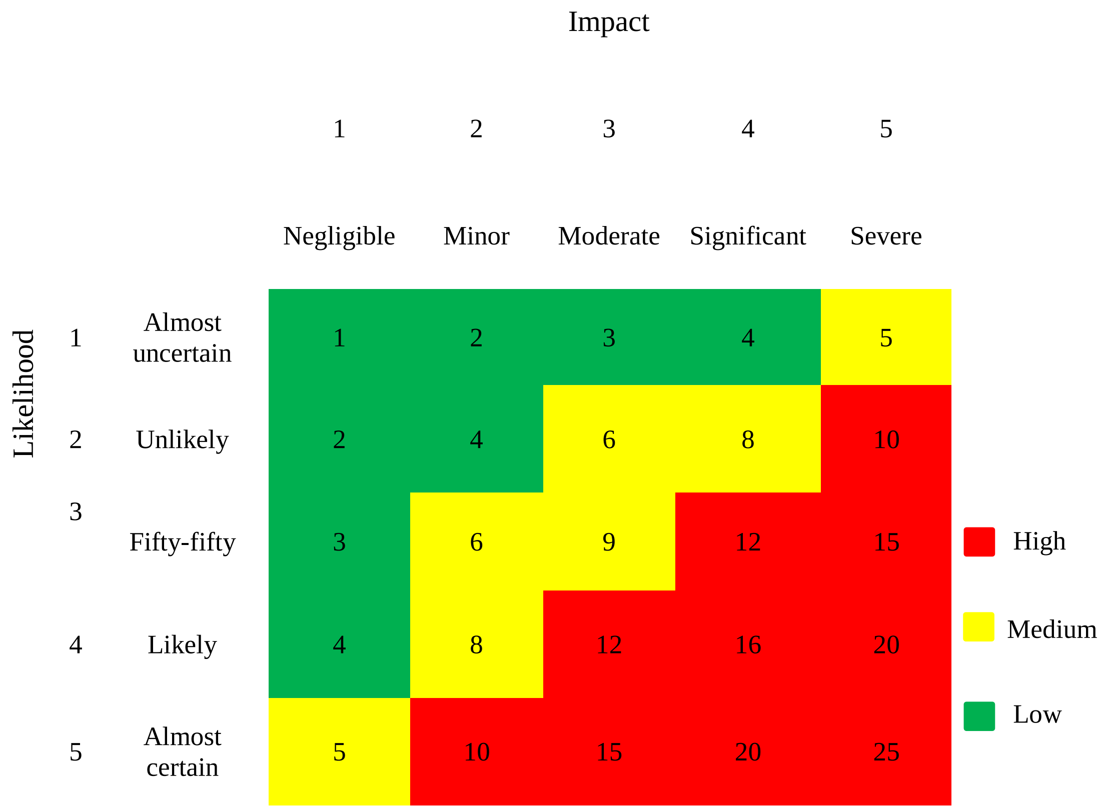

Figure 9: Risk matrix representing the risk zones.

4.2.2. Survey validity and reliability. Experts were asked to review the draft survey with respect to its comprehensiveness and overall content relative to this study's objectives. Experts agreed that the survey was adequate for capturing its intended information and validated its overall content. To measure internal consistency, a recommended approach by the literature, Cronbach's alpha coefficient of reliability, was applied. Cronbach's alpha coefficient is designed as a measure of internal consistency (i.e., do all items within the instrument measure the same thing) [100].Values of Cronbach alpha fall between 0 and 1. A value of 0.7 is considered acceptable and 0.8 or higher indicates good internal consistency [101]. With the help of statistical analysis software (SAS) Cronbach alpha for all factors was obtained as 0.95, which shows a very good consistency of the data.

Table 6: Risks exposures.

Srl.	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23
1	4	10	9	1	2	20	8	9	4	15	1	2	1	1	5	1	2	5	25	12	5	15	5
2	3	6	8	20	16	20	9	16	16	9	10	4	6	12	12	25	4	4	12	10	20	25	20
3	16	8	4		12	4	16	16	9	8	4	16	3		1	16	12	12	16	4	1	1	6
4	5	20	4		15	2	2	1	1	12	1	2	1	1	1	1	1	3	2	3	1	1	1
5	20	15	12	25	12	12	9	12	16	15	20	20	4	6	3	9	12	16	15	20	16	4	12
6	20	15	2	20	12	9	9	12	4	20	25	16	4	4	4	9	20	20	20	25	12	8	20
7	15	25	10	25	15	12	16	16	25	25	6	20	1	25	25	15	15	20	20	20	20	20	20
8	25	10	20	20	15	20	16	25	9	25	10	25	6	10	10	6	20	20	25	25	8	12	12
9	16	20	25	16	20	20	12	12	20		16	15	12	12	12		20	16	20	20	16	16	20
10	9	4	6	8	4	6	4	9	1	12	3	12	1	3	3	1	6	6	16	9	2	2	2
11	15	15	25	25	25	25	25	20	20	20	9	16	9	9	9	9	9	16	20	16	15	12	9
12	25	25	25	25	25	25	20	20	25	5	25	20	20	20	20	5	25	25	25	25	25	25	25
13	9	4	3	8	12	6	6	8	12	16	20	15	15	6	4	20	8	2	15	12	12	6	16
14	15	10	9	10	16	20	25	20	9	9	16	6	3	9	20	25	20	6	16	25	15	15	25
15	16	5	12	15	10	12	9	16	4	20	4	20	2	4	4	2	12	12	25	16	3	6	6
16	4	4	9	12	9	12	9	6	6	6	1	4	1	1	1	1	1	4	6	4	3	2	1
17	9	12	16	9	12	12	6	6	12	3	9	8	6	6	6	3	12	9	12	12	9	9	12
18	25	25	5	3	25	12	20	12	25	25	25	12	6	10	25	25	15	20	25	25	25	25	25
19	10	10	16	20	16	20	16	12	12	12	4	9	4	4	4	4	4	9	12	9	8	6	4
20	9	4	6	6	4	20	20	12	4	25	20	16	1	4	1	1	4	4	16	6	4	4	16
21	16	9	12	12	9	25	25	20	9	25	25	25	4	10	4	4	9	9	25	12	9	9	25
22	4	1	2	2	1	12	12	6	1	16	12	9	1	3	1	1	1	1	9	2	1	1	9
23	16	12	16	12	12	20	10	2	12	9	8	12	2	2	5	6	20	9	16	15	20	6	9
24	4	15	6	2	3	15	15	9	4	3	10	3	2	3	10	1	1	4	3	3	2	5	10
25	10	10	6	2	6	9	4	25	12	15	8	4	2	2	5	2	6	4	9	4	10	5	5

4.3. Bayesian Belief Network (BBN)

The resulting significance index assuming independence of each risk is shown in Table 7. The significance score represents the probability of high risk exposure resulting from that risk. The "Customer Service quality" risk is ranked first with the highest score of 0.7821; followed by the risk of competition and the risk of shipment returns ranked second and third, respectively. The least ranked risks based on the independence approach were Noise pollution, Harmful emission, Natural disasters, and Operations waste. Taking a look at the first scheme categorization, the independence based ranking lists the economic risks on the top of the list. In contrast, the environmental risks are being rated as the least important.

Table 7: Independence based risks ranking.

		Independence based ranking	
Srl	**Risk**	**Score**	**Rank**
1	Customers unavailability	0.5897	6
2	Package damage/loss	0.6282	5
3	Customers Density	0.4359	12
4	Cash on delivery	0.5848	7
5	Shipment return	0.6667	3
6	Competition	0.7582	2
7	Economic conditions	0.5513	8
8	Traffic congestion	0.6282	5
9	Size and weight limitation	0.4744	11
10	Capacity fluctuations	0.6533	4
11	IT risks	0.5128	9
12	Delivery location identification	0.5897	6
13	Noise pollution	0.1282	18
14	Harmful emission	0.2870	16
15	Natural disasters	0.2922	15
16	Operations waste	0.2533	17
17	Delivery inconvenience	0.4744	11
18	Delivery window	0.3974	13
19	Customer Service quality	0.7821	1
20	Delivery time	0.6282	5
21	Privacy concerns	0.4769	10
22	Workforce Protection	0.3590	14
23	Laws and regulations	0.5513	8

However, as mentioned earlier, these ranks do not account for interdependencies between the risks; thus, this ranking can be misleading for the decision makers in the last mile delivery process. In order to consider the interdependencies between the risks, a Bayesian Belief Network model for the last mile delivery process performance was developed by utilizing PC algorithm of Bayes server

[102]. After discretizing the data. Figure 12 illustrates the constructed network. The network shows that there are interdependencies between some of the risks within the network, where other risks are independent and therefore are not affected by other risks.

Three nodes interdependent risks are shown in figure 10 as an example to illustrate the interdependency between risks and the network impact on the overall risk exposure. The arcs between the nodes indicate the relation between the corresponding risks. In this example, the competition is dependent on both customer density as well as economic conditions. This implies that the increase in customer density will affect the risk exposure and lead to an increase in the competition risk. Figure 11 represents the network impact with respect to the mitigation and realization of the customer density risk, respectively.

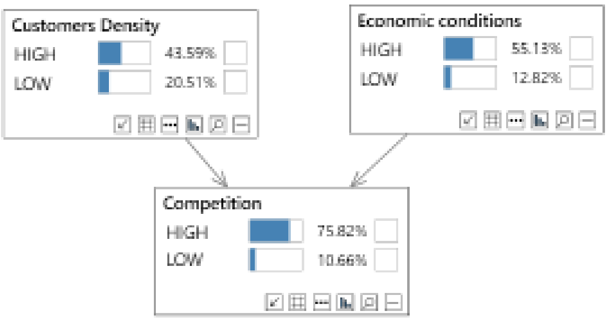

Figure 10: Risks interdependency.

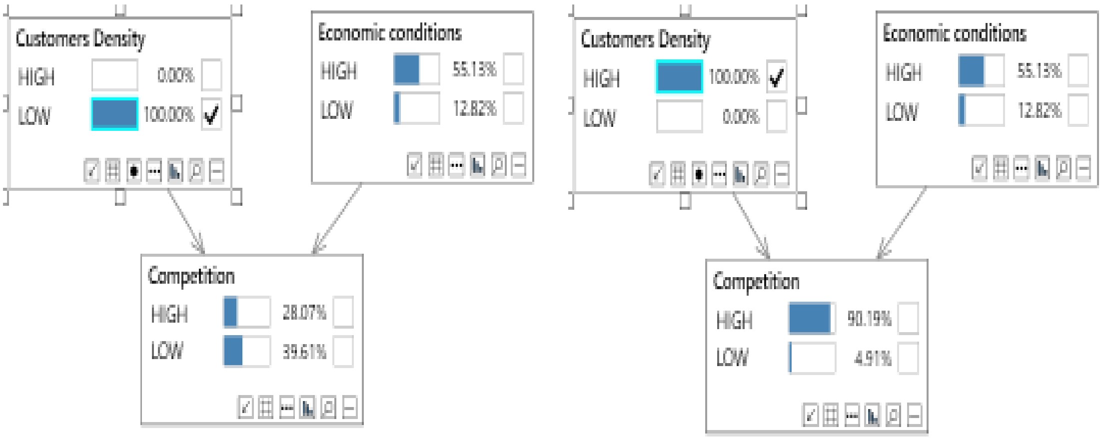

Figure 11: Mitigation and realization of customer density risk.

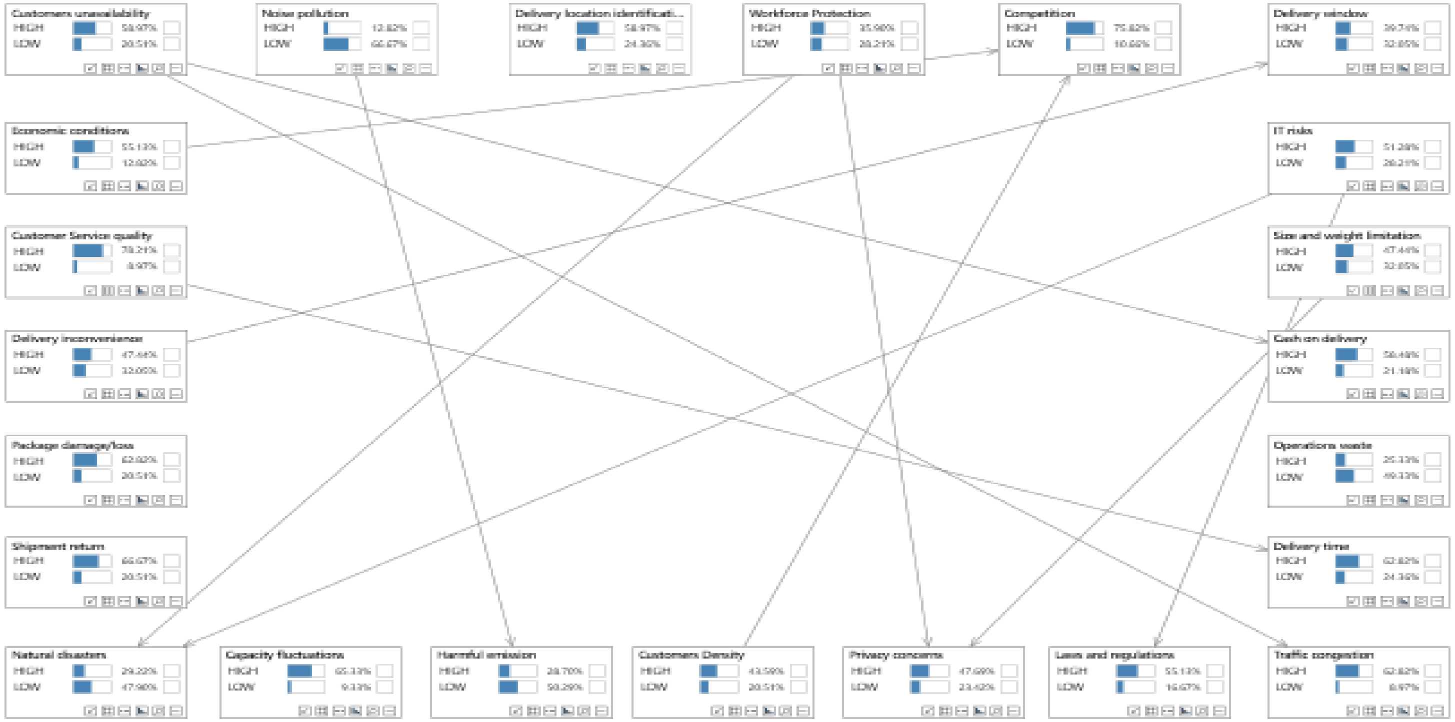

Figure 12: Bayesian Belief Network of last mile delivery risks.

In order to investigate the relations within the network and to capture the impact of each risk across the network, the network propagation impact was calculated for each risk using equation (3) and is reported in Table 8. After accounting for the network effect and the interdependencies; Privacy concerns, IT risks, and Natural disasters were ranked the top three risks with NPI of 0.1055, 0.1009 and 0.1002 respectively, where these three risks are all connected together and connected to three additional risks within the network as shown in Figure 13.

Figure 13: Interdependencies between highest ranked risks.

It is noticed that the two approaches results in different ranks as shown in Table 9 as the independence based ranking scheme does not account for the interdependencies between the risks. For instance, the independence based ranking listed the economical risks on the top of the list and the environmental risks were on the bottom of the list. However, the risk network based on the NPI value listed a social risk (privacy concerns) as the most important risk. Therefore, decision makers in last mile delivery should consider the interdependencies and the network effect in order to decide on their risk management strategies.

Table 8: Interdependence based risks ranking.

Srl	Risk	Interdependence based ranking	
		NPI	Rank
1	Customers unavailability	0.0939	5
2	Package damage/loss	0.0435	19
3	Customers Density	0.0706	15
4	Cash on delivery	0.0764	8
5	Shipment return	0.0435	19
6	Competition	0.0615	17
7	Economic conditions	0.0751	10
8	Traffic congestion	0.0745	12
9	Size and weight limitation	0.0738	13
10	Capacity fluctuations	0.0435	19
11	IT risks	0.1009	2
12	Delivery location identification	0.0435	19
13	Noise pollution	0.0654	16
14	Harmful emission	0.0554	18
15	Natural disasters	0.1002	3
16	Operations waste	0.0435	19
17	Delivery inconvenience	0.0749	11
18	Delivery window	0.0812	6
19	Customer Service quality	0.0759	9
20	Delivery time	0.0787	7
21	Privacy concerns	0.1055	1
22	Workforce Protection	0.0726	14
23	Laws and regulations	0.0957	4

It is noticed that the two approaches results in different ranks as shown in Table 9 as the independence based ranking scheme does not account for the interdependencies between the risks. For instance, the independence based ranking listed the economical risks on the top of the list and the environmental risks were on the bottom of the list. However, the risk network based on the NPI value listed a social risk (privacy concerns) as the most important risk. Therefore, decision makers in last mile delivery should consider the interdependencies and the network effect in order to decide on their risk management strategies.

Table 9: Comparison between study's ranking schemes.

		Interdependence based ranking		Independence based ranking	
Srl	**Risk**	**NPI**	**Rank**	**Score**	**Rank**
1	Customers unavailability	0.0939	5	0.5897	6
2	Package damage/loss	0.0435	19	0.6282	5
3	Customers Density	0.0706	15	0.4359	12
4	Cash on delivery	0.0764	8	0.5848	7
5	Shipment return	0.0435	19	0.6667	3
6	Competition	0.0615	17	0.7582	2
7	Economic conditions	0.0751	10	0.5513	8
8	Traffic congestion	0.0745	12	0.6282	5
9	Size and weight limitation	0.0738	13	0.4744	11
10	Capacity fluctuations	0.0435	19	0.6533	4
11	IT risks	0.1009	2	0.5128	9
12	Delivery location identification	0.0435	19	0.5897	6
13	Noise pollution	0.0654	16	0.1282	18
14	Harmful emission	0.0554	18	0.287	16
15	Natural disasters	0.1002	3	0.2922	15
16	Operations waste	0.0435	19	0.2533	17
17	Delivery inconvenience	0.0749	11	0.4744	11
18	Delivery window	0.0812	6	0.3974	13
19	Customer Service quality	0.0759	9	0.7821	1
20	Delivery time	0.0787	7	0.6282	5
21	Privacy concerns	0.1055	1	0.4769	10
22	Workforce Protection	0.0726	14	0.359	14
23	Laws and regulations	0.0957	4	0.5513	8

Privacy concerns, IT risks, natural disasters, laws and regulations, Customers unavailability are considered high risks relatively with NPI value around 0.1, have both high probability and high severity. Mitigation strategies are recommended to be developed and implemented for privacy concerns risk, IT risks, and customer unavailability risk. However, natural disaster risk and law and regulations are beyond management's control and can be regarded as Force Majeure or an industry crisis. This is where management should be encouraged to transfer these risks by purchasing insurance to hedge against these risks and does not need to take any mitigating action upon themselves for these risks.

Organizations should also monitor the rest of the risks to identify the potential trends in their probability or consequences. Some proactive mitigation strategies for these risks also should be made.

Chapter 5. Conclusion

Last mile delivery is viewed of being the most polluting section of the entire logistics chain and the most expensive. However, it has a remarkable impact on e-commerce and logistics companies, as it is the final leg of the supply chain and reflects the company's image. In last mile delivery, it is important to meet customers' expectations to gain their satisfaction, considering the cost of the process and the environmental impact. This is achieved by efficient last mile delivery planning; where the service provider must have a clear knowledge of the risks that last mile delivery faces. Therefore,it should focus on risk assessment for identifying the specific risks it faces and take action according to a proper risk response strategy.

Although the last mile delivery is one of the most complex, costly and inefficient processes along the entire logistics fulfillment chain in an e-commerce context, there are no studies up to date investigating the assessment of its risks. This study proposed a comprehensive framework on risk identification and analysis in last mile delivery considering any possible interdependency among the risks.

Risks have been deduced from the available literature on last mile delivery and others have been induced through semi-structured interviews with experts in the field to get more understanding about risks, finding new risks that are not mentioned in the literature, validating and ranking them.

To achieve the study goal, data of risks impact and likelihood of occurrence were collected based on a structured online survey. As the last mile delivery efficiency is affected by the combination of various risk factors, the conventional approach of mapping the risk factors on a risk matrix falls short because it assumes that risks are independent and ignores the complex interdependencies between different risk elements. Therefore this study utilizes Bayesian Belief Network in order to capture and analyze the interdependency among risks as well as the network effect on the overall performance.

After accounting for the network effect and the interdependencies, it was found that privacy concerns risk, IT risks, and natural disasters risk are ranked the top three risks, where on the other hand based on the independent ranking scheme, they ranked 10, 9, and 15 respectively.

This study adds to the literature body a comprehensive investigation of last mile delivery risks, help logistics service providers to ultimately decide the solutions of last mile delivery that need to be utilized by prioritizing last mile delivery possible risks to increase their competitiveness, increase their market share, and minimize delivery costs. The limitations of this study affect the accuracy of the developed Baysian Belief Network, these limitations are represented by the small sample size of the collected data, the values assigned to the risks exposure are based on expert judgments not a real data from the field. Moreover, risks were assigned to the last mile delivery process in general not for a specific solution. It is recommended for future studies to collect more responses as more data improve model's prediction help develop more precise and targeted models.

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Appendix A. Survey Form

Last Mile Delivery risks survey

Introduction

Dear participant,

The remarkable boom of e-commerce has marked the latest years of different industries around the world. The e-commerce surge arises, driven by customers, from the final leg of the supply chain, the last mile. As the growing flow of e-commerce orders continues to produce new annual revenue records, key players in the last mile are facing the challenges of increasing client demands and transportation volumes. The last mile delivery is one of the most complex, costly and inefficient processes along the entire logistics fulfillment chain in an e-commerce context, last mile delivery corresponding risks are major contributors to delivery failure. This study proposes a comprehensive framework on risk identification and analysis in the last mile delivery to support the delivery planning.

This survey is a part of partial fulfillment of the requirements for degree of Master of Science in Engineering Systems Management from American University of Sharjah. It aims to study the risk affecting the last mile delivery process.

I would greatly appreciate if you can spare five minutes to fill in this survey.

The information of this survey will be used for broad research purposes only, your personal information and responses will be kept confidential and anonymous at all times.

Content of the survey:

This survey is divided into two sections to accomplish the proposed aim of the research:

Section one: Respondent’s Background

Section two: Relative importance index of last mile delivery risks in terms of occurrence and impact

Best Regards,
Hajed Mismar.

Section 1: Respondents Information.

1. Name*

2. Industry*

3. Organization Size*

Mark only one option.

- o Small
- o Medium
- o Large

4. Total years of experience*

Mark only one option.

- o (0-5) years
- o (5-10) years
- o (10-15) years
- o +15 years

5. Total years of experience in supply chain*

Mark only one option.

- o (0-5) years
- o (5-10) years
- o (10-15) years
- o +15 years

6. Years of experience in Ecommerce*

Mark only one option.

- o None
- o (0-5) years
- o (5-10) years
- o (10-15) years
- o +15 years

7. Years of experience in risk management*

Mark only one option.

- None
- (0-5) years
- (5-10) years
- (10-15) years
- +15 years

Section 2: Relative Importance Index.

A. The likelihood of the occurrence of each risk

From the previous literature, it was found that the following risks affect the LMD process. Please express your opinion on the level of likelihood of the occurrence of each risk from (1 to 5) where:

1 = Almost uncertain   2 = Unlikely   3 = Fifty-fifty

4 = Likely   5 = Almost certain

8. *

Mark only one oval per row.

	1	2	3	4	5
Absence of parcels recipients	☐	☐	☐	☐	☐
Package damage/loss	☐	☐	☐	☐	☐
Cash on delivery	☐	☐	☐	☐	☐
Shipment return	☐	☐	☐	☐	☐
Competition	☐	☐	☐	☐	☐
Economic conditions	☐	☐	☐	☐	☐
Traffic congestion	☐	☐	☐	☐	☐
Size and weight limitation	☐	☐	☐	☐	☐
Capacity fluctuations	☐	☐	☐	☐	☐
IT risks	☐	☐	☐	☐	☐
Delivery location	☐	☐	☐	☐	☐

Identification	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐
Harmful emission	☐	☐	☐	☐	☐
Natural disasters	☐	☐	☐	☐	☐
Operations waste	☐	☐	☐	☐	☐
Delivery inconvenience	☐	☐	☐	☐	☐
Delivery window	☐	☐	☐	☐	☐
Customer service quality	☐	☐	☐	☐	☐
Delivery time	☐	☐	☐	☐	☐
Privacy concerns	☐	☐	☐	☐	☐
Workforce protection	☐	☐	☐	☐	☐
Laws and regulations	☐	☐	☐	☐	☐

B. The associated impact of each risk

Please express your opinion on the level of the associated impact of each risk from (1 to 5) where:

1 = Negligible 2 = Minor 3 = Moderate

4 = Significant 5 = Severe

9. *

Mark only one oval per row.

	1	2	3	4	5
Absence of parcels recipients	☐	☐	☐	☐	☐
Package damage/loss	☐	☐	☐	☐	☐
Customer density	☐	☐	☐	☐	☐
Cash on delivery	☐	☐	☐	☐	☐
Shipment return	☐	☐	☐	☐	☐
Competition	☐	☐	☐	☐	☐
Economic conditions	☐	☐	☐	☐	☐
Traffic Congestion	☐	☐	☐	☐	☐
Size and weight limitation	☐	☐	☐	☐	☐
Capacity fluctuations	☐	☐	☐	☐	☐
IT risks	☐	☐	☐	☐	☐

Delivery location Identification	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐
Harmful emission	☐	☐	☐	☐	☐
Natural disasters	☐	☐	☐	☐	☐
Operations waste	☐	☐	☐	☐	☐
Delivery inconvenience	☐	☐	☐	☐	☐
Delivery window	☐	☐	☐	☐	☐
Customer service quality	☐	☐	☐	☐	☐
Delivery time	☐	☐	☐	☐	☐
Privacy concerns	☐	☐	☐	☐	☐
Workforce protection	☐	☐	☐	☐	☐
Laws and regulations	☐	☐	☐	☐	☐

Vita

Hajed Mismar was born in 1992, in Amman, Jordan. He received his primary and secondary education in IEC schools in Amman, Jordan. He received his B.Sc. degree in Industrial Engineering from the University of Jordan in 2015.

In August 2017, Mr. Mismar joined the Engineering System Management master's program in the American University of Sharjah as a graduate teaching assistant, his research interests are operations research and supply chain management.