AN ALTERNATIVE LAST MILE DELIVERY MODE FOR LOGISTIC COST REDUCTION

By

MRS. Noppakun SANGKHIEW

A Thesis Submitted in Partial Fulfillment of the Requirements

for Doctor of Philosophy (ENGINEERING MANAGEMENT)

Department of INDUSTRIAL ENGINEERING AND MANAGEMENT

Graduate School, Silpakorn University

Academic Year 2021

วิธีทางเลือกการส่งมอบไมล์สุดท้ายสำหรับการลดต้นทุนโลจิสติกส์

โดย
นางนพคุณ แสงเขียว

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปรัชญาดุษฎีบัณฑิต
สาขาวิชาการจัดการงานวิศวกรรม แบบ 2.1 ปรัชญาดุษฎีบัณฑิต
ภาควิชาวิศวกรรมอุตสาหการและการจัดการ
บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร
ปีการศึกษา 2564

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Title	An Alternative Last Mile Delivery Mode for Logistic Cost Reduction
By	Noppakun SANGKHIEW
Field of Study	(ENGINEERING MANAGEMENT)
Advisor	Associate Professor Dr. CHOOSAK PORNSING

Graduate School Silpakorn University in Partial Fulfillment of the Requirements for the Doctor of Philosophy

....Dean of graduate school
(Associate Professor Jurairat Nunthanid, Ph.D.)

Approved by

....Chair person
(Associate Professor Dr. Pungsak Uttaphut)

....Advisor
(Associate Professor Dr. CHOOSAK PORNSING)

....Co advisor
(Associate Professor Dr. Shunichi Ohmori)

....Committee
(Associate Professor Dr. PRACHUAB KLOMJIT)

....Committee
(Dr. Krissada Surawathanawises)

60405805 : Major (ENGINEERING MANAGEMENT)

Keyword : LAST MILE DELIVERY, TOPSIS, SIMULATION, LOCKER SHARING

MRS. NOPPAKUN SANGKHIEW : AN ALTERNATIVE LAST MILE DELIVERY MODE FOR LOGISTIC COST REDUCTION THESIS ADVISOR : ASSOCIATE PROFESSOR DR. CHOOSAK PORNSING

This dissertation is a study on the Last mile delivery (LMD) and is divided into three main parts. In the first part, the researcher reviews previous works on LMD. A questionnaire will be created to query all the stakeholders. It will be a questionnaire about LMD modes, including home deliveries (attended and unattended) and collection points (manned and unmanned). Respondents or decision-makers often have difficulty rating alternatives to the feature under consideration. The data is aggregated ratings of fuzzy data denoted by triangular fuzzy numbers. Then, existing last mile delivery modes are compared from the perspectives of all stakeholders by Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (Fuzzy TOPSIS). The results show that customers and merchants are concerned about security and safety criteria. Therefore, they selected the attended home delivery and manned collection point modes, respectively. On the other hand, delivery providers are focused on cost and delivery flexibility. Therefore, unmanned collection points are the most preferable choice. In addition, delivery service experts and merchant experts will be interviewed in depth. The service providers and businesses thought that good service and low prices would influence a customer's choice of the last mile delivery.

In the second part, locker sharing mode is presented as a novel mode of last mile delivery. The proposed mode is compared to existing modes by using a simulation technique. The arena simulation program is used as a research tool. Then, the data output from the simulation is applied to calculate the last mile delivery cost per parcel. It is found that the proposed mode is more efficient than other modes. This mode has the lowest cost compared to competitive modes. Its locker utilization is also higher than the current unmanned collection point. It is seen that the combination of lockers between companies could reduce costs for delivery service. It will enable delivery service

providers to reduce service charges for customers as well. The locker sharing mode is optional for the delivery provider. Furthermore, offering a locker sharing service could be a novel delivery strategy.

In the third part, a business model for the proposed mode will be created and analyzed. Data for the business model canvas was gathered through interviews, a literature review, and a search of related provider' websites. The BMC of the proposed mode shows that the value proposition can meet customer needs because it can solve problems that customers focus on, including safety, convenience, and cost. There is also a SWOT analysis of the lockers' strengths, weaknesses, opportunities, and threats. At the break-even point, the minimum number of slots for one area point was computed. Each country has varied investments, and adds the extra profit that each company requires in terms of cost. On the other hand, if the delivery service provider adopts this locker sharing service, the cost of maintaining the delivery provider's lockers is reduced, and there is no need to invest in more lockers to reach customers. This improves delivery efficiency while lowering expenses.

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere thanks to my advisor, Assoc. Prof. Dr. Choosak Pornsing, for his great assistance and continual support during this study. I am most grateful for his guidance and counsel, not only for the research methodology, but also for many other difficulties in my life. I would not have achieved this far and this dissertation would not have been completed without all the support that I have always received from him. Besides my advisor, I would like to thank the co-advisor, Assoc. Prof. Dr. Shunichi Ohmori, for his continued help and kind support to me. In addition, I am grateful for the committee members: Assoc. Prof. Dr. Prungsak Uttaphut, Assoc. Prof. Dr. Prachuab Klomjit, Dr. Krissada Surawathanawises, and Dr. Thanongsak Thepsonthi for suggestions and detailed feedback that have been very important to me.

I also would like to thank all my dissertation members and all the other members of my department. My friends are Pimchanok Sitthithesanond, Kanokkarn Ruksa, Tawinan Suksangjan, Chaninporn Nakrang, and other friends who deserve my thanks for directly and indirectly providing me with valuable suggestions during the course of this study.

Finally, I must express my very profound gratitude to my parents, Tawee and Srinual Tiwapat, for their constant love and support, keeping me motivated and confident throughout my life. My sister and her family, Noppawan, Yotha, Narapholphum, and Phattanaphum Butchumseang, for their unfailing support and continuous encouragement. My dear brother, Woraphol Tunpiriyakul, for the confidence you have in me. My second mother, Thanaporn Sangkhiew, for her support. Last but not the least, my husband and son, Wanchana and Phattarakhun Sangkhiew, for their love and inspiration.

This study was partially supported by a research grant from Research, Innovation and Creativity, Department of Industrial Engineering and Management, Silpakorn University.

MRS. Noppakun SANGKHIEW

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

1.1 Motivation

As the growth of internet technology, retail e-commerce or online shopping has rapidly increased. In 2019, retail e-commerce sales worldwide expect to 3.45 trillion US dollars [2]. Many customers have changed to e-commerce instead of traditional commerce because e-commerce is flexibility, time saving, and convenience, etc. In online shopping, customers can be 'one-click' for access to online shopping and on-demand services [3]. Then, the merchants or delivery providers will deliver the products to the customers' desired destinations.

There are business models such as business-to-business (B2B), business-to-customer (B2C), and customer-to-customer (C2C). Since 2015, China has already become the world's largest market for e-commerce. In China, 60% of the total retail e-commerce sales, are generated from B2C, and it is becoming more popular globally [4]. Therefore, this research focuses on the B2C model. B2C model is the direct commercial transactions through the internet between online stores and individual customers. When a customer orders, merchants would directly ship products to the customer's place. Merchants usually have options for shipping products to their customers such as home delivery, same day delivery, store pick up, and cash on delivery. Merchants may self-deliver or use third-party logistics providers (3PLs) such as UPS, FedEx, DHL, and Kerry Express to ship products to end customers, where they must respond to the needs and expectations of both merchants and customers. It is worth noting that a part of logistics which is an important part to support the e-commerce, is "Last Mile Delivery (LMD)".

Last Mile Delivery (LMD) is the final leg in a B2C delivery service whereby the product is delivered to the recipient, either at the recipient's place or at a collection point and it has become one of the bottlenecks of e-commerce [5, 6]. LMD is regarded as the most expensive part that the cost is between 13% and 75% of the total supply chain costs [5, 7]. In B2C last mile delivery, it is understandable that parcels are delivered directly from merchant to customers. For example, assume the distance between the merchant and each customer is 1 mile —the last mile. If the merchant has to deliver 1,000 customers and the cost per mile is 1 unit, the total cost is 1,000 units which is considered a high cost, as shown in Figure 1 Furthermore, it also generates traffic, noise, air pollutions, and consequences [7]. In order to assure optimal operation, delivery providers must optimize their delivery operations that is enormous challenges for delivery providers to deliver goods in the urban areas [8].

Last mile delivery expenses are significant as a percentage of overall shipping costs. Also, the rapid growth of "Free shipping" which means customers are not willing to pay for shipping fees, causing merchants and delivery providers to shoulder the costs. In 2018, Amazon delivery costs accounted to 27.7 billion USD, up from 21.7 billion USD in the previous year [9]. In the second quarter of 2019, Amazon responded to customer needs and increased efficiency in LMD, Amazon paid 800 million USD to provide Prime subscribers with one-day delivery. The cost of fulfillment, or shipping items to clients, has risen by more than 16 percent since 2018 [10]. There are universal costs that affect the delivery costs, including inventory management, internal and external fleets, as well as operational processes.

The main LMD problem on home deliveries is the failed first time delivery, which is called "First Time Hit Rate (FTHR)". By the definition, FTHR is referred to the delivery of parcel to the customer's place and it is successfully delivered at first time [11]. Song at el. (2013)[12] report that the FTHR lies between 12% and 60%. It will raise the delivery cost substantially [13]. Moreover, there will be many consequences which are mentioned above—traffic, noise, pollution, and others. Accordingly, an innovation LMD is needed.

A novel LMD is necessary and important. The last mile delivery cost-reducing will make the business more profit. Thus, this research aims to propose an alternative mode of last mile delivery which is low cost, effective delivery, and high first time hit rate. Firstly, the study is reviewing the related works LMD. Then, existing last mile delivery modes are compared in perspectives of all stakeholders by Fuzzy Technique for Order

Preference by Similarity to an Ideal Solution (Fuzzy TOPSIS). Secondly, an alternative mode of last mile delivery will be proposed and compared with existing ones by using simulation technique. Finally, a business model of the proposed mode will be created and analyzed.

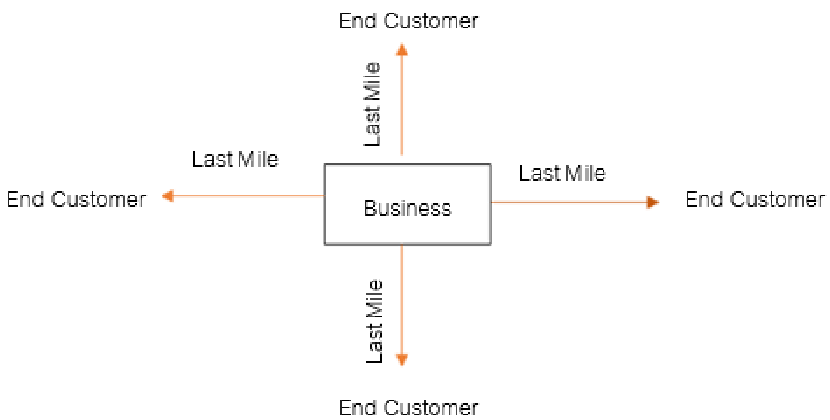


Figure 1 Last mile of products

1.2 Research Objective

1. To compare of existing last mile delivery modes in perspectives of all stakeholders by using Fuzzy TOPSIS technique.
2. To propose an alternative mode of last mile delivery for businesses in which compared to existing modes.
3. To create and analyze business model of the proposed mode.

1.3 Research Contribution

1. The last mile delivery mode which near an ideal by Fuzzy TOPSIS comparison.
2. A new mode of last mile delivery.
3. A novel business model of an alternative mode of last mile delivery.

CHAPTER 2
LITERATURE REVIEW

This chapter will be reviewed the related literature carefully. The aim is to review the fundamental concepts and information. These will be used as the basic conceptual line in further analysis. The rest of this chapter is organized as follows. Section 2.1 describes electronic commerce about timeline, types, advantages, and disadvantages. Section 2.2 explains the Last Mile Delivery. This section expresses modes and efficiencies of LMD, sustainability, and trends. Section 2.3 presents details of Technique for Order Preference by Similarity to an Ideal Solution, i.e., the classical TOPSIS method for a single decision making and group decision making, Fuzzy TOPSIS, weight determining, and its advantages and disadvantages. Section 2.4 briefly reports the simulation theory. Conclusions of this chapter are drawn in section 2.5.

2.1 Electronic Commerce

2.1.1 Introduction

Electronic commerce, also called e-commerce, is expanding around the globe. In 2019, retail e-commerce sales worldwide will expect the amount to 3.45 trillion U.S. dollars [2]. E-commerce has a long history that started in primitive electronic data transactions in 1960s. E-commerce refers to the seamless use of information and communication technology from a point of origin to a point of termination of commercial activities across the whole value chain. It is computer-assisted and tailored to meet a specific commercial objective [14]. E-commerce have the facilitation of the leading technologies such as electronic data Interchange (EDI), electronic data processing (EDP), and Electronic Funds transfer (EFT). Kalakota and Whinston (1997) [15] propose a definition of e-commerce which depend on the perspectives:

> In communication perspective, e-commerce is the flow of information, products/services, or payments via telephone lines, computer networks, or any other method in terms of communication.

In merchant process perspective, e-commerce is the use of technology to automate commercial transactions and workflows.

In service perspective, e-commerce is a technology that allows businesses, customers, and management to reduce service costs while enhancing product quality and speeding up service delivery.

In online perspective, e-commerce refers to the capacity to buy and sell goods and services through the Internet and through other online services.

Moreover, there are also many definitions of e-commerce, such as; The General Council, a committee of World Trade Organization (WTO), adopted the meaning of electronic commerce in which "to mean the production, distribution, marketing, sale or delivery of goods and services by electronic means". Organization for Economic Co-operation and Development (OECD) defined e-commerce transaction. That is the selling or buying of products or services, conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders [16].

Nowadays, the internet is spread out around the world. Consequently, online shopping is more interesting than the traditional shopping. The customers can be 'one-click' to access an online store [3]. It offers a convenience, flexibility, up-to-date information, and time efficiency to customers. Moreover, as the website is the main contact point and interface between merchants and customers, it also offers an accessible, reliable, and traceable choices to customers [17].

2.1.2 Timeline of e-commerce

In this section, timeline of e-commerce is descripted as shown in Table 1.

Table 1 Timeline of e-commerce

Year	Description
1960	- The Electronic Data Interchange (EDI) let to beginning the ecommerce revolution. EDI replace traditional document mailing and faxing with a digital data transmission from one computer to another [18].
1969	- The initial emergence of the online service industry is drove by CompuServe company [19].
1979	- Contemporary e-commerce, e-business and online shopping are invented by Michael Aldrich [20]. - The American National Standard Institute (ANSI) introduce ASC X12, it is a data exchange standard [21].
1981	- Thomson Holidays, the world's first introduce Business to Business (B2B) online shopping system [20].
1982	- France Télécom introduced Minitel (a pre-Internet service), it use for online ordering.
1984	- Gateshead SIS/Tesco launche the world's first B2C online shopping system with an innovative concept of online shopping trolley [22].
1985	- Nissan UK sells automobiles and loans to buyers online from dealer lots, with credit checks.
1990	- Tim Berners-Lee use a NeXTcomputer to create the first web server and wrote the first web browser, call WorldWideWeb (WWW) [23].
1994	- The commercial of the web begin with the introduction of the Netscape browser. It was a popular web browser. Then, Netscape 1.0 use SSL encryption that made transactions secure [24]. - Pizza Hut offer online ordering on its Web page [25].

Table 1 (continued) Timeline of e-commerce

Year	Description
1995	- Jeff Bezos launch Amazon.com. The company start with an online bookselle [26]. - Ebay is the first online auction site. The inception of Yahoo is a search engine web.
1998	- In the United States, Google is the most used search engine. PayPal is a global ecommerce startup that is bought by a bank and now processes payments for online merchants, auction sites, and other commercial users. - The dot.com boom [27].
1999	- Epinions provid users with the choice of open reviews, star ratings, gift recommendations, and forums. It is referred to as a “community of trust.” - The feature “buy rings” on Amazon’s website serve the same goal as today’s well-known recommendation systems and customer forums [28]. - Alibaba Group is established in China, it led by Jack Ma.
2000	- E-commerce has increasingly been used for business service between business and customers [29].
2001	- Amazon.com launch the first mobile commerce site. The dot.com bust [27].
2002	- Alibaba.com become profitable. - The C2C platform is launched by Taobao [30].
2004	- Online payment system, Alipay is launched.
2005	- Social commerce is introduced by Yahoo. It is widely acknowledged. It is a commercial activity that is mediated by social media [28].
2007	- Alisoft is launched by an internet-based business software company.
2010	- Pinterest is launched as a closed beta site [31].

Table 1 (continued) Timeline of e-commerce

Year	Description
2011	- Facebook commerce is introduced [25]. It can be credited to social interaction that leads to word-of-mouth marketing [32]. This revolutionary progression has expanded customer marketplaces in the social commerce. - Google launched Chrome Web Store [33].
2012	- Twitter Corporation announce its upcoming t-commerce [25].
2014	- The social networking services specifically for Facebook, Google+ and Twitter has been growing. Also, impressive is a trend toward conducting e-commerce via mobile devices. - Alibaba launch Tmall Global (G2C), expanding its business from the domestic market to the global market [30].
2016	- Facebook launch Facebook Live streaming [34].
2017	- Amazon.com dominate the online retail market with a staggering 44% of all U.S. e-commerce sales [35].
2018	- Turban et al. (2017)[36] discuss the newest e-commerce trends, such as smart commerce, social commerce, social cooperation, shared economy, innovations, and mobility.
2020	- Live-stream shopping has grown into a tool for merchants marketing and a driving factor behind e-commerce sales growth [37].

E-commerce has been developed for a long time. Internet technology's role is increasing importance in e-commerce. It also features Internet of Things (IoTs) technology, which makes online buying far more convenient than previously. Furthermore, e-commerce, a new trade technology, can boost inter-city trade and reduce spatial consumption disparities. It lowers the effects of distance on trade costs by eliminating the fixed cost of market access [38]. Presently, many e-commerce players are popular such as Amazon, eBay, and Alibaba.

2.1.3 Types of e-commerce

Sachs (1999) [39] extends the taxonomy segregating e-commerce companies into business to business (B2B), business to customer (B2C), customer to business (C2B) and customer to customer (C2C). These will be called four traditional types of e-commerce.

1) Business to business (B2B) refers to internet-based commercial transactions between merchants, such as between a manufacturer and a wholesaler, or a wholesaler and a retailer. It increases cooperation between merchants, which is lower transaction costs and more competitive sourcing opportunities for the buyer organization [40].

   B2B websites are classified into several categories: company websites, product supply, procurement exchanges, specialist search sites, and trade and industry standards organization sites [41]. Company-to-government (B2G) e-commerce is a subset of B2B e-commerce if governments are considered an act of merchants.

   Electronic Data Interchange (EDI) is commonly used to carry out these transactions (EDI). This provides for greater transparency in the merchants. Therefore, the business can work more efficiently. According to Sila (2013) [42], the growth of B2B e-commerce is predicted to exceed that of B2C e-commerce. B2B e-commerce makes up the bulk of global e-commerce. By 2020, sales from business-to-business e-commerce are expected to reach $6.7 trillion [43].

   B2B marketing began with industrial marketing. Industrial marketing focuses on raw material transactions that businesses use in their operations, such as rubber, gasoline, iron ore, and office supplies. The concept of industrial marketing has increasingly been displaced by the term B2B marketing as the manufacturing sector has slowed and the service industry and technology have grown [44]. Since February 2000, Large corporations such as GM, Boeing, Ford, and British Airways have said that they are developing or participating in B2B marketplaces [45].

B2B e-commerce will become much more dynamic and efficient. As a result, enterprises will adopt it more widely [46]. An auction is an important tool in B2B e-commerce platforms for providing the dynamic trading ability to both providers and buyers. Auctions create value by bringing buyers and merchants together. The reverse auction function allows buyers to bid on the lowest-priced things, and the price is determined by the pleased provider. Suppliers may find satisfied and qualified customers by using advanced auctions [47].

In B2B e-commerce, the business model has shifted to 'many to many,' which implies that each participant, whether a supplier or a customer, has established relationships with others, and a newcomer will be approached by prior e-commerce participants, as illustrated in Figure 2 [47]. Therefore, in B2B e-commerce, supplier relationship management (SRM) is important. SRM refer to the utilization of the latest technology to build a mutually beneficial network that brings benefits to both large companies and their suppliers. On the other side, SRM focuses on removing supplier obstacles, whilst the supplier focuses on simple and low-cost solutions [45].

In small and medium enterprises (SMEs), B2B e-commerce is a long-term investment, and small businesses lack the resources of large corporations. It should be executed with caution. The company's information, external, qualitative, and quantitative elements are all factors to consider [48].

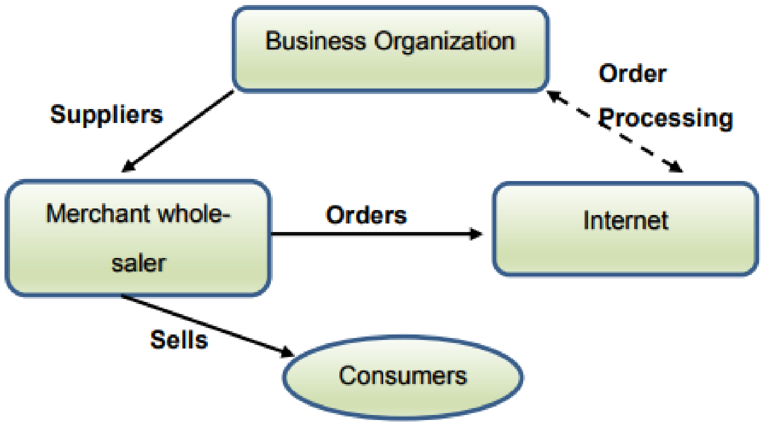


Figure 2 B2B e-commerce model

source: Tutorialspoint (2016) [49]

2) Business to customer (B2C) e-commerce is the direct exchange of goods and services between online shops and individual customers through the internet. The B2C e-commerce is shown in Figure 3. In the 2000s, although the failures of dot-com businesses, B2C e-commerce has continued to grow steadily. Many people think that Amazon.com is an innovator in B2C e-commerce. In addition, the internet's rise created a new B2C business channel in the shape of e-commerce, or the sale of products and services via the internet. The good relationships between B2C merchants and customers will ensure that the customer will return to service.

The evolution of B2C e-commerce has been formed through various generations [50]. In 2018, global B2C e-commerce sales reached to 2.36 trillion U.S. dollars [2]. B2C e-commerce is currently gaining popularity as more customers recognize its convenience and advantages. It might provide a quicker response to customer requests, increasing product and service availability [51]. Furthermore, e-shopping allows customers to order goods from the comfort of their own homes. The merchandise would then be sent straight to her home by merchants. In terms of the shopping model, B2C e-commerce is extremely different from traditional commerce.

The differences between B2C e-commerce and traditional commerce are product present, customer group, and service time. These lead to the difference in pricing strategy. The pricing of B2C e-commerce directly affects to perceives utilities and feedback that after the order. Therefore, merchants must set reasonable profit margins and prices [52]. Customers are encouraged to post recommendations on B2C websites after they have completed their purchases [53]. Furthermore, the new B2C e-commerce retailing model changed people's purchasing behaviors and made customer loyalty even more important than it is in traditional retail.

B2C e-commerce has challenging for inventory management which are seasonality, product popularity, reverse logistics, stock-outs, and other factors. As a result, there is a danger of lost revenue and customers. These are risk of loss of sales and loss of customers. Appropriate strategies might help to limit the risks such as drop shipping or hybrids. It will protect the online store from a number of risks while also increasing customer happiness [54].

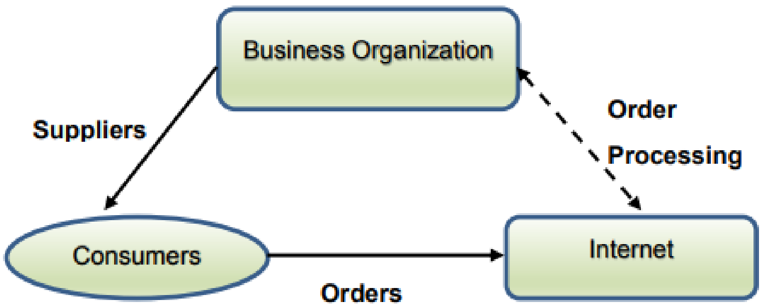


Figure 3 B2C e-commerce model

source: Tutorialspoint (2016) [49]

3) Customer to Business (C2B) e-commerce is transactions between customers and businesses, same as the B2C model; however, the customer will specify the services, product, or requirements of the business. Moreover, C2B must

have an intermediary dealing with the connection between merchants and buyers, as shown in Figure 4. An example is Fotolia.com which is a global stock photography service where users can purchase and sell photographs to illustrate professional and commercial brochures, commercials, websites, and other materials.

The first of C2B e-commerce was grown up in America. It is a popular model that is a strong purchase group by forming many customers together. It enhances efficient negotiation for customers [55]. A buyer coalition creation model is sometimes used to describe collective purchasing [56]. Businesses may extract value from customers using the C2B approach. Customers develop personalized demands or product requirements, and firms then manufacture products or services to meet those needs. In 2014, Jack Ma interviewed about C2B: "In the future, it will be a C2B world where businesses produce what the customers require and the level of individualization of products is much higher".

In C2B e-commerce, customers can easily and fast create, search, compare, and evaluate their products. According to a study by Forrester (2016)[57], "Customers have more flexibility of action, which impacts brand strategy, and their need for a consistent and quality individual digital experience,". Many businesses are responding to these developments more quickly than in the past. Companies focus primarily on customer service and less on manufacturing. The automation of information processing is part of this customer centralization which must be instantaneous, connected, customized, and data analysis. This refers to interaction data, descriptive, and behavioral, enables proactive customer demand response.

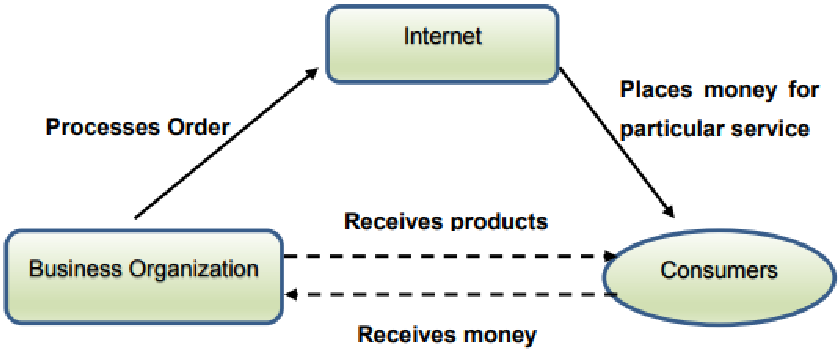


Figure 4 C2B e-commerce model

source: Tutorialspoint (2016) [49]

4) Customer to customer (C2C) e-commerce is a basic phenomenon that existed before the internet and is the oldest form of commerce. C2C e-commerce may also be called person-to-person (P2P) e-commerce. C2C e-commerce refers to the purchase and sale of services or products between customers. In C2C, one individual sells a product or service to another through an online marketplace such as eBay as Figure 5 illustrates the C2C model.

C2C online auctions are popular because it provides a private, convenient, and efficient platform of price negotiation for customers [58]. C2C systems enable users to communicate with buyers and merchants from a wider range of locations. Its platforms, on the other hand, are not free. In general, networking services for C2C users are centered on charging merchants or buyers a fixed charge or commission [59, 60].

In present, C2C e-commerce increased because it cuts out the costs of using another company. The highlight of this type is each person that will be the product owner. They open their shop but the volume of their products is low value. Therefore, it still not worth to invest on e-business.

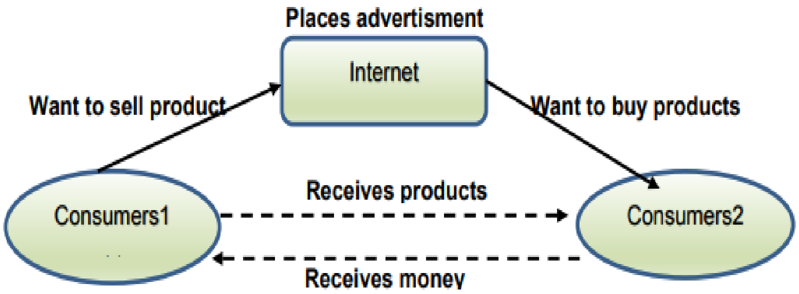


Figure 5 C2C e-commerce model

source: Tutorialspoint (2016) [49]

In addition to the four traditional type of e-commerce as described above, there are also many variants of e-commerce such as Business to Government (B2G), Government to Business (G2B), Government to Customer (G2C), Customer to Government (C2G), Government to Government (G2G), Business-to-People (B2P), Peer-to-peer (P2P), Business to Employee (B2E), Business to Business to Customer (B2B2C). The descriptions are as below;

Business to Government (B2G) or Government to Business (G2B) is used to describe transactions that take place between enterprises and the government. Business-to-government (B2G) refers to services supplied by companies to government agencies in order to enable public access to government services. G2B refers to business operations that are geared toward helping firms meet government service needs [18].

Government to Customer (G2C) or Government to Citizen is government service to the citizen through electronic media such as information service, and tax payment via the internet. Customer to Government (C2G) or Citizen to Government is an e-government program that allows citizens to pay bills and provide vital input to the government.

Government to Government (G2G) is cooperation and communication between the government's departments or agencies. It also includes the internal exchange of information and commodities. Business-to-People (B2P) is carried out by any firm that is willing and able to obtain feedback from individual customers, whether those individuals are end customers or clients of other businesses.

Peer-to-Peer (P2P) is the data and information that users directly share with other users without the assistance of a middleman or a central web server. Users from the P2P network's nodes who are both providers and customers exchange computer resources such as storage space, internet bandwidth, and data [18].

Business to Employee (B2E) is a paradigm in which an organization provides its workers with services, information, or goods. It allows managers to communicate with employees via email while streamlining time-consuming and labor-intensive organizational operations [61].

Business to Business to Customer (B2B2C) is a marketplace for merchants and buyers to connect. For a large number of small and medium-sized businesses, providing sales platforms also includes a payment function. This is a direct line of communication between suppliers, vendors, and customers. It is open and global, with no time or space constraints. Furthermore, as compared to traditional modalities such as B2B and B2C, it has cheaper business expenditures [62].

2.1.4 Traditional commerce and e-commerce

Traditional trading is buying and selling in physical stores through physical interactions between customer and salesman/company/product [63]. The comparisons between traditional commerce and e-commerce as follows [64]:

Cost-effective: e-commerce is very cost-effective because of it is a direct link between business and customer, while traditional commerce has a middleman who is present to sell the product.

Time-saving: traditional commerce is time-consuming as compare to e-commerce because customers can order the product and transaction in a few minutes via the internet.

Convenience: e-commerce customers can browse the product through catalogs, compare their prices and choose the products at anytime and anywhere.

Geographical accessibility: e-commerce sites are easily enlarging the size of the market from regional to global by just hosting a website on the internet. It is relatively easy to attract customers from global markets at a little cost.

Introduction of a new product: e-commerce is easily launching a new product on the website. It gets the instant comment of the customers about the product. Traditional commerce takes lots of time and money to launch.

Profit: e-commerce increases the profit of the business by cutting the cost of the middleman which exists in traditional commerce.

Physical check: e-commerce websites do not allow users to physical examination of the goods. The customer's decision depends on the images of the products that presented on the websites. In traditional commerce, the customers can physically check the product or goods before purchasing.

Time accessibility: traditional commerce offers a limited-service period but e-commerce provides the service at any time.

Technology specialists: e-commerce environments require technical persons, who have talented skills to update themselves in the changing electronic world. In traditional commerce, there is no a such problem.

Customer interaction: in traditional commerce, the providers physically interact with the customers. On the other hand, e-commerce is a virtual market, the interaction is limited.

Business relationship: in traditional commerce, the business relationship with customers is vertically or linear. However, the e-commerce relationship identified by end to end.

Fraud: the number of reported cases of fraud in e-commerce has increased over the years. This is due to the lack of physical presence in the market and unclear legal issues give loopholes for fraud. Traditional commerce is fewer fraud cases because there is personal interaction between buyers and merchants.

2.1.5 Advantages and disadvantage of e-commerce

1) Advantages

- Easily locate products.
- Fastest mode of selling and buying.
- Availability 24 hours, 7 days for buying and selling.
- Don’t need the physical store.
- The decrease in the functioning costs.
- Low-cost advertising.
- A paperless office, reducing fuel.
- One store set up for all the customers’ business needs.
- Unlimited access to information and different products.
- Increased potential market share for a business.
- New possibilities for performing direct marketing.

2) Disadvantage

- Some websites are not user-friendly.
- Product quality is not guaranteed.
- Unable to examine products personally.
- Online purchasing security.
- Maintenance of website.
- Website stickiness and low customer loyalty.

2.2 Last Mile Delivery

2.2.1 Introduction

> Last mile logistics is the last part of a B2C delivery process. It takes place within a predefined delivery area (e.g. urban area); including the upstream logistics to the last transit point until the destination point of the parcel. It involves a series of activities and processes, of critical value to all the involved stakeholders (e.g. Customer, Industry and Institution) within the delivery area.

Wohlrab et al (2012) [65]

Last Mile Delivery (LMD) originated in the telecommunications industry and refers to the final leg of a network [66]. In e-commerce, LMD denotes the final leg of the business-to-customer (B2C) delivery service whereby the product is delivered to the recipient, either at the recipient's home or at a collection point. It has become one of the bottlenecks of e-commerce and has emerged as one of the most problematic ones to manage, optimize, actuate, and control [5, 6]. In addition, LMD is expected to grow because of increased online retail transactions.

The rise in worldwide online retail sales over the last decade has resulted in a massive increase in the number of goods that need to be delivered. It changes in demand for products from overseas and increases the complexity of logistics and supply chain networks [67]. The success of an e-commerce company strongly correlates with its logistics performance. Furthermore, last mile delivery is just one link in the e-commerce supply chain that involves direct, face-to-face interactions with clients [68]. The last mile of customer home delivery is observed as 'one of the biggest challenges in B2C ecommerce' [69].

Gevaers et al. (2011) [5] proposed LMD as the most expensive, least efficient aspect of a supply chain and the one with the most impact on the environment. The freight transport of parcels is done by road transportation such as vans, trucks, and motorbikes. LMD freight traffic impacts on environmental sustainability because it increases carbon emissions, pollution, and traffic congestion [3].

The main LMD problem in home deliveries is failed first time delivery. Its rates are between 12% and 60% due to, customers not being at home (not at home problem) [12]. The parcels may be delivered two or three times before they are successfully delivered [11]. Accordingly, it will drive the delivery costs substantially high, which depends on the failed first-time delivery rate [13]. As the importance of LMD has increased, stakeholders have worked hard to enhance LMD, which has resulted in significant improvements in package delivery and city logistics [68].

Nowadays, the solution of LMD has implemented various methods, such as using VRP or adding a new mode of delivery service. For LMD management, stakeholders should be aware of its delivery mode first. The modes of LMD will be presented in the next section.

2.2.2 Modes

As an alternative for customers, merchants have a shipping option, although they must use their own delivery or make use of third-party logistics providers (3PL). The mode of last mile delivery can be divided by a perspective of analysts. Gevaers et al. (2009) [70] divide the LMD into 5 modes: reception boxes, collection points, post offices, attended home deliveries, and unattended home deliveries, as shown in Figure 6. On a meta-level, Wang et al. (2014) [6] divide it into 3 modes: attended home deliveries, reception boxes, and collection-and-delivery points. Hepp (2018) [71] divides the modes into three prevalent delivery methods that are currently commercially in use: home delivery, post office/parcel shops/collection points, and parcel lockers. Moroz and Polkowski (2016) [72] present delivery methods as home deliveries (attended and unattended) and collection points (manned and unmanned), as shown in Figure 7. Hepp (2018) [71] classifies delivery methods as stationary models, intercept models, and personalized models, as shown in Figure 8. According to McKinsey & Company (2016) [73], by 2025, autonomous vehicles will perform 80% of all deliveries worldwide. Customers' demands put pressure on e-commerce companies to provide more quickly.

Autonomous ground vehicles with package lockers, drones, droids, crowdsourcing, and semi-autonomous ground vehicles are examples of future delivery options.

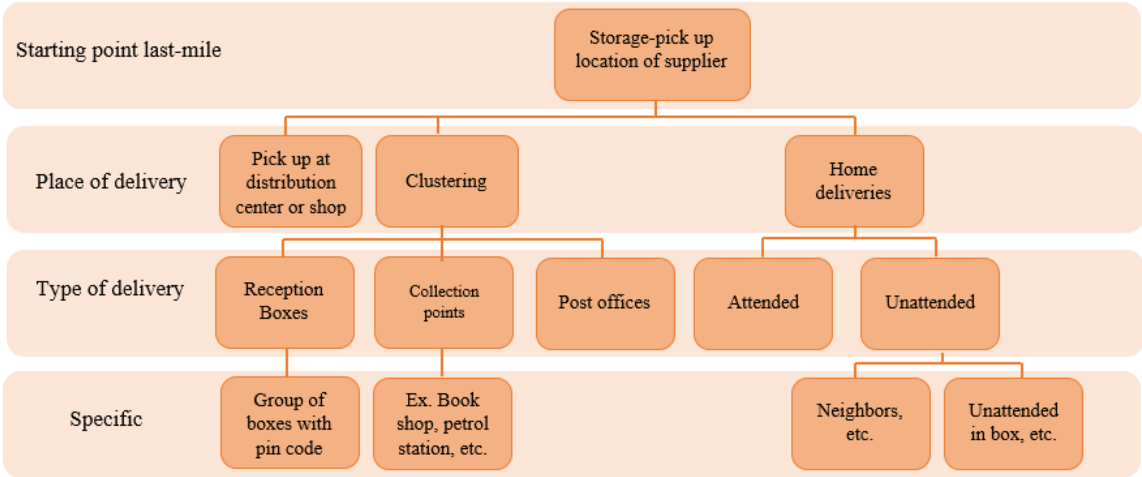


Figure 6 Classified of last mile delivery

source: Gevaers et al. (2009) [70]

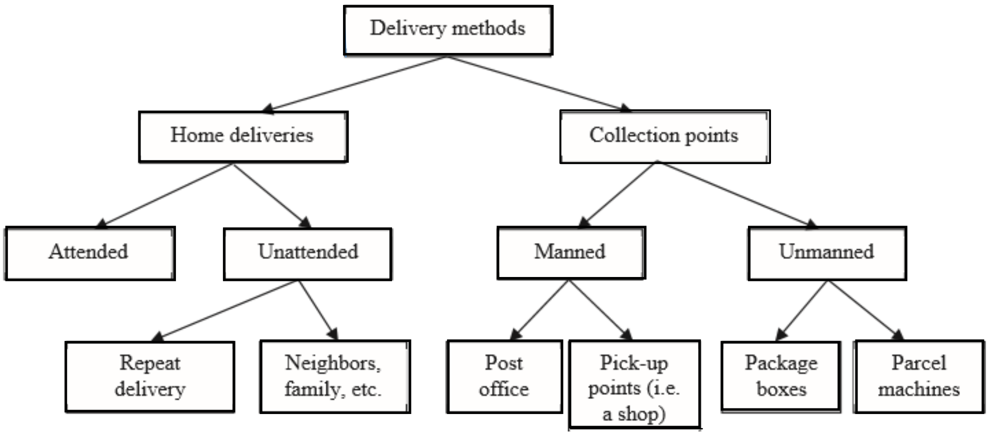


Figure 7 The methods to overcome the problem of the last mile

source: Moroz and Polkowski (2016) [72]

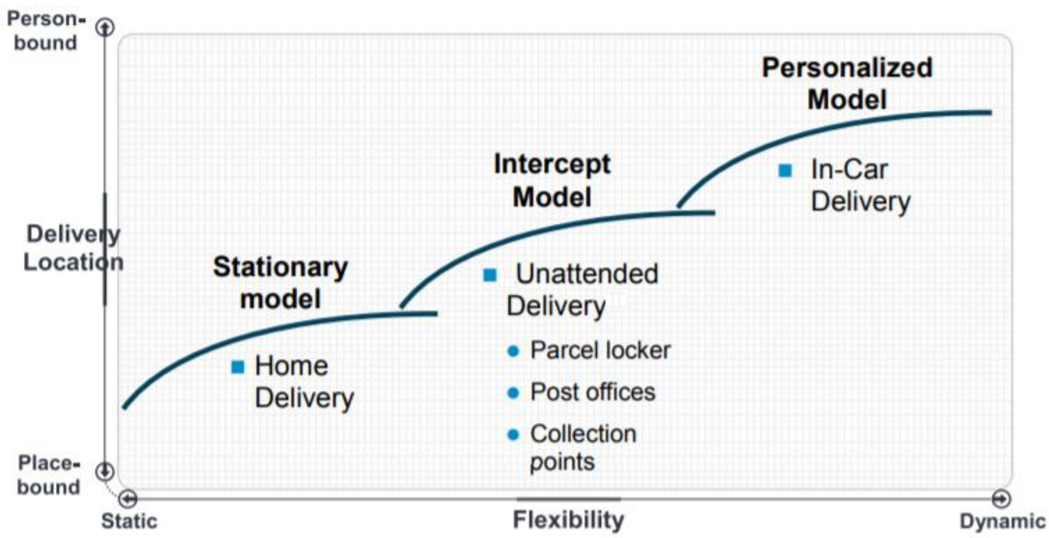


Figure 8 Classification of delivery methods

source: Hepp (2018) [71]

Home delivery has time limitations, poor quality home delivery services, and a lack of diversity of delivery alternatives. Because of the long delivery time per client, inefficient home delivery limits expansion. Last mile delivery modes have different characteristics and delivery efficiencies [6]. To save money and assure timely delivery to clients, the supplier must choose a suitable delivery option. Furthermore, delivery mode selection is sometimes influenced by time frames, neighborhood density, and the number of orders per day, among other factors. Moroz and Polkowski (2016) [72] describe the last mile delivery modes as follows:

1) Home deliveries

In e-commerce, many of the online purchases are home delivered. The online shop may deliver the product on its own or use the 3rd party service. Home delivery can be divided into 2 cases as below.

Attended home delivery

Attended home delivery (AHD) is a widely used and popular mode of delivery. The parcel is delivered to the customer's doorstep by an LMD supplier. Due to the delivery of perishable or bulky items and/or safety considerations that need customers to be at home during service execution, she must wait for the client to sign and accept the parcel [74]. The AHD supplier can meet with the customers in person; however, this is a time-consuming process [6].

Gevaers et al. (2009) [70] observe five main problems with attended home deliveries: (1) the high degree of failed deliveries; (2) The high degree of 'empty running'; (3) issues with security; (4) the critical mass for generating an efficient route is sometimes too small for some regions; and (5) the majority of door-to-door deliveries are made by small vans. Each problem creates extra costs, extra kilometers, and extra emissions. Moreover, the carbon footprint per kg created by a small van is higher than that of transport by a larger truck.

Punakivi and Tanskanen (2002) [75] suggest that the most expensive service model among the ones generally used is attended delivery on the following day in one-hour delivery windows. The attended home delivery concept is a vehicle routing planning with time window [76]. As a result, AHD has the lowest first-time hit rate of all the modes. As AHD services have a relatively high cost, they require an optimization strategy in their operations [74]. According to Punakivi and Saranen (2001) [69], the transportation expenses of attended home deliveries with 1-hour time windows are 2.7 times greater than unattended deliveries.

To provide a high service level and to avoid AHD failures as much as possible, an AHD provider should contact the customer in order to set the delivery time windows before dispatching the delivery vehicle. The time windows offering does not only impact customer satisfaction, but also the expected delivery efficiency [77, 78]. Therefore, both the delivery provider and the customer must agree on a time window, which ideally is rather short, during which delivery is guaranteed. Typically, a Capacitated Vehicle Routing Problem with Time Windows forms the underlying optimization problem of the AHD delivery [79]. Moreover, changing the destination address, where the consignee should be present, could increase the delivery efficiency. Unattended reception allows a greater operating efficiency without influencing the service level [80].

Unattended home delivery

Unattended home delivery (UAHD) could offer a choice of solutions to the 'not at home' and 'time windows' problems. As the concept of UAHD, the parcels are delivered on someone's doorstep, in their garden shed, mailbox, or neighbor [5, 81]. The UAHD process is shown in Figure 9.

As compared to AHD mode, in terms of security, delivery time, and failed first time delivery rate, UAHD mode could be very successful in situations that AHD fails but customers will concern about security if parcels are a perishable or high value [13].

McKinnon and Tallam (2003) [82] investigates UAHD's safe choices, such as home security access systems, integrated boxes, exterior boxes, mobile receiving boxes, workplace collection, and collecting point. There is evidence that these choices increase home delivery to accommodate customers' hectic schedules while keeping the LMD supplier viable. From the standpoint of cost effectiveness in home delivery transportation, unattended reception is the best service model. It enables for increased operational efficiency without compromising service quality.

In terms of delivery time, UAHD is a more efficient mode than AHD because UAHD does not concern the limit of delivery time [78]. UAHD can be modeled as an open time window problem. It leads to better vehicle routing optimization in terms of transport cost [76]. Moreover, it reduces the failed first-time delivery rate and saves the delivery time.

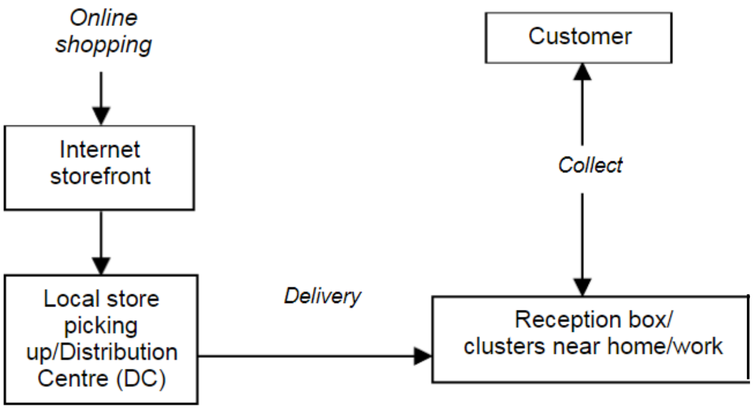
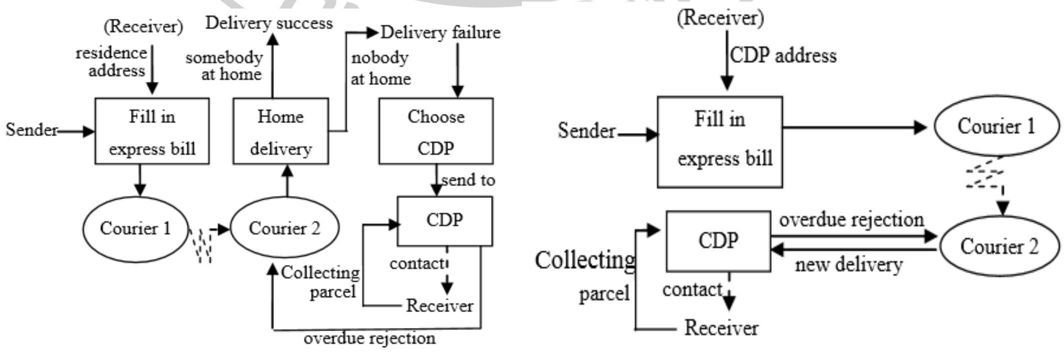


Figure 9 Unattended home delivery process

source: Xu et al. (2008) [81]

2) Collection points

Currently, a delivery option that has become prevalent is the collection point or collection-and-delivery points (CDPs) [83]. CDPs are a rapidly expanding solution. CDP deliveries are less expensive than home deliveries, and there is no chance of missed delivery. These options are supplied by online shops as well as shippers' firms and transportation providers [84]. Xu et al. (2011) [85] design CDP systems for two scenarios in foreign countries: serving as a backup for home delivery (Figure 10a) and delivering directly to a CDP (Figure 10b).



(a) for failure of home delivery (b) delivery to CDP directly

Figure 10 Delivery process in CDP system

source: Xu et al. (2011) [85]

CDPs delivery increases the service level. The main advantage is that all of the packages are delivered. This arrangement is beneficial for both carriers and local companies who profit from the collaboration in terms of advertising and possible customer growth [86, 87]. In addition, web shops would promote this mode by charging no or less transport fee when people pick up their goods at a pickup station instead of delivery to the home. CDP delivery is usually a consolidated delivery, therefore this is more cost-efficient [88]. Transport distance and time cost for final delivery have not been only reduced, but customers also have more locations and time slots to choose from for collecting their parcels. Customer can choose any CDPs to visit in accordance with daily trip chain [89]. Moroz and Polkowski (2016) [72] classified Collection and Delivery Points (CDPs) as manned or unmanned as follows;

Manned Collection point

Manned Collection point (service point) or attended is a built-in shop-in-shop concept, where customers can pay, collect, and return goods. Service points are located near residential locations such as schools, local stores, and local hospitals, or at customers' route areas such as railway stations, petrol stations, etc. [58, 90, 91]. The service point is only open during the shop's operating hours, which are frequently closed around lunchtime, on weekends, or during holidays. Customers and drivers must wait for service at a service station [87]. From the customer perspective, receiving parcels at a service point may be less convenient than at home. The cost savings may translate into lower shipment tariffs. Moreover, some customers are avoiding the need to synchronize with the courier, which may be desirable [92].

- **Post office**

The post office is a traditional local service point mode. The post office provides three main services: (1) ordinal postal services such as letters and parcels; (2) postal savings; and (3) postal life insurance. The operating costs of each are covers by its user fees [93].

The parcels that did not make it through the first delivery attempt will be returned to the post office. As a result, clients may come to the local post office to pick up their packages. In addition, a customer can choose to pick up their parcels at the post office [94]. In addition, the post office provides a location where customers may pay for, pick up, and return packages [95]. This mode was grouped with the reception box mode and CDPs by Gevaers et al. (2011) [5]. Furthermore, local post offices are commonly chosen as CDPs, and a large number of individuals will walk to their CDPs [13, 94].

In terms of efficiency, the post office is comparable to the CDPs mode. It is face-to-face service. A customer may pickups her parcel at a neighbor post office. As a result, she may expect a short distance for picking up.

Unmanned Collection point

Unmanned Collection point (locker point), or unattended point, is a shared reception box that is installed in a public area. Goods are delivered to the unattended point, where customers can pay, collect, and return goods. Locker point has several limitations on parcels. One parcel per delivery is allowed, and the parcel cannot exceed the size of the locker. Because of the driver's software, some customers believe the parcel lockers are difficult to use [87].

- Reception boxes

Reception boxes also called parcel locker or smart locker solves unattended delivery problems and also reduces home delivery costs for providers [96]. Customers have the option of using reception boxes (RB). As a result, it helps both customers and delivery provider. Furthermore, RB is a development of the post offices [71]. It enables the commercialization of previously unutilized places, the creation of new social gatherings, and the use of lockers for advertising and sustainable development [97]. As shown in Figure 11, reception boxes vary in size, placement, and whether they are normal or temperature-controlled lockers.

The topic of constructing a smart locker network for B2C delivery was investigated by Deutsch and Golany (2018) [98]. To optimize profitability, they are employing an impaired facility location model to determine the ideal number, position, and size of smart lockers.

To save money on delivery, companies like Streamline in the United States and SOK in Finland employ receiving boxes. Groceries are delivered to homeowners in sealed refrigerated cartons. Customers can become independent of delivery schedules by employing reception boxes, which allow them to receive items without having to be at home. Kämäräinen et al. (2001) [96] found that the reception boxes helped companies save money on residential delivery.

According to a study from Poland [99], the reasons for locker use include the low cost of delivery, their availability, and their location. The most significant requirements for locker users in terms of location are that they be close to home or on their way to work, and that parking is accessible. The position of the locker is a key component in maximizing the potential of these systems. The objective is to integrate travel from home to work with transit to the locker. As a result, supermarkets, retail malls, service stations, pedestrian zones, and other similar locations are ideal.

Torrentellè et al. (2012) [100] investigate parcel lockers' advantages, disadvantages, and possibilities. In terms of advantages, the authors highlight the possibility to accept shipments whenever clients want them, as well as cheaper delivery costs and shorter delivery distances. The researchers' emphasis on essential customer moves is a flaw since certain customers may be unable to accept these changes. There are advantages such as easy system exporting to all nations and increased efficiency for shipping company, albeit it should be emphasized that the potential for an infinite rise in the number of locker sites in the city, as seen in Table 2, is due to the continual expansion of e-commerce. There are three different types of receiving boxes [6, 99]:

Shared reception boxes, also known as collection and delivery points (CDP), can be found near petrol stations, in bus or subway stations, or anywhere else the store considers customers would find them useful [75].

The parcels are delivered to closed receiving boxes located in public spaces. Multiple customers are able to utilize the same reception box. The customer will be given the box number as well as the code to open the box. A shared reception box allows many orders to be dropped off at once, reducing delivery time per client. Researchers found that a shared reception box is very successful [75, 96].

Own reception boxes: The customer's own reception box is located outside of her home, such as in the garage or front yard, and she must set the passcode to access it. The time windows are unaffected by having your own receiving box. The company has the ability to deliver packages at any time. Due to the different places of customers, this type of LMD mode has a poor efficiency [96]. In contrast, the own reception box is convenient for customers.

Delivery boxes: A delivery box is a safe, insulated box with a locking mechanism [69]. The box owner is the LMD provider. At the customer's site, they will be temporarily fastened to a fixed locking device on the wall in a secure area. The packages will be taken from the delivery box by the customers. The LMD supplier will then retrieve and reuse the empty delivery box. The delivery boxes will be recovered or reused for future deliveries [99]. The customers will find the delivery box as well as the personal reception box mode to be handy. The distance to deliver and receive items is affected by the location of receiving boxes. Furthermore, the reception box is located in public areas. It’s quite easy to steal.

Furthermore, there are locker-banks, which are similar to collection points but are located in apartment towers, offices, car parks, train stations, and other locations rather than at each customer's residence. To maximize utilization, customers are not normally assigned to their own locker (lockers have electronic locks with a variable opening code, and can be used for different customers on different days). They might be allocated to a single delivery business or shared by a number of them. Customers may receive a message informing them of the arrival of their package, as well as the box number and location, as well as the code to unlock the box. Customers must complete the final part of the journey while using a locker bank. On the other hand, Locker-banks are strategically placed so that customers’ travels are as short as possible.

The home deliveries cost is compare to reception boxes. It saves between 40 and 60% on logistical expenses [69, 96]. The security implications were assessed by McKinnon and Tallam (2003) [82]. “Smart tagging” is a solution to security issues. Reception boxes can save money on logistics as well as reduce greenhouse gas emission [101]. According to Lemke et al. (2016) [102] parcel lockers will become more popular in the next few years, and parcel lockers located near tram/bus stations will reduce automobile use. As a result, considering the environmental effect of the delivery system, the use of parcel lockers becomes an appealing option.

Currently, parcel lockers are found in places with a higher population density but a better employment-to-population ratio. Lockers are more common in areas where there are more Internet-connected families. Furthermore, parcel lockers have a higher activation cost, which includes the cost of the structure, installation commissioning, land tax, and ICT maintenance system, but they are useful in the case of break-even volume deliveries, which ensure economies of scale. On the other hand, cost is not confined to the activation phase [87].

Table 2 SWOT analysis of parcel lockers

Strengths	Weaknesses
- Customers have the possibility to access to their packages 7 days per week and 24 hours per day - Customers are informed of deliveries via SMS or e-mail - Reduction of freight transport trip km in comparison with attended delivery, thereby reduction of emissions, noise and energy consumption - Low delivery costs	- Parcel lockers are a private action, and the public authorities do not have information about the impacts - The final leg of the journey have to be made by the customers
Opportunities	**Threats**
- Efficiency gains for delivery providers - Transferable to other cites	- E-commerce is expected to grow further in the future, and this can cause a higher freight mileage due to high number of parcel lockers

source: Torrentellé et al. (2012) [100]

Figure 11 Reception box or parcel locker

In compared to the locker point mode, the service point mode is more customer-friendly since it gives face-to-face assistance. The service point mode, on the other hand, has limited office hours. In terms of security and risk, the shipments are at a high risk at the locker point. As a result, the payment option is not available in this mode [91]. The service point mode is less costly, has lower activation expenses than the locker point mode, and just requires the signing of a cooperation agreement with the retailers. However, they may conceal additional indirect expenses (such as delays, lines, and closure days) [87]. Table 3 shows the CDP comparisons offered by Xu et al. (2011) [85].

In conclusion, CDPs' operations have significantly enhanced LMD since they were able to provide customers with a range of service alternatives and flexible office hours [6]. Furthermore, it greatly lowers the failure rate of first-time home deliveries [103]. Browne (2001) [90] stated that CDPs were a potential method of delivering tiny goods, but that implementing an unattended point system would be challenging.

Table 3 Comparisons of service point and locker point

Topic	Type of CDPs	
	Service point mode	Locker point mode
Opening hours	–	+
Security	+	–
Payment option	+	–
Storage possibility	+	–
Ease use	+	–
Time needed	–	+
Anonymity	–	–
Loss of parcels	+	–

Table 3 (continued) Comparisons of service point and locker point

Topic	Type of CDPs	
	Service point mode	Locker point mode
Face-to-face service	+	–
Returned parcels	+	–

source: Tiwapat et al. (2018) [1]

Tiwapat et al. (2018) [1] compare of LMD modes that are shown in Table 4. The modes are compared in perspectives of customers, delivery providers, and stakeholders. The signs in the table are "+" which means positive value, "–" which means negative value, and "0" which means neutral value. Please noted that "stakeholders" means merchants, delivery providers, customers, and all people in the community.

Table 4 Comparisons of last mile delivery modes

Topic	In perspectives of	Modes							
		Reception Box			CDPs		Post office	AHD	UAHD
		Shared	Own	Delivery box	Service point	Locker point			
Opening hours	Customers	+	+	+	–	+	–	–	–
Convenience	Customer	–	+	+	0	–	0	+	0
Security	Stakeholders	–	0	0	+	–	+	+	–
Failed first-time delivery	Delivery providers	+	+	+	+	+	0	–	+
Delivery cost	Delivery providers	+	+	–	+	+	–	–	+
Sustainability	Stakeholders	+	+	0	+	+	0	–	+

2.2.3 Sustainability

People are increasingly concerned about protecting the globe due to global warming, which has consequences for all mankind, animals, and the environment. Greenhouse gas (GHG) is the cause of global warming. It is caused by human activities. Some examples are the burning of coal and fuel, chemicals containing GHG, and forest destruction. Therefore, we have to reduce the cause of global warming by decreasing the use of fuel and using it efficiently.

The largest share of GHG emissions is transportation activity. It is not only generating CO2, but also NOx, PM10, SO2, noise, traffic congestion, and accidents, with relevant direct consequences on human health and urban life quality [104]. GHG is emitted from transportation primarily come from burning fossil fuel. The freight transport of parcels is road transportation such as vans, trucks, and motorbikes. LMD freight traffic impacts environmental sustainability because it increases carbon emissions, pollutions, and congestions [3].

In the last mile delivery, the majority of GHG emission relates to failed first-time delivery. The share of GHG emission is increased after the proportion of failed first-time delivery increases [12]. In addition, CO2 from the second time delivery has increased the emissions per drop between 9% and 75% [13]. Song et al. (2009)[94] found that the rates of failed first-time deliveries are between 12% and 60% of the total number of deliveries. Therefore, the choices of delivery mode are critical factors to reduce GHG emission. Song et al. (2013) [12] suggested that the CDPs can reduce the environmental impacts of failed home deliveries. A CDP network would reduce the overall GHG emissions most effectively when: 1) 30% or more householders who experienced a failed first-time home delivery travel to the carrier's depot to retrieve goods; 2) The proportion of failed first-time home deliveries is significant; 3) post offices are used as CDPs.

In the future, delivery trucks and vans would be more used. It would make home delivery more sustainable when home deliveries are organized on a local level as with city logistics for two reasons: (1) to have a more consolidated delivery, (2) to make use of more environmentally friendly vehicles [88]. In addition, emissions are affected not only by the number of kilometers driven, but also by the type of fuel used, the engine technology used (vehicle type), as well as the vehicle's speed, load, and driving behavior [105]. Therefore, as the fast pacing of technology development, the modes of last mile delivery will be increased. There will be many choices of delivery modes for customers. The wellbeing of mankind will be better than before. Finally, reducing greenhouse gas is a good way to save the world.

2.2.4 Trends

Last mile delivery is a crucial competitive advantage. Providers of LMDs must continually improve to improve their delivery efficiency on a regular basis. To expand their operations, the providers have implemented unique concepts and technology. The Internet of Things (IoT) and Artificial Intelligence (AI) are the technologies of this era. Many businesses have included IoT or AI into the creation of LMD. As a result, this section recommends the following trends for integrating IoT and AI into last mile delivery [1]:

1) Mobile Application: there are mobile applications that can accurately track your cargo status using GPS technology on the cloud for accurate location information and other tracking information in terms of delivery [3]. It allows logistics companies to organize and send information to customers. As a result, the shipment time could be correctly forecast.

2) Smart reception box: the temperature of the smart reception box is regulated by an RFID smart tag [106]. The delivery providers can use a wireless connection to read and write data on the smart tag in real time, from any location.

3) Crowdsourcing: customers' friends or acquaintances on social media are used to crowdsource last mile deliveries. Friends from social media help reduce delivery costs and overall emissions while assuring fast and dependable delivery [107].

4) Autonomous unmanned aerial vehicles (AUAV): drones are another name for it [108]. In recent years, drone delivery has been a big subject in the market. Unmanned

Aerial Vehicles, or UAVs, are gaining popularity as a delivery service for small products in metropolitan areas [109]. The drones lift off and fly to their destinations fully independently, guided by GPS.

5) Autonomous unmanned ground vehicles (AUGV): it's also known as delivery robots, and they're subject to different regulations than traditional delivery trucks. A delivery robot has been created in recent years. One of these ideas is based on a truck-launched autonomous delivery robot. A truck pulls toward the city center after loading items in the central warehouse. Small autonomous robots are on board, each of which may be filled with goods and sent off the truck to deliver a single client. It's also known as delivery. After that, the self-driving robots deliver packages to clients. Return to a robot depot in the city center after completing the delivery. This allows deliveries to be done at a time period that the client specifies. Small packages, such as groceries, medication, food, or gifts, can be delivered by delivery robots [110, 111].

2.3 Technique for Order Preference by Similarity to an Ideal Solution

2.3.1 Introduction

Multi-criteria decision making (MCDM) is the process of selecting the best alternative from a restricted number of options depending on many, often conflicting criteria. There are two different types of MCDM problems. One set of issues is the traditional MCDM set, in which the ratings and weights of criteria are assessed in precise numbers. Another set of problems is the many criteria decision-making set, in which the ratings and weights of criteria based on partial data, imprecision, subjective judgment, and ambiguity are frequently described as interval numbers, linguistic phrases, fuzzy numbers, or intuitive fuzzy numbers.

In research, industry, government, and engineering, multi-conditional decision making (MCDM) is one of the most extensively utilized decision procedures. By making decision-making procedures explicit, logical, and effective, MCDM approaches can assist to enhance the quality of decision-making. In a decision-making process, choices are made based on hierarchical comparisons of various possibilities, which are frequently based on conflicting criteria.

One of the most popular and widely applied MCDM methods is Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). In 1981, the TOPSIS method was first developed by Hwang and Yoon. As depicted in Figure 12, the chosen alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. The benefit criteria are maximized while the cost criteria are minimized in the positive-ideal solution. The cost criteria are maximized while the benefit criteria are minimized in the negative-ideal solution. As a result, the positive-ideal solution is made composed of all the best possible criteria values, whereas the negative-ideal solution is made up of all the worst possible criteria values [112]. The classical TOPSIS technique is based on attribute information from the decision maker and numerical data; the solution is targeted at assessing, prioritizing, and choosing, using weights as the only subjective input.

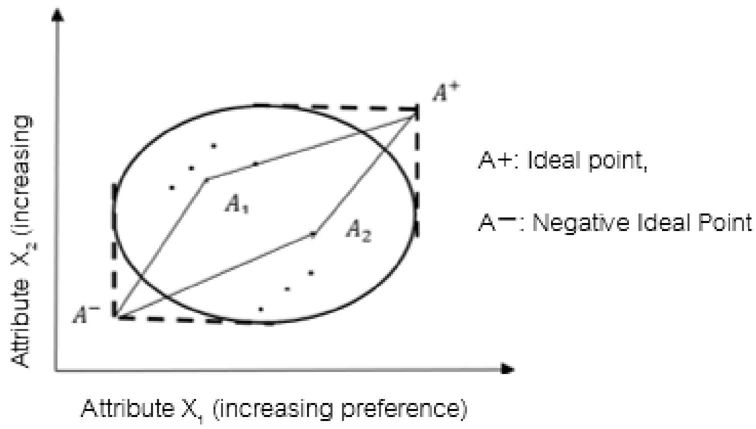


Figure 12 Basic concept of TOPSIS method

source: Balioti et al. (2018) [113]

2.3.2 The classical TOPSIS method for a single decision making

The idea of classical TOPSIS procedure can be expressed in a series of following steps [112, 114, 115]:

Let us consider the decision matrix D, which consists of alternatives and criteria, described by:

$$D = \begin{array}{c} \\ A_1 \\ A_i \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_j & C_n \end{array} \\ \begin{pmatrix} x_{11} & x_{1j} & x_{1n} \\ x_{i1} & \ddots & x_{in} \\ x_{m1} & x_{mj} & x_{mn} \end{pmatrix} \end{array} \qquad (1)$$

where $A_1, A_2, \ldots, A_m$ are variable alternatives, and $C_1, C_2, \ldots, C_n$ are criteria, X_{ij} indicates the rating of the alternative A_i according to C_j. The weight vector $W = (w_1, w_2, \ldots, w_n)$ is composed of the individual weights $w_j = (j = 1, \ldots, n)$ for each criterion C_j satisfying $\sum_{j=1}^{n} w_j = 1$.

Step 1: Construct a Normalized Decision Matrix. To convert the multiple attribute dimensions into non-dimensional attributes, allowing for attribute comparison. The normalized decision matrix $R = \left[r_{ij} \right]_{m \times n}$ with $i = 1, \ldots, m$ and $j = 1, \ldots, n$. The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum X_{ij}^2}} \qquad (2)$$

Step 2: Construct the Weighted Normalized Decision Matrix. After normalization, we calculate the weighted normalized decision matrix $V = \left[v_{ij} \right]_{m \times n}$ with $i = 1, \ldots, m$ and $j = 1, \ldots, n$ by multiplying the normalized decision matrix by its associated weights. The weighted normalized value v_{ij} is calculated as:

$$V_{ij} = w_i r_{ij} \quad \text{with } i = 1, \ldots, m \text{ and } j = 1, \ldots, n \qquad (3)$$

Step 3: Identify the positive ideal solutions A^+ (benefits) and negative ideal solutions A^- (costs) as follows:

$$A^{+} = (A_1^{+}, A_2^{+}, \ldots, A_m^{+}) \tag{4}$$

$$A^{-} = (A_1^{-}, A_2^{-}, \ldots, A_m^{-}) \tag{5}$$

where

$$A_j^{+} = \left\{ \left(\max_i v_{ij}, j \in J_1 \right), \left(\min_i v_{ij}, j \in J_2 \right) \right\} \tag{6}$$

$$A_j^{-} = \left\{ \left(\min_i v_{ij}, j \in J_1 \right), \left(\max_i v_{ij}, j \in J_2 \right) \right\} \tag{7}$$

Where J_1 and J_2 represent the criteria benefit and cost, respectively.

Step 4: Calculate the separation measure from the positive ideal solution A^{+} (benefits) and the negative ideal solution A^{-} of each alternative A_j, respectively as follows:

$$d^{*} = \sqrt{\sum \left(v_{Aj} - v_j^{+} \right)^2} \text{ with } i = 1, \ldots, m \tag{8}$$

$$d^{-} = \sqrt{\sum \left(v_{Aj} - v_j^{-} \right)^2} \text{ with } i = 1, \ldots, m \tag{9}$$

Step 5: Calculate the relative closeness C_i for each alternative A_i with respect to positive ideal solution as given by:

$$C_i = \frac{d_i^{-}}{\left(d_i^{*} + d_i^{-} \right)} \text{ with } i = 1, \ldots, m \tag{10}$$

$$C_i^{*} = \begin{cases} 1 \text{ if } A_i = A^{+} \\ 0 \text{ if } A_i = A^{-} \end{cases}$$

Step 6: Rank the alternatives according to the relative closeness. The best alternatives are those that have higher value C_i and therefore should be chosen because they are closer to the positive ideal solution.

2.3.3 The classical TOPSIS method for group decision making

In this part, the detailed TOPSIS procedure for group decision making is explained, it is based on Shih et al. (2017)[116] as follow:

Let $X^k = (x_{ij}^k)$ be a decision matrix, $W^k = \left[w_1^k, w_2^k, \ldots, w_n^k \right]$ weight vector for $k-$ decision maker or expert, where $x_{ij}^k \in R,\ w_j^k \in R,\ w_1^k + w_2^k + \ldots + w_n^k = 1$ for $k = 1, 2, \ldots, K$.

Step 1: Calculate the normalized decision matrix for each decision maker. In this step some of the earlier described methods of normalization can be used.

$$r_{ij}^k = \frac{x_{ij}^k}{\sqrt{\sum_{i=1}^{m} (x_{ij}^k)^2}} \tag{11}$$

Step 2: Determine the positive ideal and negative ideal solutions for each decision maker.

$$A^{k+} = \{r_1^{k+}, r_2^{k+}, \ldots, r_n^{k+}\} \tag{12}$$

$$A^{k-} = \{r_1^{k-}, r_2^{k-}, \ldots, r_n^{k-}\} \tag{13}$$

where

$$A_j^{k+} = \left\{ \left(\max_i \left(r_{ij}^k \right), j \in J_1 \right), \left(\min_i \left(r_{ij}^k \right), j \in J_2 \right) \right\} \tag{14}$$

$$A_j^{k-} = \left\{ \left(\min_i \left(r_{ij}^k \right), j \in J_1 \right), \left(\max_i \left(r_{ij}^k \right), j \in J_2 \right) \right\} \tag{15}$$

Where J_1 and J_2 represent the criteria benefit and cost, respectively.

Step 3: Calculate the separation measure for individuals.

The separation of i^{th} alternative A_i from the positive ideal solution A^{k+} for each $k-$ decision maker is given as

$$d_i^{k+} = \left(\sum_{j-1}^{m} w_j^k (r_{ij}^k - r_j^{k+})^p\right)^{\frac{1}{p}} \text{ with } i = 1, \ldots, m \tag{16}$$

The separation of i^{th} alternative A_i from the positive ideal solution A^{k-} for each $k-$ decision maker is given as

$$d_i^{k-} = (\sum_{j-1}^{m} w_j^k (r_{ij}^k - r_j^{k-})^p)^{\frac{1}{p}} \text{ with } i = 1, \ldots, m \tag{17}$$

where $p \geq 1$, for $p = 2$ we have the Euclidean metric.

Step 4: Calculate the separation measure for the group.

The aggregation for measure for the group measures of the positive ideal d_i^{*+} and negative ideal solution d_i^{*+} for the i^{th} alternative A_i is given by one of the operators:

arithmetic mean:

$$d_i^{*+} = \frac{\sum_{k=1}^{K} d_i^{k+}}{K} \text{ and } d_i^{*-} = \frac{\sum_{k=1}^{K} d_i^{k-}}{K} \tag{18}$$

or

geometric mean:

$$d_i^{*+} = \sqrt[K]{\prod_{k=1}^{K} d_i^{k+}} \text{ and } d_i^{*-} = \sqrt[K]{\prod_{k=1}^{K} d_i^{k-}} \tag{19}$$

Step 5: Calculate the relative closeness to the positive ideal solution.

$$C_i = \frac{d_i^-}{\left(d_i^* + d_i^-\right)} \text{ with } i = 1, \ldots, m \tag{20}$$

where $0 \leq C_i \leq 1$. The larger the index value, the better the evaluation of the alternative.

Step 6: Rank the alternatives according to the relative closeness. The best alternatives are those that have higher value C_i and therefore should be chosen because they are closer to the positive ideal solution.

2.3.4 Fuzzy TOPSIS

TOPSIS has been extended to fuzzy TOPSIS. Due to the classical TOPSIS method, which represents crisp values of the performance judgments of alternatives. It is unsuitable for real world applications [117, 118]. Fuzzy models based on triangular fuzzy numbers have been shown to be particularly useful in handling decision-making issues with imperfect information.

1) Fuzzy set and fuzzy number

Zadeh (1965) [119] presented fuzzy set theory, which is an extension of ordinary set theory for dealing with uncertainty and imprecision associated with information. The preliminary fuzzy set theory used for the development of the fuzzy TOPSIS method as follows:

Definition 1. (Fuzzy set) In a universe of discourse X a fuzzy set $\tilde{A}$ is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associate each element x in X , a real number in the interval $[0,1]$. Membership function $\mu_{\tilde{A}}(x)$ is termed as the grade of membership of x in $\tilde{A}$ [119].

Definition 2. (Fuzzy number) A fuzzy number is a quantity whose value is imprecise, rather than exact as is the case with “ordinary” (single-valued) numbers. Any fuzzy number may be thought of as a function whose domain is a certain set of numbers, generally the set of real numbers, and whose range is the range of non-negative real numbers between 0 and 1. Each numerical value in the domain is assigned a specific “degree of membership,” with 0 being the lowest possible grade and 1 being the highest [120]. A fuzzy number $\tilde{a}$ is defined by a triplet $\tilde{a}=(a,\ b,\ c)$ as shown in figure 13. The membership function is defined by:

$$\mu_{\tilde{A}}(x)=\begin{cases}0, & x<a\\ \dfrac{x-a}{b-a}, & a\le x\le b\\ \dfrac{c-x}{c-b}, & \mathrm{b}\le x\le c\\ 0, & x>c\end{cases} \tag{21}$$

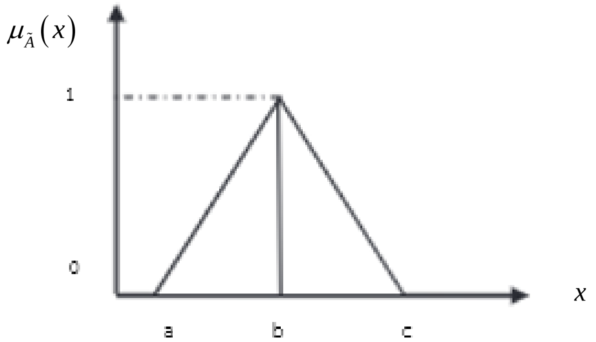


Figure 13 The membership function of a triangular fuzzy number

Definition 3. Let $\tilde{a}(a_1, b_1, c_1)$ and $\tilde{b}(a_2, b_2, c_2)$ be two triangular fuzzy numbers, then the operation with these fuzzy numbers are defined as follows:

$$\tilde{a} \oplus \tilde{b} = (a_1 + a_2,\ b_1 + b_2,\ c_1 + c_2) \quad (22)$$

$$\tilde{a} \ominus \tilde{b} = (a_1 - a_2,\ b_1 - b_2,\ c_1 - c_2) \quad (23)$$

$$\tilde{a} \otimes \tilde{b} = (a_1 \times a_2,\ b_1 \times b_2,\ c_1 \times c_2) \quad (24)$$

$$\tilde{a} \oslash \tilde{b} = (a_1 \div a_2,\ b_1 \div b_2,\ c_1 \div c_2) \quad (25)$$

$$k\tilde{a} = (k \times a_1,\ k \times b_1,\ k \times c_1) \quad (26)$$

Definition 4. Be two triangular fuzzy numbers $\tilde{a}(a_1, b_1, c_1)$ and $\tilde{b}(a_2, b_2, c_2)$ then the distance between them is calculated by:

$$d(\tilde{a},\tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2\right]} \quad (27)$$

2) The fuzzy TOPSIS

Chen (2000) propose the fuzzy TOPSIS to solve the real world problems under fuzzy environment. The mathematics concept of fuzzy TOPSIS can be described as follows [120-123]:

Step 1. Choose the linguistic ratings for criteria and alternatives with respect to criteria. The linguistic term is a very helpful concept to assess alternatives under fuzzy environment. The fuzzy linguistic terms and their corresponding values proposed by Yazdani-Chamzini and Yakhchali

(2012)[123] is shown in Table 5 and Table 6. Figure 14 presents the relationship between linguistic variables and the membership functions of preference rating

Table 5 The fuzzy linguistic terms for evaluation criteria

Linguistic	Fuzzy Number	TFNs (l, m, u)	Triangular fuzzy reciprocal scale
Equally important	$\tilde{1}$	(1, 1, 1)	(1, 1, 1)
Moderately more important	$\tilde{3}$	(1, 3, 5)	(1/5,1/3,1)
Strongly more important	$\tilde{5}$	(3, 5, 7)	(1/7,1/5,1/3)
Very strongly more important	$\tilde{7}$	(5, 7, 9)	(1/9,1/7,1/5)
Extremely more important	$\tilde{9}$	(7, 9, 9)	(1/9,1/9,1/7)

Table 6 The fuzzy linguistic terms for alternative

Linguistic	Corresponding triangular fuzzy number
Very poor (VP)	(0, 1, 3)
Poor (P)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Good (G)	(5, 7, 9)
Very good (VG)	(7, 9, 10)

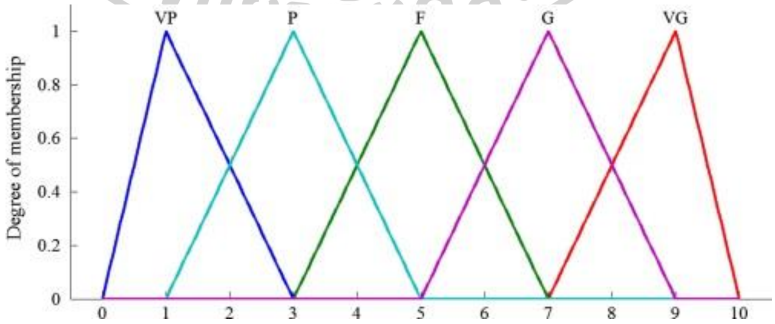


Figure 14 The relationship between linguistic variables and the membership functions of preference rating

source: Yazdani-Chamzini and Yakhchali (2012)[123]

Step 2. Construct the fuzzy decision matrix. The fuzzy decision matrix will be obtained with m rows and n columns, where n is the number of criteria and m is the number of alternatives. The matrix is as follows:

$$\begin{array}{cc} & \begin{array}{ccc} C_1 & C_j & C_n \end{array} \\ \tilde{D} = \begin{array}{c} A_1 \\ A_i \\ A_m \end{array} & \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{1j} & \tilde{x}_{1n} \\ \tilde{x}_{i1} & \ddots & \tilde{x}_{in} \\ \tilde{x}_{m1} & \tilde{x}_{mj} & \tilde{x}_{mn} \end{pmatrix} \end{array} \quad (28)$$

where $\tilde{x}_{ij}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$ is linguistic triangular fuzzy number and $w_j, j = 1, 2, \ldots, n$ is non-fuzzy numbers.

Note that $\tilde{x}_{ij}$ is the performance rating of the i^{th} alternative, A_i, with respect to the j^{th} criterion, c_j and w_j represents the weight of the j^{th} criterion, c_j.

Step 3. The normalization of the fuzzy decision matrix is accomplished using a linear scale transformation. The different criteria scales are converted into a comparable scale, then

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m \times n} \text{ with } i = 1, \ldots, m \text{ and } j = 1, \ldots, n \quad (29)$$

where, for fuzzy data denoted by triangular fuzzy number as $\left(a_{ij}, b_{ij}, c_{ij}\right)$, the normalized values for benefit-related criteria and

cost-related criteria are calculated as follows:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right), \forall_j \in B, \quad (30)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{a_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{c_{ij}}\right), \forall_j \in C, \quad (31)$$

$c_j^+ = \max_i c_{ij} \text{ if } \forall_j \in B,$

$a_j^- = \min_i a_{ij} \text{ if } \forall_j \in C,$

where B = set of benefit criteria and C = set of cost criteria.

Step 4. Calculate the weighted normalized fuzzy decision matrix. The weighted normalized value v_{ij} is calculated as follows:

$$\tilde{V} = \left[\tilde{v}_{ij}\right] m \times n, i = 1, 2, \ldots, m \text{ and } j = 1, \ldots, n \tag{32}$$

where

$$\tilde{V} = \tilde{r}_{ij} \otimes \tilde{w}_{ij}, i = 1, 2, \ldots, m \text{ and } j = 1, \ldots, n \tag{33}$$

Step 5. Determine the positive ideal solution and the negative ideal solution. Because the positive triangular fuzzy numbers are included in the interval [0,1], fuzzy positive-ideal solution (FPIS A+) and the fuzzy negative-ideal solution (FNIS A-) can be defined as

$$A^{+} = \left(\tilde{v}_1^{+}, \tilde{v}_2^{+}, \ldots \tilde{v}_n^{+}\right) = \left\{\left(\max_i v_{ij}\right) \middle| i = 1, 2, \ldots, m; j = 1, 2, \ldots, n\right\} \tag{34}$$

$$A^{-} = \left(\tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots \tilde{v}_n^{-}\right) = \left\{\left(\min_i v_{ij}\right) \middle| i = 1, 2, \ldots, m; j = 1, 2, \ldots, n\right\} \tag{35}$$

where $\tilde{v}_j^{+} = (1, 1, 1)$ and $\tilde{v}_j^{-} = (0, 0, 0)$, $j = 1, 2, \ldots, n$

Step 6. Calculate the distances of each initial alternative to FPIS A+ and FNIS A-. Each alternative's distance from a fuzzy positive ideal reference point and a fuzzy negative ideal reference point may be calculated as follows.

$$d_i^{+} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_{ij}^{+}),\ i = 1, 2, \ldots, m \tag{36}$$

$$d_i^{-} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_{ij}^{-}),\ i = 1, 2, \ldots, m \tag{37}$$

where the distance measurement between two fuzzy number can calculated by equation (27).

Noted that d_i^{+} represents the distance of alternative A_i from FPIS A+, and d_i^{-} represents the distance of alternative A_i from FNIS A-.

Step 7. Calculate the closeness coefficient. Calculate the closeness coefficient (CC) of each alternative as

$$CC_i = \frac{d_i^-}{\left(d_i^+ + d_i^-\right)} \text{ with } i = 1, \ldots, m \quad (38)$$

Step 8. Rank preference order. The ranking of the alternatives can be determined according to the closeness coefficient in descending order.

3) The Fuzzy TOPSIS for group decision making

The process of acquiring a solution or solutions for a problem based on information provided by several decision makers is known as group decision making. When the DMs' understanding of the analyzed subject is incomplete, or when they are working in a fuzzy environment [124].

Step 1. Choose the linguistic ratings for criteria and alternatives with respect to criteria.

Step 2. Construct the fuzzy decision matrix. The fuzzy decision matrix will be obtained with m rows and n columns, where n is the number of criteria and m is the number of alternatives. The matrix is equation (28) where $\tilde{x}_{ij}$ is calculated as follows:

$$\tilde{x}_{ij} = \frac{1}{k}\left(\tilde{x}_{ij}^1 \oplus \ldots \oplus \tilde{x}_{ij}^k\right) \quad (39)$$

Note that $\tilde{x}_{ij}^k$ is the performance rating of the i^{th} alternative, A_i, with respect to the j^{th} criterion, C_j evaluated by k^{th}, decision-maker and $\tilde{x}_{ij}^k = \left(l_{ij}^k, m_{ij}^k, u_{ij}^k\right)$.

Step 3. The normalization of the fuzzy decision matrix $\tilde{R}$ is shown as

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m \times n} \text{ with } i = 1, \ldots, m \text{ and } j = 1, \ldots, n \quad (40)$$

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+} \right) \tag{41}$$

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}^+}, \frac{l_j^-}{m_{ij}^+}, \frac{l_j^-}{l_{ij}^+} \right) \tag{42}$$

where $u_j^+ = \max_i \left\{ u_{ij} \middle| i = 1, 2, \ldots, n \right\}$ - benefit criteria

and $l_j^- = \min_i \left\{ l_{ij} \middle| i = 1, 2, \ldots, n \right\}$ - cost criteria

Step 4. Calculate the weighted normalized fuzzy decision matrix. The weighted normalized value v_{ij} is calculated as follows:

$$\tilde{V} = \left[\tilde{v}_{ij} \right] m \times n, i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \tag{43}$$

where

$$\tilde{V} = \tilde{r}_{ij} \otimes \tilde{w}_{ij}, i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \tag{44}$$

Step 5. Determine the positive ideal solution and the negative ideal solution. Because the positive triangular fuzzy numbers are included in the interval [0,1], fuzzy positive-ideal solution (FPIS A+) and the fuzzy negative-ideal solution (FNIS A-) can be defined as

$$A^+ = \left(\tilde{v}_1^+, \tilde{v}_2^+, \ldots \tilde{v}_n^+ \right) = \left\{ \left(\max_i \tilde{v}_{ij} \right) \middle| i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \right\} \tag{45}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots \tilde{v}_n^- \right) = \left\{ \left(\min_i \tilde{v}_{ij} \right) \middle| i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \right\} \tag{46}$$

Step 6. Calculate the distances of each initial alternative to FPIS A+ and FNIS A-. The distance of each alternative from fuzzy positive ideal reference point and fuzzy negative ideal reference point can be derived, respectively, as follows

$$d_i^+ = \sqrt{\frac{1}{3} \sum_{j=1}^{n} \left(\tilde{v}_{ij} - \tilde{v}_j^+ \right)^2} \tag{47}$$

$$d_i^- = \sqrt{\frac{1}{3} \sum_{j=1}^{n} \left(\tilde{v}_{ij} - \tilde{v}_j^- \right)^2} \tag{48}$$

Step 7. Calculate the closeness coefficient. Calculate the closeness coefficient (CC) of each alternative as

$$CC_i = \frac{d_i^-}{\left(d_i^+ + d_i^-\right)} \text{ with } i = 1,\ldots,m \quad (49)$$

Step 8. Rank the alternatives according to the relative closeness. The best alternatives are those that have higher value C_i and therefore should be chosen because they are closer to the positive ideal solution.

2.3.5 Determining weights

Determining attribute weights are necessary step. The weights have divided to 2 method as subjective weights and objective weights. The weight selected is based on the data analyzed. The weights are usually used as the weight determination method for TOPSIS such as;

1) Entropy weights (EW)

Entropy weights is an objective weight approach was selected based on the raw data from the normalized. Shannon and Weaver created the entropy concept, which is a probability theory-based measure of information uncertainty. The EM is simple in calculation. This approach also reduces the effort of questionnaire because responders need not to answer the questionnaire with respect to the weight of criteria.

<u>Calculation Steps</u>

Step 1. Calculate entropy measure of every index.

$$P_{ij} = \frac{x_{ij}}{\sum_j x_{ij}} \quad (50)$$

$$E_j = -K\sum_{j=1}\left[P_{ij} \times \ln P_{ij}\right] \text{ where } K = \frac{1}{\ln(m)} \quad (51)$$

Step 2. Define the divergence.

$$div_j = 1 - E_j \tag{52}$$

Step 3. Obtain the normalized weights of indices.

$$W_j = \frac{div_j}{\sum_j div_j} \tag{53}$$

2) Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) was developed by Thomas Saaty in order to evaluate alternatives by comparing all the criteria of each alternative. AHP method builds on the pair-wise comparison model to determine the weights of every unique criterion [48].

<u>Calculation Steps</u>

Step 1. Structure the decision hierarchy by taking the goal of the study into account and determine the criteria and sub-criteria.

Step 2. Establish a set of all judgments in the comparison matrix in which the set of elements are already compared by using the fundamental scale of pair-wise comparison.

Step 3. Determine the relative importance of factors by calculating the corresponding Eigenvectors to the maximum Eigen values of comparison.

Step 4. Verify the consistency of judgments across the Consistency Index (CI) and the Consistency Ratio (CR).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{54}$$

where $\lambda_{\max}$ is the Eigen value corresponding to the matrix of pair-wise comparisons and n is the number of elements being compared.

Consistency ratio (CR) is defined as:

$$CR = \frac{CI}{RI} \tag{55}$$

where RI is a random consistency index.

A value of CR that is less than 0.1 is generally acceptable; otherwise the pair-wise comparisons should be revised to reduce incoherence.

3) Delphi method

To reach expert consensus, the Delphi approach employs an iterative procedure. That is used to make a judgment, an assessment, or to undertake predictive research. The four fundamental components of the conventional Delphi approach are anonymity, iteration, controlled feedback, and statistical summary. The expert is always two or three rounds of iterative discussions for consensus.

4) Rank Order Centroid (ROC)

This method determines the weights based only on a criteria ranking order. This weight distribution pattern is usually consistent with the function of the weight criterion influencing peopled's choice, which is generally steep and non-linear [125]. Its equation is shown below.

$$W_j = \frac{1}{j}\sum_{j=1}\frac{1}{r_j} \tag{56}$$

where $j = 1, 2, \ldots, j$ criteria, r_j is the ranking order of criterion j. The most important criterion is ranked first $(r_j = 1)$, while the least important one has $r_j = 1$.

2.3.6 Advantages and disadvantages of TOPSIS

The advantages and disadvantages of this method are the following [126]:

Advantages

– Simple, logical, and understandable notion,

– The reason of human decision is represented by intuitive and straightforward logic,

– Ease and high efficiency of computation,

– Able to use a simple mathematical form to calculate a scalar number that accounts the best and worst alternatives' capacity to quantify relative performance for each alternative,

– Visualization is a possibility.

Disadvantages

- It is difficult to maintain consistency judgement because the Euclidean distance used disregards the correlation among attributes.

2.4 Simulation Theory

At Los Alamos, there were numerous research proposals from 1946 to 1952 for inventing efficient thermonuclear. Coincidently, the computer simulation techniques were one of those research proposals. The scientists cultivated the advantages of the computer simulation techniques over the actual experiments which are lower cost, more safety, and low time-consuming experiments [127]. Even since computer simulation techniques have become an important tool in science and technology research as well as in engineering design [128]. Technically, the computer simulation techniques made use of computer technology; in order to generate random numbers, tally the outcomes, and compute the probabilities faster and more accurately than human beings. Behind the computational technology, the computer simulation techniques are based on the Monte Carlo theory. Galison (1996) [129] discussed this theory extensively, it is sometimes introduced as the origin of simulation and inseparable from simulation techniques [130, 131].

2.4.1 Simulation classification

Law and Kelton (2000)[132] classify simulation models along three different dimensions:

Static vs. Dynamic Simulation Models: a static simulation model is a representation of a system at a certain point in time, or one that may be used to describe a system when time is irrelevant.

Deterministic vs. Stochastic Simulation Models: a deterministic simulation model is one that does not contain any probabilistic (i.e. random) components; an example would be a complicated and analytically intractable system of differential equations representing a chemical reaction. Even though it may take a lot of computer time to assess what it is in deterministic models, the output is "determined" after the set of input values and relationships in the model has been described. Many systems, on the other hand, must be represented using at least some random input components, which leads to stochastic simulation models.

Continuous vs. Discrete Simulation Models: the modeling of a system as it grows over time using a representation in which the state variables change instantly at different points in time is known as discrete-event simulation. The modeling of a system throughout time by a representation in which the state variables change continuously with regard to time is referred to as continuous simulation. Typically, continuous simulation models use differential equations to represent connections between state and variable rates of change across time.

Digital simulation models, often known as computer simulation models, are a sort of computer model whose goal is to describe the target system's dynamic behavior (i.e., its temporal evolution). The implementation can be done using a general-purpose programming language or with a particular language defined as a modeling or simulation language, which is more efficient.

Discrete event simulation models and continuous system simulation models are two types of computer simulation models. The system state evolves discretely at discrete time instants in the former. The event generation is linked to the temporal distance between discrete time instants, hence it is changeable. In event-driven models, the event schedule is explicitly maintained, whereas in process-oriented models, it is handled implicitly. Discrete event models have been effectively used to a variety of biomedical engineering challenges, including resource organization in health care [133].

2.4.2 Simulation modelling

There are techniques for simulating the behavior of real-world systems. It necessitates the creation of a model that represents the selected system's or process's features, behaviors, and functions. The simulation represents the system's functioning through time, whereas the model represents the system itself.

Agent-based simulation (ABS) and discrete-event simulation (DES) are two typical simulation methodologies used in operational management systems. Other simulation approaches, such as mathematical simulation and Monte Carlo simulation, can be used in combination with these [134].

Agent-based simulation (ABS) or Agent-based modeling and simulation (ABMS) is a new approach of modeling systems made up of autonomous components, also known as agents, that communicate with one another [135]. Computer science, biology, sociology, and economics are just a few of the fields that employ agent-based models. The Complex Adaptive System (CAS), which is one of the applications of agent-based modeling, is studied not only for the behavior that emerges from agent interactions, but also for the agents' capacity to adapt in response to prior interactions [136].

Discrete-event simulation (DES) provides a tool to model organizational activities and system responses to discrete events in the operational flow. DES supports Monte Carlo analysis and can be used for manufacturing flows, operational processing flows, supply chain flows, and flows of information through an organization. DES is a flexible modeling method characterized by the ability to represent complex behavior within, and interactions between individuals, populations, and their environments [137]. In addition, DES is adequate for problems that consist of queuing simulations, and variability is represented through stochastic distributions.

2.4.3 Simulation language

It's difficult to choose a simulation language. There are several competing languages, each with its own set of benefits and drawbacks. Programming abilities in a general-purpose language like FORTRAN, Visual Basic, C/C++, or Java are required. The creation of specialized simulation languages has been prompted by the processing power and storage capacity of computers. For continuous or discrete simulation, certain languages have been created. Others can be used for combined continuous or discrete modeling. All simulation languages include certain basic programming features, but how the user utilizes these facilities varies [138].

2.4.4 Simulation methodology

The computer model is used for simulation. The model must operate as a real work system. Rossetti (2015)[138] outlined the following broad framework for applying simulation to problem solving:

1) Problem formulation
    (a) Define the problem
    (b) Define the system
    (c) Establish performance metrics
    (d) Build conceptual model
    (e) Document model assumptions
2) Simulation model building
    (a) Model translation
    (b) Input data modeling
    (c) Verification
    (d) Validation
3) Experimental design and analysis
    (a) Preliminary runs
    (b) Final experiments

(c) Analysis of results

4) Evaluate and iterate

(a) Documentation

(b) Model manual

(c) User manual

5) Document programs and report results

6) Implementation (it recognizes that simulation projects often fail if there is no follow through on the recommend solutions).

These steps are generally applied in sequence. The most important step is problem formulation. Due to changes in scope and objectives of the study, it can waste a lot of time and money on the project. Therefore, this step must be carefully processed.

2.4.5 Simulation program

Many simulation software are free and paid. The researcher was interested in the Arena program and FlexSim program. Both of these programs are widely use. The researcher wants to study both programs and compare to select the program that will be used as a research tool.

Simio is a one-of-a-kind multi-paradigm modeling tool that combines object simplicity with process flexibility to allow quick modeling without the need for scripting. Simio can be utilized in healthcare, military, airports, manufacturing, supply chain, ports, mining, lean-six-sigma, and other disciplines to forecast and enhance the performance of dynamic, complex systems.

Arena program is one of the most popular tool for creating and experimenting models. The model will be tested on a computer for system behavior study. Then, it led to a way to analyze and improve the system to be more efficient. In addition, the Arena program can create virtual animations on the computer screen. This program ease to use, and the availability of student versions. Arena is a process-description-based language at its fundamental. That is, the modeler defines the process that a “entity” goes through as it flows through or uses the system’s pieces [138].

FlexSim program assists all engineers, managers, and decision-makers who want to verify, enhance, or just learn more about their current or future processes. FlexSim is written in the C++ programming language and uses Open GL technology to provide users more flexibility in designing models that fit their operations. FlexSim is meant to represent complicated processes, and the performance and output statistics are chosen to properly react to the metrics that are most relevant in the planning of production systems. Users record information on a variety of performance parameters, including machine utilization, transport time, machine status statistics, waiting time, work-in-process levels, machine breakdown and repair time metrics, space allocation, and more. Even the consequences of unanticipated system failures can be assessed. The program automatically generates accurate and timely performance data that can be used to monitor every area of the system.

2.4.6 Model validation and verification

Model verification is commonly described as "ensuring that the computer program of the computerized model and its implementation are correct," which is the definition used in this paper. Model validation is commonly characterized as "proof that a computerized model is within its sphere of applicability and has a reasonable range of accuracy compatible with the model's intended application." [139].

In Table 7, validation techniques are some of the most frequent validation approaches and tests used in model verification and validation. The majority of the approaches mentioned here can be found in the literature, albeit some may be described differently [139].

Table 7 The validation techniques and tests commonly used

Techniques	Describes
Animation	As the model progresses over time, the operational behavior of the model is graphically displayed.
Comparison to other models	The simulation model being validated various results (e.g., outputs) are compared to the results of other models.
Extreme condition tests	Any extreme and unlikely combination of levels of components in the system should be feasible for the model structure and outputs.
Face validity	Essentially, it is appropriate to use expert intuition to verify a model that its behavior is reasonable.
Historical methods	The three historical methods of validation are rationalism, empiricism, and positive economics.
Internal validity	To estimate the level of (internal) stochastic variability in a stochastic model, several replications (runs) are performed.
Multistage validation	This validation approach includes (1) creating the model’s assumptions based on theory, observations, and general knowledge, (2) experimentally evaluating the model's assumptions, and (3) comparing (testing) the model’s input-output connections to the real system.
Operational graphics	As the model runs through time, the values of several performance parameters, such as the number of people in line and the proportion of servers that are busy, are graphically.

Table 7 (continued)The validation techniques and tests commonly used

Techniques	Describes
Traces	In isolating faulty behavior in a model, trace outputs can be extremely useful. The behaviors of various sorts of specific entities in the model are traced (followed) to see if the model's logic is true and the required accuracy is achieved.
Turing tests	Expert who know how the system being modeled works are asked if they can tell the difference between system and model outputs.
Predictive validation	The model is used to predict (forecast) the behavior of the system, and then comparisons between the system's behavior and the model's forecast are done to see if they are the same.
Degenerate tests	Degeneracy testing ensures that the model works even when system and workload (input) parameters are set to extremes.
Event validity	The simulation model's occurrence events are compared to those of the real system to see if they are similar.
Historical data validation	If historical data is available, part of it is utilized to develop the model, while the rest is used to determine (test) if the model acts like the system.
Parameter variability - sensitivity analysis	Sensitivity Analysis involves changing the values of a model's input and internal parameters to see how they affect the model's behavior or output.

2.5 Conclusion

In chapter 2, related literature were reviewed. Firstly, electronic commerce was reviewed. Electronic commerce, commonly known as e-commerce, was on the rise all over the world. It had a long history that started with primitive electronic data transactions in the 1960s. E-commerce had been developed for a long time. Internet technology was an important role in e-commerce. It also had Internet of Things (IoT) technology that made the world of online shopping much easier than before. E-commerce was classified into four traditional types: business-to-business (B2B), business-to-customer (B2C), customer-to-business (C2B), and customer-to-customer (C2C). There were also many variants of e-commerce, such as Business to Government (B2G), Government to Business (G2B), Government to Customer (G2C), Customer to Government (C2G), Government to Government (G2G), Business-to-People (B2P), Peer-to-peer (P2P), Business to Employee (B2E), Business to Business to Customer (B2B2C). In e-commerce, one of the factors that the merchant considered was the delivery of services or products. Home delivery services, in particular, were the favored alternative among online customers. Most merchants used delivery services for shipping. Speed, service quality, convenience, and dependability were becoming increasingly crucial to customers and merchants in terms of logistics. Therefore, merchants emphasized the high-level of services or reasonable cost of product deliveries.

Secondly, the literature review was Last Mile Delivery (LMD) which denotes the final leg in a business-to-customer (B2C) delivery service whereby the product was delivered to the recipient, either at the recipient’s home or at a collection point. It had become one of the bottlenecks of e-commerce and had emerged as one of the most problematic ones to managed, optimized, actuated, and controlled. The main LMD problem in home deliveries was failed first time delivery. Last mile delivery modes were divided by the perspective of analysis. Therefore, this research divided LMD modes into home deliveries and collection points. Moreover, this section expressed the efficiencies of LMD, sustainability, and trends. Last mile delivery management was necessary and important. The last mile delivery cost-reduction made the business more profitable. Accordingly, an innovative LMD is needed.

Thirdly, this chapter presented the details of Technique for Order Preference by Similarity to an Ideal Solution. It was a method at hand which the researcher was interested in using as a comparison tool in this study. Its basic concept was that the chosen alternative should be the closest to the positive-ideal solution while being the furthest away from the negative-ideal solution. The benefit criteria were maximized while the cost criteria were minimized in the positive-ideal solution. The cost criteria were maximized while the benefit criteria were minimized in the negative-ideal solution. As a result, the positive-ideal solution was made up of all the best values for criterion, whereas the negative-ideal solution was made up of all the worst values for criteria. The classical TOPSIS technique was based on the decision maker's qualities and numerical data; the solution was intended at assessing, prioritizing, and selecting, with weights as the only subjective input. In some cases, the classical TOPSIS method was unsuitable for real world applications. Therefore, Fuzzy TOPSIS was also being studied.

Finally, this chapter reviewed simulation theory about simulation classification, simulation modelling, simulation language, simulation methodology, simulation program package, and model validation and verification. The simulation program which was reviewed in this study were Simio program, Arena program and FlexSim program. Simio was a one-of-a-kind multi-paradigm modeling tool that combined object simplicity with process flexibility to allow quick modeling without the need for programming. Arena was a competent platform for distinct events. It provided a solid foundation in the form of simple flow chart modules that used to create a wide range of simulations. The documentation provided was moderate, while the GUI's usability was mediocre. Flexsim looked to be a capable discrete event simulation tool for manufacturing processes and industrial operations simulation.

CHAPTER 3

THE LAST MILE DELIVERY MODE COMPARISON USING FUZZY TOPSIS

In this chapter, existing last mile delivery modes are compared in perspectives of all stakeholders by using Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (Fuzzy TOPSIS). In addition, logistics service experts and merchants' experts will be interviewed in depth. Research Tools are questionnaire about LMD modes, and the Fuzzy TOPSIS method.

A questionnaire will be created to query all the stakeholders. It will be a questionnaire about LMD modes, including home deliveries (attended and unattended) and collection points (manned and unmanned). The questionnaire will have different questions depending on the status of the respondents, which are merchants, customers, and delivery providers.

Decision-makers often have difficulty rating alternatives to the feature under consideration. The advantage of using the Fuzzy method is that it determines the relative importance of an attribute by using Fuzzy numbers instead of precise numbers. Then, Fuzzy TOPSIS will be used to compare existing last mile delivery modes. Its basic concept is that the chosen alternative should have the shortest distance from the positive-ideal solution and the farthest from the negative-ideal solution. The positive-ideal solution maximizes the benefit criteria and minimizes the cost criteria. The negative-ideal solution maximizes the cost criteria and minimizes the benefit criteria.

In addition, an objective weight approach was selected based on fuzzy data, which was converted into crisp data with the center of area method. One of the advantages of this method over the other subjective weight approaches like the Delphi method or the Analytical Hierarchy Process (AHP) is that the weight can be derived based on the rating of alternatives themselves instead of the subjective evaluation. This fact-based approach is more accurate and reflects decision makers' preferences in a better way. This approach also eliminates the need for a questionnaire or survey, as respondents need not answer the questionnaire with respect to the weight of criteria.

This is advantageous, especially when the number of criteria and alternatives is large, because it allows decision-makers to focus on the ratings.

3.1 Criteria

The criteria that are used to evaluate each LMD alternative were extracted from the literature survey process as stated in Chapter 2. The criteria of customer, delivery provider, and merchant are shown in Tables 8, 9, and 10, respectively. To verify the validity of these criteria, the questionnaire was composed based on the 'Index of Item Objective Congruence' method and interviewed 3 delivery providers and 3 merchant experts. Detailed answers were summarized in Appendix B.

From the customer's perspective, questions were designed based on 8 criteria: appropriate opening hours (C1), payment options (C2), high convenience in service (C3), high security (C4), low delivery price (C5), environmentally friendly (C6), highly flexible in delivery times (C7), and delivered directly to the recipient (C8).

Table 8 List of criteria of customer's perspective

No.	Criteria	Description
C1	Appropriate opening hours	The appropriate opening hours of the service points in picking up goods.
C2	Payment options	Varieties of payment options: pay directly at the counter, cash on delivery, pay by credit card, etc.
C3	High convenience in service	High convenience for recipients in terms of delivery service,
C4	High security	Parcels are safe, unbroken, undamaged, trackable, and not lost.
C5	Low delivery price	Delivery price is low.
C6	Environmentally friendly	Delivery process emits less pollution, noise, and traffic congestion.

Table 3.1 (continued) List of criteria of customer's perspective

No.	Criteria	Description
C7	Highly flexible delivery and receipt times	Delivery time is set to be of advantages for the costumers to pick up their orders. Alternatively, on the application or online panel, customer can set delivery time at their convenience.
C8	Delivered directly to the recipient	Goods are delivered directly to the recipients' doorstep.

In delivery provider's perspective, questions were designed based on 6 criteria: high security (C1), low failed first time delivery (C2), low delivery cost (C3), environmentally friendly (C4), highly flexible in delivery times (C5), delivered directly to the recipient (C6) as shown below.

Table 9 List of criteria of delivery provider's perspective

No.	Criteria	Description
C1	High security	Parcels are safe, unbroken, undamaged, trackable, and not lost.
C2	Low failed first time delivery	The delivery of parcel to the customer's place and it is successfully delivered at first time.
C3	Low delivery cost	Delivery cost is low.
C4	Environmentally friendly	Delivery process emits less pollution, noise, and traffic congestion.
C5	Highly flexible delivery times	Delivery time is set to be of advantages for the costumers to pick up their orders. Alternatively, on the application or online panel, customer can set delivery time at their convenience.
C6	Delivered directly to the recipient	Goods are delivered directly to the recipients' doorstep.

In merchants's perspective, questions were designed based on 8 criteria: high security (C1), high convenience in service (C2), payment options (C3), low delivery cost (C4), environmentally friendly (C5) as shown below.

Table 10 List of criteria of merchants's perspective

No.	Criteria	Description
C1	High security	Parcels are safe, unbroken, undamaged, trackable, and not lost.
C2	High convenience in service	High convenience for recipients in terms of delivery service
C3	Payment options	Varieties of payment options; pay directly at the counter, cash on delivery, pay by credit card etc.
C4	Low delivery cost	Delivery cost is low.
C5	Environmentally friendly	Delivery process emits less pollution, noise and traffic congestion.

From the interview results, criteria other than "environmentally friendly" were mentioned. However, any expert has not mentioned this criterion. The possible reason is that LMDs are very competitive and many operators are more focused on services and prices that are more directly valued by their customers. On the other hand, many existing studies emphasize sustainability, and, in recent years, an increasing number of companies are considering environmental impact and delivering their services in line with the United Nations' Sustainable Development Goals and the organization's Creating Service Value (CSV) policy. For this reason, this study decided not to cut "environmentally friendly" off and used it as an evaluation item from the perspective of long-term goals rather than short-term goals. It is justified that the evaluation items listed in this study are appropriate.

3.2 The Customer Perspectives

In this section, questionnaires were used to collect the data from customers with online shopping experiences. The sample size was calculated by using the Taro Yamane's table at 97% confidence, ±3 error. The overall samples were collected from 1,112 people from different countries. The statistics summary of respondents is shown in Table 11.

Table 11 The statistics summary of customer respondents

Sample Size	1,112
Region	Asia 65%, North America 20%, Europe 15%
Country of Origin/nationality	23 Countries: Australia, Canada, China, France, Germany, Hong Kong, Iceland, India, Indonesia, Japan, Korea, Laos, Malaysia, New Zealand, Norway, Singapore, Sri Lanka, Sweden, Taiwan, Thailand, Turkey, UK, and USA.
Area	Urban: 57%, Sub urban:26%, Rural: 16%, Remote area: 1%
Value of Items	<50$: 58%, 50$-100$: 28%, >100$: 14%
Developed or Developing country	Developed 54%, Developing 46%

Respondents were asked to rate on a five-point Likert scale varying from "Strongly disagree" (1) to "Strongly agree" (5). Therefore, triangular distribution is conducted for calculation. It is a very useful way of expressing uncertainty, which cannot determine the actual distribution of random variables [140]. Table 12 shows aggregated ratings of the alternatives of customer.

In decision making process, using of triangular distribution is advantageous, because it is simply specified by three parameters: minimum (L), maximum (H) and most probable (M) value. Therefore, the individual judgments of the DMs are aggregated into triangular numbers. Lets $\tilde{a}\left(l_{ij}^{k}, m_{ij}^{k}, u_{ij}^{k}\right)$ be an element of matrix, representing the group performance rating of an alternative $A_i\left(i=1,2,\ldots,m\right)$ attribute $C_j\left(j=1,2,\ldots,n\right)$ specified by k^{th} DMs. Aggregation of the *DM* preferences is described below [117]:

$$l_{ij}^k = \min_k x_{ij}^k \quad (57)$$

$$m_{ij}^k = \sqrt[k]{\prod_{k=1}^{k} x_{ij}^k} \quad (58)$$

$$u_{ij}^k = \max_k x_{ij}^k \quad (59)$$

The normalization of the fuzzy decision matrix is accomplished using a linear scale transformation. For fuzzy data denoted by triangular fuzzy number calculated by using the equation (40) – (42), as shown in Table 13.

For calculating criteria weights with Shannon entropy, the center of area method was used to change fuzzy data into crisp data *[*141*]*:

$$x_{ij} = \frac{\left[\left(u_{ij}-l_{ij}\right)+\left(m_{ij}-l_{ij}\right)\right]}{3}+l_{ij} \quad (60)$$

Then, the criteria weight will be calculated by equation *(*50*)* – *(*53*)*. The decision matrix for Shannon entropy and criteria weight is shown in Table 14, and the normalized fuzzy decision matrix weight is shown in Table 15*.*

Hereafter, data is calculated following the Fuzzy TOPSIS procedure. The relative proximity to the ideal solution was calculated. Then, the alternatives according to the relative closeness were ranked. As considered in Table 16, attended home delivery and manned collection point are ranked the first and second respectively.

Table 12 The aggregated triangular decision matrix of customers

Criteria / Alternative	C1	C2	C3	C4	C5	C6	C7	C8
1. Attended home delivery	(2, 4.187, 5)	(2, 4.246, 5)	(1, 4.233, 5)	(2, 3.942, 5)	(1, 3.460, 5)	(1, 3.559, 5)	(1, 3.640, 5)	(2, 4.290, 5)
2.Unattended home delivery	(1, 3.601, 5)	(1, 3.711, 5)	(1, 3.775, 5)	(1, 3.058, 5)	(1, 3.435, 5)	(1, 3.474, 5)	(1, 3.369, 5)	(1, 3.369, 5)
3. Manned Collection point	(2, 3.940, 5)	(2, 4.064, 5)	(1, 3.765, 5)	(1, 3.893, 5)	(1, 3.721, 5)	(1, 3.675, 5)	(1, 3.615, 5)	(1, 3.615, 5)
4. Unmanned Collection point	(1, 3.710, 5)	(2, 3.580, 5)	(1, 3.546, 6)	(1, 3.174, 5)	(1, 3.672, 5)	(1, 3.624, 5)	(1, 3.169, 5)	(1, 3.169,5)

Table 13 Triangular decision matrix of customers

Criteria / Alternative	C1	C2	C3	C4	C5	C6	C7	C8
1. Attended home delivery	(0.4, 0.837, 1)	(0.4, 0.849, 1)	(0.2, 0.847, 1)	(0.4, 0.788, 1)	(0.2, 0.692, 1)	(0.2, 0.712, 1)	(0.2, 0.728, 1)	(0.4, 0.858, 1)
2.Unattended home delivery	(0.2, 0.720, 1)	(0.2, 0.742, 1)	(0.2, 0.755, 1)	(0.2, 0.612, 1)	(0.2, 0.687, 1)	(0.2, 0.695, 1)	(0.2, 0.749, 1)	(0.2, 0.674, 1)
3. Manned Collection point	(0.4, 0.788, 1)	(0.4, 0.813, 1)	(0.2, 0.753, 1)	(0.2, 0.779, 1)	(0.2, 0.744, 1)	(0.2, 0.735, 1)	(0.4, 0.732, 1)	(0.2, 0.723, 1)
4. Unmanned Collection point	(0.2, 0.742, 1)	(0.4, 0.716. 1)	(0.2, 0.709, 1)	(0.2, 0.635, 1)	(0.2, 0.734, 1)	(0.2, 0.725, 1)	(0.2, 0.737, 1)	(0.2, 0.634, 1)

Table 14 The criteria weight of customer's perspective

Criteria / Alternative	C1	C2	C3	C4	C5	C6	C7	C8
1. Attended home delivery	0.7458	0.7497	0.6822	0.7295	0.6307	0.6373	0.6427	0.7527
2.Unattended home delivery	0.6401	0.6474	0.6517	0.6039	0.6290	0.6316	0.6496	0.6246
3. Manned collection point	0.7294	0.7376	0.6510	0.6595	0.6481	0.6450	0.7108	0.6410
4. Unmanned collection point	0.6473	0.7053	0.6364	0.6116	0.6448	0.6416	0.6458	0.6113
W_j	0.2010	0.1348	0.0275	0.2485	0.0074	0.0026	0.0760	0.3020

Table 15 The normalized fuzzy decision matrix weight

Criteria / Alternative	C1	C2	C3	C4	C5	C6	C7	C8
1. Attended home delivery	(0.080,0.168,0.201)	(0.054,0.114,0.135)	(0.005,0.023,0.027)	(0.099,0.196,0.249)	(0.001,0.005,0.007)	(0.001,0.002,0.003)	(0.015,0.055,0.076)	(0.121,0.259,0.302)
2.Unattended home delivery	(0.040,0.145,0.201)	(0.027,0.100,0.135)	(0.005,0.021,0.027)	(0.050,0.152,0.249)	0.001,0.005,0.007)	(0.001,0.002,0.003)	(0.015,0.057,0.076)	(0.060,0.204,0.302)
3. Manned collection point	(0.080,0.158,0.201)	(0.054,0.110,0.135)	(0.005,0.021,0.027)	(0.050,0.194,0.249)	0.001,0.006,0.007)	(0.001,0.002,0.003)	(0.030,0.056,0.076)	(0.060,0.218,0.302)
4. Unmanned collection point	(0.040,0.149,0.201)	(0.054,0.097,0.135)	(0.005,0.019,0.027)	(0.050,0.158,0.249)	(0.001,0.005,0.007)	(0.001,0.002,0.003)	(0.015,0.056,0.076)	(0.060,0.191,0.302)

Table 16 Preference ordering of customer's perspective

Alternatives	TOPSIS index	Rank
1. Attended home delivery	0.6143	1
2. Unattended home delivery	0.5210	4
3. Manned collection point	0.5663	2
4. Unmanned collection point	0.5273	3

The results indicate the importance of product safety which is safe, unbroken, undamaged, trackable and not lost. From Table 14, the customers gave the most weight on C8 and C4. Considering the criteria weight of them, these are the safety criteria. The manned collection point is also the second highest value on C8 and C4. Therefore, attended home delivery and manned collection points are the preferred choices of customers. However, the unattended home delivery mode is the least satisfying among the modes. This mode has low product security because the parcels can be delivered to someone's doorstep, which is at risk of being lost.

3.3 The delivery Provider Perspectives

In this section, questionnaires were used to collect the data from delivery provider. The sample size was calculated by using the Taro Yamane's table at 95% confidence, ±5 error. The data were collected from 400 people from different countries. The statistics summary of respondents is shown in Table 17.

Table 17 The statistics summary of delivery provider respondents

Sample Size	400
Region	Asia 71%, North America 18%, Europe 11%
Country of Origin/nationality	21 Countries: Azerbaijan, China, Cyprus, Germany, Hungary, Hong Kong, Iceland, Indonesia, Japan, Korea, Laos, Malaysia, Myanmar, New Zealand, Norway, Singapore, Sweden, Taiwan, Thailand, UK, and USA.
Area	Urban: 53%, Sub urban:31%, Rural: 14%, Remote area: 2%
Transport vehicle	Motorcycle: 43%, Pickup truck: 27%, Van: 29%, Other: 1% (Airfreight planes, Truck)
Delivery per day	< 8 hours: 2%, 8 hours: 78%, >8 hours: 20%

Respondents were asked to rate on a five-point Likert scale varying from "Strongly disagree" (1) to "Strongly agree" (5). See the aggregated ratings of the alternatives of delivery provider, and the normalization of the fuzzy decision matrix in Table 18, 19, respectively.

Then, for ranking alternatives, Fuzzy TOPSIS method is applied. Based on fuzzy decision matrix and weights of alternatives selection criteria in Table 20, weighted normalized fuzzy decision matrix and ranking alternatives are shown in Tables 21, 22, respectively.

Table 18 The aggregated ratings of delivery provider's perspective

Criteria / Alternative	C1	C2	C3	C4	C5	C6
1. Attended home delivery	(4, 4.890, 5)	(2, 3.982, 5)	(1, 2.242, 4)	(2, 3.529, 5)	(3, 3.635, 4)	(4, 4.819, 5)
2.Unattended home delivery	(1, 1.764, 5)	(1, 2.967, 5)	(1, 3.027, 5)	(2, 3.670, 5)	(3, 3.732, 5)	(2, 3.017, 5)
3. Manned Collection point	(3, 4.262, 5)	(4, 4.472, 5)	(1, 3.317, 5)	(3, 3.958, 5)	(4, 4.152, 5)	(1, 3.066, 5)
4. Unmanned Collection point	(2, 2.797, 5)	(2, 3.655, 5)	(4, 4.150, 5)	(4, 4.308, 5)	(4, 4.308, 5)	(2, 2.997, 5)

Table 19 Triangular decision matrix of delivery provider's perspective

Criteria / Alternative	C1	C2	C3	C4	C5	C6
1. Attended home delivery	(0.8, 0.978, 1)	(0.4, 0.796, 1)	(0.2, 0.448, 0.8)	(0.4, 0.706, 1)	(0.6, 0.727, 0.8)	(0.8, 0.964, 1)
2.Unattended home delivery	(0.2, 0.353, 1)	(0.2, 0.593, 1)	(0.2, 0.605, 1)	(0.4, 0.734, 1)	(0.6, 0.746, 1)	(0.4, 0.603, 1)
3. Manned Collection point	(0.6, 0.852, 1)	(0.8, 0.894, 1)	(0.2, 0.663, 1)	(0.6, 0.792, 1)	(0.8, 0.830, 1)	(0.2, 0.613, 1)
4. Unmanned Collection point	(0.4, 0.559, 1)	(0.4, 0.731, 1)	(0.8, 0.830, 1)	(0.8, 0.862, 1)	(0.8, 0.862, 1)	(0.4, 0.599, 1)

Table 20 The criteria weight of delivery provider's perspective

Criteria / Alternative	C1	C2	C3	C4	C5	C6
1. Attended home delivery	0.9260	0.7321	0.4828	0.7020	0.7090	0.9212
2.Unattended home delivery	0.5176	0.5978	0.6018	0.7113	0.7821	0.6678
3. Manned Collection point	0.8174	0.8981	0.6211	0.7972	0.8768	0.6043
4. Unmanned Collection point	0.6531	0.7104	0.8767	0.8872	0.8872	0.6664
W_j	0.2903	0.1315	0.2974	0.0576	0.0508	0.1724

Table 21 The weighted normalized fuzzy decision matrix of delivery provider's perspective

Criteria / Alternative	C1	C2	C3	C4	C5	C6
1. Attended home delivery	(0.232, 0.284, 0.290)	(0.053, 0.105, 0.131)	(0.059, 0.133, 0.238)	(0.023, 0.041, 0.058)	(0.030, 0.037, 0.041)	(0.138, 0.166, 0.172)
2.Unattended home delivery	(0.058, 0.102, 0.290)	(0.026, 0.078, 0.131)	(0.059, 0.180, 0.297)	(0.023, 0.042, 0.058)	(0.030, 0.038, 0.051)	(0.069, 0.104, 0.172)
3. Manned Collection point	(0.174, 0.247, 0.290)	(0.105, 0.118, 0.131)	(0.059, 0.197, 0.297)	(0.035, 0.046, 0.058)	(0.041, 0.042, 0.051)	(0.034, 0.106, 0.172)
4. Unmanned Collection point	(0.116, 0.162, 0.290)	(0.053, 0.096, 0.131)	(0.238, 0.247, 0.297)	(0.046, 0.050, 0.058)	(0.041, 0.044, 0.051)	(0.069, 0.103, 0.172)

Table 22 Preference ordering of delivery provider's perspective

Alternatives	TOPSIS index	Rank
1. Attended home delivery	0.6419	2
2. Unattended home delivery	0.4918	4
3. Manned Collection point	0.6186	3
4. Unmanned Collection point	0.6473	1

From Table 20, the unmanned collection point mode has a higher weight on C3, C5 than among the modes. Although the higher weight on C1 is the attended home delivery mode, this mode is also the least satisfying than the unmanned collection point mode.

As considered in Table 22, unmanned collection points and attended home deliveries are ranked first and second, respectively. This is interesting. Looking at Table 20, it can be seen that the delivery provider is more concerned about cost than other criteria. Therefore, unmanned collection points are the most preferable choices for the target delivery provider.

3.4 The Merchant Perspectives

In this section, questionnaires were used to collect the data from merchants that sold products through internet. The sample size was calculated by using the Taro Yamane's table at 95% confidence, ±5 error. The data were collected from 400 people from different countries. The statistics summary of respondents is shown in Table 23.

Table 23 The statistics summary of merchant respondents

Sample Size	400
Region	Asia 68%, North America 19%, Europe 13%
Country of Origin/nationality	16 Countries: Cambodia, England, Finland, France, Germany, Iceland, India, Japan, Korea, Laos, Malaysia, Mexico, Philippines, Singapore, Thailand, and USA.
Value of the product delivered	< 50$: 37%, < 100$: 52%, > 100$: 11%.

Respondents were asked to rate on a five-point Likert scale varying from "Strongly disagree" (1) to "Strongly agree" (5). The aggregated ratings of the alternatives of merchant is presented in Table 24, and the normalization of the fuzzy decision matrix in Table 25.

Then, for ranking alternatives, Fuzzy TOPSIS method is applied. Based on fuzzy decision matrix and weights of alternatives selection criteria in Table 26, weighted normalized fuzzy decision matrix is shown in Table 27. Finally, the evaluated results about the alternatives are presented as Tables 28.

Table 24 The aggregated ratings of merchant's perspective

Criteria / Alternative	C1	C2	C3	C4	C5
1. Attended home delivery	(4, 4.492, 5)	(4, 4.527, 5)	(3, 4.241, 5)	(2, 3.443, 5)	(2, 3.893, 5)
2.Unattended home delivery	(2, 3.040, 4)	(2, 3.677, 5)	(2, 3.287, 5)	(2, 3.662, 5)	(2, 3.791, 5)
3. Manned Collection point	(3, 4.134, 5)	(3, 4.107, 5)	(3, 4.075, 5)	(2, 3.947, 5)	(3, 4.136, 5)
4. Unmanned Collection point	(2, 3.163, 4)	(2, 3.423, 5)	(2, 3.397, 5)	(3, 3.657, 5)	(3, 4.166, 5)

Table 25 Triangular decision matrix of merchant's perspective

Criteria / Alternative	C1	C2	C3	C4	C5
1. Attended home delivery	(0.8, 0.898, 1)	(0.8, 0.905, 1)	(0.6, 0.848, 1)	(0.4, 0.689, 1)	(0.4, 0.779, 1)
2.Unattended home delivery	(0.4, 0.608, 1)	(0.4, 0.735, 1)	(0.4, 0.657, 1)	(0.4, 0.732, 1)	(0.4, 0.758, 1)
3. Manned Collection point	(0.6, 0.827, 1)	(0.6, 0.821, 1)	(0.6, 0.815, 1)	(0.4, 0.789, 1)	(0.6, 0.827, 1)
4. Unmanned Collection point	(0.4, 0.633, 1)	(0.4, 0.685, 1)	(0.4, 0.679, 1)	(0.6, 0.731, 1)	(0.6, 0.833, 1)

Table 26 The criteria weight of merchant's perspective

Criteria / Alternative	C1	C2	C3	C4	C5
1. Attended home delivery	0.8995	0.9018	0.8161	0.6962	0.7262
2.Unattended home delivery	0.6027	0.7118	0.6858	0.7108	0.7194
3. Manned Collection point	0.8089	0.8071	0.8050	0.7298	0.8091
4. Unmanned Collection point	0.6109	0.6949	0.6931	0.7771	0.8111
W_j	0.5728	0.2101	0.1233	0.0327	0.0611

Table 27 The weighted normalized fuzzy decision matrix of merchant's perspective

Criteria / Alternative	C1	C2	C3	C4	C5
1. Attended home delivery	(0.458, 0.515, 0.573)	(0.168, 0.190, 0.210)	(0.074, 0.105, 0.123)	(0.013, 0.022, 0.033)	(0.024, 0.048, 0.061)
2.Unattended home delivery	(0.229, 0.348, 0.458)	(0.084, 0.154, 0.210)	(0.049, 0.081, 0.123)	(0.013, 0.024, 0.033)	(0.024, 0.046, 0.061)
3. Manned Collection point	(0.344, 0.474, 0.573)	(0.126, 0.173, 0.210)	(0.074, 0.101, 0.123)	(0.013, 0.026, 0.033)	(0.037, 0.051, 0.061)
4. Unmanned Collection point	(0.229, 0.362, 0.458)	(0.084, 0.144, 0.210)	(0.049, 0.084, 0.123)	(0.020, 0.024, 0.033)	(0.037, 0.051, 0.061)

Table 28 Preference ordering of merchant's perspective

Alternatives	TOPSIS index	Rank
1. Attended home delivery	0.7459	1
2. Unattended home delivery	0.4357	4
3. Manned Collection point	0.6315	2
4. Unmanned Collection point	0.4473	3

From Table 26, the objective criteria weight showed that merchants gave the most weight on C1 which is product security. Furthermore, the attended home delivery is the preferred mode of ordering, with a higher preference than other modes. On the other hand, the unattended home delivery mode is the least satisfied among the modes.

3.5 Last Mile Delivery Factors in All Stakeholders' Perspectives

In this section, the factors that affect the last mile delivery selection mode from the perspective of the stakeholders are classified and summarized. These are considered by the weights obtained from the calculations and expert interviews.

Last mile delivery factor for all stakeholders' perspective is shown in Table 29. The signs in the table 1) "***" indicates 'highly affected' 2) "**" indicates 'moderately affected' and 3) "*" indicates 'less affected'.

Table 29 Last mile delivery factor for all stakeholders' perspective

Criteria or factor	Perspective of		
	Customer	Delivery provider	Merchant
Appropriate opening hours	**		
Payment options	**		**
High service convenience	**	***	***

Table 29 (continued) Last mile delivery factor for all stakeholders' perspective

Criteria or factor	Perspective of		
	Customer	Delivery provider	Merchant
High security	***	***	***
Low delivery price	*	**	**
Low delivery cost		***	**
High flexibility in delivery times	*	*	
Delivered directly to the recipient	***	**	
Speed of delivery		**	
Service areas			*
Low failed first time delivery		*	*

As shown in Table 29, all stakeholders concern about 'product security' and 'high service convenience', respectively. Therefore, it is suggested for delivery providers to pay more attention to the safety of the goods while designing and developing LMD service.

3.6 Conclusion

In this chapter, existing last mile delivery modes were compared in perspectives of all stakeholders by the Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (Fuzzy TOPSIS). The questionnaires were used to collect data. The individual ratings of the decision-makers were aggregated into triangular numbers. An objective weight approach was selected. Based on the fuzzy data, which was converted into crisp data using the center of area method. Then, the data was analyzed by the Fuzzy

TOPSIS technique. Moreover, delivery provider experts and merchants' experts will be interviewed in depth.

The last mile alternative mode selection was varied by stakeholder perspective. Customers and merchants considered product security. They were concerned that parcels were safe, unbroken, undamaged, trackable and not lost. Therefore, the attended home delivery and manned collection point modes could fully satisfy the customers and merchants' satisfaction. On the contrary, unattended home delivery was low product security because the parcels can be delivered to someone's doorstep, which was at risk of being lost. Whereas the unmanned collection point was a delivery provider-friendly mode due to its low cost. The parcels were dropped many pieces per locker point. This made it possible to save both money and time. Overall, attended home delivery was the preferred choice of all stakeholders.

In delivery providers' opinion, customers considered service and price. Also, merchants that selected last mile delivery depend on service and price. In addition, the delivery provider should consider the matter of the customer segments because of the difference in customers' needs. For example, the customer is divided by age: young customers often wanted fast delivery; working-age groups focused on the quality of service, while the elderly group will focus on convenience. However, delivery providers should focus on improving product security and safety.

CHAPTER 4
A NOVEL LAST MILE DELIVERY MODE

In this chapter, a novel mode of last mile delivery will be proposed. Then, it will be compared to existing modes by using simulation techniques. This method has been used extensively. The Arena simulation program will be used as a research tool. This program Arena's flowchart modeling methodology is an easy and intuitive way to model any process without the need for customized code or programming.

In addition, the last mile cost per unit shipped is calculated. The calculated numbers are based on the data obtained from the simulations, literature reviews, and the delivery provider. This calculation assumes that the goods will not be returned, and the packaging used is considered standard packaging.

4.1 Last Mile Delivery Alternatives Design

This section aims to design alternative last mile delivery mode that can meets a stakeholder's needs. According to the findings of Chapter 3, all stakeholders are concerned about product safety and the convenience criteria. Considering the existing alternative modes, an unmanned collection point will be developed.

In thorough literature reviews and studying data from delivery providers, each provider only delivers goods to its own lockers. Customers can go pick up the parcel. The lockers are installed in public areas such as gas stations, parks, in front of department stores, etc. However, the number of lockers available is too low in some areas. So, if the distance between the locker is too far from the customer's home, customers can not be accessible to lockers. Adding locker points is high the activation cost, i.e., the cost of the structure, installation, commissioning, land tax, and ICT maintenance system. The company considers that it may not be cost-effective. Because the number of deliveries at some lockers is low, it's not worth the investment.

This study would like to present an alternative to locker sharing among all delivery providers. This alternative will save locker costs for delivery providers. It will enable delivery providers to reduce service charges for customers as well. In this research, locker sharing is a term used. Therefore, the existing alternative modes and alternative design mode that are studied in this chapter are shown in Table 30.

Table 30 LMD modes in this study

Number	LMD mode
1	Home delivery
2	The current unmanned collection point
3	Locker sharing delivery

Alternative mode 1: home delivery

Home delivery is widely used by customers. The working principle is a normal delivery model as shown in Figure 15. The parcels will be loaded onto the delivery vans at the depot. Then, the parcel is delivered directly to the customer's doorstep. A customer is requested to be present during service execution, sign and receive the parcel from the hands of a delivery provider [74]. If customers are not home, the parcels will be brought back to the depot, and will be attempted to be delivered the next day.

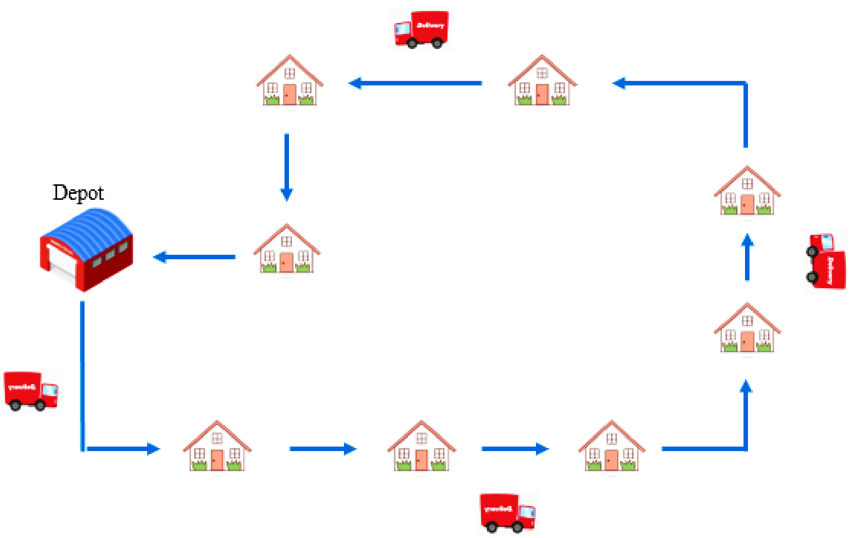


Figure 15 Alternative 1: home delivery

Alternative mode 2: the current unmanned collection point

This delivery operation mode is the same as alternative 1, i.e. the driver loads the parcel at the depot. After loading the delivery van, the driver will drive towards the delivery area and deliver the parcels. The parcel will be delivered to customer home address. If customers are not home, the parcels will be brought back to the depot or dropped off at the provider's locker point. In addition, some parcels are defaulted to drop off at lockers. This alternative is divided into 2 scenarios that are classified according to the locker location. In alternative 2.1, the locker will be located in front of a department store like Walmart. Whilst alternative 2.2 states that the locker will be located based on the literature review data, which is the appropriate distance between the locker and the customer's home. If the product is unable to be delivered, it will be attempted the following day. The working principle is the delivery model in Figure 16.

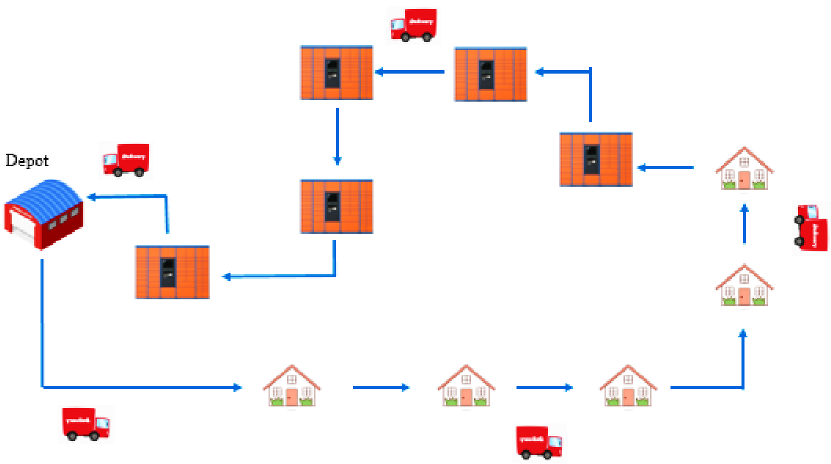


Figure 16 Alternative 2: the current unmanned collection point

Alternative mode 3: locker sharing delivery (the new one)

The working principle of this mode is similar to the alternative mode 2. The operation is loading parcels onto the van at the depot. In this mode, parcels are divided by order as parcels to be delivered at home and parcels to be delivered at lockers. Then, the driver will drive to the customer's home to deliver it. If the customer is not at home, the parcel will be returned to the depot or delivered to the locker sharing point. Locker sharing will be located according to the literature review data, which is the proper distance between the locker and the customer's home. When the work time expires, if the parcels are not delivered, they will be re-delivered the next day. The working principle is the delivery shown in Figure 17.

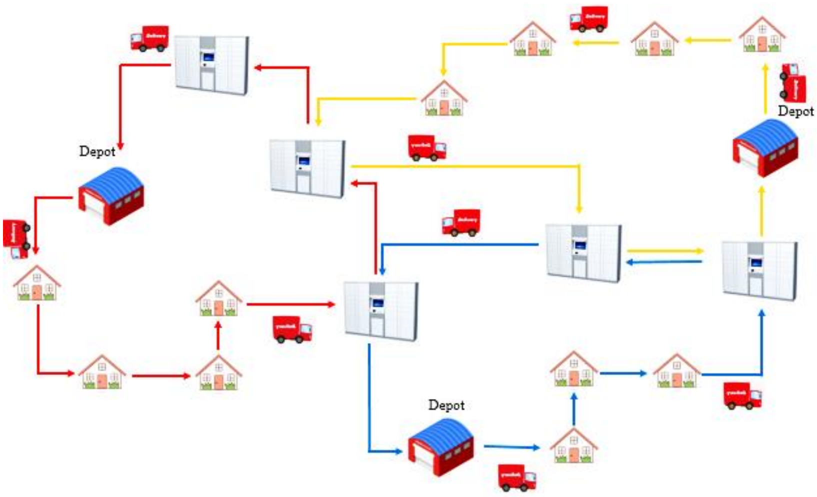


Figure 17 Alternative 3: locker sharing delivery

4.2 Simulation

In this section, methods and procedures for modeling are discussed for alternative last mile modes. The model will be created with the Arena program, which is shown in Appendix D. In addition, to ensure that the generated model works as intended, the model will be verified. The number of replication runs is computed to determine an appropriate number of repetitions. The number of replication runs is determined to be 30 repetitions from the calculation according to the equation of Harrel et al. (2003) [142]. To ensure that the model can show results that are close to the real system as possible, the model will be validated by face (experts) validation that evaluates the conceptual model to determine if it is correct and reasonable [139].

The simulations are not a particular to the study area. Therefore, the data used in the simulations will be based on interviews with experts and literature reviews. The triangulation method is used to check for ensuring that the data is valid.

Routes of the vehicle were not considered in model. The distances at each delivery point were determined by population density as shown in Table 31, 32, 33. The distance of the locker in alternative 2.1 was obtained from the distance of the department store. The locker distance in alternatives 2.2 and 3 was obtained from the literature review. This model includes two different inputs and four different outputs. The data inputs are the variables that do not vary for the different simulation scenarios as shown in Table 34. Regarding the other input variables, they differ amongst the different scenarios, depending on the scenario as shown in Table 35. This model simulates all the alternatives designed in Section 4.1, where each alternative has a total of 9 zones. According to Zhang et al. (2018) [143], 23% of private parcels are delivered directly to a locker. Therefore, in alternatives 1.1, 1.2, and 2, the percentage of parcels dropped at lockers was simulated at 23%. 30%, 37%, 44%, and 51%. Hence, this study will simulate a total of 144 scenarios.

Table 31 Distance between customers

Zone	Density (customers/km^2)		Meters		
	Min	Max	Min	Mid	Max
1	0	50	1000.0	200.0	141.4
2	51	200	140.0	89.3	70.7
3	201	400	70.5	57.7	50.0
4	401	600	49.9	44.7	40.8
5	601	800	40.8	37.8	35.4
6	801	1000	35.3	33.3	31.6
7	1001	1200	31.6	30.1	28.9
8	1201	1500	28.9	27.2	25.8
9	1501	2000	25.8	23.9	22.4

Table 32 Distance details for alternative 2.1

Zone	Distance between locker and customer (km)		Distance between 2 lockers (km)	
	Min	Max	Min	Max
1	23.01	56.01	32.5	79.2
2	23.01	56.01	32.5	79.2
3	8.05	10.13	11.4	14.3
4	8.05	10.13	11.4	14.3
5	6.78	8.05	9.6	11.4
6	6.76	8.05	9.6	11.4
7	4.83	8.05	6.8	11.4
8	4.83	8.05	6.8	11.4
9	4.83	8.05	6.8	11.4

Table 33 Distance details for alternative 2.2 and 3

Zone	Distance between locker and customer (km)		Distance between 2 lockers (km)	
	Min	Max	Min	Max
1	0.5	30	0.7	42.4
2	0.5	20	0.7	28.3
3	0.5	10	0.7	14.1
4	0.5	3	0.7	4.2
5	0.5	3	0.7	4.2
6	0.5	3	0.7	4.2
7	0.5	1	0.7	1.4
8	0.5	1	0.7	1.4
9	0.5	1	0.7	1.4

Table 34 Details of input data

Variable	Value	References
Working hours	8 hrs.	
Working day	7 days	
Capacity locker	38 parcels	
Dropping time at home	2-5 min.	[6, 11, 80]
Droping time at locker/percel	0.2-0.3 min.	[6, 144]
Van capacity	150 – 250 parcel	[11, 145]
FTHR	75 – 100%	
Loading time	15 – 30 min	Expert interviews, [11]

Table 35 Details of variable

Variable	Value	References
Number of delivery vans (depending on alternative)	One van for alternative 1, 2.1, 2.2. Three van for alternative 3.	
Percentage of drop off at locker	23% , 30% , 37% , 44% , 51%	
Van velocity (depending on zone)	Zone 1: 80 km/hr Zone 2: 80 km/hr Zone 3: 60 km/hr Zone 4: 60 km/hr Zone 5: 60 km/hr Zone 6: 45 km/hr Zone 7: 45 km/hr Zone 8: 45 km/hr Zone 9: 30 km/hr	[6], Speed limit base on UK.

4.3 Simulation Results

Every alternative has been designed and performed without any bugs or failures, which is simulated for a week of delivery, with eight hours of work per day. The simulation was conducted by Arena and operated on a Windows computer. The simulation experiments run 30 repetitions for each scenario that has been used.

The abbreviations for each option are used as follows: A1 is alternative 1, A2.1.x% is alternative 2.1 in a given percentage, A2.2.x% is alternative 2.2 in the given percentage, and A3.x% is alternative 3 in the given percentage. The simulation outputs are as follows: the number of parcels delivered successfully, the average number of failed parcels delivered, the number of parcels delivered to the locker, the number of stops, and the distance as shown in the Table 36 - 39.

The results indicate that alternatives 2.1, 2.2, and 3 can deliver on average more parcels than alternative 1: home delivery. Considering the number of parcels delivered in the neighboring zone, the number of parcels delivered is quite similar. Due to this, there are variables to consider, such as vehicle speed. In urban areas, the van velocity is low, but in rural areas it is high. Therefore, parcels can be delivered in similar amounts. On the other hand, each zone will be a distinct distance. The high-density zone distance is shorter than the low-density zone. Furthermore, the drop off locker percentage affects the number of parcels delivered. The percentage is high which means that the number of parcels is more delivered per stop. The number of stops per route also affects the delivery time and cost.

Table 36 Alternative 1

Zone	Average successful delivery	Average fail delivery	Total STOP	Distance (km)
1	768.23	116.07	884	398.28
2	829.47	117.37	947	95.02
3	831.90	119.10	951	56.46
4	838.50	121.30	960	43.15
5	838.67	118.83	958	36.18
6	840.40	118.23	959	31.76
7	837.33	120.93	958	28.68
8	841.20	120.87	962	25.98
9	837.93	119.90	958	23.32

Table 37 Alternative 2.1

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
23%					
1	763.53	113.33	36.43	877.90	497.51
2	815.43	114.53	55.47	931.77	259.09
3	817.67	117.63	56.30	937.40	97.31
4	825.93	116.43	55.17	944.17	79.36
5	822.40	118.23	79.20	943.47	81.63
6	819.47	115.57	70.17	937.37	70.04
7	821.23	116.90	72.17	940.70	65.43
8	825.17	117.97	51.53	945.00	51.70
9	819.63	116.37	62.70	938.20	54.03
30%					
1	766.67	110.30	29.10	877.90	472.60
2	802.30	115.00	83.93	931.77	356.31
3	796.40	115.77	140.63	937.40	157.69
4	795.67	113.50	160.23	944.17	162.49
5	799.90	115.73	140.70	943.47	119.11

Table 37 (continued) Alternative 2.1

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
30%					
6	797.33	111.67	137.90	937.37	114.10
7	803.47	113.77	144.37	940.70	102.25
8	798.20	115.90	142.60	945.00	99.13
9	797.30	117.10	141.70	938.20	96.67
37%					
1	762.87	111.73	34.03	875.50	481.53
2	790.23	113.43	131.27	907.87	422.11
3	773.27	110.83	253.00	894.03	217.53
4	765.83	111.67	272.97	888.67	226.86
5	768.20	109.73	276.67	890.00	194.20
6	763.53	109.03	283.03	885.00	195.40
7	767.13	108.90	261.23	887.57	160.54
8	767.67	111.43	269.80	890.53	158.05
9	761.57	108.37	246.90	880.10	141.27

Table 37 (continued) Alternative 2.1

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
44%					
1	767.43	112.43	30.40	880.67	471.52
2	778.23	111.67	149.17	894.23	433.25
3	746.77	107.37	344.53	867.70	269.74
4	706.17	102.20	467.83	830.97	385.59
5	724.97	106.83	457.40	853.43	303.92
6	709.30	102.27	465.83	833.93	309.86
7	721.97	101.73	454.37	845.33	263.26
8	718.30	100.07	477.73	841.47	275.58
9	703.37	101.77	438.03	826.37	254.89
51%					
1	767.67	108.70	29.03	877.13	464.04
2	781.17	109.73	146.03	895.13	421.40
3	740.00	105.50	352.63	859.47	271.35
4	690.20	97.17	545.97	811.73	406.60
5	672.00	97.47	668.73	803.60	439.37

Table 37 (continued) Alternative 2.1

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
51%					
6	653.27	92.27	637.87	778.03	416.62
7	655.93	95.13	662.30	785.17	378.63
8	667.20	93.33	646.30	793.27	364.87
9	640.43	90.10	597.43	760.53	336.64

Table 38 Alternative 2.2

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
23%					
1	763.47	111.47	37.83	876.20	408.23
2	819.37	114.83	63.53	936.40	118.85
3	818.37	118.77	53.77	938.87	77.11
4	824.07	121.50	60.37	947.70	50.99
5	826.33	121.63	66.33	950.37	44.73
6	824.13	114.90	83.17	942.13	43.04
7	823.70	117.53	72.47	943.93	32.62

Table 38 (continued) Alternative 2.2

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
23%					
8	824.17	121.23	60.73	947.60	29.22
9	819.70	121.27	70.13	943.60	27.21
30%					
1	755.73	111.37	76.80	870.17	424.76
2	804.17	113.93	128.00	923.40	146.31
3	805.63	117.20	120.27	927.80	106.06
4	808.67	115.73	158.40	931.30	64.22
5	807.97	116.93	164.57	932.17	58.60
6	813.07	113.07	139.13	932.27	50.67
7	817.53	114.10	124.17	936.90	35.61
8	815.57	116.07	151.20	938.03	34.37
9	808.17	118.97	132.27	932.93	30.88
37%					
1	750.77	108.63	123.00	863.40	428.25
2	780.47	110.97	253.80	902.30	193.38

Table 38 (continued) Alternative 2.2

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
37%					
3	772.93	111.30	293.27	896.90	172.19
4	784.83	116.53	306.27	915.33	83.44
5	793.33	114.40	285.17	920.07	73.48
6	788.53	110.90	276.87	911.67	69.62
7	790.43	111.80	285.03	915.73	44.62
8	796.53	110.80	294.57	919.87	41.74
9	792.67	110.30	286.67	915.27	38.51
44%					
1	748.30	104.00	148.70	856.53	424.39
2	744.33	105.33	476.83	871.77	280.50
3	734.50	105.37	478.47	863.07	255.68
4	756.50	110.67	514.53	892.93	112.99
5	764.83	108.47	488.97	896.83	101.69
6	757.17	109.20	501.00	890.67	101.31
7	763.07	110.00	533.93	899.60	59.67

Table 38 (continued) Alternative 2.2

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
44%					
8	767.30	108.53	513.63	901.23	55.53
9	757.90	108.43	518.80	892.57	54.16
51%					
1	748.17	107.93	145.90	860.23	429.90
2	727.40	104.97	540.93	855.23	288.53
3	686.37	96.63	679.87	818.37	345.36
4	727.97	102.80	697.63	867.23	140.78
5	728.00	105.77	712.40	870.77	134.08
6	721.77	101.57	708.67	859.67	132.24
7	737.13	104.33	705.20	878.03	69.35
8	740.63	104.73	695.20	881.00	66.01
9	730.10	106.30	703.23	872.67	64.16

Table 39 Alternative 3

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
23%					
1	2305.13	327.07	84.10	2636.23	1229.35
2	2452.23	349.70	180.00	2810.50	370.35
3	2457.83	354.47	175.80	2820.87	259.88
4	2466.33	356.23	207.93	2833.50	163.96
5	2478.53	352.53	208.00	2841.57	143.13
6	2481.27	348.10	188.43	2838.60	125.32
7	2480.20	354.37	192.47	2844.37	99.39
8	2478.43	354.27	208.57	2843.57	92.53
9	2465.03	358.43	194.37	2832.87	82.96
30%					
1	2284.80	327.70	141.13	2620.07	1258.47
2	2396.20	344.73	418.67	2764.13	492.89
3	2403.03	344.23	400.07	2769.40	377.85
4	2438.93	350.57	394.40	2811.47	194.33
5	2444.23	342.07	421.83	2809.07	177.39

Table 39 (continued) Alternative 3

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
30%					
6	2430.77	349.00	406.03	2800.60	158.34
7	2438.47	352.83	442.83	2815.87	116.72
8	2435.67	352.70	463.30	2814.47	110.50
9	2420.83	351.50	472.70	2798.33	102.87
37%					
1	2273.70	325.40	171.33	2620.17	1425.80
2	2330.20	335.63	608.67	2728.87	956.13
3	2322.73	335.63	744.57	2701.07	552.65
4	2374.60	335.33	818.90	2756.93	264.21
5	2366.60	338.83	876.43	2757.83	255.38
6	2363.13	337.43	817.30	2747.40	229.01
7	2375.00	342.43	871.77	2770.47	148.89
8	2377.77	345.30	880.47	2774.53	138.88
9	2357.60	338.63	872.53	2749.03	132.54

Table 39 (continued) Alternative 3

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
44%					
1	2255.53	321.87	189.23	2612.50	1594.26
2	2274.53	325.40	712.80	2711.90	1529.96
3	2182.17	310.07	1230.83	2600.57	1204.66
4	2273.40	326.87	1473.47	2696.57	391.37
5	2270.90	330.43	1475.37	2701.23	377.01
6	2252.63	323.77	1458.40	2672.87	361.25
7	2300.37	323.67	1533.67	2726.30	201.83
8	2289.03	329.73	1546.47	2720.80	194.15
9	2269.03	321.43	1511.23	2691.07	184.05
51%					
1	2244.87	319.17	194.17	2609.40	1711.64
2	2214.63	311.20	744.40	2704.10	2344.60
3	1992.60	283.40	1372.13	2510.83	2711.42
4	2136.70	306.60	1936.70	2733.83	1130.13
5	2165.13	306.47	2100.90	2626.47	513.35

Table 39 (continued) Alternative 3

Zone	Average successful delivery	Average fail delivery	Drop off at Locker	Total STOP	Distance (km)
51%					
6	2129.23	307.40	2097.47	2587.03	486.19
7	2205.57	316.17	2131.70	2673.23	251.69
8	2200.87	316.30	2120.23	2671.13	247.79
9	2166.07	310.63	2124.00	2635.53	245.20

4.4 Locker Utilization

The route of the vehicle is not considered in the simulation. It is assumed that the parcels are delivered to the customer’s home before being delivered to the locker. The parcel will be dropped off at the first locker until it is full. Then, the parcels will be delivered to the next locker. The maximum time will be 3 days that the parcel is in the locker.

The results of the 23% drop-off at lockers can be seen that A3 has the highest percentage of locker usage, obviously in zones 1, 3, 4, 5, 7, and 8. At the same time, A2.2 and A3 have similar average usage percentages in zones 2, 6, and 9 , as shown in Figure 18.

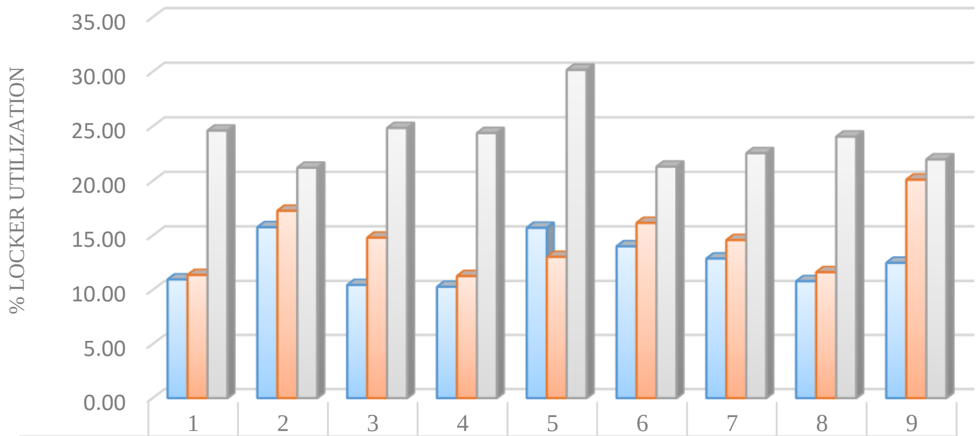
The results of the 30% drop-off at lockers can be seen that A3 has the highest percentage of locker usage in all zones. At the same time, A2.1 and 2.2 have similar average usage percentages in all zones, as shown in Figure 19.

The results of the 37% drop-off at lockers can be seen that A3 has the highest percentage of locker usage in all zones. Meanwhile, the average percentage of alternatives is not much lower than A3 in zones 3, 4, 5, 6, 7, and 8, as shown in Figure 20.

The results of the 44% drop-off at lockers can be seen that that A3 has the highest percentage of locker usage in all zones and was evident in zones 1, 2, and 3. Meanwhile, the average percentage of alternatives is not much lower than A3 in zones 4, 5, 6, 7, 8, and 9 as shown in Figure 21.

The results of the 51% drop-off at lockers can be seen that that A3 has the highest percentage of locker usage in all zones and was evident in zones 1, 2, 3, and 4. Meanwhile, the average percentage of alternatives is not much lower than A3 in zones 5, 6, 7, 8, and 9 as shown in Figure 22.

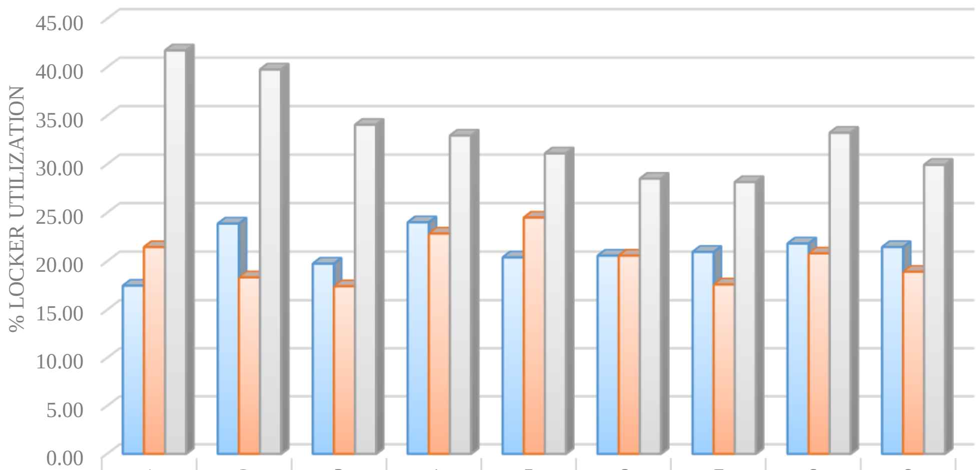
It can be seen that alternative 2.1 (A2.1.x%) has the lowest average percentage of locker utilization. Meanwhile, alternative 3 (A3.x%) has a higher percentage of locker utilization than all other alternatives. In particular, A2.1, which is delivered to its own lockers, and the distance between the customer's home and the locker is the largest.



	1	2	3	4	5	6	7	8	9
A2.1.23%	10.97	15.76	10.46	10.29	15.71	14.01	12.88	10.81	12.50
A2.2.23%	11.38	17.27	14.80	11.28	13.04	16.15	14.58	11.64	20.11
A3.23%	24.61	21.21	24.85	24.38	30.17	21.30	22.54	24.05	21.97

ZONE

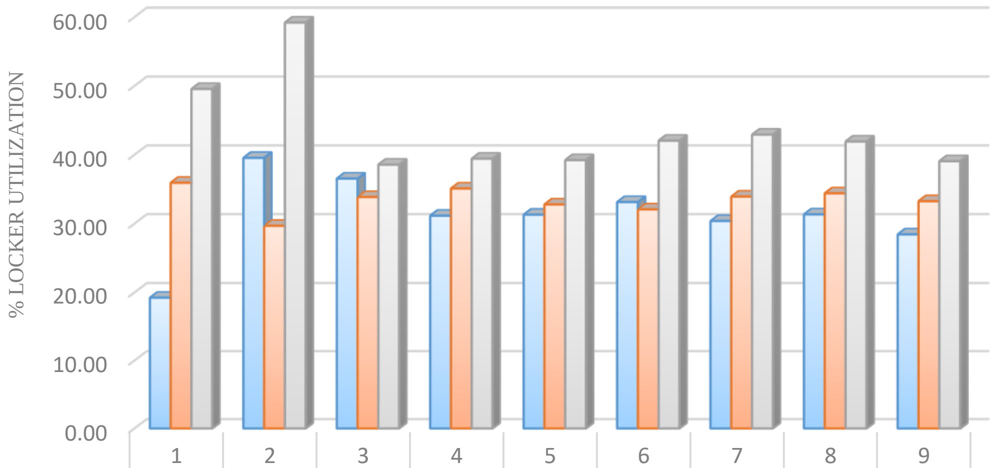
Figure 18 23% drop off at locker



	1	2	3	4	5	6	7	8	9
A2.1.30%	17.49	23.89	19.76	24.02	20.40	20.58	20.97	21.84	21.47
A2.2.30%	21.46	18.35	17.43	22.87	24.51	20.59	17.62	20.82	18.92
A3.30%	41.74	39.77	34.07	32.96	31.12	28.51	28.17	33.25	29.94

ZONE

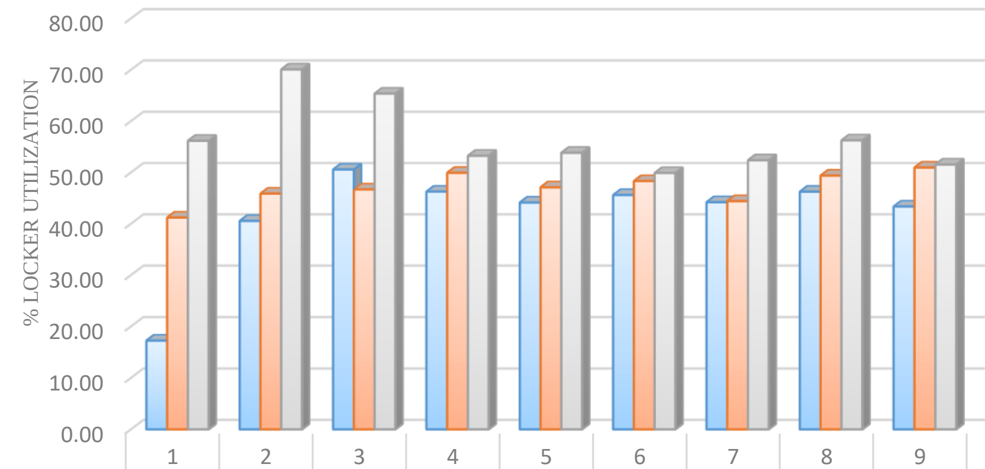
Figure 19 30% drop off at locker



	1	2	3	4	5	6	7	8	9
A2.1.37%	19.24	39.55	36.55	31.16	31.30	33.13	30.39	31.34	28.44
A2.2.37%	35.94	29.69	33.86	35.10	32.79	32.08	33.93	34.41	33.27
A3.37%	49.56	59.20	38.57	39.44	39.23	42.05	42.93	41.93	39.08

ZONE

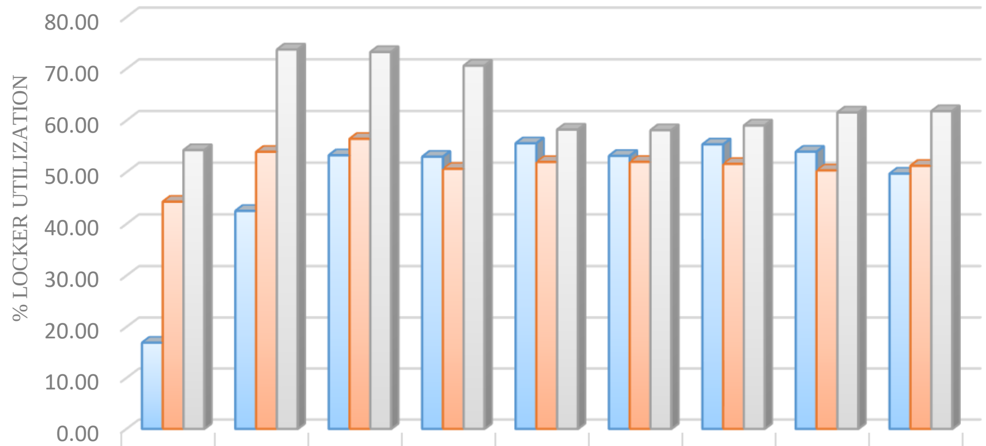
Figure 20 37% drop off at locker



	1	2	3	4	5	6	7	8	9
A2.1.44%	17.26	40.56	50.57	46.27	44.13	45.60	44.20	46.26	43.36
A2.2.44%	41.22	45.88	46.69	49.93	47.11	48.33	44.41	49.39	50.96
A3.44%	56.17	70.07	65.37	53.24	53.83	49.89	52.38	56.25	51.54

ZONE

Figure 21 44% drop off at locker



	1	2	3	4	5	6	7	8	9
A2.1.51%	16.91	42.52	53.28	53.00	55.60	53.17	55.38	53.97	49.72
A2.2.51%	44.30	53.96	56.46	50.65	51.99	52.01	51.60	50.36	51.24
A3.51%	54.27	73.73	73.24	70.60	58.23	58.12	59.03	61.56	61.80

ZONE

Figure 22 51% drop off at locker

4.5 Last Mile Delivery Costs

Blauwens et al. (2010) [146] present the last mile delivery cost function has been designed based on general cost, time, and distance transport functions. However, some cost data is company confidential information. Therefore, all knowledge and information obtained from literature and interviews assumptions will be used. The standard of this function is:

$$TC = T \bullet t + D \bullet d + Z \tag{57}$$

where:

TC	=	total transport cost
T	=	duration/time of the transport
t	=	the time/hour coefficient
D	=	the distance driven/travel for the transport
d	=	the distance coefficient
Z	=	extra costs not related to distance and/or time

The total time costs are the multiplication of the total time driven/worked by the driver (T) with the time coefficient (t). The total distance costs are the multiplication of the total distance driven (D) with the distance coefficient (d). Therefore, the total transport costs (TC) can be obtained from the sum of the total time costs, the total distance costs and some possible extra costs which are not time and distance based (Z).

Gevears et al. (2014) [11] proposed B2C last mile cost per unit shipped is defined as the home delivery whereby no time windows or lead times were agreed upon. The receiver must sign when the parcel is delivered. The delivery address is located in a region that is served by the shipper's standard route or delivery provider. In addition, it assumes that the goods will not be returned. The packaging used is considered standard packaging. The last mile cost per unit shipped is:

$$LMC = \frac{(T \times t) + (D \times d \times v)}{\left[\left(\frac{STOP}{w}\right) \times (ip \times ad \times cp \times Q \times p \times pac)\right]} \times (1+r) + \left(\frac{r \times lc \times ht}{Q}\right) + Z \qquad (58)$$

where

$STOP$	=	Average number of stops (addresses) per delivery route per driver
Q	=	Average quantity of products in the parcel
w	=	Time window coefficient
v	=	Vehicle type coefficient
r	=	Reverse logistics coefficient
lc	=	Logistics handling cost coefficient
ht	=	Average handling time in the reverse leg of a chain
ip	=	First time hit rate coefficient
cp	=	Collection points coefficient
ad	=	Area density coefficient
p	=	Pooling of parcels coefficient
pac	=	Packaging coefficient

Z = Extra cost

This calculation data is obtained from literature, simulation output data, and provider’s website as shown in Table 40, 41, and 42.

Table 40 Input value of costs

Symbol	Value	Unit	Note
T	56	hours	
t	23.70	-	Reference from Gevears et al. (2014) [11].
D		km	Value from simulation results are used.
d	0.23	-	Reference from Gevears et al. (2014) [11].
Q	1.1	-	Reference from Gevears et al. (2014) [11].
$STOP$			Value from simulation results are used.
w	1		If there is no time window: w = 1
v	0.23	-	
r		-	No reverse leg, r = 0, reverse leg, r = 1
lc	17	USD	On average the wage of UPS Delivery worker is 17 USD per hour.
ht	0.5	hour	
ip		-	Value from simulation results are used.
cp		-	Alternative 1 => cp = 1, Others alternative => cp => 1 (Value from simulation results are used.)
ad		-	Depending on area density as Table 33.
p	1	-	
pac	1	-	
Z	1.05	USD per parcel	According to UPS, Parcel insurance costs $1.05 for each $100 of value that you are shipping.

Table 41 Coefficients per density class

No of inhabitants per square km	No of inhabitants per square km
0-50	0.5
51-200	0.93
201-400	1.09
401-600	1.24
601-800	1.31
801-1000	1.35
1001-1200	1.38
1201-1500	1.39
>1500	1.41

source: Gevears et al. (2014) [11]

Table 42 Average costs for road haulage

Type	Time coefficient (t)	Distance coefficient (d)
Delivery van 0.5 tons	22.26	0.16
Lorry 5 tons	23.70	0.23
Lorry 8 tons	24.88	0.27
Lorry 20 tons	28.52	0.33
Tractor + semi-trailer 28 tons	29.74	0.37

source: Gevears et al. (2014) [11]

Table 43 Last mile delivery cost per parcel of A1 and A2.1

Zone	Alternative 1		Alternative 2.1									
			23%		30%		37%		44%		51%	
	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)
1	4.31	14.06	2.70	10.85	2.70	10.85	2.70	10.85	2.70	10.85	2.70	10.85
2	2.67	10.78	1.93	9.30	1.93	9.31	1.94	9.31	1.94	9.32	1.94	9.31
3	2.42	10.29	1.80	9.03	1.80	9.04	1.80	9.04	1.80	9.05	1.80	9.05
4	2.24	9.93	1.71	8.85	1.71	8.86	1.71	8.86	1.71	8.87	1.71	8.87
5	2.18	9.81	1.67	8.78	1.67	8.79	1.67	8.79	1.68	8.79	1.68	8.80
6	2.15	9.74	1.65	8.75	1.65	8.75	1.66	8.75	1.66	8.76	1.66	8.76
7	2.12	9.69	1.64	8.72	1.64	8.72	1.64	8.72	1.64	8.73	1.65	8.73
8	2.11	9.67	1.63	8.71	1.64	8.71	1.64	8.72	1.64	8.72	1.64	8.72
9	2.10	9.64	1.63	8.69	1.63	8.70	1.63	8.70	1.63	8.70	1.63	8.71

Table 44 Last mile delivery cost per parcel of A2.2

Zone	Alternative 2.2									
	23%		30%		37%		44%		51%	
	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)
1	2.70	10.84	2.70	10.84	2.70	10.84	2.70	10.84	2.70	10.84
2	1.93	9.29	1.93	9.30	1.93	9.30	1.93	9.30	1.93	9.31
3	1.80	9.03	1.80	9.04	1.80	9.04	1.80	9.04	1.80	9.05
4	1.71	8.85	1.71	8.85	1.71	8.85	1.71	8.86	1.71	8.86
5	1.67	8.78	1.67	8.78	1.67	8.78	1.67	8.78	1.67	8.79
6	1.65	8.74	1.65	8.74	1.65	8.75	1.65	8.75	1.65	8.75
7	1.64	8.72	1.64	8.72	1.64	8.72	1.64	8.72	1.64	8.72
8	1.63	8.71	1.63	8.71	1.63	8.71	1.63	8.71	1.64	8.71
9	1.63	8.69	1.63	8.69	1.63	8.69	1.63	8.69	1.63	8.69

Table 45 Last mile delivery cost per parcel of A3

Zone	Alternative 3									
	23%		30%		37%		44%		51%	
	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)	No reverse (USD)	Reverse (USD)
1	1.65	8.74	1.62	8.68	1.62	8.68	1.63	8.69	1.63	8.70
2	1.38	8.19	1.35	8.13	1.35	8.14	1.36	8.16	1.37	8.18
3	1.33	8.10	1.30	8.04	1.30	8.05	1.31	8.06	1.32	8.09
4	1.29	8.03	1.27	7.98	1.27	7.98	1.27	7.98	1.28	8.00
5	1.28	8.00	1.26	7.96	1.26	7.96	1.26	7.96	1.26	7.96
6	1.27	7.99	1.25	7.94	1.25	7.95	1.25	7.95	1.25	7.95
7	1.27	7.98	1.25	7.93	1.25	7.94	1.25	7.94	1.25	7.94
8	1.27	7.98	1.25	7.93	1.25	7.93	1.25	7.93	1.25	7.93
9	1.26	7.97	1.24	7.93	1.24	7.93	1.24	7.93	1.24	7.93

Based on the calculation of the last mile delivery cost per parcel, the cost per parcel for A1 will be 4.3 times higher on average if the parcel fails first time delivered (reverse). Meanwhile, zone 9's cost per parcel is as low as 2.10 USD for the first successful delivery (no reverse) and 9.65 USD for the reverse parcels as shown in Table 43.

Table 43 also shows that for A2.1, the cost per parcel of all drop percentages at the lockers is the same. The reverse parcel cost is 5 times higher on average than the cost of no reverse parcel. Zone 9's cost per parcel is as low as 1.63 USD for no reverse parcel, 8.70 USD for the reverse parcel. Meanwhile, zone 1's 2.70 USD for no reverse and 10.85 USD for the reverse parcels

Table 44 shows that the cost per parcel of all drop percentages at the lockers is the same. The reverse parcel cost is 5 times higher on average than the cost of no reverse parcel. Zone 9's cost per parcel is as low as 1.63 USD for no reverse parcel, 8.70 USD for the reverse parcel. Meanwhile, zone 1's 2.70 USD for no reverse and 10.84 USD for reverse parcels.

Table 45 shows that the cost per parcel of all drop percentages at the lockers is the same. The reverse parcel cost is 6.2 times higher on average than the cost of no reverse parcel. Zone 9's cost per parcel is as low as 1.24 USD for no reverse parcel, 7.93 USD for the reverse parcel. Meanwhile, zone 1's 1.63 USD for no reverse and 8.70 USD for reverse parcels.

The results indicate the cost per parcel in zone 9 is the lowest among the zones. The number of parcels successfully delivered is high with a low total distance. In addition, the LMD cost increases dramatically many times when a parcel fails first time delivered. The cost per parcel of A1 is the highest. On the other hand, the cost per parcel of A3 is the lowest. The A3 is 1.25 times cheaper than the A2, and 1.57 times cheaper than the A1.

4.6 Conclusion

In this chapter, a novel mode of last mile delivery was proposed. Then, it was compared to existing modes by using a simulation technique. This method had been used extensively. The Arena simulation program was used as a research tool. The home delivery mode and the current unmanned collection point were simulated and compared with the locker sharing delivery mode, which was the proposed mode. In addition, the data output from the simulation was used to calculate the last mile delivery cost per parcel.

The proposed mode was more efficient than other modes. This mode had the lowest cost of all the modes. Its locker utilization was also higher than the current unmanned collection point. It was seen that the combination of lockers between companies could reduce costs for them. In addition, this study found that the average locker utilization percentage of a low-density area was higher than that of a high-density area.

The higher the cost per parcel in a densely populated area, the lower the cost. The failed first time delivery dramatically affected the cost. The LMD cost raised considerably compared to the first successful delivery. Furthermore, the LMD cost of the proposed mode per parcel was 1. 25 times less than the current unmanned collection point mode and 1.57 times less than the home delivery mode.

The locker sharing delivery mode is optional for the delivery provider. Moreover, it may be a new business approach to open a locker sharing service. However, the delivery provider will have to reconsider whether it is worthwhile to combine with another delivery provider, or rent a locker from another delivery provider. If the delivery provider can reduce the cost, the service fee will be lower. Furthermore, the service fee is the criterion that both customers and merchant are interested in.

CHAPTER 5
BUSINESS MODEL OF THE PROPOSED MODE

In this chapter, business model will be created to conduct an economic analysis of the proposed mode. Business Model Canvas (BMC) is employed to model template. It was developed and presented by Alexander Osterwalder in 2010. Business Model Canvas is a strategic management and lean startup template for developing new or documenting existing business models. It is a visual chart with elements describing a firm's or product's value proposition, infrastructure, customers, and finances. Consequently, business models will help to understand the business image as a whole.

SWOT analysis is also conducted to provide an overall view of the locker sharing. The purpose of the following analysis is to extract useful information from each category in order to have a better understanding of the locker sharing as a whole.

In addition, the number of locker slots available at the break-even point is calculated. The break-even point is important when deciding on the selling price as well as the number of products to be sold.

5.1 Data Collection

5.1.1 Primary data

The LMD provider company experts are interviewed. Due to LMD provider company is one of the target group. This is an interview to get information from the perspective of entrepreneurs and customers. The resulting data will be analyzed to develop a business model. This study used content analysis to analyze content from interview recordings.

5.1.2 Secondary data

The collection data for this research is from documents/websites of major operators of last mile delivery. In addition, an academic literature review is collected. The academic literature search was focused on identifying the relevant subjects and research concepts like business models for last mile delivery, logistics, or parcel delivery. The database used for the search is Web of Science, Google Scholar, Scopus etc. Moreover, the LMD provider company experts are interviewed. Due to LMD provider company is one of the target group. In addition, the secondary data obtained will be validity using the data triangulation method.

5.2 Business Model Canvas of Locker Sharing Mode

The simulation in Chapter 4 showed that the alternative of locker sharing will improve parcel deliveries and collections. Therefore, in this section, locker sharing will be analyzed feasibility from a business perspective by using business model canvas (BMC). The business model canvas is a shared language for describing, visualizing, assessing and changing business models. It describes the rationale of how an organization creates, delivers and captures value. BMC is consisting of 9 elements as (1) Offer, Value proposition (2) Customer segment (3) Distribution channels (4) Customer relationships (5) Revenue streams (6) Key resource (7) Key activities (8) Key partners, and (9) Cost structure. The BMC of locker sharing is shown in Figure 23.

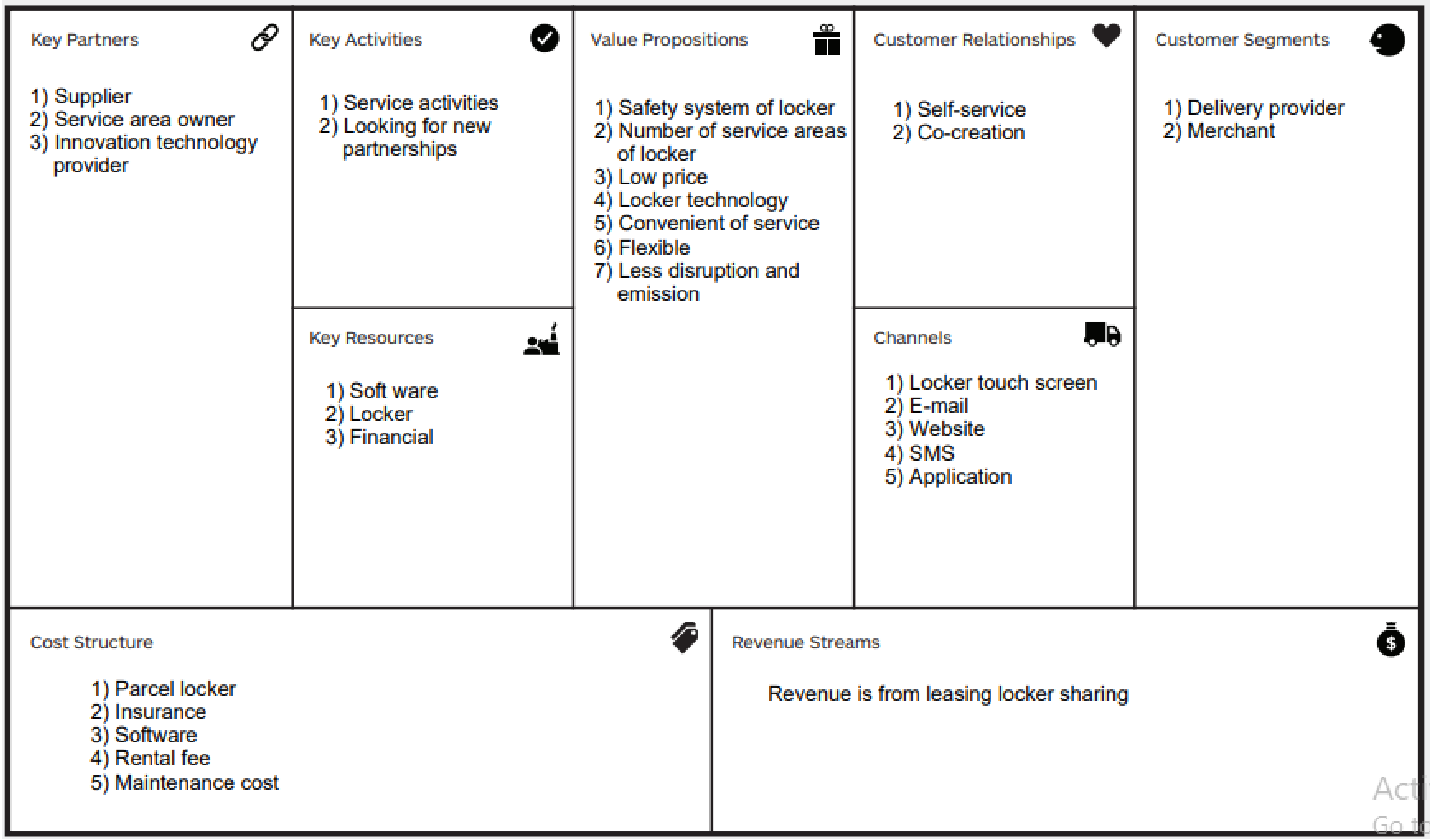


Figure 23 Business model canvas

5.2.1 Value proposition

The value proposition describes a combination of products and services that are offered to the selected customer. The value proposition is the core element of each business. It is the reason why customers choose a specific company over that of the other. The value propositions are follows:

1) Safety system of locker

2) Number of service areas of the locker

3) Low price

4) Locker technology

5) Convenient of service

6) Flexible

7) Less Disruption and emission

5.2.2 Customer segment

The customers might be the most important element of the business model canvas, as it shows which groups of people you are targeting. Determining a good target customer that meets the product characteristics will lead to more chances of success. Target customers are two groups as following:

1) Delivery provider

2) Merchant

5.2.3 Distribution channels

The channels are in a tight connection between value proposition and customer service. This help customer to evaluate the company’s value proposition. Channels are the way to communicated and provide services to customers. Analyzing channels that can respond to customers thoroughly and meet the target group, there are 5 channels:

1) Locker sharing touch screen

2) E-mail

3) Website

4) SMS

5) Application

5.2.4 Customer relationships

Customer relations are being driven to acquire new customers, retain customers, and increase sales. Relationships building with customers is necessary and important for business operations. According to Osterwalder and Pigneur (2010) [147], this BMC has customer relations as

1) Self-service. It means that customers help themselves, and they don't have direct contact with the company, but company offered the ability for the customer to help himself.

2) Co-creation. It is a more extended version of a customer-vendor relationship. It is relationship between a customer and the company by creating value together with the customer.

5.2.5 Revenue streams

Revenue stream represents money that the company generates from each customer segment. Types of revenue streams can be sales or service based where revenue comes from successful sales or service fees. This BMC revenue is from leasing locker sharing.

5.2.6 Key resource

Key resource is the most important assets the company owns. It is these resources that will enable the company to create value proposition, reaching out to the market, retaining relationships with customer segments, and create revenue. The main resources that are required are follows:

1) Soft ware

2) Locker

3) Financial

5.2.7 Key activities

Key Activity is about a list of activities, which company needs to have and do in order to perform well and also better in the future. Identifying key activities must be carried out to achieve the objectives. Main activities include production, provision of services, products/services that solve problems for customers, platform network building, etc. Key activities of model as following:

1) Service activities

2) Looking for new partnerships

5.2.8 Key partners

Key Partners are the network of suppliers and partners. An alliance can be created to benefit the company's business model, reduce risk or gain resources. Key partners who support and assist in business operations are as follows:

1) Supplier

2) Service area owner

3) Innovation technology provider

5.2.9 Cost structure

The cost structure describes the key costs a company has by using a business model. Through the defined key factors, activities and partnerships, the costs can easily be calculated. The cost structure of this BMC are follow:

1) Parcel locker

2) Insurance

3) Software

4) Rental fee

5) Maintenance cost

5.3 SWOT Analysis

In the 1960s, Stanford Research Institute's Albert Humphrey created the SWOT analysis approach as a strategic planning tool. The preliminary characters of the four terms "strengths, weaknesses, opportunities, and threats" are combined to form the SWOT acronym. This qualitative strategic technique is used to identify the key internal (strengths and weaknesses) and external (opportunities and threats) strategic factors that an organization (group, person, etc.) faces and how they affect its objectives as a robust strategic planning and environmental analysis tool. Based on the outcomes of this method, relevant plans to optimize strengths, reduce weaknesses, exploit opportunities, and counter threats may be established [148]. Therefore, the SWOT of the locker sharing mode is shown in Figure 24.

5.3.1 Strengths

- Locker sharing is open all the time, customers can access to locker sharing all day and night.
- Locker sharing is supported by high-technology in terms of service and safety.
- The service fee for using the locker sharing is low.

5.3.2 Weaknesses

- Customers must pick up the parcel by themselves.
- To provide a comprehensive service area, the investment in the first year is quite high.

5.3.3 Opportunities

- The use of locker sharing is less disruption, emission, pollution, noise, and energy use.
- The company may expand, become more stable, and produce cash flow.
- The number of locker sharing service areas makes it convenient for customers.
- Loyal customers can be gained by installing lockers in a good location.
- Delivery providers benefit from increased efficiency.

5.3.4 Threats

- Rental spaces in business districts are priced too high.
- Locker sharing services must be developed over time in order to be able to meet the needs of customers.
- New technologies.

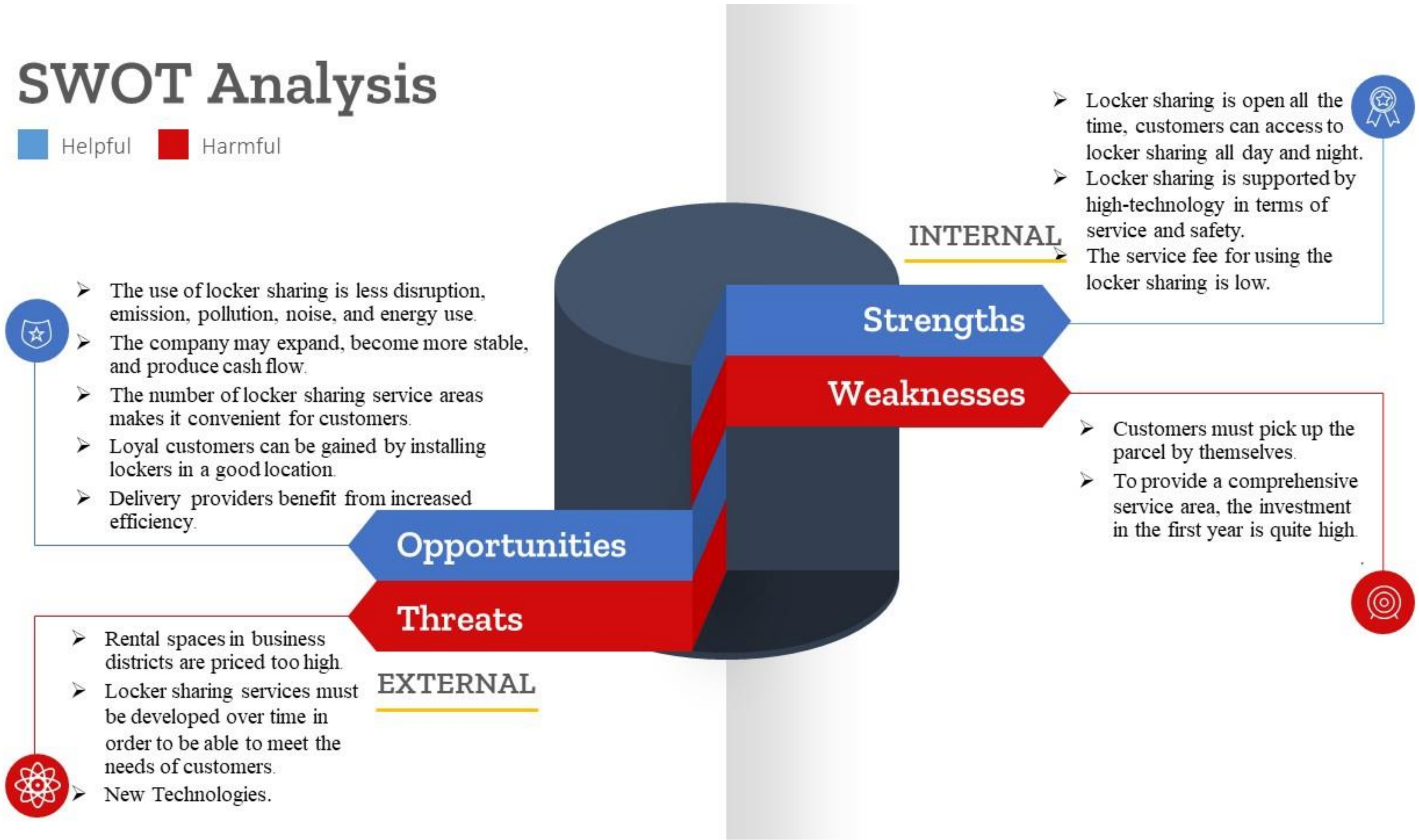


Figure 24 SWOT of locker sharing mode

5.4 Break Even Point Analysis

The break-even point (BEP) is the quantity of items that a company must produce and sell in order to break even financially. In other words, the break-even point is the amount of monthly revenues that will cover the business's monthly operating expenses.

In this section, the number of locker slots available at the break-even point is calculated. However, this equation of BEP is calculated for number of slots per one service area. Therefore, the BEP of locker sharing as follow:

From

$$BEP = \frac{FC}{P - VC} \tag{59}$$

$$c = \frac{FC}{N} + VC \tag{60}$$

$$P = c + x \tag{61}$$

Thus,

$$n = \frac{FC}{Nx + FC} \times N \tag{62}$$

where

c = Cost per unit

FC = Fixed costs

VC = Variable costs per unit

N = Capacity of locker per month or year

n = Number of slots

P = Sales price per unit

x = Additional margin

For an illustrative example, the lockers will be installed in the province of Thailand. From the population density, Bangkok can be defined as an urban area, Nonthaburi is a suburban area, and Chiang Rai is a rural area. Then, the costs are assumed as in Table 46.

Table 46 The locker sharing costs

Cost	Value (USD)	Note
FC	1100 for Bangkok, 750 for Nonthaburi, 600 for Chiang rai.	Fixed costs are locker depreciation, salary per month, area rental, and etc.
VC	0.2	Variable costs are electricity bill, maintenance, and etc.
N	1140	Assumed that capacity per locker per day is 38 units.
x	Partner 0.23 for Bangkok, 0.17 for Nonthaburi, 0.14 for Chiang rai. Regular delivery provider 0.58 for Bangkok, 0.42 for Nonthaburi, 0.36 for Chiang rai.	20% for partner, 50% for regular delivery provider .

Noted that the costs are an approximate cost.

Hereafter, calculate toward by using the equation (59) – (62). Then, the number of locker slots available at the break-even point are presented.

Table 47 The number of locker slots for each area

Area	Number of lockers (unit per month)		P (USD)	
	x = 20%	x = 50%	x = 20%	x = 50%
Bangkok	919	712	1.40	1.75
Nonthaburi	905	692	1.03	1.28
Chaing rai	897	677	0.87	1.09

As considered in Table 47, in urban area, sales price is higher than rural due to the cost is more expensive. In addition, number of locker slots in rural is less than other area. Reasonably, from chapter 5, it can be seen that the locker utilization in low population density is low.

There is no constant in the equation because each provider's investment varies, such as the location of the lockers, the size of the lockers, the technology utilized, the installation cost, etc., In addition, the corporation adds profit margin as needed. As a result, the above equation may be used to determine the number of unit that are available on a cost-effective basis.

5.5 Conclusion

In this chapter, a business model of the proposed mode was created and analyzed in term of economic. The BMC could help businesses to define their values and actions. In business model canvas, the data were obtained from the interviews, literature review, searching from related companies' website. Based on the results of the Chapter 3, this BMC of proposed mode showed that the value proposition met customer needs. Because it solved problems that customers focused on, including safety, convenience and cost.

There was also a SWOT analysis of the lockers' strengths, weaknesses, opportunities, and threats. At the break-even point, the minimum number of slots for one area point was computed. Each country had varied investments, and added the extra profit that each company requires in terms of cost. Therefore, equation was no constant variable. If the delivery provider, on the other hand, adopted this locker sharing service, the cost of maintaining the company's lockers was reduced, and there was no need to invest in more lockers to reach customers. This improved delivery efficiency while lowering expenses.

CHAPTER 6
CONCLUSIONS

Last mile delivery (LMD) is a part of logistics that supports e-commerce and is one of the challenges in the e-commerce supply chain. It is the final delivery of goods from distribution centers to the destination that is the only connection in the e-commerce supply chain that involves direct, face-to-face interaction with customers. Presently, last mile delivery is not only in the business-to-customer (B2C) model, but also in other business models of e-commerce. In the e-commerce supply chain, LMD is regarded as the most complex and costly task to manage and operate. The main LMD problem is failed first time delivery. It means the courier driver delivers a parcel to a customer, but the delivery is not successful. Therefore, the parcel may be delivered two or three times before it is successfully delivered. Accordingly, it will increase the delivery costs substantially, which depends on the failed first-time delivery rate. This problem affects the time and cost of the logistics operations. In addition, it causes other consequences, such as carbon emissions, pollution, traffic congestion, and other effects. Therefore, last mile delivery management is necessary and important. Its cost-reduction will make the merchants more profitable and bring down the other problems mentioned above. Furthermore, increasing last mile delivery efficiency makes customers more satisfied, which sustains merchants.

This research started with literature reviews: last mile delivery, simulation, Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and related works. Then, the existing Last Mile Delivery modes in perspectives of all stakeholders were compared. The questionnaire was used as a tool that inquiries from all stakeholders. Fuzzy TOPSIS was used to analyze the data. The data collected from a variety of respondents. The data was uncertainty and fuzzy. In addition, respondents were asked to rate on a five-point Likert scale. Therefore, triangular distribution was conducted for calculation. The decision-makers, individual rate was combined into triangular numbers. The objective weight method was chosen. Based on the center of area approach, which was used to convert fuzzy numbers into crisp data. The results shown that the customer and merchant are always concern that parcels would be safe, unbroken, undamaged, trackable and not lost. Therefore, the attended home delivery mode was the preferred choice of customer and merchant. On the other hand, the unmanned collection point was the preferred choice of delivery provider, due to its low cost. The parcels would drop many pieces per locker point. This made it possible to save both money and time.

Furthermore, delivery provider experts and merchant experts were interviewed in depth. In delivery providers' opinion, customers considered service and price. Also, merchants that select last mile delivery depended on service and price. In addition, the delivery provider should consider the matter of the customer segments because of the difference in customers' needs. For example, the customer was divided by age: young customers often want fast delivery; working-age groups focus on the quality of service, while the elderly group would be focused on convenience. However, deliver providers should be focused on improving product security and safety.

According to the report, all stakeholders were concerned about product safety and the convenience criterion. Moreover, delivery providers' highest focus was cost. As a result, locker sharing presented as a new mode of last mile delivery. Then, using simulation techniques, it was compared to existing modes. The simulation program for the arena was used. Also, the simulation's output data was applied to calculate the last mile delivery cost per parcel. Other modes were less efficient than the proposed mode. The cost of this mode was the cheapest of all the modes. It also had a greater locker utilization rate than the present unattended collection point. It was observed that combining lockers amongst providers saved money. The delivery provider could choose to use the locker sharing delivery approach. Additionally, offering a locker sharing service could be a novel company strategy.

Finally, a business model for the proposed mode was developed. The template was created using a Business Model Canvas (BMC). Delivery provider may use the BMC to outline their values and behaviors. The proposed mode's BMC demonstrated that the value proposition may match customer expectations by discussing problems that customers care about, such as safety, convenience, and affordability. A SWOT analysis was also conducted on the locker sharing. The required number of slots for one area point was calculated at the break-even point. Each country had different investments, and each business demands a different amount of return in terms of cost. When a delivery provider used this locker sharing service, the cost of maintaining the company's lockers was decreased, and there was no need to invest in additional lockers to reach customers. This increased the efficiency of deliveries while lowering expenses.

Appendix

Appendix A
The List of Experts

1. Index of Item Objective Congruence

Delivery Provider Perspective

1. Mr. Kazuhiko Izumi

    Logistics Manager, Kantsu Co., Ltd., Japan

2. Ms. Pimchanok Sitthithesanond

    Indonesia-Logistics Account Executive, SCG Barito Logistics, Indonesia

3. Mr. Joel Ong

    Regional COO Ninja Van, Ninja Logistics Pte. Ltd., Singapore

4. Mr. Mohamad Faizal Bin Suhairee

    VP Operation, Customer Experience, Ninja Logistics Pte. Ltd., Singapore

Customer Perspective

1. Ms. Tawinan Suksangjan

    Transport Solutions Manager, MAERSK, Thailand

2. The 3 anonymous expert

Merchant Perspective

1. Ms. Siriporn Noibath

    Shop management service, Shopee Thailand Co., Ltd., Thailand

2. Mr. Anucha Worachak

    Supervisor (Loading), Better way (Thailand) Co., Ltd., Thailand

3. The 2 anonymous expert

2. The Depth Interview

Delivery provider's perspective

1. Mr. Kazuhiko Izumi

    Logistics Manager, Kantsu Co., Ltd., Japan

2. Ms. Pimchanok Sitthithesanond

Indonesia-Logistics Account Executive, SCG Barito Logistics, Indonesia

3. The anonymous expert

Merchant Perspective

1. Ms. Siriporn Noibath

    Shop management service, Shopee Thailand Co., Ltd., Thailand

2. Mr. Anucha Worachak

    Supervisor (Loading), Better way (Thailand) Co., Ltd., Thailand

3. The anonymous expert

3. Simulation validation

1. Mr. Apiwit Assawariddumrong

    Store manager, J&T Express (Thailand), Thailand

2. Ms. Tawinan Suksangjan

    Transport Solutions Manager, MAERSK, Thailand

3. Ms. Pimchanok Sitthithesanond

    Indonesia-Logistics Account Executive, SCG Barito Logistics, Indonesia

4. Ms. Kanokkarn Ruksa

    Regional operations manager (Middle mile, Ninja Logistics Pte. Ltd., Singapore

5. The anonymous expert

4. Business Model Canvas and SWOT Analysis

1. Ms. Kanokkarn Ruksa

    Regional operations manager (Middle mile, Ninja Logistics Pte. Ltd., Singapore

2. Mr. Mohamad Faizal Bin Suhairee

    VP Operation, Customer Experience, Ninja Logistics Pte. Ltd., Singapore

3. Ms. Tawinan Suksangjan

    Transport Solutions Manager, MAERSK, Thailand

4. Mr. Apiwit Assawariddumrong

    Store manager, J&T Express (Thailand), Thailand

5. The 2 anonymous expert

Appendix B

The Depth Interview

This appendix made use of in-depth interviews as a research tool. In-depth interviews are an effective qualitative method in which people would share their personal experiences, opinions and feelings. Data on the perspective of delivery providers was collected from in-depth interviews with 3 logistic experts who work with third-party logistics provider (3PLs) companies. For Merchant' s perspective, data was collected from in-depth interviews with 3 professionals who works with e-commerce companies or online sales companies.

In the in-depth interview and discussions with the delivery provider experts, the questions are the following:

Q1) what do you think about the current last mile delivery?

Q2) what factors do you think that influence a customer in choosing a last mile delivery mode?

Q3) what do you think about last mile delivery in the next 10 years?

Q4) how should last mile delivery be improved to meet customers' needs?

Merchant experts are also asked the following three questions:

Q5) what do you think about the current last mile delivery?

Q6) what factors do affect your choice of last mile delivery?

Q7) how should last mile delivery be improved to meet customers' needs?

Detailed answers to each question are summarized as follows:

Major findings of delivery provider's perspective

Q1. What do you think about the current last mile delivery?

Last mile delivery situation is various and different in each country. Still, enterprises and corporates are paying great attention and efforts in improving the delivery service in order to meet the needs of the customers. " In Japan, last mile deliveries are still failing in delivery time. Therefore, communication between the recipient and the delivery provider is very important." (Kazuhiko Izumi). " Last mile deliveries service is highly competitive. The company emphasizes the importance of price and quality. The main attributes are low price, fast delivery, and good service. Unfortunately, there is no way to perfectly achieve goods delivery with all three attributes." (Pimchanok Sitthithesanond). "Last mile deliveries are constantly evolving to respond customers' needs. So, many companies are profoundly competing to meet the needs of their customers." (Anonymous).

Q2. What factors do you think that influence a customer in choosing a last mile delivery?

The answers from interviewees were all in the same direction regarding the service factors that influences the selection of choices of last mile delivery service; "'Speed' and 'Convenience'. The preferable delivery speed that the customers can receive the product is within two hours. The convenience mentioned is an autonomy of the customers to choose their pickup points." (Kazuhiko Izumi). "'Price', 'Speed', and 'Convenience', but our current customer base is more focused on the fee they have to pay. They don't hold much purchasing power due to the adverse economic condition." (Pimchanok Sitthithesanond). "'Price' and 'the quality of service'. The lower the price, the likely more feasibility for the customers to choose the service. Regarding the good service, the customers are concerned that the parcel has no damage." (Anonymous).

Q3. What do you think about last mile delivery in the next 10 years?

Technology and innovations will be even more involved in last mile delivery. “In ten years, robots will be used in last mile delivery. Technology will play its roles a lot in the future.” (Kazuhiko Izumi). “This kind of logistic business will grow exponentially. If the service quality can be maintained at good level, delivery providers and merchants will put the light on new technologies. In the future when technologies would have been developed to replace 50-70% of manpower, the delivery cost the customers have to pay will be probably reduced.” (Pimchanok Sitthithesanond).“In the next ten years, technologies will be brought in. Last mile deliveries will be more efficient and able to meet customer needs.” (Anonymous).

Q4. How should last mile delivery be improved to meet customers’ needs?

Last mile delivery improvements should be considered in customer segments. “In order to improve last mile delivery, delivery area and customer age should be put into concern. Speed and convenience are important for young people in city areas but we should shine the light on the elderlies in urban areas as well. Because Japan is entering aging society stage, convenience of goods delivery for the elderlies is important. It is the challenges for delivery providers to face and cope with” (Kazuhiko Izumi). “We need to clearly classify and select the focused segment groups. For example, in the working-age group, people will primarily take convenience in concern, both in the command of the application and the service mind. At present, social media is very influential with so many rooms for customers to express their compliments and complaints on each service, so ‘the service mind’ choice is difficult to control” (Pimchanok Sitthithesanond). “We will improve the speed of delivery. Most customers who use this LMD service, they want the parcel to arrive as quickly as possible. However, we should also consider different needs and expectations of each customer groups” (Anonymous).

From the in-depth interviews, the last mile delivery service is highly competitive. Although it can be seen that situation in each country is different, commercials pay great attention in LMD service development in order to achieve in meeting customers' needs. Considering the perspective of delivery providers, most of the customers focuses on price, speed, and convenience. To improve LMD, examination and determination on the service needs of different customer groups are crucial. In the future, technology will be even more involved in LMD services. More and more delivery providers tend to adopt innovations into account to reduce the cost and improve their service.

Major findings of Merchant perspective

Q4. What do you think about the current last mile delivery?

Merchants may use their own delivery methodologies or deploy third-party logistics providers. Therefore, the comments from merchants vary. "Nowadays, last mile delivery becomes more convenient than before. The company can deliver products to customers faster and customers are very satisfied with the services provided." (Siriporn Noibath). "Most companies have their own delivery service available for the customers. Therefore, last mile delivery service is controlled under the company's standards." (Anucha Worachak). "The number of last mile delivery providers is increasing. So, we have more options. The shop in our platform can choose the company that best suits the customer's condition." (Anonymous).

Q5. What factors affect your choice of last mile delivery?

Everyone's opinions are led to the same direction; the service factor is the main thing. "'Service areas' and 'Convenience'. Some delivery providers have limitations to reach every customer's residence area. So, to some customer, it is not convenient." (Siriporn Noibath). "'Convenience' and 'Price' because our service must be in line with standards. The product must not be lost or broken. The safety of our delivery is very high. Moreover, we have various options for the customer. If the product price reaches the specified target, the delivery is free-of-charge." (Anucha Worachak). "'Price' and

'Service'. The customers prioritize primarily a delivery provider with the cheapest shipping cost. Then, they will consider the service." (Anonymous).

Q6. How should last mile delivery be improved to meet customer needs?

The opinions of each interviewee vary as the vision and situation of each company is different. "Product safety and security should be improved. the speed and services of some companies are good but the products have higher possibility to be damaged. Some of our products are high-priced. Still, the last mile delivery providers will be responsible for some costs when the products are damaged. As a result, most expenses are on us when the customers complain and ask for compensation." (Siriporn Noibath). "We would improve delivery speed. Sometimes we cannot deliver our products as scheduled on time. So, we consider using the last mile delivery company. In consequence, it increases the delivery costs." (Anucha Worachak). "Now, we provide our delivery service for an online shop. We are considering on adding more access to customers' locations to deliver goods and, at the same time, reducing the delivery cost. Moreover, we will increase delivery efficiency. These are the important factors that convince customers to choose our delivery service." (Anonymous).

In this section, merchants may either apply their own delivery service or deploy third-party logistics providers. Last mile delivery service at present is much more convenient than before. There are many 3-party service companies for merchants to choose from. Although it is evident that the 3 specialists have different business models, they choose last mile delivery based on price and convenience factors. Apart from that, product safety and delivery speed are essential and should be put into consideration because, in case that the product is lost or damaged, they are the ones who are responsible for and cover the cost/compensation together with the delivery carrier which results in rising expenses for the merchants.

Appendix C

Index of Item Objective Congruence

1. Conformity index between the criteria and the purpose of the last mile delivery mode selecting: Delivery Provider Perspective

Criteria	Expert review score				IOC Score	Result
	1	2	3	4		
1	+1	+1	+1	+1	1	Available
2	+1	+1	+1	+1	1	Available
3	+1	+1	+1	+1	1	Available
4	0	+1	+1	+1	0.75	Available
5	+1	+1	+1	+1	1	Available
6	+1	+1	+1	+1	1	Available

2. Conformity index between the criteria and the purpose of the last mile delivery mode selecting: Customer Perspective

Criteria	Expert review score			IOC Score	Result
	1	2	3		
1	+1	0	+1	0.67	Available
2	0	+1	+1	0.67	Available
3	+1	+1	+1	1	Available
4	+1	+1	+1	1	Available
5	+1	+1	+1	1	Available
6	0	+1	+1	0.67	Available
7	+1	+1	+1	1	Available
8	+1	+1	+1	1	Available

3. Conformity index between the criteria and the purpose of the last mile delivery mode selecting: Merchant Perspective

Criteria	Expert review score			IOC Score	Result
	1	2	3		
1	+1	+1	+1	1	Available
2	+1	+1	+1	1	Available
3	+1	+1	+1	1	Available
4	+1	+1	+1	1	Available
5	+1	0	+1	0.67	Available

Appendix D
Model Simulation

1. Model

1.1 Based model: Alternative 1

The working principle is a normal delivery model. The parcels will be loaded onto the delivery vans at the depot by the driver. Then, the parcel is delivered directly to the customer's doorstep. A customer is requested to be present during service execution, sign and receive the parcel from the hands of a courier [74], If people are not home, the parcels will be brought back to the depot, and will be attempted to be delivered the next day. A based model or alternative 1 is created for the 9 zones as shown in Figure 25. The working steps in each zone are the same, but the input data differs according to the information mentioned in Chapter 4.

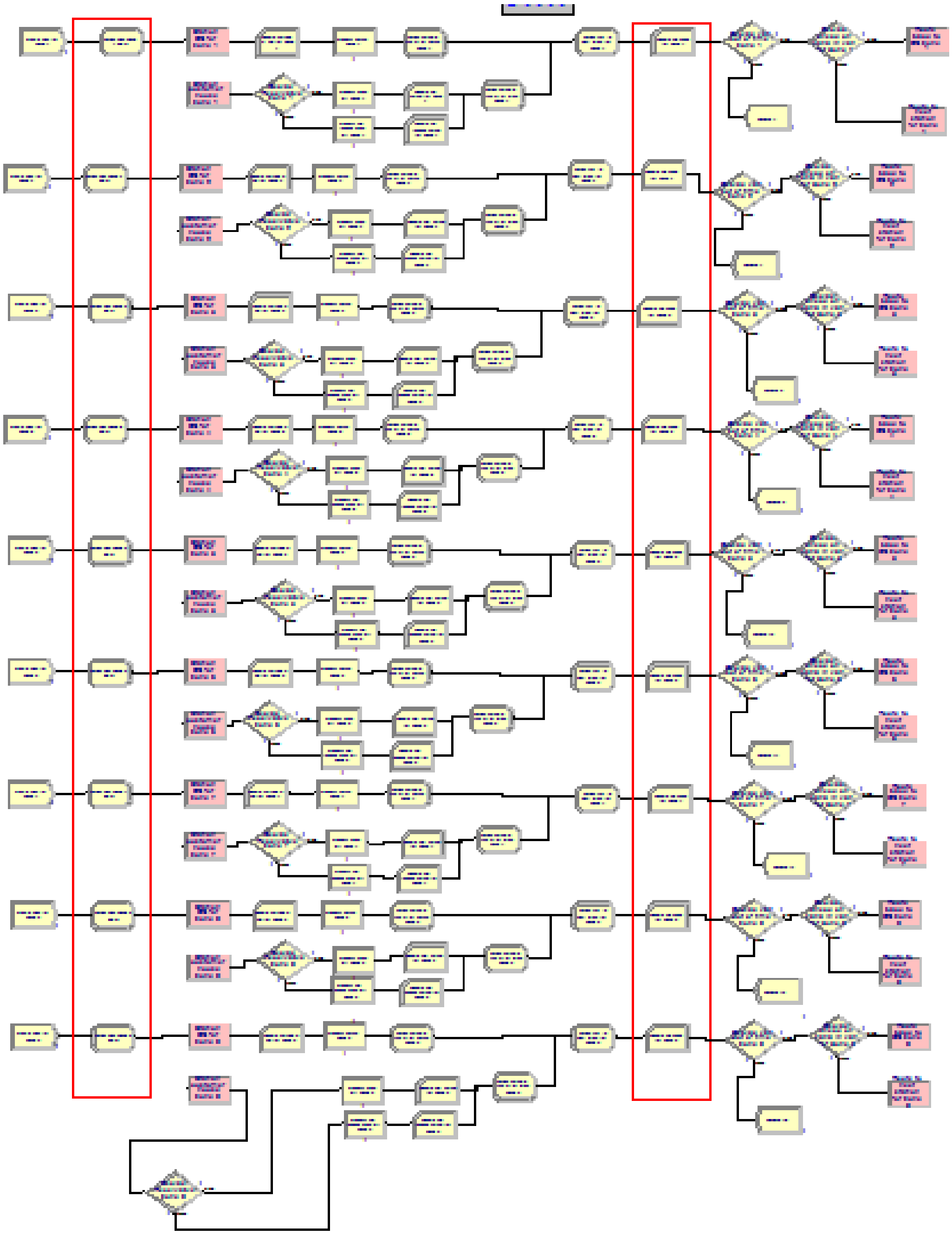


Figure 25 A based system scenario using the arena program.

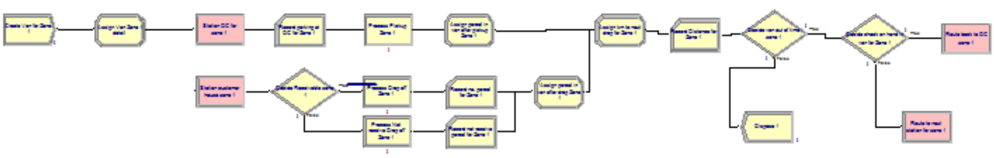


Figure 26 A based scenario of the model

As shown in Figure 26, the A1 scenario can be described as follows:

- Create Module “Create van for Zone x” to set the van to delivery per day.
- Assign Module “Assign van zone x detail” to assign values to vans such as on hand van, speed, time start.
- Station Module “Station DC to zone x” to know the steps that the van will come in and out of the next station
- Record Module “Record parking at DC for zone x” to record the number of times the van enters DC.
- Process Module “Process pickup zone x” to pick up the parcels into the van and prepare it for delivery
- Assign Module “On hand van” to assign parcels in vans after pick up.
- Assign Module “Next KM” to assign distance of next station.
- Record Module “Record distance for zone x” to record the distance that the van route travels.
- Decide Module “Decide van out of time zone x” to check working time. If time out, it is work done. In contrary, if time is not yet over, the model will work next step.
- Decide Module “Decide check on hand in van for zone x” to check that the parcel is out of stock or not. If it out, it will be checked distance. Then, the van goes back to DC. In contrary, if there are still parcels, the van will travel to the next location.
- Decide Module “Decide receivable zone x” to check that customer at home or not.
- Process Module “Process drop off zone x” to delivery process, it takes 2-5 minute for process.
- Process Module “Process not customer at home zone x”, it takes 2 minute.
- Assign Module “Assign parcel in van after delivery zone x” to minus parcel on hand van.

Then, the model will check the distance. Continue working according to the steps until the working time is over.

1.2 Alternative 2 and 3

This delivery operation mode is the same as alternative 1, i.e. the driver loads the parcel at the depot. After loading the delivery van, the driver will drive towards the delivery area and deliver the parcels. The parcel will be delivered to your home address. If people are not home, the parcels will be brought back to the depot or dropped off at the company's locker point. However, in this mode, some parcels will be dropped off at the locker point as well.

As shown in Figure 27, this model is developed from the base model. By adding, there are additional modules as follows.

- Assign Module "Assign parcel in van after pickup zone x" to assign drop at locker percent and drop at customer's home percent. In addition, the condition will be set in order to be able to deliver parcels at the locker without exceeding the locker capacities.
- Separate Module "Separate zone x" to create entity the parcel.
- Hold Module "Hold zone 1" to holds the parcel while the customer picks it up.
- Delay Module "Delay zone x" to solve bug.
- Process Module "Pick up zone x" to customer pick up the parcel.
- Decide Module "Decide which locker zone x" to check whether the locker is full or not. If it is full, it will go to drop off the next available locker.
- Process Module "Process drop off at locker n zone x" to drop off process.
- Assign Module "Assign parcel in van after drop at locker n zone x" to minus parcel on hand van.
- Decide Module "Decide locker n zone x" to check capacity locker and number of parcels that drop off at locker. If the locker is still available and the number of parcels dropped off at the locker is not out, the parcels will be dropped off at the locker.

- Record Module “Record numbers parcel drop at locker n zone x” to record numbers parcel that drop off at locker.
- Process Module “Process locker n zone x” to locker storage process.
- Assign Module “Assign km to next locker” to assign distance between locker.

In addition, the difference with each additional zone is the number of lockers and setting locker conditions. However, models A1 and A2 are the same, but they differ in the number of lockers and the number of delivery vehicles. As show in Figure 28, it is A2 model for zone 1, it’s more complicated.

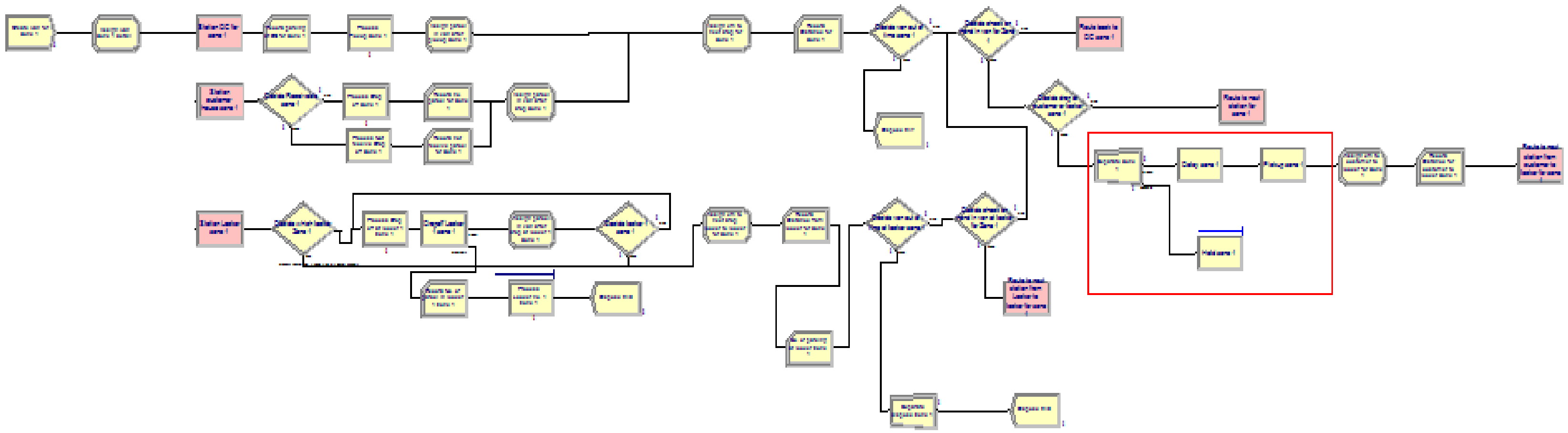


Figure 27 The scenario example of the A2 model

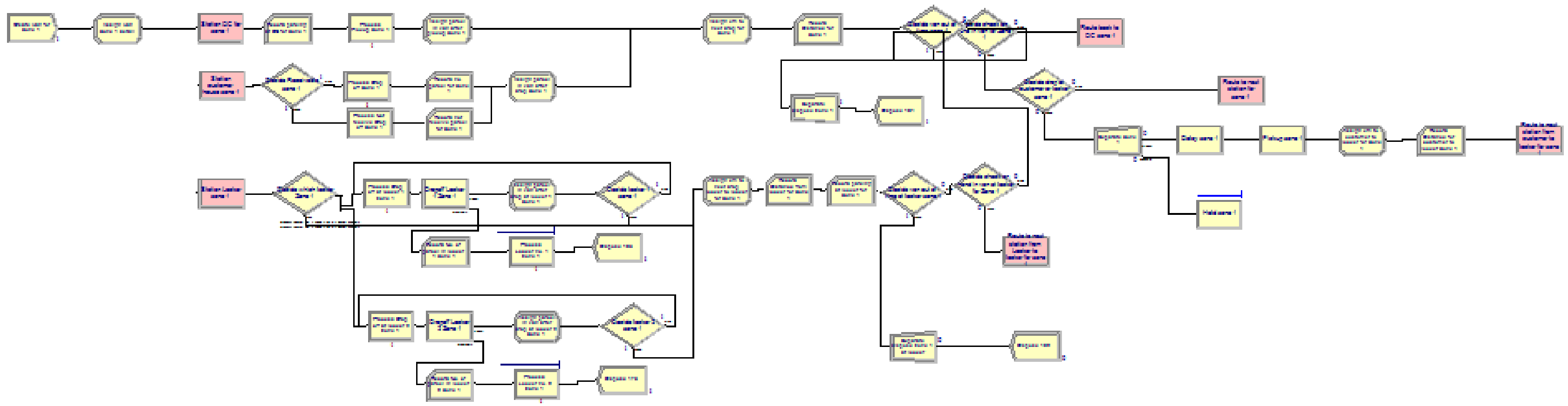


Figure 28 The scenario example of the A3 model

2. Trace Result of Model Verification

The home delivery mode is the basis of the model. So, a trace result of home delivery is conducted to verify it.

```
0.0 Hours>
0.0 Hours>STEP

SIMAN Run Controller.
 *    1 13$            CREATE,1,DaysToBaseTime(0.0),Van 1:
                           DaysToBaseTime(1),1:
                           NEXT(14$);

0.0 Hours>STEP

 *    2 14$            ASSIGN:
                           Create Van for Zone 1.NumberOut=Create Van for Zone
                           1.NumberOut+1:
                           NEXT(0$);

0.0 Hours>STEP

 *    3 0$             ASSIGN:Van no.=1:On hand Van=0:NEXT(1$);

0.0 Hours>STEP

 *    4 1$             STATION,Station DC;

0.0 Hours>STEP

 *    5 19$            DELAY:0.0,,VA:NEXT(2$);

0.0 Hours>STEP

 *    6 2$             ASSIGN:
                           Process Pickup zone 1.NumberIn=Process Pickup zone 1
                           .NumberIn+1:
                           Process Pickup zone 1.WIP=Process Pickup zone 1.WIP+
                           1;
```

Figure 29 Trace result of home delivery (a)

Start the model at time = 0.0 and create an entity named Van 1. Set the Create Van for Zone 1 model to have an additional entity. Use module assignment to specify the number of parts on Entity Van 1 = 0. Start work at Station DC. It takes 0.0 hours to enter the station (because it is the starting station). In Module Process, enter the parcel picking process by adding a process task + 1 entity.

```
0.0 Hours>STEP

 *    7 21$            DELAY:0.250000000000000,,VA;

0.0 Hours>STEP

SIMAN Run Controller.
 *    8 68$            ASSIGN:
                           Process Pickup zone 1.NumberOut=Process Pickup zone
                           1.NumberOut+1:
                           Process Pickup zone 1.WIP=Process Pickup zone 1.WIP-
                           1:
                           NEXT(6$);

0.25 Hours>STEP

 *    9 6$             ASSIGN:On hand Van=10:NEXT(3$);

0.25 Hours>STEP

 *   10 3$             ASSIGN:Next KM=100:NEXT(4$);

0.25 Hours>STEP

 *   11 4$             COUNT:Van distance set(Van no.),Next KM:NEXT(12$);

0.25 Hours>STEP

 *   12 12$            BRANCH,1:
                           If,On hand Van==0,71$,Yes:
                           Else,72$,Yes;

0.25 Hours>STEP

 *   14 72$            ASSIGN:
                           Decide check on hand in van.NumberOut False=Decide c
                           heck on hand in van.NumberOut False+1:
                           NEXT(5$);
```

Figure 30 Trace result of home delivery (b)

In the picking process, it took 0.25 hours (15 minutes). Exit Module Process to leave the parcel picking process by reducing the workload on Process (-1 entity). Parcels quantity on hand van: 10 parcels. The KM for the next label is set. The trial model is 100 meters. The record command is conducted to record the accumulated kilometers. The conditions are checked. On hand van = 0 or not. If it = 0, the van will travel back to DC, but if not, the van will travel to the customer's house.

```
0.25 Hours>STEP

 *   16 5$              ROUTE:
                            (Next KM*0.001)/van zone 1 speed,
                            Station customer house;

0.25 Hours>STEP

SIMAN Run Controller.
 *   17 7$              STATION,Station customer house;

0.25166667 Hours>STEP

 *   18 75$             DELAY:0.0,,VA:NEXT(9$);

0.25166667 Hours>STEP

 *   19 9$              ASSIGN:
                            Process Drop off.NumberIn=Process Drop off.NumberIn+
                            1:
                            Process Drop off.WIP=Process Drop off.WIP+1;

0.25166667 Hours>STEP

 *   20 77$             DELAY:0.0333333333333333,,VA;

0.25166667 Hours>STEP

SIMAN Run Controller.
 *   21 124$            ASSIGN:
                            Process Drop off.NumberOut=Process Drop off.NumberOu
                            t+1:
                            Process Drop off.WIP=Process Drop off.WIP-1:
                            NEXT(10$);

0.285 Hours>STEP

 *   22 10$             ASSIGN:On hand Van=On hand van-1:NEXT(11$);
```

Figure 31 Trace result of home delivery (c)

Next, the van travels to the customer's house using time from the calculation (Next km x 0.001)/Van zone 1 speed; next km = 100 m, van zone 1 speed = 60 km/hr. It would take 0.00167 hours to travel from DC to the customer's home 1. The van arrives at the customer's home station at exactly 0.25167. Then, the drop-off process starts. The customer receives a parcel and signs that it will take 0.03 hours (2 minutes). Exiting drop off process, number On hand van - 1 = 10 - 1 = 9.

```
0.285 Hours>STEP

 *   23 11$            COUNT:no.of parcel set(Van no.),1:NEXT(3$);

0.285 Hours>STEP

 *   10 3$             ASSIGN:Next KM=100:NEXT(4$);

0.285 Hours>STEP

 *   11 4$             COUNT:Van distance set(Van no.),Next KM:NEXT(12$);

0.285 Hours>STEP

 *   12 12$            BRANCH,1:
                           If,On hand Van==0,71$,Yes:
                           Else,72$,Yes;

0.285 Hours>STEP

 *   14 72$            ASSIGN:
                           Decide check on hand in van.NumberOut False=Decide c
                           heck on hand in van.NumberOut False+1:
                           NEXT(5$);

0.285 Hours>STEP

 *   16 5$             ROUTE:
                           (Next KM*0.001)/van zone 1 speed,
                           Station customer house;

0.285 Hours>STEP

SIMAN Run Controller.
 *   17 7$             STATION,Station customer house;

0.28666667 Hours>STEP

 *   18 75$            DELAY:0.0,,VA:NEXT(9$);
```

Figure 32 Trace result of home delivery (d)

A Module Record is conducted to record the number of parcels. The KM for the next label is set. The trial model is 100 meters. The record command is conducted to record the accumulated kilometers. The conditions are checked. On hand van = 0 or not. If it = 0, the van will travel back to DC, but if not, the van will travel to the customer's house. Next, the van travels to the customer’s house using time from the calculation (Next km x 0.001)/Van zone 1 speed; next km = 100 m, van zone 1 speed = 60 km/hr. It would take 0.00167 hours to travel from DC to the customer's home 1. The van arrives at the customer's home station at exactly 0.25167.

```
0.6 Hours>STEP

 *   23 11$              COUNT:no.of parcel set(Van no.),1:NEXT(3$);

0.6 Hours>STEP

 *   10 3$               ASSIGN:Next KM=100:NEXT(4$);

0.6 Hours>STEP

 *   11 4$               COUNT:Van distance set(Van no.),Next KM:NEXT(12$);

0.6 Hours>STEP

 *   12 12$              BRANCH,1:
                             If,On hand Van==0,71$,Yes:
                             Else,72$,Yes;

0.6 Hours>STEP

 *   13 71$              ASSIGN:
                             Decide check on hand in van.NumberOut True=Decide ch
                             eck on hand in van.NumberOut True+1:
                             NEXT(8$);

0.6 Hours>STEP

 *   15 8$               ROUTE:(Next KM*0.001)/van zone 1 speed,Station DC;

0.6 Hours>STEP

SIMAN Run Controller.
 *    4 1$               STATION,Station DC;

0.60166667 Hours>STEP

 *    5 19$              DELAY:0.0,,VA:NEXT(2$);
```

Figure 33 Trace result of home delivery (e)

However, the conditions are checked. On hand van = 0 or not. If it = 0, the van will travel back to DC, but if not, the van will travel to the customer's house. In some cases, the on-hand van = 0 so it returns to DC. Next, the van travels to the DC using time from the calculation (Next km x 0.001)/Van zone 1 speed; next km = 100 m, van zone 1 speed = 60 km/hr. It would take 0.00167 hours, which is the time it takes a van to travel from DC to a customer's home. At 0.25167, the van arrives at the DC station. It will begin the picking process again. Then, the parcel will be delivered via the same procedure as above.

Identifier	Count	Limit
Van distance zone 1	1600	Infinite
Van distance zone 2	0	Infinite
Van distance zone 3	0	Infinite
Van distance zone 4	0	Infinite
Van distance zone 5	0	Infinite
Van distance zone 6	0	Infinite
Van distance zone 7	0	Infinite
Van distance zone 8	0	Infinite
Van distance zone 9	0	Infinite
No.of parcel Zone 1	14	Infinite
No.of parcel Zone 2	0	Infinite
No.of parcel Zone 3	0	Infinite
No.of parcel Zone 4	0	Infinite
No.of parcel Zone 5	0	Infinite
No.of parcel Zone 6	0	Infinite
No.of parcel Zone 7	0	Infinite
No.of parcel Zone 8	0	Infinite
No.of parcel Zone 9	0	Infinite

Figure 34 Trace result of home delivery (f)

User Specified

Counter

Count	Value
[illegible]	[illegible]
No. of parcel Zone 2	0.00
No. of parcel Zone 3	0.00
No. of parcel Zone 4	0.00
No. of parcel Zone 5	0.00
No. of parcel Zone 6	0.00
No. of parcel Zone 7	0.00
No. of parcel Zone 8	0.00
No. of parcel Zone 9	0.00
Van distance zone 1	1600.00
Van distance zone 2	0.00
Van distance zone 3	0.00
Van distance zone 4	0.00
Van distance zone 5	0.00
Van distance zone 6	0.00
Van distance zone 7	0.00
Van distance zone 8	0.00
Van distance zone 9	0.00

Figure 35 Trace result of home delivery (g)

The model will continue to run until the time runs out. Therefore, this model takes an hour to run. The van delivers 14 parcels with a total of 1600 meters.

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VITA

NAME	Noppakun Sangkhiew
DATE OF BIRTH	1 December 1991
PLACE OF BIRTH	Yasothorn
HOME ADDRESS	29 moo 9 Klang, Selaphum, Roi-et
PUBLICATION	1. Tiwapat, N., Pomsing, C., & Jomthong, P. (2018, September). Last mile delivery: modes, efficiencies, sustainability, and trends. In Proceeding of International Conference on Intelligent Transportation Engineering, 313-317, Singapore, September 3-5, 2018. (IEEE) 2. Sangkhiew, N., Pornsing, C., and Ohmori, S. (2021). Comparison of Last Mile Delivery Mode in Thailand Using Topsis Technique. In E-Proceeding The 11th International Science, Social Science, Engineering and Energy Conference, 116-122. Thailand, June 24. 3. Sangkhiew, N., Pornsing, C., Ohmori, S., and Phudpong, R. (2021). Last Mile Delivery Mode Selection in Customer Perspective Using Topsis Technique. In Abstract Proceeding of Silpakorn International Conference on Total Art and Science 2021, 151. Thailand, November 3-5, 2021. 4. Sangkhiew, N., Pornsing, C., Ohmori, S., and Watanasungsuit, A. (2022). An Integrated fuzzy AHP-TOPSIS for the Last Mile Delivery Mode Selection. Science & Technology Asia, Vol.28, No.1, January-March, 2023. (Scopus Index)