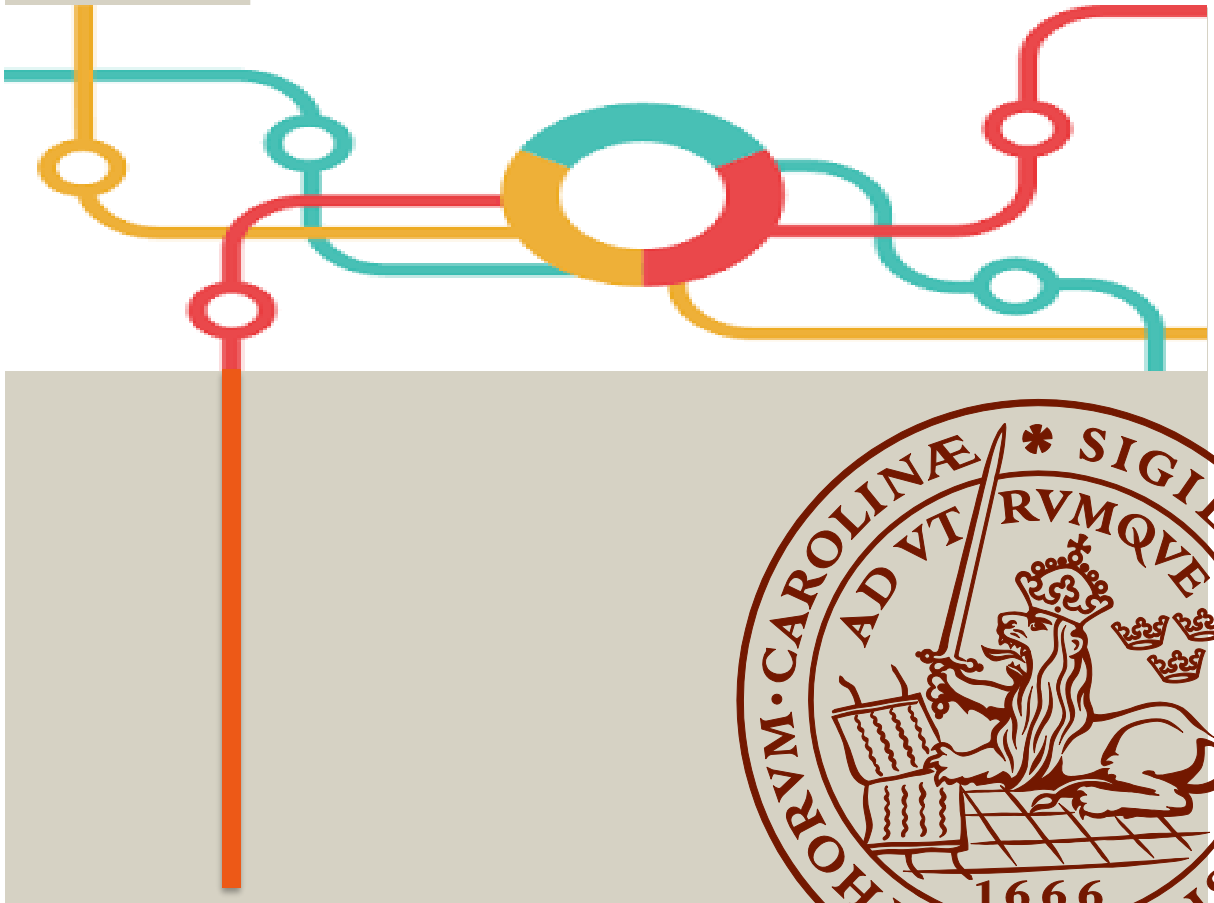
Performance of frozen meal packaging system in the cold supply chain

Manava Bhushan Dhamodharan

DIVISION OF PACKAGING LOGISTICS | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS



Performance of frozen meal packaging system in the cold supply chain

Manava Bhushan Dhamodharan

LUND
UNIVERSITY

FIPDes
Food Innovation & Product Design

Performance of frozen meal packaging system in the cold supply chain

Published by
Division of Packaging Logistics
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Food Packaging Design (MTTM01)
Division: Packaging Logistics
Supervisor: Dr. Giana Carli Lorenzini
Examiner: Dr. Annika Olsson

This Master´s thesis has been done within the Erasmus Mundus Master Course FIPDes:

Food Innovation and Product Design.
www.fipdes.eu

ISBN 978-91-7895-186-4

Acknowledgements

First and foremost, I praise and thank God whose blessings have been bestowed in me, which gave me the will, power, and confidence to carry out my project work successfully at Lund University, Sweden and therefore achieving a new milestone in my professional life.

I express my sincere gratitude to Dr. Erik Andersson and Dr. Jenny Schelin, Lund University, Sweden. Who is always available to answer any question related to academic and non-academic related things, and their support and guidelines during the thesis period.

For the loving kindness, genuine cooperation and moral support lavished on me from the early stage of my thesis and providing me with many valuable inputs in every stage in my work, for the successful completion of this work. I record my heartfelt gratitude to my respected supervisor Dr. Giana Carli Lorenzini, Packaging Logistics, Lund University.

I am immensely thankful to the examiner Dr. Annika Olsson, Packaging Logistics, Lund University for reading patiently the thesis.

I feel it is pleasure to be indebted to the Company (or industrial) supervisors for their effective suggestions, friendly and valuable guidance, and enhancing my knowledge and helping me to expose my skills and ability during the course of this project. I also thank them for supporting and trusting me while carrying out this project, through which I have learned a lot during this project.

I express my special thanks to various supply chain actors and consumers for their supports and inputs in this project, and who been a major part for the successful completion of this project.

It is a pleasure to express my deep sense of gratitude to all staffs and employees of packaging logistics for their cooperation, friendly interaction, help and encouragement.

Also, I would like to thank all FIPDes consortium members for providing me with an opportunity to take this programme. I also want to thank all my FIPDes friends, who made this 2-year of master's journey very exciting. I would also thank FIPDes Lund friends and other friends who supported me in this journey in various period.

Heart filled with growing love, I express my very profound gratitude to my father, Dhamodharan; my mother, Saraswathi; my brother Bharath Bhushan; my sisters, Subhashini; Divya, for their inspiration, motivations and supports in all the aspects in this project and my life, and last but not least I express my thanks to my best friends, Thank you.! Lund, June 2019! Manava Bhushan Dhamodharan.

Abstract

Packaging helps to protect the product and safety handover the product from producer to end user. When the packaging leaves the closed loop it creates environmental issues. Also, the material focused packaging development process creates trade-off among supply chain actors. The sustainable packaging would reduce the overall cost and environmental impact, increase the value of the packed product in the whole system. The project is handled by company X and the company is interested in knowing the sustainable packaging for a frozen meal. The purpose of the project is to select two types of the frozen meal packaging system and to analyse their packaging performance in the supply chain, and to find out the important packaging features of the supply chain that need to be considered while developing a sustainable frozen meal packaging system. Two types of packaging, i.e. carton frozen meal packaging system and plastic frozen meal packaging system were selected and mapped in the supply chain from the producer level to consumer level. The detailed activity mapping was established for each actor in the supply chain to understand the different stages and ways of packaging handling. Fifteen packaging features were identified under four areas: product waste, logistics, value adding and packaging material. The data was collected through interviews, observations and survey. The collected data was interpreted and analysed in packaging scorecard and scatter plot. The plastic packaging system performed better with producer and the carton packaging system performed better with all other supply chain actors. The packaging features such as product protection and production efficiency were given the highest importance by the producer. Volume and weight efficiency, convenience and packaging waste were given the highest importance by other supply chain actors. The convenience and packaging waste were given the highest importance by consumers. Further, the top 5 important packaging features were identified for the supply chain actors and for consumers, and found that the product protection, circular economy and convenience are most important features for the whole supply chain and for the frozen meal packaging system. The result suggests the carton based sustainable packaging system could be developed for the frozen meal, due to better handling of packed product and packaging waste. The development process could be carried out in a holistic view by incorporation the supply chain actor’s requirements.

Key words: Frozen meal packaging, packaging performance, packaging features, supply chain.

Executive Summary

Introduction

The sustainable packaging is a trend nowadays, which aims to reduce the environmental impact and increase the value of the packed product. The holistic view of sustainable frozen meal packaging development process avoids the risk of sub-optimization. The process includes all the requirements, such as product requirements, supply chain actor's requirements, consumer requirements, etc.

Purpose of the project

To identify the performance of frozen meal packaging in the supply chain for carton and plastic packaging system, and to find out the important packaging features of the supply chain that need to consider while developing the sustainable frozen meal packaging system.

Methodology

Carton packaging system and plastic packaging system were selected for analysing the performance in the supply chain. The packaging scorecard methodology framework described by Pålsson (2018) was used in this study. The framework further developed into four steps, at step 1: The supply chain was mapped from the point of product production to the point of product consumption and the detailed activity mapping was carried with each supply chain actors to visualize the packaging system and supply chain. Then 15 packaging features were identified and developed the packaging system interaction framework to understand which packaging features are applicable to whom in the supply chain. Step 2: Data was collected through interviews and observations. At step 3: The collected data was analysed through packaging scorecard and scatter plot and presented in graphically, and also analysed the supply chain challenges. At step 4: the supply chain actors' requirements were found as top 5 important packaging features, i.e. for the producer, distributor and retailer. Further, consumer interviews and survey were conducted to find out the consumers requirements as top 5 important packaging features.

Result and Discussion

1. Overview of the product and packaging

Product A and product B contains vegetables with sauces as main ingredients. Product A is produced in one of the Scandinavian countries and product B is

produced middle Europe, and both the products sold in Scandinavian countries in frozen condition (18ºC or colder).

Primary packaging

The product A's primary packaging consists of carton tray, sealed with LDPE film and carton box. The product B's primary packaging consists of the plastic tray, sealed with LDPE film and carton wrap.

Secondary packaging

The product A and product B uses a corrugated cardboard box. Both the secondary packaging consists of 8 primary packaging.

Tertiary Packaging

Product A and product B uses euro pallet and roll container. Product A's tertiary packaging (pallet) contains 56 secondary packages. The product B's tertiary packaging (pallet) contains 45 secondary packages.

2. Supply chain mapping

Product A and product B uses similar supply chain activities. The supply chain activities were carried out from the point of product manufacturing to the point of product consumption. The products are produced in the production plant sent to the distributor warehouse by distributor truck and then the products are sent to the retailer warehouse. Further, the products are sent to the retailer stores through third-party transportation. Finally, the consumer purchases the products from the retailer store and consumes the product in homes, workplaces, etc.

Further detailed activity mapping was developed for the producer, distributor, retailer warehouse, retailer store and consumer, and visualize the activities and analysed the different activities taking place within the supply chain actors and consumers.

3. Packaging system performance

The packaging performance is analysed based on 15 packaging features by importance vs satisfaction of each packaging features, where importance means 'how much importance is given for a particular packaging features by an actor' and satisfaction means 'how much an actor is satisfied with that particular packaging features'.

At the producer level, the plastic packaging system performed better. This is due to the convenient handling of the packaging system, less packaging cost and efficient in production efficiency. At the distributor warehouse level, the carton packaging system performed better, due to the effective logistic performance. At retailer warehouse level, the carton packaging system performed better, due to the volume and weight efficiency and size of the packaging. At retailer store, the carton packaging performed better, due to the convenience, unitization and size of the

packaging. At the consumer level, carton packaging performed better, the difference is observed due to the fact of environmental concern, that is related to the packaging waste handling.

4. Supply chain challenges

Lead Time: The products are maintained under the frozen condition and it consumes high energy to maintain the temperature. Thus, the reduction of lead time would reduce the total energy consumption.

Temperature: The temperature monitoring process increases the complexity of the supply chain because the monitoring process takes place at different stages in the supply chain. The rise of temperature deteriorates the product's sensory and quality properties. Frozen transportation and storage are highly costly because it requires energy to maintain the temperature, and the frozen temperature affects the working environment.

High environmental impact: The frozen supply chain has a negative impact on environmental, due to the emission of CO_2 from the transport refrigeration and the cold storage refrigeration.

Premium Product: The products are positioning in premium categories and lead to higher consumer expectation in terms of product quality as well as the appearance of the product. The packaging damages are avoided throughout the supply chain.

5. Supply chain actors' requirements and consumer requirements

According to literature, the sustainable packaging development process is looked in a holistic view (Hellström and Olsson, 2017; Vernuccio et al., 2010; Azzi et al., 2012). The holistic view includes the different supply chain actors' requirements, consumer requirements, etc. These requirements are expressed in terms of packaging features as described in the methodology. The important packaging features are identified as top 5 important packaging features for supply chain actors, i.e. producer, distributor and retailer based on the scatter plot. Further consumer requirements are found as top 5 important packaging features. Further supply chain actors' requirements and consumers requirements are summarized and mentioned in Table 1. Table 1 shows the top 5 important packaging features for the frozen meal packaging system.

Primary packaging	***Secondary packaging***	***Tertiary packaging***
- Protection and containment	- Protection and containment	- Protection and containment
- Size of the packaging	- Volume and weight Efficiency	- Volume and weight Efficiency
- Convenience to handle	- Track and traceability	- Track and traceability
- Circular economy	- Convenience to handle	- Circular economy
- Production efficiency	- Circular economy	- Unitization.

Conclusion and further research

It is important to develop the sustainable packaging system, which aims to reduce the overall cost and environmental impact, increase the value for the packed product with the supply chain actors and consumers. The packaging performance was performed for both the packaging system with the supply chain actors based on the 15 packaging features and found that the carton-based packaging system performed better with most of the supply chain actors and with consumers. The plastic packaging performed better only with the producer of frozen meal. The features: product protection was ranked highest importance among all the supply chain actors, consumers for all level of packaging. Volume and weight efficiency were seen as the highest importance for secondary and tertiary packaging. Circular economy of packaging was seen among all level of packaging system as well as among supply chain actors. The study suggests the company X to include the requirements of producer, distributor, retailer and consumer while designing the packaging system.

Further studies can be focused in these areas:

1. Study to find out the packaging performance with other actors, such as packaging material supplier and packaging waste handler.
2. Study to analyse the detailed environmental impact of the packaging system for product A and product B, for example, LCA, EEFP tool, etc.
3. Study to find out other requirements such as a) Product requirements, b) Marketing requirements, c) Co-packer/ Producer requirements/facilities, d) Packaging supplier requirements/demands d) Packaging waste handler requirements.
4. This research aimed to find out the different supply chain actor's requirements, and do not include the design thinking process. So, after gathering all the requirements, further study could be done for designing/developing the sustainable frozen meal packaging system.

Table of contents

List of acronyms and abbreviations

FFP: Frozen Food Packaging

FMP: Frozen Meal Packaging

PD: Packaging Development

PE: Polyethylene

PF: Packaging Features

PS: Packaging Scorecard

SC: Supply Chain

SPD: Sustainable Packaging Development

List of Tables

List of Figures

1.Introduction

This chapter introduces the background, problem faced and its description, purpose of the project and the research questions. The delimitation of the project and the outline followed are also discussed in this chapter.

1.1 Background

1.1.1 Packaging and supply chain

Food is a basic need for human being to survive and it is highly perishable in nature. Preservation technique is used to preserve the food (Sohail et al., 2018). The most commonly used preservation techniques are drying (Sun, 1999; Pu and Sun, 2016; Pu and Sun, 2017), cooling (Wang and Sun, 2001; Sun and Eames, 1996) and freezing (Sun and Pu, 2016; Pu et al., 2015). In addition, packaging plays a major role in protecting the product and prolonging the shelf life (Yam et al., 2005). Further, the packaging helps to transfer the product from the producer to consumers in every day (Molina-Besch, 2018). Packaging is often looked as a whole system, which consists of primary, secondary and tertiary packaging (Jonson, 2000).

Packaging affects the supply chain operations, interns of performance and efficiency (Klevås and Saghir, 2004). In supply chain, the packaging is handled by multiple actors and it affects the environmental and logistics efficiency (Jahre and Hatteland 2004). Molina-Besch and Pålsson (2014) mentioned that supply chain operations need to be considered for developing the packaging system. The change of packaging system would affect the entire supply chain operation, for e.g. warehouse system, transport system, handling equipment and information system.

Sustainable packaging being a trend now a days, which aims to reduce the environmental impact and increase the value of packed product (Research and markets (10AD), 2018). Many authors concluded that the development of sustainable packaging needs to include all the actors, who are involved in the entire process that is from the stage of production to the stage of consumption (for e.g. product manufacturer, marketing, logistics, consumer etc.). Holistic view of

packaging development avoids the risk of sub optimizations (Svanes et al., 2010; Verghese and Lewis, 2007). One of the ways to do so, is to find out the trade-offs with the existing packaging system and to identify the potential area to incorporate into the new packaging system.

Trade-offs is used between the actors and packaging features to evaluate the packaging performance in the supply chain (Pålsson, 2018). Often it is hard to satisfy all the actors in the supply chain, as some packaging features are more favourable to some actors. For example, product manufacturing focuses on packaging cost and filling efficiency, whereas marketing focuses on information and packaging design. Also, the change in one packaging feature will affect another packaging feature. For example, reducing the packaging material will reduce the material cost but increase the need for material stack-ability. This makes an evaluation process more complex and challenging. It is important to identify the right packaging features that has the highest degree of benefits. Zoom-in and zoom-out tool could be used to analyse, each actor individually and the whole system as together (Pålsson, 2018). Zoom-in means viewing an individual part in the whole supply chain, to understand the detail activities taking place inside the individual actor. Whereas, zoom-out means viewing the links between each actors and the overall supply chain activities (Pålsson, 2018). This approach helps to understand the balance between the packaging features and the actors in the supply chain.

1.1.2 Frozen meal and packaging

The demand for a frozen meal in Scandinavian countries is increasing nowadays, due to lifestyle changes (Hexa research, 2019). Scandinavian countries showing the compound annual growth rate (CAGR) of 2.3% and the market volume of CAGR increased with 1.7% and reached the total volume of 2014.4 million kilograms in 2017 (Market research, 2017). Sweden leads the frozen food consumption compare to other Scandinavian countries. (Frozen food Europe, 2018). Economic growth makes the consumers to buy the food which is easy to prepare and consume. Frozen meal is described as *"raw material or agricultural commodity, which is processed/minimally processed, packaged, and then stored and sold under frozen condition (-18ºC or colder)"* (Mallett, 1993). Frozen/freezing technique helps to preserve the food for longer period with required quality standards. The food waste with frozen meals is less, while compare to other ready-made food commodities during the storage and distribution (Janssen, 2017).

Packaging material of frozen meals needs to have sufficient barrier properties to protect against microorganism attacks, dehydration, soiling, etc (Interpack processing and packaging, 2019). Combination of packaging materials used from decades to achieve the required barrier properties (Sun, 2016). Further, the

packaging withstands the cold temperature during storage and distribution, hot temperature during microwaveable heating. The most common types of frozen meal packaging are cartons, plastics and aluminium (Sun, 2016). Frozen temperature in the cold supply chain affect the packaging performance. For example, gain of moisture from the environmental to the packaging material will reduce the material strength and effect in stack-ability. Packaging features helps to understand the trade-offs among the packaging functions and the supply chain.

1.1.3 Business approach

The author of this project has signed a confidentiality agreement with the project handling company, and as per the agreement the company's name is kept anonymous (further referred to as "Company X"). The Company X comes under the categories of food industries and operates as a group of business. The company is located in one of the Scandinavian countries and works closely to minimize the environmental impacts through sustainable production in the entire food chain. The company's objectives are defined, such as energy, waste, raw material loss, water, sustainable farming and environmental awareness. These objectives are carried out through the company's environmental program.

As mentioned above, the company is giving higher importance for environmental related issues in the ongoing and future projects. The company's project (environmental program) is focused on the food packaging, where the future food packaging and packaging system need to be more sustainable/environmentally friendly. Thus, the company aims to develop a sustainable packaging for frozen meals, and also aims that the developed packaging needs to be fully recyclable or it should not cause any undesirable effect to environmental.

Environmental labelled packaging and ethical concerns are influenced by consumers for their product choice (Rokka and Uusitalo, 2008). Also, the product choice is influenced by sustainable packaging (Lindh et al., 2016). In this direction, the company aims to develop the sustainable packaging for frozen meal by taking the aspect of account environmental, social and economic requirements. For that, this project aims to understand and to evaluate two types of frozen meal packaging and to come up with an idea of what kind of packaging material and what packaging features need to be considered for developing the sustainable packaging.

1.2 Problem discussion

Globalization and industrialization are one of the main reasons for environmental issues, and this causes an in-favourable effect on water and land spices. Now a days

many organizations, national and international bodies are more concern about the environmental impact. Sustainability could be an option to reduce the environmental impact. Sustainability is defined as fulfilling the current needs without taking/consuming the future generation's needs (World Commission on Environment and Development, 1987).

Food production is highly dependent on natural resources and it consumes 70% of freshwater, 30% of earth's land (Wohner et al., 2019) and 80% of deforestation, and it emits 30% of greenhouse gas (Nellemann, 2009). These resources have been wasted when the produced food is not consumed. The food and agricultural organization (FAO) say that around 1.3 billion metric tons of foods are wasted every year. According to Wohner et al., (2019) one-third of the produced food is being wasted every year and this waste is equivalent to around 3.3 billion metric tons of CO_2, 1.2 billion hectares of land and 250 km3 of blue water (FAO, 2013). Most of the food waste is accrued at the primary production stage and at retailer stage (Parfitt et al., 2010), and it continued along the supply chain (Gustavsson et al., 2011).

Packaging plays a crucial role in protecting and saving food from getting wasted (Parfitt et al., 2010; Williams and Wikstrom, 2011). Packaging is made up of any material, which is placed over the goods, and it is a coordinated system (Hellström and Olsson, 2017). In the supply chain, food waste can be reduced by appropriate packaging (Manalili et al., 2014). Apart from saving the food, packaging helps to communicate to the end user about how to handle and store the food. Food industries use different types of packaging materials, for example, plastics, glass, etc., to have efficient protection (shelf life) and transportation (volume efficiency).

As mentioned above, the packaging provides several applications in day to day life and finally end up as packaging waste, and when it ends up into land and water, it causes environmental effects. The food products come under FMCG (Fast Moving Consumer Goods), hence the demand for the food products are higher, and would increase the need for packaging.

Marsh and Bugusu (2007) mentioned two- thirds of the packaging waste are coming from food packaging. Plastics and combination of plastics are being dominant in frozen meal categories, due to the benefits, such as cheap material cost, good barrier properties (Krochta, 2006). In 2013, 78 million metric tons of packaging plastics are produced, in that 32% ended into land and ocean habitats (World Economic Forum, 2016).

In order to reduce the environmental impact, there is a need to move towards sustainability. As mentioned earlier, sustainability aims to reduce environmental impact. The environmental effects of the packed products (frozen meals) are classified as direct and indirect effects (Pålsson, 2018). The direct effect relates to the packaging material, that occur at the production stage, and at the end stage as packaging waste. The indirect effect relates to supply chain, such as transport

efficiency, preventing the product waste. Often the indirect effect is greater than the direct effect (Pålsson, 2018).

Hence, this project aim to evaluate frozen meal packaging (carton and plastic) in the supply chain. The frozen meal is maintained under frozen condition in the supply chain to maintain the quality properties and the freshness of the product (Sun, 2016). Refrigeration uses a high amount of energy in the supply chain, as it needs to keep the temperature under control. In many cases, the refrigeration condition is not fully utilized. For example, the trucks are not fully loaded during the logistics operations and the space in the pallets are not fully utilized. Analysing the trade-offs between the actors, helps to understand, where and what needs to be improved. Many authors concluded, the holistic view on packaging could improve the supply chain efficiency (Jahre and Hatteland 2004). The small change in the packaging system could affect the entire supply chain operation. Packaging scorecard is used to identify the trade-offs in the supply chain for the frozen meal packaging.

1.3 Purpose and scope of the project

The purpose of the project is to select two types of the frozen meal packaging system and to analyse their packaging performance in the supply chain, and to find out the important packaging features of the supply chain that need to be considered while developing a sustainable frozen meal packaging system.

The scope of the project is to map the cold supply chain from the stage of product production to the stage of product consumption for frozen meal (carton and plastic packaging). Packaging scorecard is used to evaluate and to present the packaging performance. Further, the packaging features help to identify the supply chain actors' requirements and consumer requirements to develop the sustainable frozen meal packaging system.

1.4 Research questions

The following research questions are identified, based on the purpose and scope of the project.

1. What is the performance of frozen meal packaging in supply chain, i.e. from production stage to consumption stage?
2. Based on a supply chain perspective, which packaging features need to be considered for developing a sustainable packaging system for frozen meal?

1.5 Research focus and delimitation

The project is focused on the cold supply chain of frozen meal packaging. The term "Cold supply chain" is described as the continuous interpretation of refrigeration for temperature control in the supply chain operations (Sykes, 2018). Carton and plastic frozen meal packaging system are analysed in this project and the type of frozen meal packaging is chosen based on the company X's suggestions and other types of frozen meal packaging are not included in this study.

Packaging is often looked like a whole system that is primary, secondary and tertiary packaging (Jonson, 2000). The study analyse the packaging as the whole system, where the higher importance has given to the primary package. The primary packaging is accounted as a sales packaging and the packaging is handled by the consumers. The secondary and tertiary packaging are well handed for reuse and recycle by the supply chain actors, and these packages are not handled by consumers. Mostly the primary packagings are end up into land and water and that effect the environment.

1.6 Outline of the thesis

The project consists of five chapters that will help the reader to follow the structure and the flow of information. The description of each chapter is mentioned as below.

Chapter 1: Introduction. This chapter describes the background study, its purpose, research questions and project focus and delimitations.

Chapter 2: Theoretical framework. This chapter describes the background study as literature review to support and accrue the relevant information.

Chapter 3: Methodology. This chapter describes an overall framework that applied to carry out the project and to solve the research questions.

Chapter 4: Result and discussion. This chapter describes the data interpretations and presents the identified results.

Chapter 5: Conclusions and limitations. This chapter describes the research finds under two research questions and the limitations of this research.
Chapter 6: Suggestions and further research. This chapter provide suggestions to the company X based on conducted research and provide recommendations for further research.

2.Theoretical Framework

This chapter introduces the theories, concepts and findings from previous research. This chapter is structured into four parts to have a better view for the reader to follow the information.

2.1 Structure

The overview structure of this chapter is mentioned in Figure 1. Firstly, the chapter describes the basic concepts of food and frozen meal and then describes the packaging system and development, and finally describes the supply chain system. Additional, subheadings are provided under each part to have a better structure for the reader.

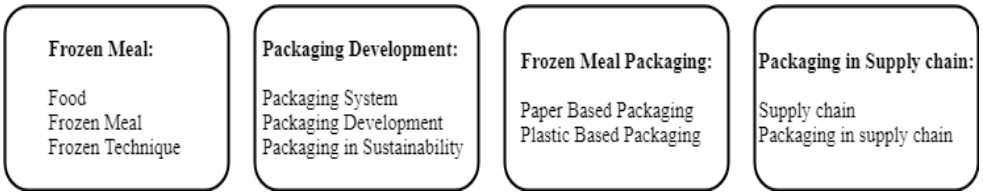


Figure 1: Structure of the theoretical framework

2.2 Frozen Meal

2.2.1 Food

Food is any form of commodity, which helps in body growth, reproduction, maintenance and repair (Manay, 2001). Food is the most basic need for survival when compared with the other two forms of needs, such as cloth and shelter (Manay, 2001). Food is a vast category, and it is available in different forms, for example, liquid, semi-liquid, solid, etc. Many authors have classified the food into several categories based on the specific applications. Monteiro et al. (2010), classified the food into three categories, such as unprocessed and less processed food, culinary

ingredients (processed and unprocessed), and ultra-processed food (Monteiro et al., 2010). Food and beverage industries are considered as one of "major industries" in global, and it handles multiple types of food in a day to day basis (Chandrasekaran, 2013). One of the significant challenges that food industries face is prolonging the product life with appropriate quality (Chandrasekaran, 2013). Freezing is a well-known technique, which is used into food to overcome the challenges mentioned above (Sun, 2016).

2.2.2 Frozen meal

Frozen meal is a prepared food which is preserved in extreme cold temperatures (-18ºC or below) that inhibit the growth of microorganisms (Robertson, 2013; Cheng, Sun, and Pu, 2016). Foods that have high in water activity such as, fruits, vegetable and ready meals are generally frozen. The water or moisture that are available for the microbial growth is converted to ice, which ultimately leads to microbial inhibition thereby increasing the shelf life of the product (Robertson, 2013; Pu, 2016). Also, Wang (2012) mentioned, freezing is a well-known and widely used long-term food preservation process. Nowadays, the demand for frozen meals is growing as more women enter into workforce and the change of lifestyles among people (Broad bia, 2016; Barbosa-Cánovas et al., 2005). Also, a frozen meal is a convenient way to enjoy healthy meals. Over the past few years, the retail food industries of Europe have witnessed significant growth in the sector of frozen meal (Barbosa-Cánovas et al., 2005). Hexa research (2019) mentioned the frozen meal market is growing in Scandinavian countries, for example per capita consumption of frozen food (includes frozen meal) is estimated as 52Kg in Sweden.

The nutritional quality of foods is also preserved during freezing. The quality of the frozen meal depends mainly upon the raw material quality and also on packaging, storage temperature, duration of storage, and the thawing procedure (Seyhun et al., 2014). Freezing technology provides better taste and quality that is close to fresh products, and it has become an essential food commodity in the retail store, fast food chain, etc. (Hui et al., 2004). Even, a slight fluctuation in temperature during manufacturing, storage and transportation can hinder the frozen meal quality.

2.2.3 Frozen technique

Several techniques are employed for the manufacturing of frozen meals. Most of the freezing techniques are developed based on these three factors i.e., 1. Freezing by indirect contact, 2. Freezing by direct contact (immersing in a refrigerant medium) and 3. Freezing in a blast of cold air (Sahay and Singh, 1996). Industrial freezing technology started up as a quick-freezing technique when Clarence Birdseye over 80 years ago found a way to flash freeze food (Valigra, 2012). In the later stage,

many novel technologies have been developed. The common industrial techniques involved for freezing are mentioned below (Khan and Mittal, 2017).

1. Air-blast freezing: refrigerated air at a certain velocity is blown over the food products.

2. Contact freezing: food products are placed in contact with metal surfaces.

3. Fluidized-bed freezing: food products are moved along a conveyor belt and kept in suspension by an upward-directed stream of sufficiently cold air.

4. Equipment utilizing a cryogenic substance (such as nitrogen or carbon dioxide).

Some of the novel and innovative freezing techniques involve impingement freezing, pressure-assisted freezing, hydro fluidisation freezing, ultrasound-assisted freezing, microwave-assisted freezing, magnetic resonance-assisted freezing, radiofrequency-assisted freezing, electrostatic-assisted freezing and dehydro-freezing (James, 2015).

2.3 Packaging development

2.3.1 Packaging

Paine's et al (1981) described the definition of packaging as:

1) packaging is a combined system that helps to prepare the goods, for handling, protection, transportation and presentation.

2) packaging helps in delivering the goods from the point of production to the point of end use in a safe condition.

3) packaging is a techno-economic function that aims to increase the efficiency in delivery and save the cost.

The founder of Tetra Pak, Mr. Ruben Rausing, used to say "*The package should save more than it costs*" which means that the packaging has a major role in protecting the goods. In another word, the packaging is described as "silent salesman" and being interference between the consumers and the product (Hellström and Olsson, 2017; Beckeman and Olsson, 2005; Olsson and Larsson, 2009). The main role of the packaging is to protect the product and to deliver to the ultimate end user (Hellström and Olsson, 2017). Packaging has several functions, which are categories into six basic functions and mentioned in below Table 1 (Lockamy, 1995; Robertson, 1990; Hellström and Nilsson, 2011; Saghir, 2004).

Table 1: Packaging functions and its descriptions.

Packaging Function	***Description***	***Example***
Protection	Protecting the product from physical, chemical and biological hazards.	Air tight packaging protect the frozen meal from freeze burn.
Containment	To hold the product and protect from external environmental	If the secondary package contains primary package evenly, then an additional support is avoided.
Unitization	The appropriate fit of the primary package into a secondary package and the second into a tertiary package	Maximum utilization of space in the packaging system.
Apportionment	To provide manageable size to supply chain actors and end consumers	Optimize the product quantity to the end consumers.
Communication	To provide information, traceability and recognition about the content	Scanning (Barcode, QR code) and printed information on the packaging system provide information to the supply chain actors and end users.
Convenience	To simply the use of end consumers	Packaging system/package provides easy to handle/use.

2.3.1 Packaging system

Packaging is considered as a coordinative system, which consists of primary, secondary and tertiary packaging (Hellström et al., 2017; Pålsson, 2018; Paine, 1981; Jonson, 2000). Primary packaging is defined as the packaging that holds or cover the product directly and it is closest to the product. The main function of the primary package is to protect from the external environment, which is often called as “retailer packaging” or “consumer packaging”. The secondary packaging contains a number of numbers of primary packages. The main function is to provide additional protection to primary package against physical abuse, which is often called a “distribution packaging”. The tertiary packaging contains the number of secondary packages. The main function is to provide convenience in movement and transportation, which is often called a “transport packaging” (Pålsson, 2018). Figure 2, shows the tertiary package in the top, which contains a number of secondary packages and the secondary packages is shown in the middle. The secondary packages contain a number of primary packages and the primary package is shown at the bottom of the figure 2.

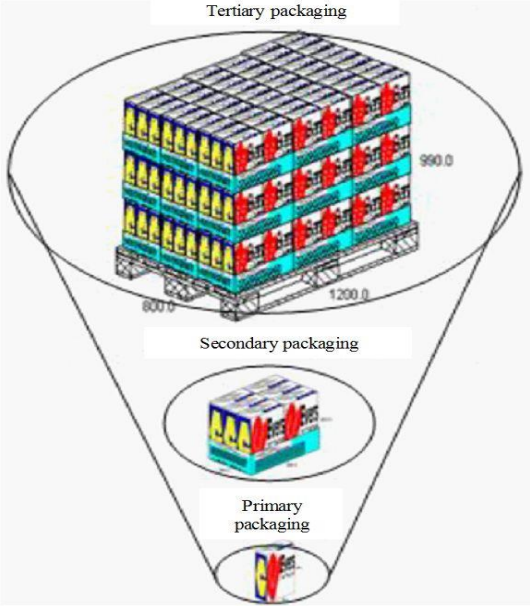


Figure 2: Packaging system level (Hellström and Saghir, 2016)

The product and the packaging are considered as an interactive component (Esse, 1989; Griffin et al., 1985). Thus, the change in the primary package will affect the product, as well as the secondary and tertiary packages (Hellström and Olsson, 2017).

2.3.2 Packaging development (PD)

The packaging development is a complex process, as it needs to fulfil the requirements of multiple actors and overcome the constraints (Molina-Besch, 2018). Often to overcome the constraints in the development process many authors suggested an integrated development process. An *onion structure of integrated packaging development* process was suggested by Hellström and Olsson (2017), where each layer represents of each actor in the supply chain, such as logistics, marketing, retailer, etc. *A conceptual framework for new packaging development* was suggested by Vernuccio et al (2010), with the integration of marketing, logistics and ethics. Azzi et al (2012) describe the PD process as an *integrated process under five areas*, such as ergonomic, safety, marketing, logistics and sustainability. Generally, the packaging development process takes place at the end of the product development stage and lesser importance is given to packaging while compared to a product (Simms, 2012; Verghese and Lewis, 2007). Thus, many researchers suggest that the development of packaging needs to be considered as an integrated

system. According to Pålsson (2018) the packaging development needs to be considered along with product development.

2.3.3 Sustainability in packaging

2.3.3.1 Sustainable development

The concept of sustainable development was introduced in 1987 by the world commission on environment and development as "*sustainable development is development process that meets the current needs without compromising the future generation's* needs" (Emas, 2015). The International Union for the Conservation of Nature and Natural Resources (IUCN) in 1991 describes as "*improving the quality of human life by taking care of surrounding environmental"* (Bluszcz, 2018). Hopwood et al., (2005) describe sustainable development is a process of achieving and maintaining the current system as environmentally friendly. The concept also includes other areas like health, democracy and freedom (Williams, 2011). Williams (2011) mentioned as the use of resources within limits and sought the equality between the generation and within the generation. When it comes to development and innovation, there is always a concern about environmental issues. The current decades have faced several issues, such as global warming, reduction of groundwater, etc (Wohner et al., 2019; Nellemann, 2009). So, it is necessary to think about sustainability, when speaking about industrial development. The term sustainability reflects in reducing the environmental impact (Morawicki, 2011).

In sustainability, a three-pillar concept was introduced, which focuses on people, plant, price (Elkington, 1997). In the simple definition, people represent – social responsibilities, planet represents – environmental consideration, the price represents – economic profitability (Hellström and Olsson, 2017).

Further, sustainable development is focused on the "waste hierarchy", based on the 3 R's concept (Hotta, 2014). The 3 R's are 1) reduce, 2) reuse, 3) recycle (Hellström and Olsson, 2017). Walmart (2014) upgraded the 3 R's into 7R's, and further to 10R's (Brad Follett, 2019; 10-R's of Sustainability 2014), the 10 R's concept is described as 1) Respect, 2) Refuse, 3) Reduce, 4) Reuse, 5) Renew, 6) Recycle, 7) Responsibility, 8) Rethink, 9) Replant and 10) Restore. The waste hierarchy needs to focus as an entire system, instead of an individual part. Because the result of alternation in one system could affect on another system, for example, reduction in packaging material could increase in product waste (Hellström and Olsson, 2017).

Many authors conclude about sustainability under three areas, such as social sustainability, economic sustainability and environmental sustainability (Hellström and Olsson, 2017; Williams, H., 2011; Elkington, 1997). To have a better sustainability, the business operation needs to have balanced importance in these three areas (Williams, 2011). According to Diabat and Govindan (2011) achieving

three-dimensional sustainability (social, economic and environmental) is hard and not easy to get success. At the same time, many types of research mainly focused on environmental suitability and it has a higher impact when compared to social and economic sustainability (Verghese and Lewis, 2007). This project includes three areas of sustainability to some extent. The higher importance is given to environmental sustainability because when the frozen meal packaging leaves from the human system, it creates environmental issues, for example, plastics ending up into oceans would affect the livelihood of water species. Also, the frozen meal required a cold supply chain and refrigeration condition during the storage and transportation of the product, and it consumes more energy. In addition to that, the carbon emission from the refrigeration system is higher and it would affect the environment.

2.3.3.2 Sustainable packaging development (SPD)

The approach of looking towards sustainability in recent years for designing and developing a packaging is to reduce the food loss and to enhance the performance that could have a lesser environmental impact (Verghese and Lewis, 2007). In 2007, Sustainable Packaging Alliance (SPA) Australia, described the definition for sustainable packaging under four principles, that is "*packaging should be effective (both cost-effective and functional for all the users in the value chain), efficient (using material resources and energy as efficiently as possible), cyclic (enabling recovery through industrial or natural systems) and safe (as non-polluting and non-toxic and therefore not posing any risk to humans and ecosystems)*". Additionally, in 2005, the Sustainable Packaging Coalition (SPC) the USA, describes as *"sustainable packaging is safe and healthy throughout its life cycle, and it meets the market requirements interns of performance and cost. Renewable or recycled material used in a clean manufactured process, that has a lesser environmental impact"*.

The companies focus on sustainability is to take into account of social responsibility (Labatt, 1997) and it also helps the companies in cost saving by enhancing the effectiveness (Hellström and Nilsson, 2011). Sustainability is a recent trend, which is used to attract the consumers as a market strategy (Alwitt, L.F. and Pitts, R.E., 1996). Consumers do give value to ethical products and environment-friendly products (Rokka and Uusitalo, 2008). Environmental impact is taken into account for developing the framework of SPD (Selke, 2012). Lewis et al (2007) mentioned the SPD needs to have balanced incorporation of different actors into the development process. Also, in an integrated system, it is often hard to find out the degree of each actors' requirements. The study could be used to identify the requirements of different actors, and it helps to find out where and who is benefited the most in the supply chain (Lai et al., 2008), for example, machinability is more beneficial for the producer.

2.4 Frozen meal packaging

Food packaging plays a virtual role in prolonging the shelf life and protecting the product from physical, chemical and biological hazards. Frozen meal food packaging (FMP) developer often develop or alter the packaging to achieve the desired shelf life and to maintain the sensory qualities (Robertson, 2009). FMP undergoes ambient temperature to freeze temperature (-18ºC) under normal distribution and storage conditions. Further, if the product is heated in the microwave, then the packaging undergoes the temperature of 300ºC or above (Kennedy, 2000; Lee, 2005).

Heldman et al. (2018) mentioned, that the frozen meal packaging system needs to withstand the temperature and to protect the product, for example from the colour fading. Barrier properties of packaging material prevent the product from 'frost', frost occurs due to gain or loss of moisture (Kennedy, 2000). However, to maintain frozen meals in perfect condition, Paine & Paine. (1992) suggested four major packaging roles as to avoid dehydration caused by moisture vapour evasion through the wall or seals of the package. Secondly, to limit oxidation promoted by enzymes not eliminated by blanching if air penetrates the package. Third, to inhibit oxidation particularly with a high-fat content, which can be accelerated by light as heat can induce increased enzyme activity and chemical and bacterial deterioration. And finally, to avoid flavour or volatile loss and the absorption of airborne odours which are unlikely to occur at the same time as pre-packaged foods remain frozen.

Frozen meals packaging maintained at a low temperature and this remains a challenge for coding. The low, wet and humid environments can impact the code adherence and legibility. When the codes are damaged the identification process in terms of date codes, lot codes and batch codes become difficult which affects the tracking throughout supply chain management. The cold temperature affects the adhesiveness and results in the seal opening. In frozen condition, the product becomes harder, sometimes like sharp edges that could damage the package and result in product loss. The atmosphere kept inside a frozen meal packaging is relatively dry. When a dry environment persists, there is a chance for the product to get freeze burn (Heldman et al., 2018). Proper packaging material with good moisture vapour transfer rate (MVTR) is needed to avoid freezer burn. Also, a suitable heat transfer packaging material helps to prepare the food in an energy efficient way, which makes convenient to the consumers.

The important developments in Frozen food packaging are listed by Sun (2016) as mentioned in Table 02, where he mentioned the decades and the developments. The advanced packaging, such as self-venting packaging, modified atmosphere packaging, vacuum packaging is being a trend in frozen meal (Sun, 2016). At the same time, active and intelligent packaging have a broader scope in frozen meals (Prasad and Kochhar, 2014).

Table 2: The Important development in frozen food packaging.

Decade	*Developments*
1960s	LDPE-coated paperboard cartons Spiral wound composite juice cans with tear-off aluminium ends Flexible pouches Boil-in/microwave-in-bags
1970s-1980s	Stand-up and resealable pouches Microwavable materials Microwave susceptors for browning and crisping
1990s-2000s	Microwaveable PP and PP-coated paperboard trays Dual-Oven able PET and PET-coated paperboard trays Microwaveable defrosting HDPE frozen juice cans Intelligent (communication and responsive) packaging Patterned microwave susceptors
2000s-2010s	Incorporation of recycled content into paperboard and plastic trays Self-venting bags, pouches and trays for steaming product during microwave cooking Susceptors capable of creating grill pattern on microwave sandwiches

Griffin et al. (1985) classified the food packaging into three forms, such as flexible – e.g. pouches, rigid - e.g. metal cans and semi-rigid - e.g. paperboard cartons. Combination of packaging materials is used in frozen meal to achieve the desired functional properties, such as barrier properties, packaging weight, etc. The most common types are paperboard, plastics and metals (Sun, 2016). Packaging world (2008) mentioned the demand of packaging for frozen food in Figure 3, where boxes and bags have the higher demands and the trays has 9% in total.

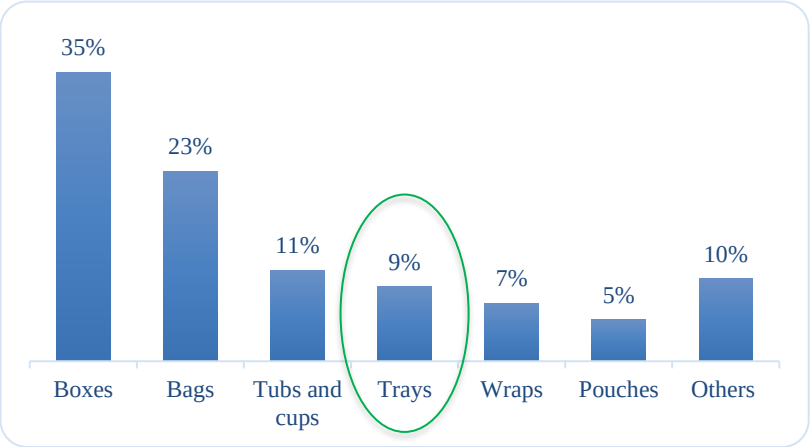


Figure 3: Demand of packaging for frozen food (Packaging world, 2008)

2.4.1 Paper based frozen meal packaging

Paper is the general term used for a wide range of matted or felted webs of vegetable fibre (mostly wood) that have been formed on a screen from a water suspension (Tanner and Amos, 2006). Paper and card are commonly used for packaging frozen foods. Card or paperboard is used to produce both folding and rigid cartons, often not in direct contact with the food product. The board often consists of plies made from different materials (Tanner and Amos, 2006). A widely used board, white lined chipboard, has a white surface on one side made from a bleached virgin pulp, with the bulk being composed of "chip," which is usually gray and made from a high proportion of recycled. Paine and Paine (1992) also state that cartons made from paperboard, originally coated with wax but now more commonly with polyethylene, with locking bases and lids and coated paper overwraps are common.

Paperboards are useful for packaging of wet products due to the enhanced water-resistant characteristics coming from the coated board. The carton itself gives physical protection and protection against moisture and oxygen transfer is provided by a barrier overwrap or a sealed inner pouch or liner. A typical overwrap is coated polypropylene. Internal liners are frequently made of polyethylene (Holdsworth, 1988).

2.4.2 Plastic based frozen meal packaging

Polymers, means ploy (many) mer (parts) is the common term used for plastics, and the plastic available in different forms such as Low-density polyethene (LDPE), High-Density polyethene (HDPE), PP, etc. polyethene terephthalate (PET) and polypropylene (PP) are the most commonly used plastics for frozen meal (Sun, 2012). Plastics are good in oxygen and moisture barrier. Plastics that using for microwave and oven should have a high melting point temperature. PP has the melting point of 171ºC and the PE has the temperature of 260ºC that makes convenient to use in frozen meal categories (Ono, 1990). Whereas LDPE has a low melting point 104ºC that perform better at the sealing process. Also, LDPE is used in carton boxes as a moisture resistant material.

2.5 Packaging logistics and supply chain

2.5.1 Supply chain

Supply chain aims to achieve a coordinative system and linkage between different actors, who involved in the entire process that is from supplier level to consumer level (Christopher, 2016). In 1982, Oliver and Webber analysed the trade-offs and understood that the traditional way of supplying the goods, such as purchasing, production and distribution is no longer worked well, and they introduced the term supply chain management. Supply chain management is described as managing the upstream and downstream with all the actors in the supply chain to deliver superior customer value (Christopher, 2016). In another word, it is called as "*demand chain management"*, where the demand raised from the market. The actual supply chain process is very complicated than how it looks like. Aitken, (1998) described the supply chain as "*a connection of network between the organization and cooperatively work together to manage, control and flow of information and material from supplier to end consumers*" and the complexity of operation is mentioned in the below Figure 4. Due to the number of operations and distribution channel, the supply chain operation affects the economic and environmental effectiveness (Fernie and Sparks, 2004).

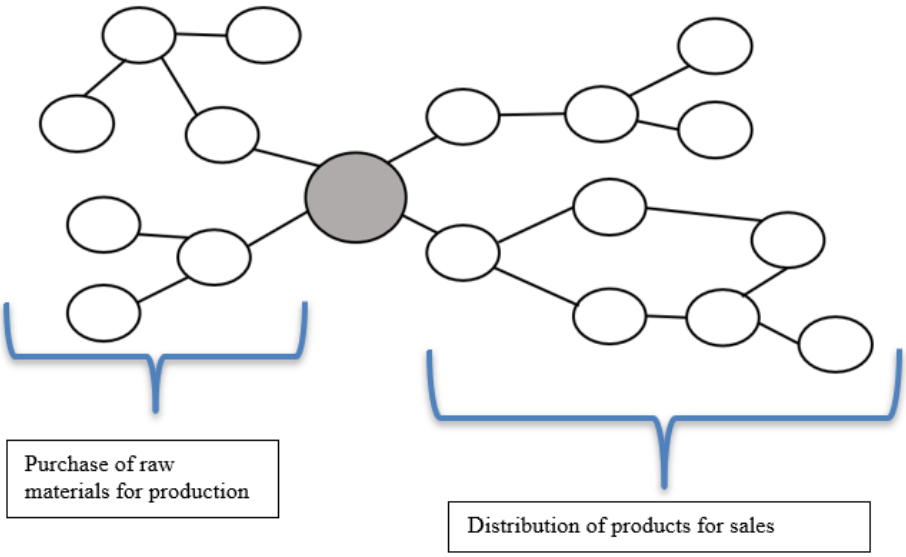


Figure 4: Complex process of supply chain (Aitken, 1998)

2.5.2 Packaging in supply chain

Packaging helps in the supply chain to hold and deliver the product to the right customer. Packaging interacts with different actors in a supply chain that is from the point of production to the point of end consumption (Pålsson and Hellström, 2016). According to Johnson (2018) packaging provides value to different actors, such as facilitating the handling, providing the information, and increasing the sales. Packaging achieves a smooth and efficient operation in an international context (Pålsson and Hellström, 2016). Packaging has a significant role in reducing the impact of carbon emission in the supply chain (Livingstone and Sparks 1994). The sustainable supply chain enhances operational efficiency and reduces the environmental impact (Lockamy III, A., 1995; Pålsson and Hellström, 2016). In order to achieve sustainability, the packaging development needs to consider as an integrated and holistic approach, rather than sub-optimization (Hellström and Saghir, 2006). The sub-optimization is required more time and energy and it accounts for the higher cost (Fernie and Sparks, 2004).

2.5.3 Packaging role in manufacturing

The frozen meal gets into contact with packaging material, during the packing process at the packaging machine. Manufacturers use a different level of packaging, such as primary, secondary and tertiary packaging (Pålsson, 2018). Food manufacturers use the largest amount of packaging material in the world while compared to other industry, as the food is consumed in every single day (Bourlakis et al., 2011). The food manufacturer key focuses on packaging material is cost effective and flexibility in the packaging machine to have higher productivity (Hellström and Saghir, 2006). These factors depend on the type of food product, packaging material and packaging machine. Hellström and Saghir (2006) mentioned that the application of label has a crucial role in the production line, as it takes extra time, labour cost. The label is applied for secondary and tertiary packaging at shop floor. This helps to provide an information throughout the process to have a smooth flow goods (Kimberley Watson packaging, 2015). For the primary packaging, online printing is carried out by the online printer at product filling stage.

The filling process of frozen meals followed as manual or automated, the process is controlled well to have the right quantity of product in the package. Further, the primary packages are filled into secondary packages. The size and the design of secondary packages affect the handling efficiency (Pålsson, 2018). The size of the secondary package depends on the primary package and their size also affect the space utilization in the tertiary package. This cause in half pallet/low volume efficiency throughout the process. The packaging material strength affects the stacking process and manufacture uses interlocking and align the stacking system. Higher the weight carrying capacity is achieved by doing the align stacking at

bottom and interlocking at the top, and the number of layers depends on the size of the pallet and secondary packages. Two types of tertiary packages such as pallets are used at the food manufacturer level.

2.5.4 Packaging role in transportation

In the supply chain, transportation is described as the movement of goods from one place to another place (Cambridge dictionary, 2019). The right packaging makes it possible to get the product from producer to warehouse and warehouse to retail store and finally to consumer's hand. Tertiary packages, such as pallet and roll container are handled during transportation in the supply chain. Hellström and Saghir, (2007) mentioned the important factors are readability, stackability and weight and volume efficiency. In addition to that Pålsson and Hellström, (2016) mentioned important factors are weight and volume efficiency, utilization and material handling. Space utilization in the truck could be an important factor for frozen meal, as the product is carried under refrigeration condition. Proper utilization of refrigeration condition helps in cost saving. Heap (2006) mentioned, around 1.2 million refrigerated trucks, 650,000 refrigerated container and 80,000 refrigerated rail cars are used in worldwide.

The packaging undergoes several vibration and handling during the process and the packaging system needs to pack in the right condition to avoid the dropping of secondary packages in the pallets (Lancioni and Chandran, 1990). The label mentioned in the pallets and roll container helps in providing the information to the right actors and reduced the waiting time. This also helps to avoid keeping the frozen meal in a normal condition for a longer period. Apart from this, packaging undergoes several movements inside each actor, for example production line, warehouse and retail shop. These movements and transport activities of packaging and packaging system result in product damage, that mainly occur during loading and unloading activities (Lancioni and Chandran, 1990).

2.5.5 Packaging role in warehouse

Once, the frozen meal is produced and packed, further, it sent to the warehouse prior to the retail store. warehouse helps in storing/accumulating the products and delivering to the right customer/retailer in time. Secondary and tertiary packages are handled at the warehouse (Hellström and Saghir, 2007). The product is stored in tertiary packaging and secondary packaging is used during picking and stacking (roll container). The plant layout, order system, equipment availability would affect the warehouse handling efficiency (Hellström and Saghir, 2007). Pålsson and Hellström, (2016) mentioned the important factors such as product protection, handleability and flow of information. The standardized packaging size/ pallet size

is easy to store and distribute which reduced the cost (Murray, 2019). The product maybe is stored for a longer duration in that case the packaging needs to withstand extreme weather condition. Packaging collapse occurs in cold storage, due to the moisture gain (Murray, (2019). Also, the damage occurs during different operational activities, such as forklift drops, pallet breakage (Warehouse fulfilment, 2017).

The consumers and customers should not face the situation - out of stock, this could happen due to transport delay or faulty stock. The warehouse also helps in postponement, and postponement is described as delaying the activities of a manufacturer, transporter or packaging in the supply chain (Pålsson, 2018). Also, Pålsson, (2018) listed the effect of packaging in postponement under four areas, such as 1) full postponement "*postponement in manufacturing and transport*" 2) manufacturing postponement "*speculation postponement in transport*" 3) logistic postponement "*postponement in transport*" 4) full speculation "*speculation postponement in manufacturing and transport*". Postponement strategy results in a cost reduction of transportation and inventory (Twede, et al., 2000).

3.Methodology

This chapter introduces the research approach and the research design. The research design describes the data collection methods, the framework of packaging scorecard. The carton and plastic frozen meal packaging were selected for the analysis.

3.1 Research approach

The project focused to solve the two identified research questions presented in chapter 1. The first research question is to determine the packaging performance of the frozen meal packaging (carton and plastic) in the supply chain. The selection of supply chain actors was carried out by a systems approach. The system approach is defined as fixing a boundary in the supply chain for the analysis. It is essential to understand what types of actors are involved in the supply chain. Once, the actors are understood well enough, then the investigation is done to understand who is handling what level of packaging. The second research question is to identify the most important packaging features that need to be considered while developing the sustainable frozen meal packaging. The packaging performance in the supply chain is affected by the packaging functions and features (Hellström and Saghir, 2007). The first two research questions are solved by using the packaging scorecard framework and scatter plot as described by Pålsson (2018).

As mentioned in chapter 1, the author had a confidentiality agreement with the company. Due to the confidentiality, the selected packed product and the supply chain actors were kept as anonymous. As mentioned in Table 3, in this research two types of packed products were selected, which are referred as Product A – Carton packaging system and Product B – Plastic packaging system. Product A – stands for *'the product (frozen meal) packed in carton tray'* which is further referred as "Carton packaging". Product B – stands for *'the product (frozen meal) packed in plastic tray'* which is further referred as "Plastic packaging". The producer name is referred as "Producer A" (for product A – Carton packaging) and "Producer B" (for product B – Plastic packaging).

Further, producer A's distributor wasrehouse is referred as "Distributor warehouse A", and producer B's distributor wasrehouse is referred as "Distributor warehouse

B". Similary the retailer is referred as "Retailer A and Retailer B". Retailer A is further referred as "Retailer warehouse A" and Reatiler store A and B), similar Retailer B is further referred as "Retailer warehouse B" and Reatiler store (C and D), as mentioned in Table 4.

The company X does not produce any frozen meals at the moment and company X is looking for the frozen meal market in the near future. The company X wants to develop a sustainable packaging system for the developing frozen meals. So, the company X aims to analyse the current frozen meal packaging which is available in the current market. Hence, company X suggested to select the two types of packaging that is carton packaging system and plastic packaging system. These two types of packaging are selected because the company X is interested to select the better-performed packaging system, i.e. carton packaging system or plastic packaging system.

Table 3: Selection of packaging for the study.

Name of the product	***Name of the producer***	***Type of Primary package***	***Referred as***
Product A	Producer A	Carton tray (Frozen meal packaging)	Product A – Carton Packaging
Product B	Producer B	Plastic tray (Frozen meal packaging)	Product B – Plastic Packaging

Table 4: Supply chain actors are referred.

Product referred as	*Producer referred as*	*Distributor referred as*	*Retailer warehouse referred as*	*Retailer store referred as*
Product A	Producer A	Distributor warehouse A	Retailer warehouse A	Retailer A
				Retailer B
Product B	Producer B	Distributor warehouse B	Retailer warehouse B	Retailer C
				Retailer D
Product A is handled by producer A, distributor warehouse A, Retailer warehouse (A and B), Retailer store (A, B, C, D)				
Product B is handled by producer B, distributor warehouse B, Retailer warehouse (A and B), Retailer store (A, B, C, D)				

3.2 Analytical framework

To align and to fulfil the purpose of the project, an overall framework is developed. The overall framework is mentioned in Figure 5, it is comprised of 6 stages. The first step starts with establishing the need and scope of the project. At the second stage, two research questions were established to fulfil the scope of the project. At the third stage, the theoretical framework was created to occur information through secondary and primary research. At the fourth stage, a detailed methodology was established to understand how to carry out the project. At stage five, the data was collected, analysed and interpreted. At the final stage, the identified results are reported and presented in the project. The detail explanations of these steps can be found in the mentioned chapter, chapter 1 (stage 1, 2), chapter 2 (stage 3), chapter 3 (stage 4), chapter 4 (stage 5), chapter 5 (stage 6).

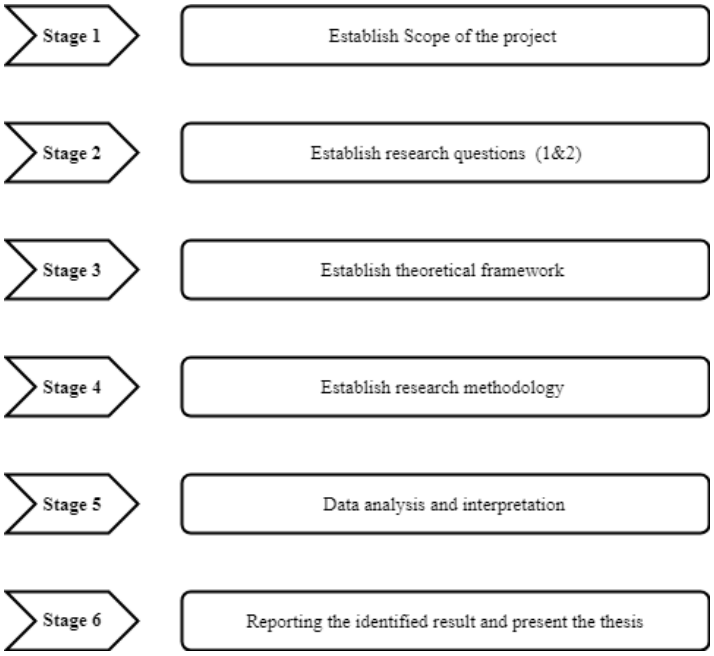


Figure 5: Overall framework

3.3 Data collection

Data collection is defined as a gathering of information and it is a fundamental step for any type of research (Athukorala, 2011). The balanced quantitative and qualitative data collection method was used (Blaikie, 2003). The data collection is

followed as secondary and primary data, and it is summarised and mentioned in Figure 6, where it shows the different steps followed for secondary and primary data collection.

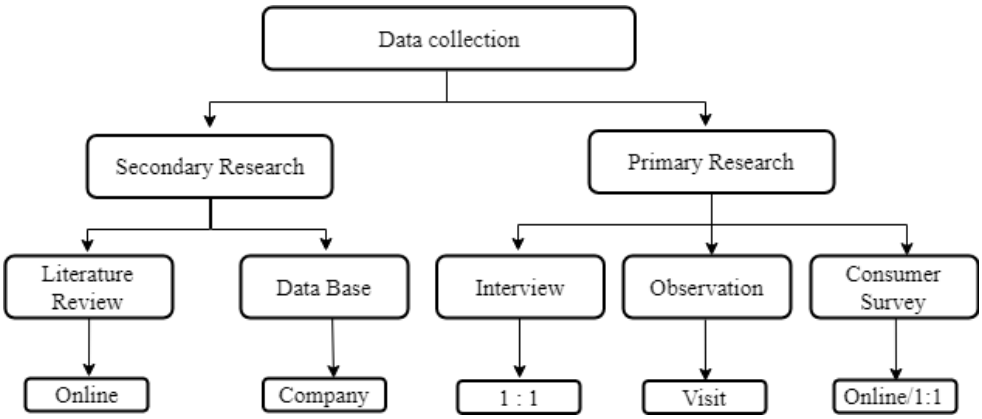


Figure 6: Primary and secondary data collection

3.3.1 Secondary research

Secondary data is described as any data that is already collected by different authors for different purposes and that is referred in the study (Blaikie, 2003). Secondary data provides information in a quick and faster way and in a cost-effective manner (Radey, 2010). Radey (2010) mentioned that secondary data is the point where the primary data takes place. The secondary data has some disadvantages as (i) researches could be used with some assumptions (ii) all the area of the research may not be included and (iii) sometimes the data could be too old to use.

In this research, the secondary data is referred to collect the holistic information of the packaging system, supply chain and their interaction in the supply chain. The data was obtained mainly from two sources, such as literature and database (information from the company). The keywords are used for collecting the secondary data, which are listed below.

1) Food/Carton/Plastic frozen meal packaging.
2) Packaging/Packaging features/Packaging logistic/Sustainable packaging development.
3) Supply chain/Cold supply chain.

The above-mentioned information was retrieved from different scientific papers, journals, specialized magazines. The primary database used in this study was from

the Lund University (LUB search) and Google search engine. Also, research articles and thesis published by Lund University in the areas of packaging logistics. The packaging recycling manual and the guidelines for the use of plastic packaging from the FTI - Förpacknings-och Tidningsinsamlingen (FTI manual, 2018) is received from the company X.

3.3.2 Primary research

The primary data is described as the data collected by the author who designs the study (Blaikie, 2003). Driscoll (2011) mentioned that the primary data is not found in any database or book and is collected as first-hand. The ultimate goal of the primary research is to learn something new and that can be agreed on by others (Driscoll, 2011).

A well-structured framework helps to collect balanced qualitative and quantitative data. A methodology framework "packaging scorecard" described by Pålsson (2018) was used in this study; the author is familiar with this methodology framework. The author used the packaging scorecard framework for the course of "packaging logistics" at Lund University, Sweden. Pålsson (2018) framework steps are mentioned in the following Table 5, where the steps, methods, descriptions and the tools are described. Further, each step is explained in the following text.

Table 5: Methodology framework

Steps	***Methods***	***Description***	***Tools and Methods***
Step 1	Map the packaging system for a frozen meal throughout the supply chain	To understand the packaging system, supply chain and product characteristics	1) Product characteristics 2) Mapping of supply chain actors 3) Packaging system interaction
Step 2	Collect data for the packaging system in the supply chain	To collect data to create the packaging scorecard.	1) Identification of packaging features 2) Interview 3) Observation 4) Survey
Step 3	Evaluate and graphically present the data.	Presenting the gathered data and visualize them in graphically.	1) Scatter plot 2) Packaging scorecard 3) Packaging challenges in the supply chain.

Step 4	Analysis of the packaging as a whole system	Presenting the results.	1) Present the performance of packaging system. 2) Present the important packaging feature specification table

3.3.2.1 Step 1: Mapping of supply chain and packaging system

The step 1 focuses on the mapping of the frozen meal packaging system and the actors in the supply chain. This step helps to get the insight about the product, packaging system and the supply chain. Three tools are used in this step, which is discussed below.

Tool 1: Product characteristics

The product characteristics are described as the attributes which added to the product definition to further illustrate the product nature, for example, price, quality, shape, and these characteristics are further used to filter or search (open bravo, 2014). Miracle (1965) explained it as the combinations of consumer and market characteristics. In a packaging point of view, this tool is used to understand what packaging features need to focus and which packaging functions need to be provided higher importance. For example, the focused product is a frozen meal, hence the product needs to be maintained at a certain temperature thought out the supply chain. Thus, to understand how each product characterises are affecting the packaging system as well as the supply chain. Product nature, supply chain conditions, production process are taken into consideration while developing the product characteristic framework.

Tool 2: Mapping of supply chain actors

The supply chain mapping is described as the linkage between different actors who are involved in the mapped system boundary (Jayaratne et al, 2012). Jayaratne (2012) also mentioned that the mapping helps to visualise the degree of each actor's involvement in the supply chain as upstream and downstream. According to Gardner and Cooper (2003), to achieve optimal performance in the supply chain, a strategic mapping of the supply chain is required. In this project, a system boundary is fixed before mapping the supply chain. The system boundaries are fixed from the point of product production, which is named as "producer" and the point of product consumption, which is named as "consumer". The supply chain actors are mapped based on the interviews and the information received form the Company X. The actors involved in the supply chain are 1) Producer (product manufacturer), 2) Transport (Distributor Transport), 3) Warehouse (Distributor warehouse), 4) Transport (Retailer Transport), 5) Warehouse (Retailer warehouse), 6) Transport (Retailer Transport), 7) Retailer store and 8) Consumer.

Tool 3: Packaging system interaction

The interaction is described as the process of two or more than two things which have an effect on each other and work together (Mayor, 2009). In this case, the packaging system's interaction with the supply chain actors. The packaging interaction for packaging system is applied to all the actors in the supply chain. Under each packaging system (primary, secondary and tertiary packaging) a table was created where the relevant packaging features (out of 15 packaging features) are mentioned. Only the relevant packaging features were analysed for that particular packaging system. For example, packaging waste is applicable to primary and secondary packaging and not applicable for tertiary packaging, so in this case the packaging waste analysis is done only for primary and secondary packaging.

3.3.2.2 Step 2: Data collection

The step 2 focuses on collecting the data for the packaging system in the supply chain. The data was collected through interviews, observation and survey which are further explained below.

Method 1: Identification of packaging features

Features are described as a typical quality or an essential part of something (Cambridge dictionary, 2019). Similarly, packaging features is a typical quality or essential part of the packaging system. Initially, the packaging features are identified based on the supply chain and the type of food product as described by Pålsson (2018). Further, the identified packaging features were discussed with the company X and selected 15 packaging features for the analysis, and it is attached in Appendix A.

After selected the required packaging features, a primary data collection was carried out with different actors in the supply chain and consumers. In this research, interview, observation and survey were selected for the primary data collection.

Method 2: Interviews

Driscoll (2011) describes an interview as asking the participants as one to one or small group setting. It can be used at any stage in the research process and it is a most flexible research tool (Breakwell, 1995). Semi-structured interview with open-ended (to collect the actor's need and suggestion) and fixed questions (to collect the information on supply chain practices) were used in this interview. The semi-structured interview questions were prepared under three categories as mentioned below.

1. Packaging features-based questions.
2. Current practices, suggestions and their needs-based questions.
3. Challenges and risk-based questions.

The prepared questions were discussed with the Company X to select the most important interview questions. The interview script is attached in Appendix B and C.

Ten interviewees were selected based on the mapped supply chain and the selected Product A and Product B. The interviewees were contacted through company's webpage, personal emails, personal phone call and direct visit to the place of interviewees. Managerial level employees were selected for the interview from the level of producer to the level of retailer store. The list of interviewees and their experiences, and the activity followed in the interview were mentioned in Table 6. The interview was organized as an individual event and performed as face to face and on phone call. The interview script was sent to some of the interviewee, because of the convenience and the interviewee's request. An introduction and the purpose of the project were explained prior the interview process.

Also, the interviews were conducted for target consumers as shown in Table 6. The target consumers were selected based on the below criteria, such as 1) diet behaviour: Flexitarian or vegetarian, because the company X is focused to develop the frozen meal for these category consumers. Flexitarian consumers refer to the people who predominantly consume vegetarian diets and occasionally consume animal products, animal products include meat and fish (Dagnelie and Mariotti, 2017). Vegetarian consumers refer to the people who consume all categories of vegetarian diets, including animal by-products, such as milk, honey, etc. Vegetarian consumers exclude animal products, such as meat and fish (Dagnelie and Mariotti, 2017). 2) Market area: Scandinavian consumers, the consumers who born and live in any one of the Scandinavian countries and International consumers, the consumers who are working or studying or living in any one of the Scandinavian countries. Hence, five interviews were conducted (three from Sweden (Swedish consumer – 2, International consumer – 1), one from Denmark (International Consumer), and one from Finland (Finish Consumer).

In the packaging scorecard framework numerical data was used in a five-point Likert scale to get the level of importance and satisfaction with respect to each packaging features. Hence, a separate document was prepared in a table format, and given to the interviewees and asked to give the score in a five-point Likert scale for each relevant packaging features. The scores and the interview answers were interpreted for the analysis.

Table 6: Interview respondents – supply chain

Actor	***Name of the company/Actor's company name***	***Respondent's Role***	***Respondent's Code***	***Total year of experiences***	***Date of interview***
Producer	Producer A	Production Manager	P-1	12	11/4/2019
	Producer B	Production Manager	P-2	17	16/4/2019
Distributor Warehouse	Distributor Warehouse A	Warehouse Manager	DW-1	15	24/4/2019
	Distributor Warehouse B	Warehouse Manager	DW-2	12	19/4/2019
Retailer Warehouse	Retailer Warehouse A	Warehouse packaging Manager	RW-1	8	7/5/2019
	Retailer Warehouse B	Warehouse Manager	RW-2	11	3/5/2019
Retailer Store	Retailer Store A	Store Manager	R-1	15	6/4/2019
	Retailer Store B	Store Manager	R-2	20	4/4/2019
	Retailer Store C	Store Manger	R-3	18	8/4/2019
	Retailer Store D	Store Manager	R-4	9	9/4/2019

Table 7: Interview respondents – Consumers

Region	Scandinavian / International consumer	Diet options	Interviewee's Code	Professional	Date of interview
Sweden	Swedish Consumer	Flexitarian	C-1	Working	3/5/2019

Sweden	Swedish Consumer	Vegetarian	C-2	Working	24/4/2019
Sweden	International Consumer	Flexitarian	C-3	Studying	24/4/2019
Finland	Finish Consumer	Flexitarian	C-4	Working	3/5/2019
Denmark	International Consumer	Flexitarian	C-5	Studying	26/5/2019

Method 3: Observations

The aim of the observation is to capture the real activities, target events, practices and occurrences in an objective way as possible. The level and unit of the analyses are based on the research objectives. Brewerton and Millward (2001) mentioned the observation into two types, such as participant and non-participant observation. In participation observation, the researcher/author is directly involved in the field and observes the activities along the target participants (Schwartzman, 1993). In non-participant observation, the researcher/author is indirectly involved and observes the activities from a distance, which could be either by recorded data (video, pictures) and without a target participant (Schwartzman, 1993).

The participant observations were carried with an employee from the respective company/actor. A checklist document was prepared based on the packaging features and in-house activity, and the document was used during the observation activity to collect the information. During the observation activity, semi-structured questions were asked to the employees and voice recorded the discussion for analysis. Packaging system handling process, storage conditions, etc were observed during the observation activity. The checklist and observation questions were mentioned in Appendix D. Table 8, shows the list of observation activities, such as supply chain actors, place, date and duration.

Table 8: Observation activity

Actor	*Name of the company/Actor's company name*	*Date of Observation*	*Duration of Observation*
Retailer Warehouse	Retailer warehouse A	07/05/2019	120 Mins
Retailer Store	Retailer store A	06/04/2019	90 Mins
	Retailer store B	09/04/2019	60 Mins
	Retailer store C	08/04/2019	90 Mins
	Retailer store D	09/04/2019	30 Mins

Method 4: Consumer survey

The consumer survey was conducted to identify the packaging performance at consumer level and aimed to identify the consumer requirements towards frozen meal packaging. The survey was conducted for target consumer based on the below criteria, such as 1) Diet behaviour: Flexitarian or vegetarian, because the company's (X) product is focused on this category consumers. 2) Market area: Scandinavian and international consumers. The consumer survey was conducted online, through Facebook, emails, and direct contact with consumers (where the survey form was printed and handed over to the consumers). 110 consumers were contacted, in that 85 respondents were received and the rate of response was 77 percentage. The survey was conducted from 28/03/2019 to 03/05/2019 and during this period the survey form was kept running to receive the consumers answers and the survey script is attached in Appendix E.

Reflection about the different methods used for data collection.

As mentioned above, three data collection methods were used in this research, such as interviews, observations and survey to acquire the qualitative data. Firstly, interviews were used to collect the information about the supply chain actors and consumers needs and their requirements for frozen meal packaging system, and to collect the information about the challenges and risks they are facing with selected packaging system (Product A and B). Also, to get their insight on the packaging system and supply chain process.

Secondly, observations were conducted to understand and to map the whole supply chain process, such as how the packaging system is handled, what tools, and physical and environmental conditions are used to handle the packaging system.

Thirdly, a consumer survey was conducted to find out the consumers requirements in general as a frozen meal packaging, such as packaging material type, buying behaviour, etc.

3.3.2.3 Step 3 and 4: Data analysis and presenting the results

Tool 1: Packaging scorecard

The packaging scorecard consists of four areas such as product waste, logistics efficiency, value adding and packaging material. The four areas include the six basic functions of packaging: protection, containment, apportionment, unitization, communication and convenience. The list of selected packaging features and their description was mentioned in Appendix A.

The interviews were voice recorded with the permission of the interviewees. The voice recorded data is then transformed into a word document-by listening the voice record, where the data/information is summarized under specific headings and mentioned in bullet points and sentences. Further information is interacted and presented in the results and discussion chapter of this thesis.

Based on the primary data, for each actor's a rationale of a packaging scorecard table was developed as mentioned by Pålsson (2018). The rationale of a packaging scorecard table was developed for each packaging feature with a five-point Likert scale. The importance and the satisfaction scores are filled in the tables based on the five-point Likert scale, which is attached in Appendix F. The importance is described as "how much importance does the actor gave for a particular packaging features (for example, protection)". And satisfaction is described as "how much is the actor satisfied with that particular packaging feature (for example, protection)". Likert scale for importance (1=least important, 2=below moderate important, 3=moderate important, 4=important, 5=very high important), and for satisfaction (1=very less satisfied, 2=below average satisfied, 3=average satisfied, 4=above average satisfied, 5=very high satisfied). Further, the importance score is normalised to have a standard scale. Normalisation is calculated by dividing each importance values by the sum of all values in the packaging scorecard. The below-mentioned formula is used to calculate the normalised average of packaging performance, which is developed by Pålsson (2018).

Normalized average packaging performance

*= Σ [(Normalized importance (PF1) * Satisfaction value (PF1)) + (Normalized importance (PF1) * Satisfaction value (PF1))] / number of packaging features.*

**PF1 – Packaging feature 1, *PF2 – packaging feature 2*

Further, the calculated values are presented in a graph, where the x-axis represents the performance (i.e. low to high satisfaction), and y-axis represent the actors (i.e. producer to consumer). This graph illustrates the performance of the each packaging level (e.g. primary packaging) with each actor in the supply chain.

Tool 2: Scatter plot

Also, a scatter plot was developed as mentioned by Pålsson (2018) by comparing the importance and satisfaction value for each packaging feature in the supply chain. This scatters plot gives the most important features that need to be considered to have high satisfaction in the supply chain and also it also shows the low important and least satisfied packaging features. Further, a specification table is prepared to list out the top 5 important packaging features in the supply chain for each packaging level and each actor.

Tool 3: Packaging challenges in the supply chain

The main function of this tool is to understand the challenges that are associated with the packed product in the supply chain. The most common challenges of the frozen meal are identified and reported.

4.Result and discussion

This chapter introduces the overview of the product and packaging system of the two types of frozen meal packaging. It describes the supply chain mapping and detailed activity mapping of supply chain actors. The packaging system interaction helped to visualize the packaging features and their interaction with supply chain actors. The scatter plot describes the importance and satisfaction level of each packaging features with the supply chain actors and consumers. Then the packaging performance score illustrates the packaging system performance. Further the specification table describes the most important packaging features of the producer, distributor, retailer and consumer.

4.1 Overview of the product and packaging

4.1.2 Product characteristics

The products chosen for this study was frozen meal packaging: Product A – Carton Package and Product B – Plastic Package. The product A – carton package contains the main food ingredients, such as vegetables with sauce. The product B – plastic package contains, pasta as the main ingredient, and with mozzarella, vegetables. The product A – carton package is produced in middle Europe and sold in Scandinavian countries, whereas product B – plastic package is produced in Scandinavian country and sold in Scandinavian countries. Both products are sold in frozen condition (-20ºC or colder) in different retail stores (R-2; R-4). The retailer A price for the product A is 28 SEK and for product B is 34 SEK, and retailer C price for product A is 28 SEK and for product B is 35 SEK. The price changes frequently depending on the season and during the promotion days. The weight of the product A – carton package is 400g and product B – plastic package is 380g. Both the product's packaging that is tray is directly placed in the oven or microwave for heating and consumption. The summarized products information is mentioned in Table 9.

Table 9: Characteristics of product A and product B

Information	***Product A*** ***(Properties and characteristics)***	***Product B*** ***(Properties and characteristics)***
Price	28 SEK (Retailer A and B)	34 SEK (Retailer A) and 35 SEK (Retailer B)
Packaging Materials	Carton tray, LDPE film, carton box	Plastic tray, LDPE film, carton wrap
Main Ingredients	Vegetables with sauces	Pasta, Mozzarella and vegetables
Product Measurement	200 X 170 X 30 mm	145 (l) X 50 (h) mm
Weight	400g	380g

4.1.2 Packaging characteristics

The packaging for both products consists of primary, secondary and tertiary packaging. The combination of primary, secondary and tertiary packaging is further referred as ‘packaging system’, which is described in detail below.

4.1.2.1 Primary packaging:

Product A – Carton packaging

The primary packaging consists of carton tray and the top of the tray is sealed with LDPE(plastic film). The carton tray is placed into the carton box that acts as a selling box, where the printing has done outside the carton box. The carton tray is rectangular in shape with the dimension of 225 X 190 X 35 mm (lxbxh), and the packaging material weight is 23.3g. The carton box is in rectangular shape with the dimension of 225 X 195 X 38 mm, and the packaging material weight is 41.3g. The plastic film which is placed on the top of carton tray has the same dimension as

carton tray, and the weight of the packaging material is 1.2g, which is shown in Table 10 and 11.

Figure 7: Product A – Carton tray

Figure 8: Product A – LDPE film

picture of carton box is not included due to confidential.

Product B – Plastic package

The primary packaging consists of plastic tray and the top of the tray is sealed with LDPE(plastic film). The plastic tray is placed into the carton wrap that acts as a selling box, where the printing has done outside the carton wrap. The plastic tray is dimension is 185 X 70 mm (lxh), and the packaging material weight is 18.6g. The plastic film which is placed on the top of plastic tray has the same dimension as plastic tray, and the weight of the packaging material is 1.0g. The carton wrap has a rectangular shape with the dimension of 185 X 160 X 60 mm (lxbxh), and the packaging material weight is 20g, which is shown in Table 9 and 10.

Figure 9: Product B – Plastic tray
Figure 10: Product B – LDPE film
picture of carton wrap is not included due to confidential.

4.1.2.2 Secondary packaging:

The secondary packaging consists of corrugated cardboard box for both the products. Eight number of primary packaging is placed on the secondary packaging. It is a stable corrugated cardboard box protecting the primary packages during handling and transportation. The corrugated cardboard box used for the product A has the dimension of 390 X 230 X 160 mm, and the weight of the packaging material is 183g. Whereas the corrugated cardboard box used for the product B has the dimension of 340 X 165 X 295 mm, and the weight of the packaging material is 150g, which is shown in Table 9 and 10.

Figure 11: Product A – Corrugated cardboard box
Figure 12: Product B – Corrugated cardboard box

4.1.2.3 Tertiary packaging:

Two types of tertiary packaging are used for both the products, namely wooden Euro pallet and roll container. The Euro pallet is used from producer level to retailer warehouse level, and the roll container is used from retailer warehouse level to retailer store. 56 secondary packaging is placed into the wooden Euro pallet (tertiary packaging) in 7 layers for product A – carton package. 45 secondary packaging is placed into the Euro pallet (tertiary packaging) in 5 layers for product B – plastic package (P-1; P-2; RW-1). The number of secondary packages (both the products) are placed into the roll container varies depend on the demand (RW-1; RW-2; R-2), which is shown in Table 10 and 11.

Table 10: Packaging characteristics for product A – carton packaging

	Primary Packaging	***Secondary Packaging***	***Tertiary Packaging 1***	***Tertiary Packaging 2***
Packaging material	Carton tray, LDPE film, Carton box.	Corrugated Cardboard box	Wooden Euro Pallet	Roll container
Packaging Measurements (mm)	225 X 195 X 38	390 X 230 X 160	1200 X 800 X 144	800 X 600 X 1600
Packaging weight (g)	66	183	2500	-
Packaging weight with product (Kg)	0.466	4.0	205	-
Number of packaging	1	9	56 (7 layer)	Depending on the demand

Table 11: Packaging characteristics for product B – plastic packaging

	Primary Packaging	***Secondary Packaging***	***Tertiary Packaging 1***	***Tertiary Packaging 2***
Packaging material	Plastic tray, LDPE film, Carton wrap.	Corrugated Cardboard box	Wooden Euro Pallet	Roll container
Packaging Measurements (mm)	185 X 160 X 60 mm	340 X 165 X 295 mm	1200 X 800 X 144 mm	800 X 600 X 1600 mm
Packaging weight (g)	40	150	25	-
Packaging weight (Kg)	.420	3.5	221	-
Number of packaging	1	8	45 (5)	Depending on the demand

4.2 Supply chain mapping

The supply chain mapping for product A – carton frozen meal packaging system was carried out from the point of product production to the point of product consumption. The product is produced in the production plant and temporarily stored in an internal storage area. Then the product A is sent to the distributor warehouse by distributor truck. The producer A (product A) uses distributor warehouse A, which is located in Sweden. The product A is stored at distributor warehouse, and then the product A is sent to the retailer warehouse which is located in Helsingborg, Sweden and retailer warehouse B which is located in Jönköping, Sweden. Further, the product A is sent to the different retailer stores in Skåne, Sweden through the third-party transportation. Finally, the consumer purchases the product A from the retailer store, and consumes the product in homes, workplaces, etc. (P-1; DW-1; RW-1).

Similar to product A, the product B – Plastic frozen meal packaging system was mapped from the point of product production to the point of product consumption. The overall activities of product B are similar to product A. The product B is produced and stored in an internal storage area at production plant, then it sent to the distributor warehouse. The producer B (product B) uses distributor warehouse B, which is located at Helsingborg, Sweden. Then the product is sent to the retailer warehouse A at Helsingborg and retailer warehouse B at Jönköping, Sweden through the distributor transport. Further, the product B is sent to the retailer stores in Skåne, Sweden through the third-party distributor, and then the consumers purchase the product B and consumes at different places (P-2; DW-2; RW-1).

Seven actors are mapped in the supply chain for the product A and product B, that is from producer level to retailer store (A and C), and producer level to retailer stores (C and D). In addition to that consumers are mapped in the supply chain. The supply chain is mapped, based on the interview with the producers and the retailers (P-1; P-2; RW-1; R-1). The whole supply chain mapping of one particular route for the product A and product B (Producer to retailer A) is described in the below Figure 13.

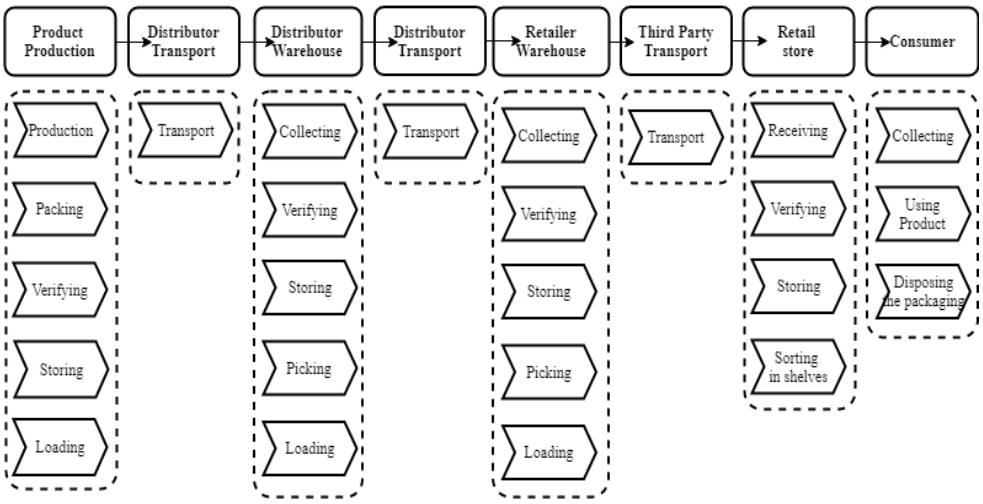


Figure 13: Supply chain mapping of product A and product B

4.2.1 Producer

4.2.1.1 Product A – Carton packaging

The production plant is located in Middle Europe. Figure 14, shows the detailed activity taking place in the production plant for product A. The production of frozen meal starts with the receipt of raw materials and the packaging materials. The different food ingredients (raw materials) are stored in different conditions, such as frozen (-18ºC or colder), chilled (-4ºC or colder) and room temperature (20ºC). The ingredients which are listed under allergic are stored separately in the storage area. The packaging materials are stored separately at room temperature. The process is controlled by the store team.

The semi-automated production process is carried out at the production plant. The machine is calibrated prior to the filling process, and the different processed products (ingredients) are filled into the carton tray at different stages in the production line. Then the top of the carton tray is sealed with LDPE (Plastic film). Then the carton tray is placed in the container and stored in frozen condition (-18ºC or colder). Then the carton tray is placed into the carton box and sealed both the edges with glue, and printed the batch code and best before date. Further, manually 8 primary packages (carton tray with carton box) are placed into the corrugated cardboard box (secondary packaging), and sealed.

The secondary packages are sent through the conveyor belt and a label is placed on each corrugated cardboard box. Then the secondary packaging is stacked into the Euro Pallet. 9 secondary packages are stacked in one layer; thus, a total of 56

secondary packaging was stacked in the tertiary packaging (Euro pallet), which contains 7 layers. Stretch film is wrapped around the pallet for stability. Further the pallet is sent to the internal storage area (frozen condition), and after receiving the order from the distributor warehouse, the pallets are moved to the dispatch area (P-1).

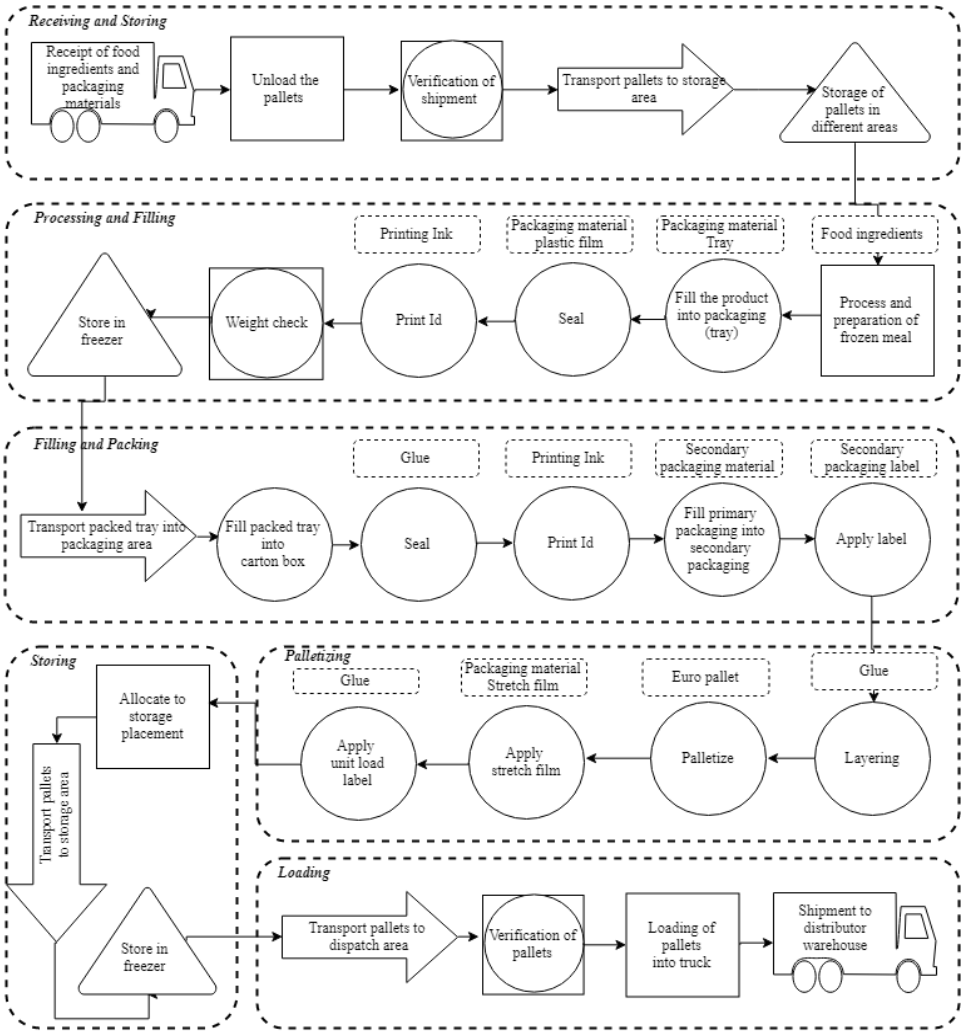


Figure 14: Activity mapping of producer A for the product – A

4.2.1.2 Product B – Plastic packaging

The production plant is located in one of the Scandinavian countries and the detailed activity followed in the production plant is similar to product A. The production of frozen meal starts with the receipt of raw materials and the packaging materials. The

different materials are stored in different conditions, and the allergic and packaging materials are stored separately in the storage area.

The fully-automated production process is carried out at the production plant. The different processed products (ingredients) are filled into the plastic tray at different stages in the production line. The packaging machine is calibrated by the machine operator to achieve the exact product weight. Once, the product is filled into the tray, then the top is sealed with LDPE (Plastic film). Then the plastic trays are placed into the container and stored in frozen condition (-18ºC or colder) in an internal storage area. Once, the product is reached the frozen condition, then the plastic tray is placed into the carton wrap and sealed the edges with glue. The batch code and the best before date is printed by the printer on the side of the carton wrap. Further, eight primary packages (plastic tray with carton wrap) are placed into the corrugated cardboard box (secondary packaging) and sealed with tape, where the operation takes place automatically.

The secondary packages are sent through the conveyor belt and a label is placed on each corrugated cardboard box. Then the secondary packages are stacked into the Euro Pallet. 8 secondary packages are stacked in one layer; thus, a total of 45 secondary packages are stacked in the tertiary packaging (Euro pallet), which contains 5 layers. Stretch film is wrapped around the pallet for stability during the material handling and transportation. Further the pallet is sent to the internal storage area (frozen condition) through the hydraulic hand lifter. once, the order is received from the distributor warehouse, the pallets are moved to the dispatch area through the fork lift (P-2).

4.2.2 Distributor transportation

The Product A – carton packaging system's temperature and the article number (the unit label in the tertiary package) are verified, then the information is updated into the warehouse management system (WMS) by scanning the unit load label. Then the product is loaded into the truck by using fork lift. Two pallets are stacked in a column wise to utilize the maximum space in the truck container. The truck is maintained the temperature -24ºC throughout the transportation stage. An automated temperature monitor system is installed in the truck, so when the temperature goes more than -22ºC, an automated notification is sent to the truck employee as well as to the distributor warehouse A's monitoring system. Thus, the temperature is controlled well throughout the transportation stage (DW-1).

The Product B – plastic packaging system followed a similar transportation process, like product A. The overall process is monitored by distributor B. The temperature-controlled system and the monitoring process works similar to distributor A system without any major changes (DW-2).

4.2.3 Distributor warehouse

4.2.3.1 Product A – Carton packaging

The product A is received from the producer to distributor A warehouse at Helsingborg by distributor and third party truck container. Figure 15, shows the detailed activity taking place in the distributor warehouse A. The activity starts with the unloading of pallets from the truck by forklift. Physical damages and number of pallets are verified by scanning the unit load label which is pasted on the tertiary packaging. The temperature is checked immediately after unloading the pallets and the information is directly updated in the warehouse management system. Further, the pallets are moved to the buffer storage area for a short time (less than one hour). The frozen meals are sensitive to temperature, so the pallets are moved immediately to the storage area, where the temperature is maintained below - 24ºC or colder. The temperature is monitored by an automated temperature monitoring system. If the temperature is going more than -22ºC, an automated notification is sent to the distributor A monitoring system. Then an immediate action is taken to maintain the temperature in the storage area. Once, the order is received from the retailer warehouse A and B, the pallets are moved to dispatch area by forklift. The number of pallets, article number and the temperature are verified and documented into the monitoring system by scanning the unit label. Then the pallets are loaded into the retailer truck and sent to retailer warehouse A and B (DW-1).

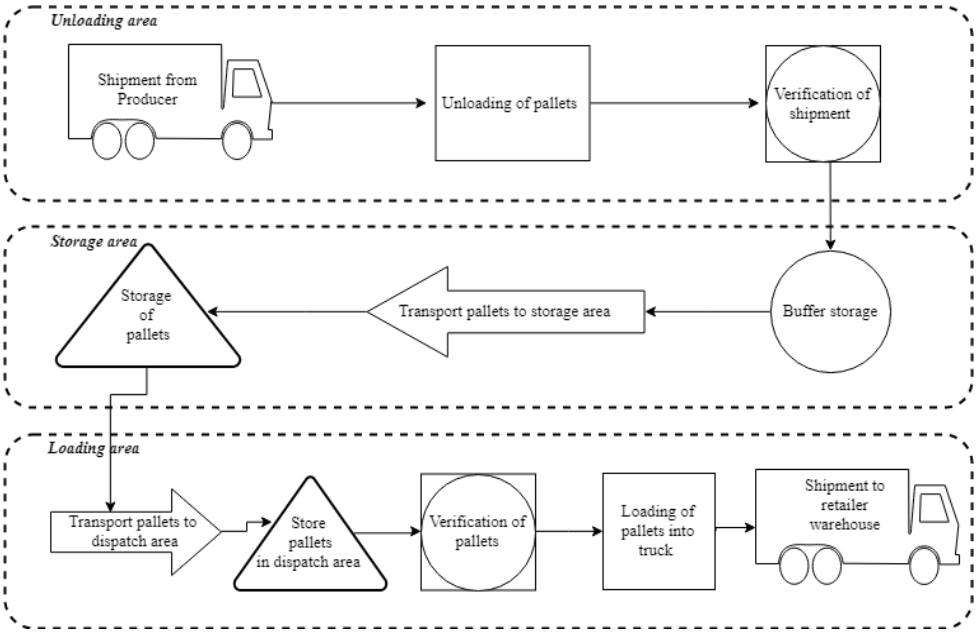


Figure 15: Activity mapping of distributor warehouse

4.2.3.2 Product B – Plastic packaging

The distributor B follows a similar procedure for the Product B – plastic packaging. The distributor B warehouse temperature monitoring and the controlled system works similar to distributor A. Also, distributor B sent the product to retailer warehouse A and B (DW-2).

4.2.4 Distributor transportation

The distributor transportation and the third-party transportation are used to deliver the products (Product A – Carton packaging system and Product B – plastic packaging system) from the distributor warehouse to retailer warehouse. The procedure and the activities are similar to the one mentioned above under distributor transportation.

4.2.5 Retailer warehouse

The product A – carton packaging system and product B – plastic packaging system is received at the retailer warehouse A. Figure 16, shows the detailed activity taking place at the retailer warehouse A. The retailer warehouse A is located at Helsingborg, from where the product is sent to the entire Skåne, Sweden. Once, the product is unloaded from the truck, the physical damages, the temperature is checked and the article number is verified by the scanner and it automatically updated into the warehouse monitoring system. If there is a temperature rise in temperature or physical damages with the products then the pallets are rejected and sent back to the distributor warehouse with the same truck. The quality accepted pallets are kept in the conveyor chain and sent to the next station, where the pallets are manually scanned again and the convey chain moves the pallets to the storage area. Two convey chains are used to move the pallets into the storage area. Once the pallets are moved inside the storage area, an automated carrier takes the pallets from the conveyor chain to the near available space. Then during the overnight hours, the automated carrier moves the pallets automatically and placed the pallets in the right serial order. Further, the pallets are moved automatically to the handling area, when there is an empty space. The products are stored up to four months and it is depending on the order and the demand. The temperature is maintained at -24ºC to -27ºC, also an automated monitoring system is installed, so when there is a temperature raise more than -22ºC, a notification is sent to the warehouse employees and the immediate action is taken to maintain the temperature.

Once the order is received from the retailer store, the employee updates the order in the forklift monitor. Then the employee opens the tertiary package by tearing-off the stretch film with a knife. Based on the order, the number of secondary packages

are stacked into the roll container. Four number of roll containers are attached with the forklift and move around different places in the handling area. In a single roll container, product A and product B along with other frozen products are stacked. The different products have different size and weight of secondary packages. The employees are skilled to stack the packed products in the roll container to achieve the maximum volume efficiency. A new unit label with an article is pasted into the roll container. Then the roll container is moved to the dispatch area to load into the trucks. The stretch films are collected in a bin and further sent to the recycling unit. The empty pallets are moved by another warehouse employee and placed into the pallet dispatch area (RW-1; OW-1).

Also, both the products are received at the retailer warehouse B. Retailer warehouse B receive the products from distributor warehouse A and B. The unloading, temperature monitoring and the verification process are followed similar to the process followed at retailer warehouse A. There is a slight variation in the automated handling, inhouse material handling and the monitoring system (RW-2)

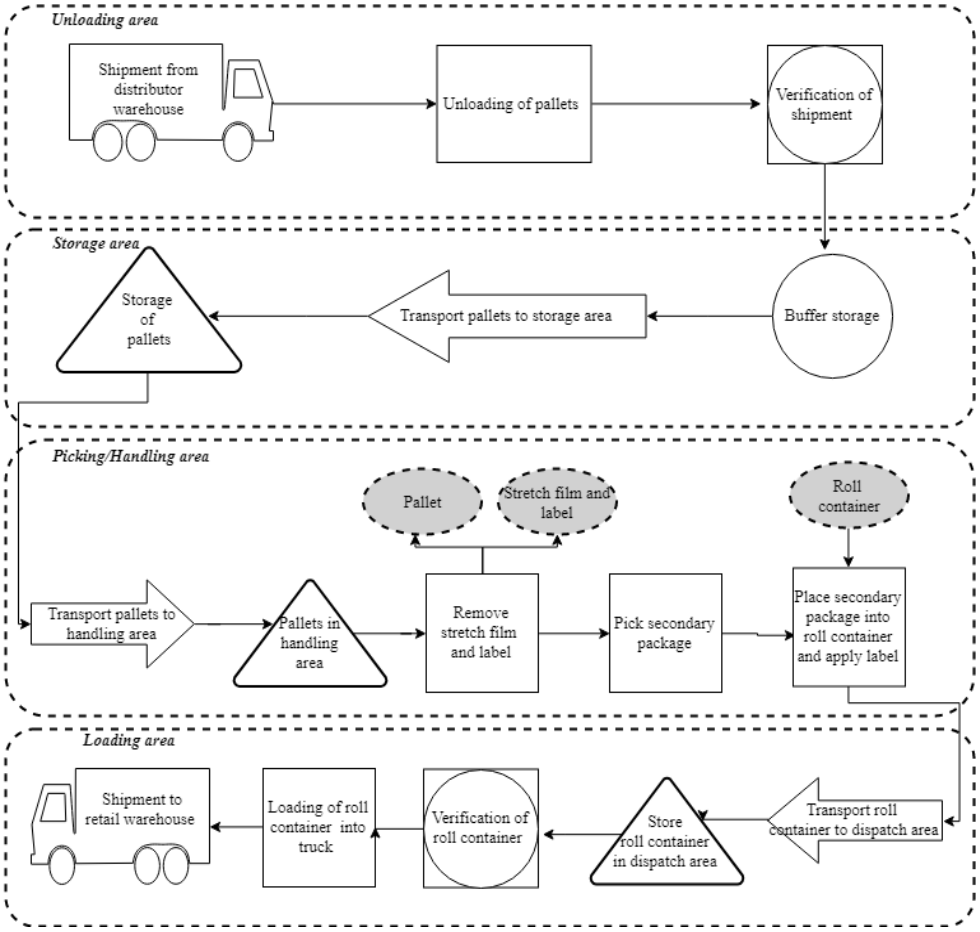


Figure 16: Activity mapping of retailer warehouse

4.2.6 Retailer – third party transportation

The delivery order is placed to the third-party transporter by the retailer warehouse A. Then the third-party transporter's truck reaches the retailer frozen - dispatch area, then the roll containers are verified by scanning the unit load label (article number) and checked the temperature by the truck employee. The information is automatically updated in the retailer monitoring system. Further, the roll containers are loaded into the truck and transport to retailer stores A and B (RW-1; OW-1).

The similar procedure is followed at retailer warehouse B to retailer store C and D (RW-2; OR-3).

4.2.7 Retailer store

Product A and product B are delivered to retailer store A thrice in a week, namely Tuesday, Thursday and Sunday. The detailed activity taking place at the retailer store A is mentioned in Figure 17. Once the truck reached the retailer store, the roll containers are unloaded. The physical damages and the temperature are checked, and if there is a major deviation then the products are sent back to the retailer warehouse. Then the unit load label is scanned by the scanner and updated into the monitoring system with the truck employee Identification Number. The temperature is maintained from -24ºC to -27ºC with an automated temperature monitoring system.

The retailer store maintains 20 primary packages under safety stock for product A – carton packages, and 25 primary packages for product B – plastic package. This is calculated internally based on sales per week. The roll containers are moved to the freezer, where the frozen meals are stored. The secondary packages are sealed with glue, so the store employee uses hand and sometimes knife to open the secondary package. Both the product's primary package (frozen meal) are stacked in a vertical freezer that gives a clear view of the product to the consumers. The new primary package (frozen meal) are placed backside in the shelf to maintain the first in – first out order (FIFO). The temperature is maintained from -20ºC to -22ºC in the freezer. The secondary package waste - corrugated cardboard is taken to the compressor in the retailer store and crushed the package and then tied with a wire. Further the packaging waste in transport to Carl F for recycling.

The consumer takes the product A – carton packaging from the shelf and placed into the retailer's basket or hand trolley and takes to the billing area. After the purchase of product - A, the consumer carries the product A (frozen meal) in a consumer carrier bag or retailer carrier bag. The consumer follows a similar process for product B (R-1; OR-1).

The retailer store B follows a similar process, such as unloading and storing process, temperature monitoring process, shop floor control and the waste handling process. The differences are in safety stock volume, capacity of the freezer shelf and storage place (R-3; OR-3).

Also, the retailer store C and D follows a similar process as mentioned above (R-3; R-4; OR-3; OR-4)

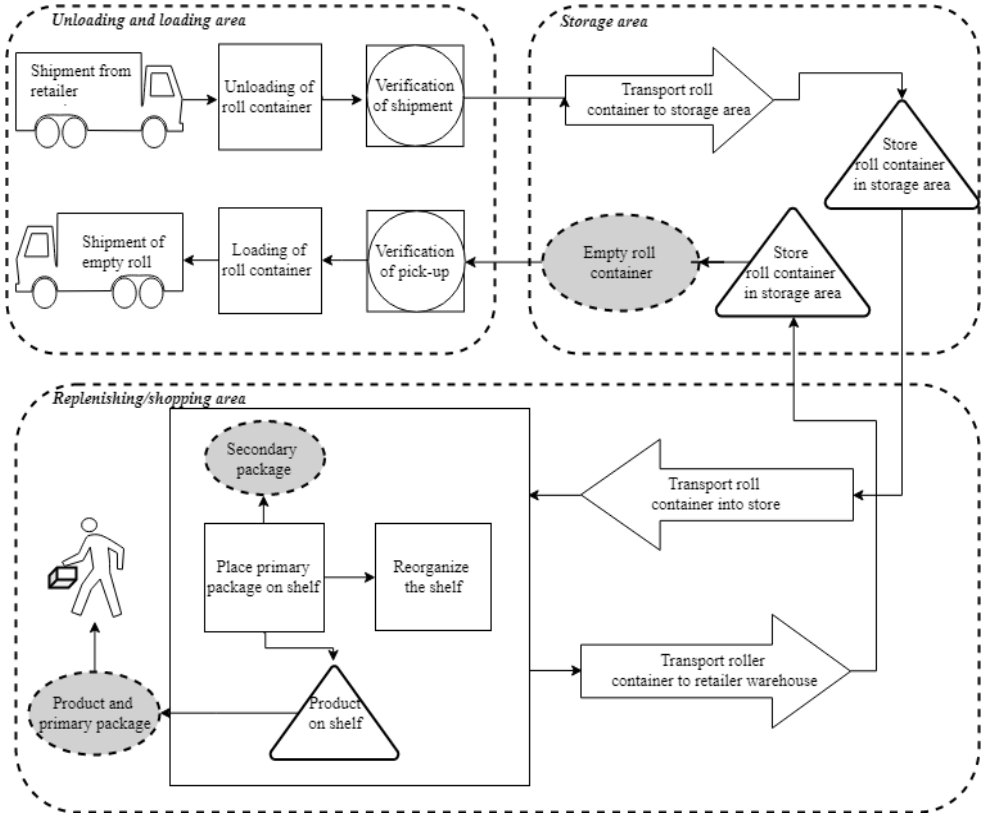


Figure 17: Activity mapping of retailer store

4.2.8 Consumer

Consumers buy the product A – carton packaging in a carrier bag and use different modes of transportation to carry the primary package (products) to their home or workplace. The detailed activity of the consumers is mentioned in Figure 18. After reaching the home or workplace, the consumer opens the carrier bag and place the primary package (products) into the freezer for later consumption. Or the consumer opens the carton box (primary package) and place the carton tray in the oven or microwave for the consumption. Further, they clean the carton tray and discard into the dust bin. Also, other packages, such as carton box and plastic film are discarded in the dust bin. Then the dust bins are moved to recycling bin which is further moved to centralized recycling unit by waste handling trucks (C-1; C-3)

The consumer uses a similar process for product B – plastic packaging.

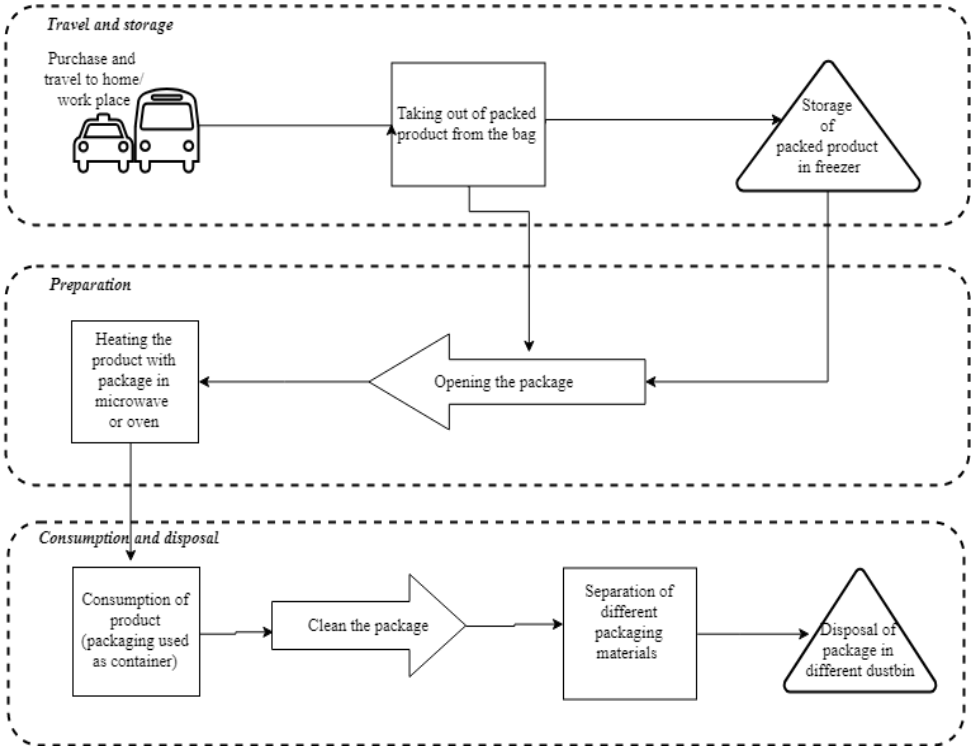


Figure 18: Activity mapping of consumer

4.3 Packaging system interaction

4.3.1 Primary packaging

The packaging performance is analysed for the whole supply chain. The selected packaging features and their interaction with the supply chain actors are identified through the interviews and the observations. As described in methodology (chapter 3.3.2.1) the packaging features interaction for the primary package (product A and product B) is shown in Table 12. The table shows, which are the packaging features applicable for the primary packaging, the applicable packaging features are marked as 'X' and the only the applicable packaging features (X) are analysed with the relevant supply chain actors. The primary package is handled by producer, retailers at store, and the consumers.

The product wastage related features are applicable for all the actors who handle the primary package in the supply chain. For example, the failure of product protection could cause direct product waste to all the actors. The logistics related features are

not relevant for the consumers, and these information are useful for the producers and the retailers, who handles a large number of products. The value adding related features information is more useful to the consumers as it gives a clear picture of the product, for example, product information, such as product characteristics and product usage

procedure. The packaging material related features are equally useful among all the actors. Packaging cost and the production efficiency are more applicable for the producers to reduce the manufacturing cost, whereas packaging waste and the circular economy are more applicable for consumers.

Table 12: Packaging features interaction with supply chain actors for primary packaging.

Area	***No.***	***Packaging Feature***	***Producer***	***Retailer Store***	***Consumer***
Product waste	PW1	Protection and containment	X	X	X
	PW2	Right amount and size	X	X	X
	PW3	Food Waste	X	X	X
Logistics	L1	Unitisation	X	X	-
	L2	Stack ability	X	X	-
	L3	Volume and weight	X	X	-
	L4	Track and trace capability	X	X	-
Value adding	VA1	Product information	-	X	X
	VA2	Convenience	X	X	X
	VA3	Promotional attributes	-	X	X
Packaging material	PM1	Packaging cost	X	X	
	PM2	Packaging waste	X	-	X
	PM3	Circular economy	-	-	X
	PM4	Safety and Security	-	X	-
	PM5	Production efficiency	X	-	-

4.3.2 Secondary packaging

The packaging features interaction for the secondary package (product A and product B) is shown in Table 13 as mentioned for primary package. The product waste and logistics related features are equally important for all the actors. The value adding related features such as product convenience is useful to all the actors, and the product information and promotional attributes are not applicable, as this information is more useful for the primary package. The packaging material related features are similar to primary packaging, the packaging cost and the production efficiency are relevant to the producer, whereas the product safety and security is more relevant to retailers.

Table 13: Packaging features interaction with supply chain actors for secondary packaging.

Area	***No.***	***Packaging Feature***	***Producer***	***Retailer Warehouse***	***Retailer Store***
Product waste	PW1	Protection and containment	X	X	X
	PW2	Right amount and size	X	X	X
	PW3	Food Waste			
Logistics	L1	Unitisation	X	X	X
	L2	Stack ability	X	X	
	L3	Volume and weight	X	X	X
	L4	Track and trace capability	X	X	X
Value adding	VA1	Product information			
	VA2	Convenience	X	X	X
	VA3	Promotional attributes			
Packaging material	PM1	Packaging cost	X		
	PM2	Packaging waste	X		X
	PM3	Circular economy			X
	PM4	Safety and Security		X	X
	PM5	Production efficiency	X		

4.3.3 Tertiary packaging

4.3.3.1 Euro pallet

The packaging features interaction for the tertiary packaging (pallet and roll container) for product A product B is shown in Table 14. The pallet is handled by producer, distributor and retailer at the warehouse. In all the four areas, a smaller number of packaging features are applicable to tertiary packaging, when compared to primary and secondary packaging. Traceability and the weight and volume efficiency are important packaging features. Packaging material related features are more relevant to distributor and retailer warehouse.

The roll container is handled by the retailer at the warehouse and retailer store. Under product waste, product protection and size are more relevant features for retailers. Circular economy and security of the packaging are given higher importance in the area of packaging material.

Table 14: Packaging features interaction with supply chain actors for tertiary packaging.

Area	***No.***	***Packaging Feature***	***Pallet***			***Roll container***	
			Producer	***Distributor Warehouse***	***Retailer Warehouse***	***Retailer Warehouse***	***Retailer Store***
Product waste	PW 1	Protection and containment	X	X	X	X	X
	PW 2	Right amount and size	X	X	X	X	X
	PW 3	Food Waste	-	-	-	-	-
Logistics	L1	Unitisation	X	X	X	X	X
	L2	Stack ability	X	X		X	X
	L3	Volume and weight	X	X	X	X	X
	L4	Track and trace capability	X	X	X	X	X
Value adding	VA 1	Product information	-	-	-	-	-
	VA 2	Convenience	X	X	-	X	X
	VA 3	Promotional attributes	-	-	-	-	-

Packaging material	PM 1	Packaging cost	X	-	-	-	-
	PM 2	Packaging waste	-	-	-	-	-
	PM 3	Circular economy	-	X	X	X	X
	PM 4	Security	-	X	X	X	X
	PM 5	Production efficiency	X	-	-	-	-

4.4 Packaging system performance

The below session visualizes the packaging performance of primary, secondary and tertiary packaging for the supply chain actors, from the stage of product production to the stage of product consumption. The session initially analyses the importance vs satisfaction of 15 packaging features and then analyse the performance score for each packaging and then the session discussed the main findings of the results as explained in methodology (chapter 3.3.2.3).

4.4.1 Primary packaging

4.4.1.1 Scatter plot – importance vs satisfaction

Product A – Carton packaging

The product A's primary packaging is handled by the producer, retailer at store and consumers, as mentioned in Table 12 (chapter 4.3.1). More number of packaging features are applicable for primary packaging. The primary packaging described as sales package that has direct interaction with the consumers (Verghese and Lewis, 2007). The importance and the satisfaction of each packaging features for primary packaging (product A) is developed and mentioned in Figure 19.

At producer level, packaging cost (PM1), product protection (PW1) and production efficiency (PM5) are given the highest importance, and followed by packaging size (PW2), food and packaging waste (PW3, PM2). The similar packaging features, such as product protection, size of the packaging (PW2) and packaging cost (PM1) are mentioned the highest importance by Pålsson and Hellström (2016). The main role of packaging is to protect the product and safely handover the product to end user (Pålsson, 2018). Also, many researches mentioned that the packaging needs to protect the product from mechanical and thermal impacts (Lindh et al., 2016). The packaging cost (PM1) and production efficiency (PM5)are important to keep the

overall product cost (PM1) as low as possible. P-1 says "we *give more importance for the primary packaging at production line. The packaging need to fit well into the packaging machine, and it has the direct influence with the production efficiency"*. The least importance is given to stack-ability (L2) and convenience (VA2) of the packaging. The production line is semi-automated, so the producer gave less importance for convenience (VA2). The similar features such as packaging cost (PM1) and product protection are scored the highest satisfaction, and the convenience (VA2) of the packaging scored the lowest satisfaction.

At retailer level, product information (VA1), stack ability (L2), unitization (L1) and convenience (VA2) are given the highest important packaging features, and the least importance is given for security (PM4), volume and weight efficiency (L3). The unitization of the packaging is given preference by the retailer, because it gives a better appearance of the packaging for the consumers. R-3 says "*We use sliding system to place the package in the rack and it is important for us, that the packaging is fitting well in the rack and also the unitization effect the work efficiency".* The volume and weight efficiency (L3)are not given more importance, because the retailer said they have enough space to store the products. The features such as, product information (VA1), Stack ability (L2)are scored the highest satisfaction, and convenience (VA2) of the packaging scored the lowest satisfaction.

At consumer level, the importance are given to packaging waste (PM2), food waste (PW3) and circular economy (PM3) which means the consumers gave more importance for environmental related issues. The convenience (VA2) and the size of the packaging (PW2) are given least important, and these features differs among consumers. But this result is controverse to the consumer interview (C-3, C-4) and it result in high importance for the size of the package (PW2). The consumers are not highly satisfied with any of the packaging features, but satisfied with above average with product information (VA1) and packaging waste (PM2).

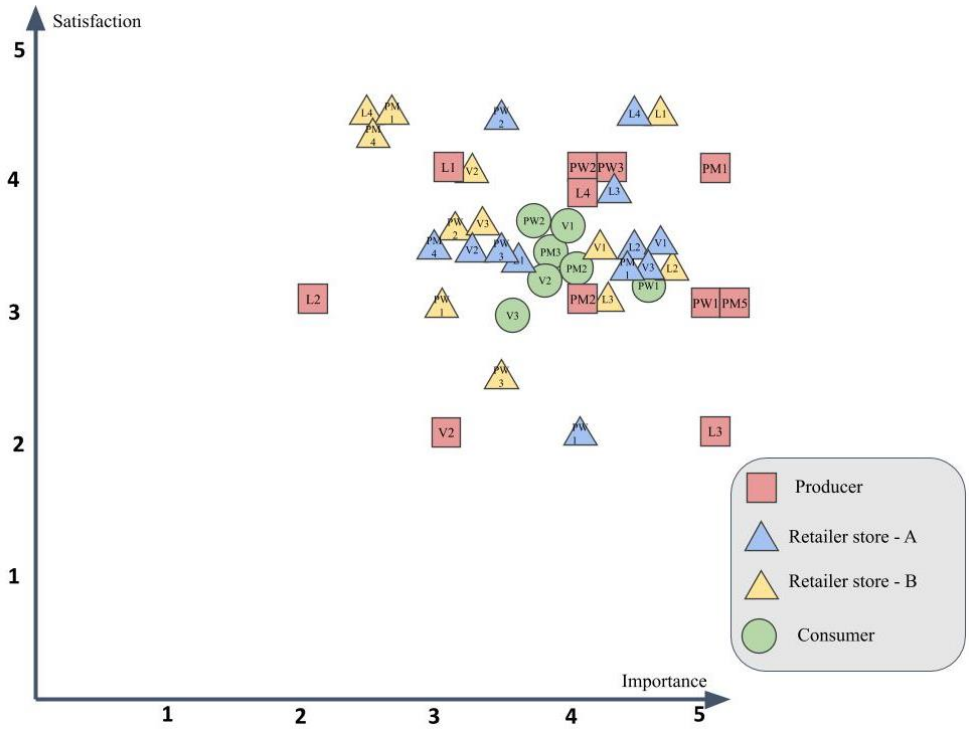


Figure 19: Scatter plot – importance vs satisfaction for primary packaging (product A)

Product B – Plastic packaging

Similar to product A, the primary packaging of product B is handled by the producer, retailers at store and consumers, as mentioned in Table 12 (chapter 4.3.1). The importance and the satisfaction of each packaging features for primary packaging (product B) is developed and mentioned in Figure 20.

At producer level, very important and important features are similar to the features found for product A. In addition to that security (PM4) and volume and weight efficiency (L3) are given very important. The stack-ability (L2) and packaging waste (PM2) are given least importance. P-2 says *"we hardly received the damaged packaging from the supplier. We use fully automated production line and the packaging is fitting well in the production line, and we will not get packaging damages".* Product protection (PW1) and packaging cost (PM1) are scored the highest satisfaction and least satisfaction is found for size of the packaging (PW2) and production efficiency (PM5).

At retailer level, product information (VA1), unitization (L1), convenience (VA2) and product protection (PW1) are given the highest importance similar to product A, and the least importance is given for security (PM4), packaging cost (PM1) and traceability (L4). The packaging cost (PM1), security (PM4), trace ability (L4) and product information (VA1) are scored the highest satisfaction.

At consumer level, the importance is given to product protection (PW1), packaging waste (PM2), and convenience (VA2) of the packaging and the least importance is given to size of the packaging (PW2). The features such as protection (PW1), convenience (VA2) and circular economy (PM3) are scored the most satisfied.

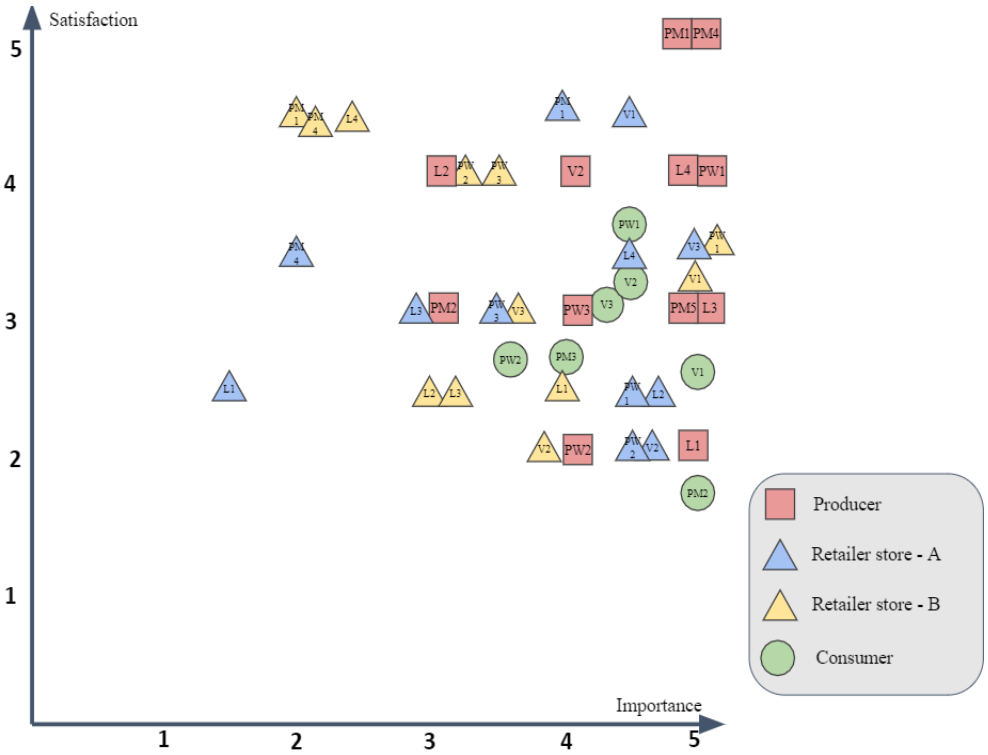


Figure 20: Scatter plot – importance vs satisfaction for primary packaging (product B)

4.4.1.2 Packaging performance – Packaging score

Based on the importance and the satisfaction score, the performance of the packaging with the supply chain actors is developed for product A – carton packaging and product B – Plastic packaging and mentioned in Figure 21.

The carton packaging performed better with retailers and consumers, where the plastic packaging performed better with the producer. The plastic packaging material has better mechanical properties compared to the carton packaging (Cai et al., 2002). Product (PW3) and packaging waste (PM2) are faced by both the

producers. According to P-1, when the tray is not fitted well into the packaging machine, the product waste occurs, and the packaging gets damaged during the top sealing process. The carton packaging used more amount of packaging material for tray, LDPE film and carton box. The overall weight of the carton packaging is double then the overall weight of plastic packaging. The size of the packaging (PW2) is not seen as major issue for both the products. Product A used fully automated production line and product B used semi-automated production line, which have an influence in production efficiency. P- 2 says "*The production line is not running with full capacity, because the product wastage occurs at filling stage"*. The producers are willing to spend some extra cost for the packaging and producer's mainly concern is "how the packaging will fit into the production line".

At retailer level, the carton package performed better, and the retailer's main issue is packaging damage. R-4 says *"The corner of the carton packaging gets damage during product handling and the consumers do not want to buy those packages, and the package will end up as waste or we will give to homeless people"*. The size of the packaging (PW2) and convenience (VA2) to handle is mostly liked by the retailers. According to Pålsson and Hellström (2016), the packaging cost (PM1) is not highlighted as important factors for retailer, but the retailers think that the increase of packaging cost will increase the product cost and they gave importance for packaging cost (R-2). R-4 says "*the packaging material should have the good thermal barrier properties; we face issues with the refrigeration system and sometimes the door does not close properly which result in rise of temperature".*

At consumer level, environmental concern has a huge influence with the packaging. Other properties, such as convenience (VA2) to handle and protection (PW1) are performed better with the plastic packaging. C-2 says *"one of the issues I am facing with the carton package is thawing, by the time I reach house from the store the product gets thawed".* The frozen meals are stored in the freezer and the consumer face challenges in the storing of the products. C-5 says *"Carton package fits well into the freezer and it does not occupy much space, whereas the plastic package takes more space in the freezer". But C-3 says "often I will remove the carton package outer box, because the package occupies the extra spaces in the freezer".*

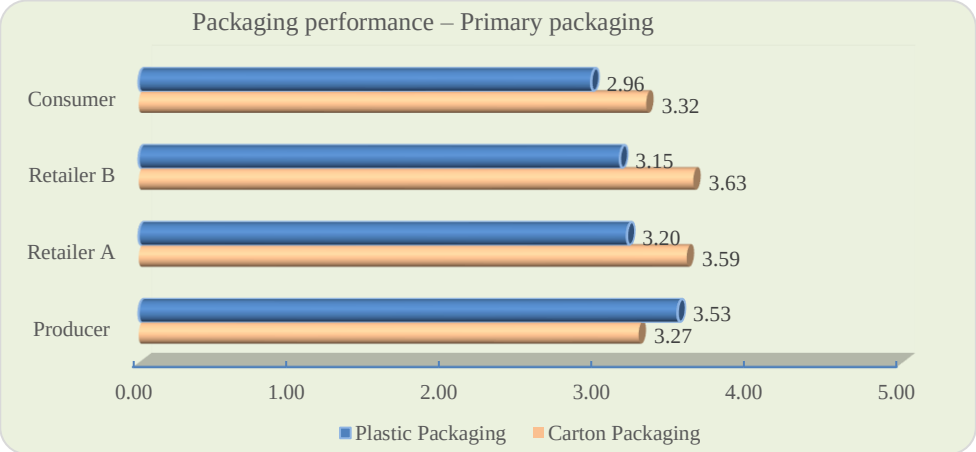


Figure 21: Packaging performance score for primary packaging

4.4.2 Secondary packaging

4.4.2.1 Scatter plot – importance vs satisfaction

Product A – Carton packaging

The secondary packaging of product A is handled by the producer, retailers' warehouse and retailers' store, as mentioned in Table 13 (chapter 4.3.2). The importance and the satisfaction of each packaging features for secondary packaging (product A) is developed and mentioned in Figure 22.

The producer gave highest importance for packaging cost (PM1) and production efficiency. Convenience (VA2) and the packaging waste (PM2) are given least importance. Wastage occurs at production plant when the packaging is not cut properly by the supplier. The size (L2) and traceability (L4) of the packaging is scored the highest satisfaction. The primary package is fitting well into the secondary packaging.

Volume and weight efficiency (L3), traceability (L4) and product protection (PW1) being the highest importance for both the retailer at warehouse. Followed to that safety and security (PM4), stack-ability (L2) are given above moderate important. Size (PW2), traceability (L4) and the security (PM4) of the packaging scored the highest satisfaction. The cold temperature affect the glue in the package and result in opening of package while handling the package and the convenience (VA2) scored below average satisfied.

The retailers gave more importance to the circular economy (PM3) of the packaging, and followed by product protection (PW1) and the convenience (VA2) of the packaging. The retailers properly handled the packaging waste and sent to the

recycling plant Carl F. Retailers highly satisfied with handling of packaging waste for circular economy (PM3), and the track and traceability (L4). The packaging is hard to unwrap while placing the primary package into the shelf.

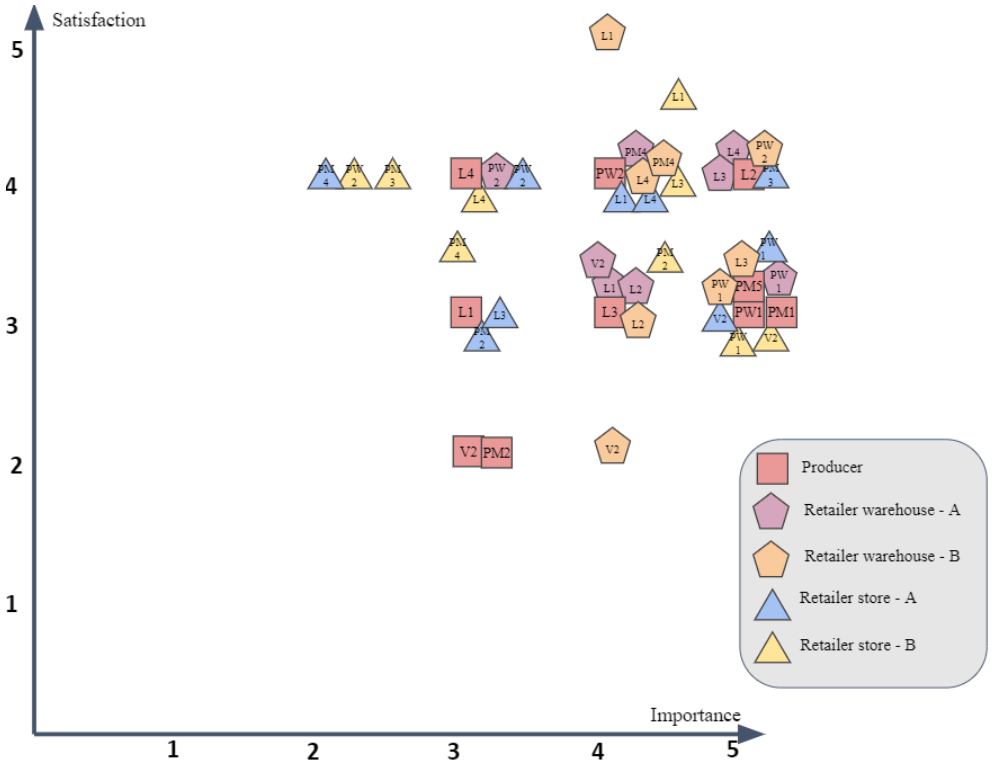


Figure 22: Scatter plot - importance vs satisfaction for secondary packaging (product A)

Product B – Plastic packaging

Similar to product A, the producer, retailers at warehouse and retailers at store handles the secondary packaging of product B, as mentioned in Table 13 (chapter 4.3.2). The importance and the satisfaction of each packaging features for secondary packaging (product B) is developed and mentioned in Figure 23.

The producer gave higher importance to the product protection (PW1), packaging cost (PM1) and the production efficiency (PM5), followed by convenience (VA2) and volume and weight efficiency (L3). The packaging material related features scored the highest satisfaction, and followed by convenience (VA2) and product protection (PW1). The packaging is not fitting well into the packaging system, and the stack-ability (L2) and unitisation (L1) scored the lowest satisfaction.

The product protection (PW1) and volume and weight efficiency (L3) are given the highest importance by the retailer's warehouse, followed by unitization (L1), convenience (VA2) and security (PM4) of the packaging. Traceability (L4), security (PM4) and protection (PW1) are scored the highest satisfaction, and volume and weight efficiency (L3), unitization (L1) are scored the lowest satisfaction.

The retailers gave highest importance for convenience (VA2), product protection (PW1) and traceability (L4) of the packaging, and followed by unitization, packaging waste (PM2). The lowest importance given to the security (PM4) of the packaging. Packaging waste (PM2) and security (PM4) are scored the highest satisfaction, and followed by protection (PW1) and stack-ability (L2).

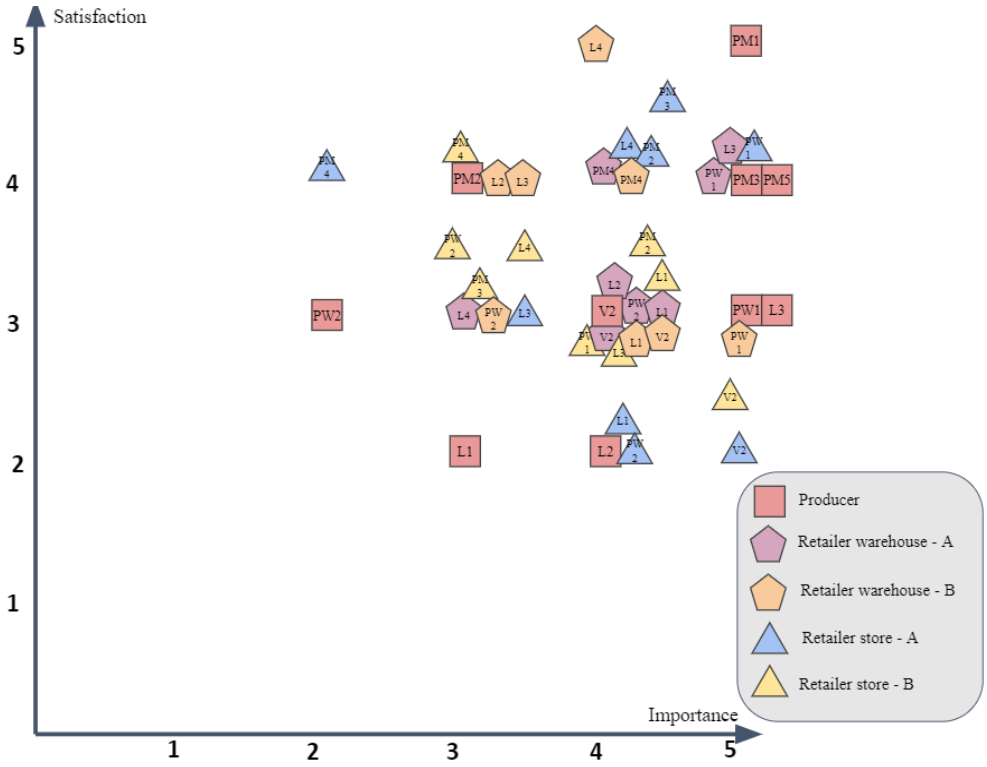


Figure 23: Scatter plot - importance vs satisfaction for secondary packaging (product B)

4.4.2. Packaging performance – Packaging scorecard

Based on the importance and the satisfaction score, the performance of the secondary packaging with the supply chain actors is developed for product A and product B and mentioned in Figure 24.

At producer level, plastic packaging performed better compared to the carton packaging. The producer B (plastic packaging) uses a fully automated production line, whereas producer A (carton packaging) used semi-automated production line. The main challenges faced by producer B are inefficient production and filling process. The producer A gave higher importance for handling of packages. Later in the supply chain carton packaging performed better, this is mainly due to the size and convenience (VA2) of the packaging. The producers used similar kind of secondary packaging, where the producer A uses glue for closing and producer B used tape for closing the packaging. RW-1 says "*The frozen temperature affects the glue in the package which result in opening of package while shifting the secondary package from pallet to roll container and it result in dropping of primary package. so, we need to allocate an extra employee to pack again the primary package into secondary packaging and in this cause, we use tape to avoid the same damages".* Also, during the visit, it was observed that the damaged packages are kept aside in the warehouse. Using tape for the packaging suits better for retailer warehouse, and it gave trade-offs to the retailer at store. According to R-1 "*The product A packaging is convenient to unwrap and we will not use knife for unwrapping. But the product B uses tape for the packaging and we need to use knife for opening and sometimes the knife damages the primary packaging.*

The product Buses coloured ink on the packaging and it has a negative impression to the retailer. According to FTI (2018) the coloured ink causes problem for the water treatment during the recycling of packaging and it will affect the quality of the recycled material. Also, the tape stays with the packaging and it will affect the recycling process. Whereas product A uses only the packaging code on the packaging. But this could cause an identification issue if the secondary label missed from the packaging, and R-4 says *"Often we get confused with the package, because the packages are stacked inside facing, which means the label is facing inside, in that case we need to cross check all the packages, and it is time consuming"*. Overall both the packages performed in a similar way and the main difference noticed is size of the packaging (PW2).

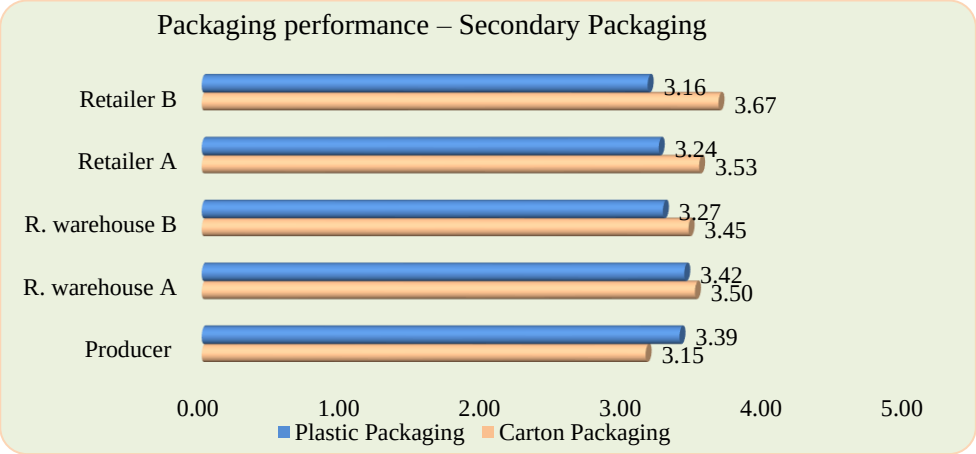


Figure 24: Packaging performance score – secondary packaging

4.4.3 Tertiary packaging

4.4.3.1 Pallet

4.4.3.1.1 Scatter plot – importance vs satisfaction

Product A – Carton packaging

The tertiary packaging Euro pallet for product A is handled by the producer, distributor warehouse and retailer warehouse, as mentioned in Table 14 (chapter 4.3.3). The importance and the satisfaction of each packaging features for tertiary packaging (product A) is developed and mentioned in Figure 25.

The producer gave highest importance for the protection (PW1) and traceability (L4) and followed by security (PM4) of the packaging. The least importance is given for the size, handling and the convenience (VA2) of the packaging. The packaging features such as protection (PW1) and traceability (L4) are scored the highest satisfaction, and followed by production efficiency (PM5). Unitisation (L1) and the size of the packaging (PW2) are scored the lowest satisfaction with the producer.

The features such as volume and weight efficiency, and security (PM4) are given the highest importance and followed by product protection (PW1), where the protection (PW1) and the traceability (L4) are scored the highest satisfaction. The least satisfaction is scored by convenience (VA2) of the packaging.

Similar to distributor warehouse, the retailer warehouse gave higher importance for volume and weight efficiency (L3)and protection (PW1), and followed by unitization of the packaging. The features such as stack-ability (L2) and circular economy (PM3) are scored the highest satisfaction, and the lowest satisfaction is scored by convenience (VA2) of the packaging.

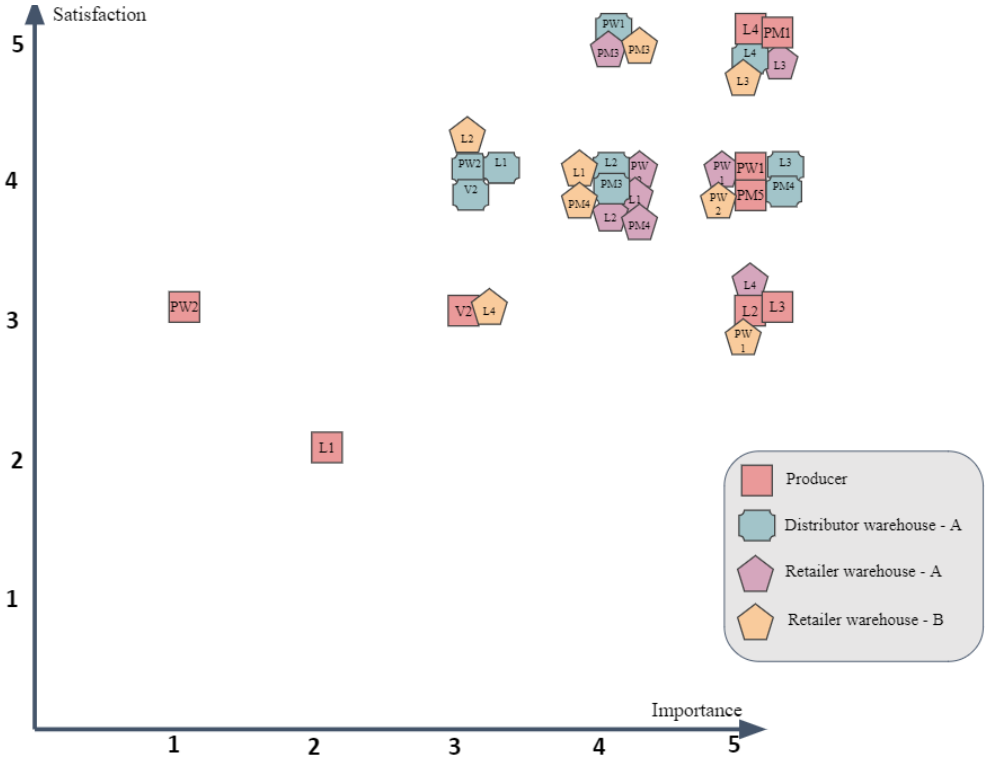


Figure 25: Scatter plot - importance vs satisfaction for tertiary packaging pallet (product A)

Product B – Plastic packaging

Similar to product A, the producer, distributor warehouse and retailer warehouse handles the tertiary packaging pallet, as mentioned in Table 14 (chapter 4.3.3). The importance and the satisfaction of each packaging features for tertiary packaging (product B) is developed and mentioned in Figure 26.

Volume and weight efficiency (L3), traceability (L4) and production efficiency (PM5) are given the highest importance by the producer, and the least importance is given to the size and convenience (VA2) of the packaging. The size and traceability (L4) are scored the highest satisfaction with the producer, followed by circular economy (PM3). Whereas the least satisfaction is scored by stack-ability (L2), convenience (VA2), volume and weight efficiency.

Product protection (PW1) and packaging size are given highest importance, followed by stack-ability (L2) and traceability (L4) of the packaging for the distributors warehouse. The features such as convenience (VA2) and unitization

(L1) are considered as least important. The size (PW2), traceability (L4) and circular economy (PM3) are scored the highest satisfaction, and the least satisfaction is scored by unitization.

Similar to distributor warehouse, the retailer warehouse gave higher importance to volume and weight efficiency (L3) and convenience (VA2), and followed by unitization of the packaging. The features such as stack-ability (L2) and circular economy (PM3) are scored the highest satisfaction, and the convenience (VA2) and traceability (L4) of the packaging are scored the lowest satisfaction.

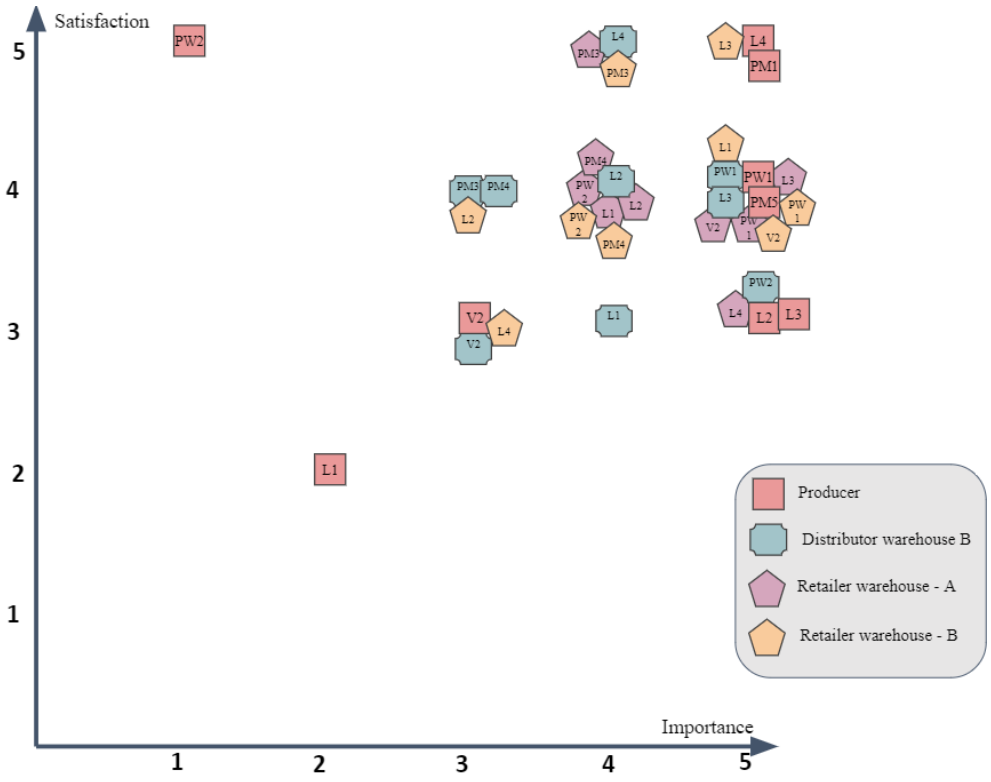


Figure 26: Scatter plot - importance vs satisfaction for tertiary packaging pallet (product B)

4.4.3.1.2 Packaging performance – Packaging scorecard

The performance of tertiary packaging pallet with the supply chain actors is developed for product A and product B and mentioned in Figure 27.

The standard tertiary packaging Euro pallet is used for product A and product B, and the similar performance is achieved with different supply chain actors. At

distributor warehouse the carton package's tertiary packaging performed higher, this is due to the difference in handling and the volume efficiency.

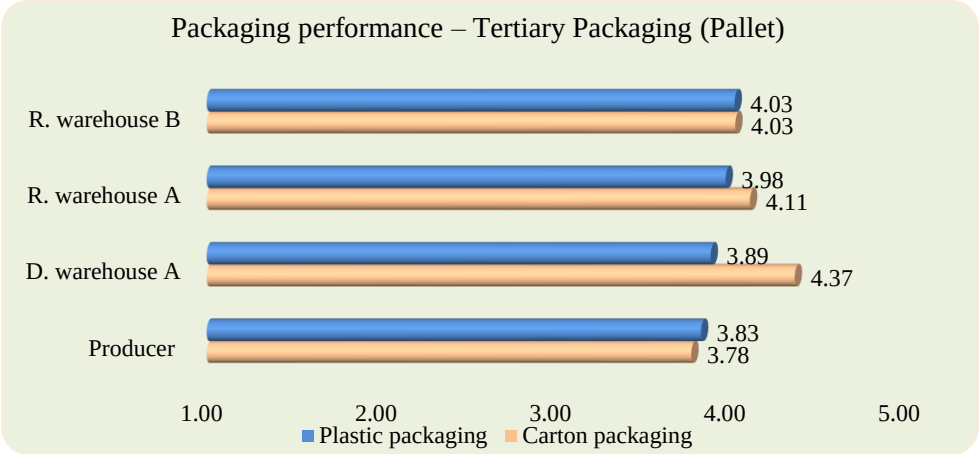


Figure 27: Packaging performance score for tertiary packaging pallet

4.4.3.2 Roll container

4.4.3.2.1 Scatter plot – importance vs satisfaction

The tertiary packaging roll container for product A and product B is handled by the retailer warehouse and retailer store, as mentioned in Table 14 (chapter 4.3.3). The retailer warehouse and the retailer store used the same tertiary packaging roll container for both the products. The importance and the satisfaction of the packaging features for tertiary packaging roll container for product A is mentioned in Figure 28, and for product B is mentioned in Figure 29.

At retailer warehouse, the right size, traceability (L4) and convenience (VA2) are marked the most important features, and followed by protection (PW1), circular economy (PM3) and security (PM4) are marked as above moderate importance. The security (PM4) of the packaging scored the highest satisfaction and the lowest satisfied features are size (PW2), unitization (L1), volume and weight efficiency (L3).

At retailer level, volume and weight efficiency, convenience (VA2) and circular economy (PM3) are scored the highest satisfaction. The features such as protection (PW1), right size (PW2) and convenience (VA2) are scored the lowest satisfaction.

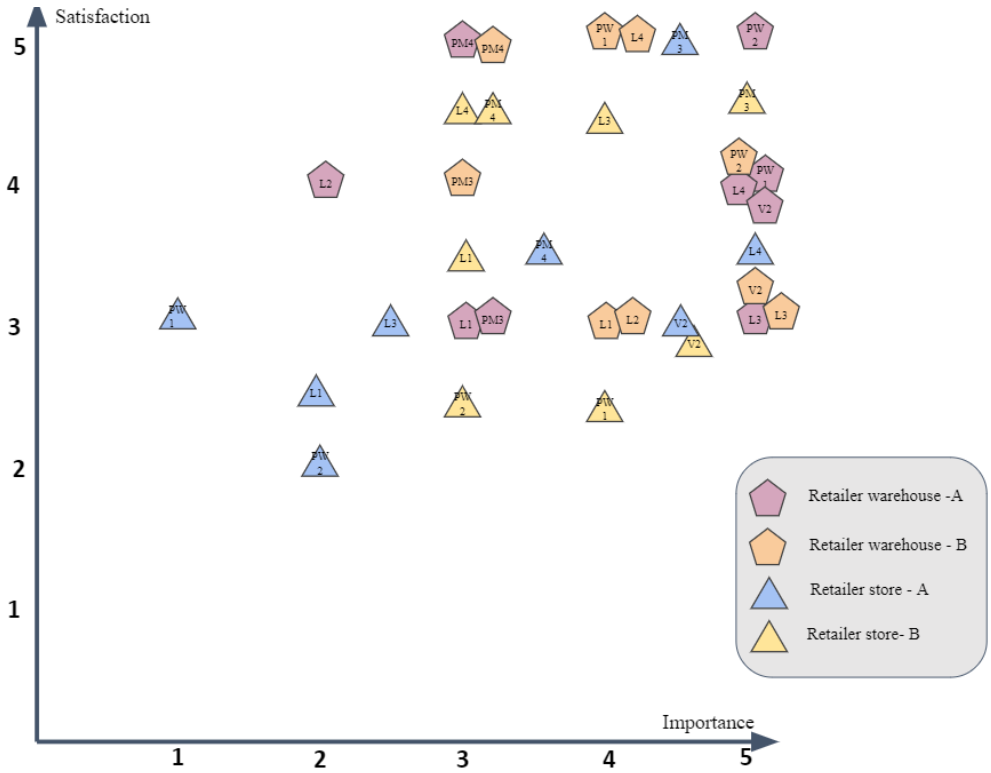


Figure 28: Scatter plot - importance vs satisfaction for tertiary packaging roll container (product A)

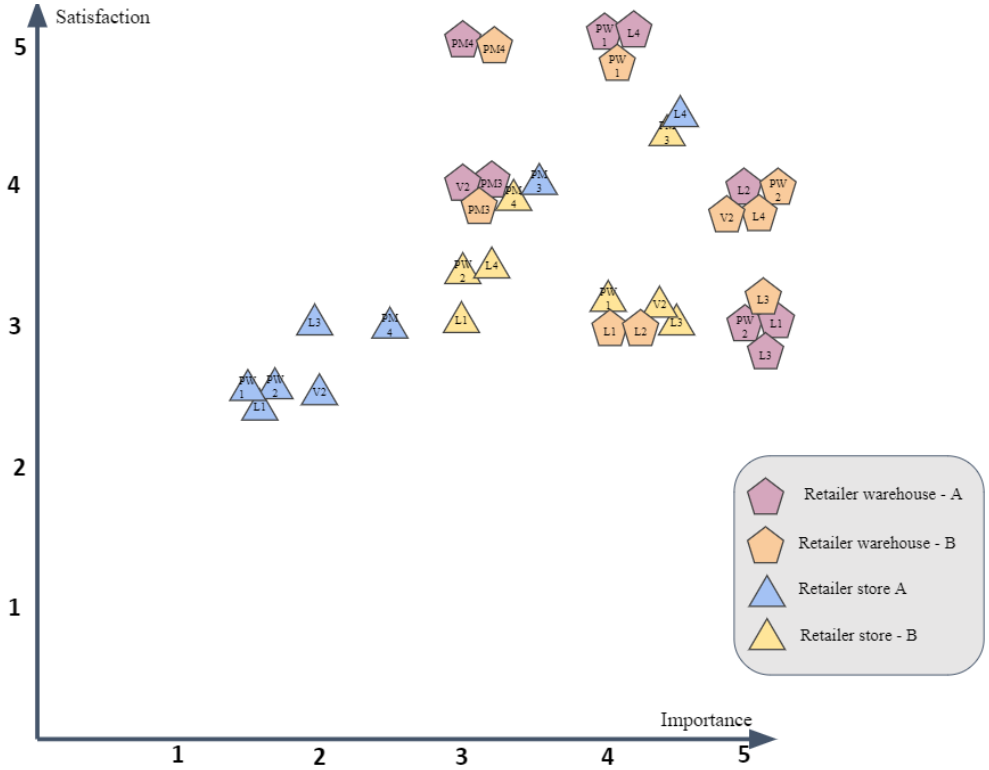


Figure 29: Scatter plot - importance vs satisfaction for tertiary packaging roll container (product B)

4.4.3.2.2 Packaging performance – Packaging scorecard

The performance of the tertiary packaging roll container for the supply chain actors is developed for product A and product B and mentioned in Figure 30. Both the packages have the similar packaging performance among retailers' warehouse and the retailers' store. The retailer store scored lesser compared to the retailer warehouse. According to the observation, the roll container's wheel got damages and are hard to move at the unloading stage and inside the store. Even though the secondary packages are stacked with the trained employee at retailer warehouse, still there are gaps between the packages. R-1 say *"we receive the roll container with different size of secondary packaging in the same roll container that damages the product and also the secondary packages are over stacked which result in falling down from the roll container during the movement, and also the packaging stacked at the bottom of the roll container often gets crushed (damages)".*

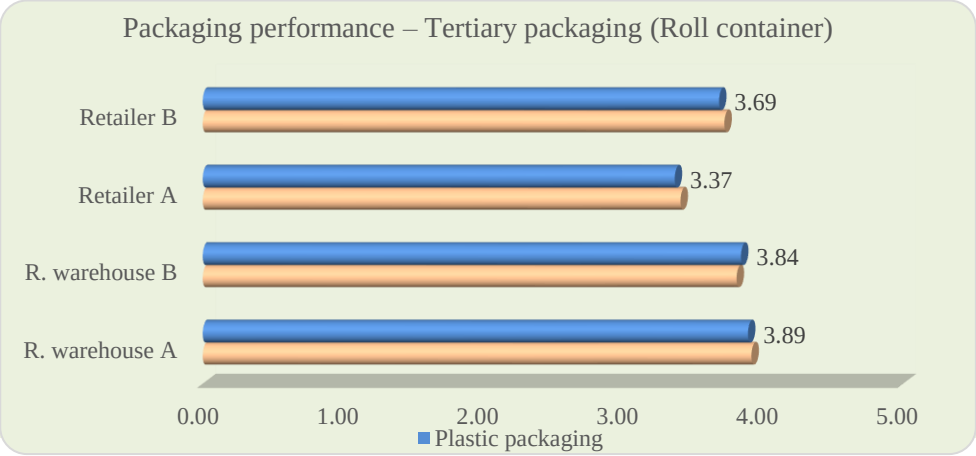


Figure 30: Packaging performance score for tertiary packaging roll container

4.5 Trade offs

The trade-offs could be used between the supply chain actors and consumers to evaluate the packaging performance. According to Pålsson (2018), trade-offs that occur in the supply chain could be two types. The first one occurs in the supply chain, due to different supply chain actors and the second one occurs in the supply chain, due to environmental and economic impacts. The various packaging features and their trade-offs among supply chain actors have mentioned in Table 14. The feature: Packaging size, the producer prefer the packaging that is easy to handle and efficient in the production line, whereas distributor and retailer warehouse prefer volume-efficient packaging, and retailer store prefers visibility of packaging that promotes sales, and consumers prefer easy handling packaging. Similarly, for labelling, producer and distributors prefer easy identification label that enables the logistics activities, retailer and consumers prefer labels with graphically clean and easy to get the required information.

Table 15: Trade-offs of the frozen meal supply chain.

Packaging Feature	***Producer***	***Distributor***	***Retailer warehouse***	***Retailer Store***	***Consumer***
Size of packaging	Easy to handle	Volume efficiency	Volume efficiency	Visibility	Convenient to handle
Unitisation	Better fitting into the production line	Volume efficiency	Volume efficiency	Better fitting into the rack	Better fitting into the freezer
Labelling	Identifiable	Identifiable	Identifiable	Graphically clean with identifiable	Graphically clean with minimal label
Packaging material	Low weight, better protection, machineability	Low weight, better protection	Low weight, better protection	Promote sales	Can be recycled
Packaging cost	Low cost	Protect properly	Protect properly	Low product price	Promotional attributes

4.6 Supply chain challenges

Lead time

The products A and product B are maintained under frozen condition throughout the supply chain, that is from the point of production to the point of consumption. Frozen condition consumes high energy to maintain the temperature. The product B travels a longer distance than product A. Thus, the reduction of lead time would reduce the total energy consumption.

Supply chain disruption resilience is one of the major challenges and gaining more importance. Lead-time could be one of the drivers of impact propagation since demand uncertainty is amplified, which disrupts the balance between supply and demand and competitive economies (Chang and Lin, 2018).

Temperature

The temperature is monitored at different stages in the supply chain, which increases the complexity in the supply chain, where the temperature monitoring and control (TMC) devices are used in the cold supply to monitor the temperature (Ashok et al., 2017). At any point in the supply chain, if the temperature rises then the products

deteriorate it's sensory and quality properties. Real-time temperature monitoring technologies, Radio Frequency Identification (RFID) tags and Wireless Sensor Networks (WSN), and Time-Temperature Integrators (TTIs) are probably the most widely employed systems used to measure, record, and monitor the product temperatures in food cold chain. (Ndraha et al., 2018)

Frozen transportation and storage are highly costly because it requires energy to maintain the temperature. Also, the frozen temperature affects the working environment, and employees need special protective cloths to withstand the cold temperature.

Track and Traceability

Better trackability and the documentation is required to ensure the food quality of the products throughout the supply chain. Traceability can provide support to public health and help authorities determine the causes of contamination or help the companies reassure customers and increase competitiveness on the market through sales and market share. Primarily, the responsibility belongs to those who develop the products and offer them to consumers. (Turi et al., 2013)

High environmental impact

The frozen supply chain has a negative impact on environmental, due to the emission of CO2 from the transport refrigeration and the cold storage refrigeration.

Premium product

Product A and product B are positioning in premium categories, which leads to higher consumer expectation in terms of product quality as well as the appearance of the product in the retailer store. Thus, the Good Handling Practices (GHP) needs to follow throughout the supply chain.

Freeze burn in the supply chain

According to Pack and Lee, (2002) frozen meals faces the freezer burn, this is due to the surface dehydration of badly packaged frozen meal. Freezer burn becomes progressively worse when badly packed or demaged packs are stored for a long time. PE are widely used to packaging for frozen meal to prevent dehydration (Robertson, 2013; Jenkins, 1991).

4.7 Consumer requirements

The below session describes the consumer requirements based on the conducted consumer interview (mentioned in chapter 3.3.2.2 method 2) and survey (mentioned in chapter 3.3.2.2 method 4). The survey results are mentioned in Appendix G.

4.7.1 Consumer characteristics

In the conducted consumer survey 55% of the consumers are flexitarians and 31% of the consumers are vegetarians. According to literature, consumer's age factor influences the food choices and the buying behaviour of food products (Yoon and Occeña, 2015; Ribeiro, 2018). R-1says *"frozen meals are purchased equally among different age group of consumers"*. 54% of the consumers from the age group of 15 to 25 years, where the consumers are grouped into three age groups, that is 1) 15 to 25 years, 2) 25 to 45 years and 45 years and above for the study. The major part of the consumer survey are conducted with the Scandinavian consumers (originally from Scandinavia), where 71% of the consumers are from Sweden, 15% of the consumers are from Denmark and 13% of the consumers are from Finland. The study is mainly conducted to the consumers who is living in Sweden, due to the lack of time and availability of resources.

4.7.1.1 Purchase of frozen meals.

The frozen meals are highly consumed by the consumers who has a busy lifestyle and not have enough time to cook the food (Broad bia, 2016). The similar responses are received from the consumer interviews. For instance, C-2 says "*I used to buy the frozen meals, when I do not have time to cook and when I am busy with my work"*. The frozen meals are not considered as a regular meal by the consumer, as mentioned earlier, most of the consumers buy frozen meal when they need a quick food. Most of the consumers say, they are always willing to cook the food, but due to the tight work schedule they are going with frozen meals. The consumer survey show 66% of the consumers buys the frozen meal once in a month and 17% of the consumers buys once in a week. One of the reasons why consumers buys frozen meals instead of fast foods, because the frozen meals are less costly and it is convenient to store at the home or workplaces.

The retailer's monitoring system shows the highest purchase of frozen meal during the weekdays, and especially on Wednesday and Thursday. 42% of the products (product A and product B) are purchased on these two days compared to rest of the week in retailer store A. The similar pattern is followed for other brands of frozen meals.

Generally, consumers have the perception that the frozen meals are not good for health, because they believe the frozen meals may contains preservatives and this

will affect the buying behaviour (C-1). The analysed products (product A and product B) do not contains preservatives.

Four main criteria, such as price of the frozen meal, health and nutritional benefits of the frozen meal, right size or quantity of the frozen meal, and environmental concern of the frozen meal are mentioned. The consumers were asked to choose two main criteria when they purchase the frozen meals. The consumers gave higher importance for price as 64%. 54% of the consumers are from the age group of 15 - 25 years, and the young adults gave higher importance to the price of the product. The similar information is found from the retailer interview. R-1 says *"It is very important for us to keep the price as low as possible for the product, and the price has the direct impact on consumer buying behaviour"*. Also, the retailers have very strict instructions with the suppliers, that means the supplier cannot increase the price for the frozen meals without any valid reasons. This means the suppliers need to give a clear and satisfied reasons for an increase of price for the frozen meals (R-1). According to the study conducted on the cheese packaging, Ribeiro et al., (2018) mentioned the price is considered as main criteria when the consumers purchase the products. Eldesouky and Mesias (2014) mentioned the low-priced product motivates the consumers to buy the food products.

Followed by price, next highest importance is given to health and nutritional benefits as 63%. The consumers are more concern about their healthy diet and they gave higher importance (Mitchell et al., 2012). C-1 say *"I spend extra time at the retailer store to read the ingredients list, because I am more concern about my diet options"*. The international consumers have a language barrier issue, as the information is mentioned in local language and it is very hard for international consumers to read the information on the packaging.

The consumers are given the highest importance to environmental related issues during the consumer interviews. But the environmental concern has given the third priority when compare to price and health benefit of the frozen meal. 40% of the consumers are given importance to environmental concern. The consumers are more aware about the environmental issues, especially with the food packaging which is ending into land and water.

4.7.2 Influences of packaging

According to the results of the consumer survey, the consumers are highly influenced by the frozen meal packaging, such as packaging shape, colour etc. The consumer survey shows 80% of the consumers are influenced by frozen meal packaging, during the product purchase. Many researchers concluded that the consumers are influenced by the packaging (Ribeiro et al., 2018; Broderick et al., 2015; Eldesouky et al., 2015). The packaging is also called as silent salesman (Hellström and Olsson, 2017; Olsson and Larsson, 2009). The marketing teams uses

different colours and designs to attract the consumers, and the packaging is used as marketing tool by the producer (Ogba and Johnson, 2010; Rundh, 2005).

4.7.2.1 Appearance and Convenience of the packaging

The consumers gave average importance for the appearance of frozen meal packaging. The consumers gave importance for the handling of frozen meal packaging. Frozen meals are handled in frozen condition and the cold temperature affects the material handling. If the product is not stored immediately into the freezer then the product deteriorates its product quality. C-3 says *"It is very hard for me to store the product in the freezer, the different brands use different size of packaging and the package won't fit well in the freezer. Some of the frozen meals uses extra packaging, sometimes I remove the outside carton box, before placing the product into the freezer"*. In this consumer survey, 36% of the consumers gave above average importance for the convenience of handling and storage of frozen meals. 22% and 16% of the consumers gave average and very high importance for the convenience of handling and storage of frozen meal packaging.

4.7.2.2 East to open and Easy to disposal of packaging.

Results from the consumer survey shows that the consumer gave very less importance for easy opening of packaging. The consumer survey includes 54% of the consumers from the age group of 15-25 years, and the age factor effects the result. According to literature, aged consumers gave more importance for the easy opening of packaging (Hensler et al., 2015). Mostly the young adults are healthy and they gave less importance for easy opening of packaging.

Disposal of the packaging material is challenging for most of the consumers. Often the frozen meals packages uses mixed packaging materials, that is a mixer of plastic and carton packaging material. C-5 says *"It is very hard to separate the packaging materials, and also it is hard to identify the type of packaging material".* FTI mentioned that the 30% of the household plastic packaging waste placed into the plastic recycling bin are other type of plastic packaging waste, and those packaging waste should not be place into the recycling bin (FTI manual, 2018). The consumers like to see more instruction about the packaging waste handling on the package, they also mentioned that some of the frozen meal packagings do not have the packaging waste handling instructions. This information is very important when the package contains several types of packaging materials. 53% of the consumers gave above average and very high importance for the easy disposal of frozen meal packaging materials.

4.7.2.3 Environmentally friendly packaging

The brand owner gave importance for the environmental concerns for their product and package to attract the consumers (Labatt, 1997; Rundh, 2005). Environmentally

friendly packaging become the marketing trend among the brand owners, because the consumers are easily attracted by the environmental related message (Rundh, 2005). In and the consumer survey, 36% of the consumers gave very high importance, followed by 29% of the consumers gave as above average importance and 18% as average importance for the environmentally friendly of frozen meal packaging.

4.7.3 Value of packaging

4.7.3.1 Reuse, Recycle and Biodegradable packaging materials

The consumers are not willing to reuse the packaging material. The frozen meal packaging-tray could be manufactured as a reusable packaging. C-3 says "*I am buying the frozen meal at least more than two times in a month, and every time I do not want to reuse the tray and it will accumulate as an extra item in my storage space. So, I prefer not to use the tray for further use".* The consumer interview and survey, most of the consumers gave average and less than average importance for reusable frozen meal packaging-tray. Whereas, Jarupan et al (2004) mentioned that the reuse of packaging has several advantages such as material saving, cost of product manufacturing and disposal operation.

Most of the frozen meal packaging are single use packages and once the product is consumed the packaging's are disposed for the recycling. 80% of the consumers gave above average and very high importance for recycling of frozen meal packaging. FTI mentioned that 92% of the Swedish consumers sort their household plastic packaging waste for recycling (FTI recycling manual, 2018). C-4 says *"I clean the frozen meal packaging tray before disposing into the recycling bin, and often I found hard to clean the packaging tray".*

The consumers gave fewer preferences for biodegradable packaging material. This consumer survey shows, 23% of the consumers gave average importance, 29% of the consumers gave above average importance, and 25% of the consumers gave very high importance for the biodegradable frozen meal packaging. The biodegradable packaging has less value in the packaging system, because the packaging is used only once and removed from the system. Many researches recommended to use the packaging in a closed loop, which means proving the second life for the packaging. The packaging could be reused or recycled to maintain in the closed loop and to create value from the packaging materials.

In recent years the use of biodegradable packaging is increased (FTI manual, 2018). The biodegradable plastic packaging are further classified into compostable, biodegradable and oxo-degradable. FTI do not have the facility to sort the biodegradable plastic packaging, and if the biodegradable plastic packaging enters

into recycling process it reduces the value of the recycled materials (FTI manual, 2018).

These results show the consumers prefer recycling-based packaging for the frozen meals rather than reuse-based packaging or biodegradable-based packaging. Even the producer manufactured the products with reuse-based packaging, the consumers still disposing the packaging into the recycling bin after the single use. The reusable packaging uses more material and it is double the thickness when compared to the single use packaging (Dubiel, 1996). So, the disposal of reusable packaging result in more energy and material waste.

4.7.3.2 Circular economy

Circular economy is an economic system, which aims to retain as much value as possible from the products by optimal reuse, remanufacturing, recycling (Rizos et al., 2017). According to EEA (2014) the circular economy is to use the waste as a resource to produce the new produces and it reduce the needs of primary resources. The consumers are well aware to use the circular economy for the frozen meal packaging to keep the packaging material in loop. 65% of the consumers gave very high importance, and 24% of the consumers gave above average importance for the circular economy.

5.Conclusions and limitations

This chapter introduces the conclusion by answering the research questions of the project, which is mentioned in chapter 1.4. The chapter aims to discuss the research findings along with the research questions and then the chapter summarizes the overall findings of the research.

5.1 Conclusions

RQ 1: What is the performance of frozen meal packaging in the supply chain, i.e. from production to consumption?

The performance of frozen meal packaging system was analysed for product A – carton packaging system and product B – plastic packaging system in the supply chain. The supply chain was analysed from the point of product production to the point of product consumption. At the producer level, the plastic packaging system performed better. This is due to the convenient handling of the packaging system, less packaging cost and efficient in production efficiency. At the distributor warehouse level, the carton packaging system performed better, due to the effective logistic performance, such as security (PM4) and unitization of the packaging system. At retailer warehouse level, the carton packaging system performed better, the secondary packaging performed better and there is no much difference with tertiary packaging. The secondary packaging performed better due to the volume and weight efficiency, size of the packaging (PW2) and hand-ability of the packaging. At retailer store, the carton packaging performed better, the difference in performance was higher with primary and secondary packaging, and no much difference in tertiary packaging. This is due to the convenience, unitization and size of the packaging (PW2). At the consumer level, carton packaging performed better, the difference is observed due to the fact of environmental concern, that is related to the packaging waste handling. In response to the research question, this study found that the carton packaging system performed better in the supply chain, except at the producer level.

RQ 2: Based on a supply chain perspective, which types of packaging features need to be considered for developing a sustainable packaging system for the frozen meal?

Important packaging features specification table – Supply chain requirements

As mentioned in the theoretical framework, the sustainable packaging development process is looked in a holistic view. The holistic view includes the different supply chain actors requirements. These requirements are expressed in terms of packaging features as described in the methodology. The following packaging features are identified as top 5 important packaging features for the packaging system based on the scatter plot and mentioned in Table 16. These features are identified based on the analysis conducted for product A and product B.

Table 16: Specification table – Supply chain requirements.

	Primary packaging	***Secondary Packaging***	***Tertiary Packaging (pallet + roll container)***
Producer	- Protection and containment - Right amount and size - Food Waste - Packaging cost - Production efficiency	- Protection and containment - Stack ability - Volume and weight efficiency - Packaging cost - Production efficiency	- Protection and containment - Right amount and size - Volume and weight efficiency -Track and trace capability - Production efficiency
Distributor warehouse	-	-	- Protection and containment - Stack ability - Volume and weight efficiency - Track and trace capability - Circular economy
Retailer warehouse	-	- Protection and containment - Volume and weight efficiency - Track and trace capability - Convenience to handle - Security	-Protection and containment - Unitisation - Volume and weight efficiency - Track and trace capability - Convenience to handle

Retailer Store	- Protection and containment - Unitisation - Product information - Convenience to handle - Promotional attributes	- Protection and containment - Volume and weight efficiency - Track and trace capability - Convenience to handle - Packaging waste	- Protection and containment - Unitisation - Volume and weight efficiency - Track and trace capability - Convenience to handle

Important packaging features specification table - Consumer requirements

This session identified the important packaging features based on the analysis conducted for product A and product B, and the conducted consumer interviews and survey. The top five important packaging features of the primary packaging under specification table is mentioned in Table 17.

Table 17: Specification table – Consumer requirements

Important packaging features based On the analysis conducted	***Important packaging features based on the consumer interview and survey***
- Protection and containment	- Protection and containment
- Product information	- Convenience to handle and store
- Convenience to handle	- Environmentally friendly packaging
- Packaging waste	- Right size of the packaging
- Circular economy	- Circular economy

Some of the packaging features are listed several times with the supply chain actors and some features are listed once as most important. Further, the important features are summarized for a frozen meal packaging system that is primary, secondary and tertiary packaging and mentioned in Table 18.

Table 18: Top 5 packaging features for the frozen meal packaging system.

Primary packaging	***Secondary packaging***	***Tertiary packaging***
- Protection and containment	- Protection and containment	- Protection and containment
- Size of the packaging	- Volume and weight	- Volume and weight
- Convenience to handle	Efficiency	Efficiency
- Circular economy	- Track and traceablity	- Track and traceablity
- Production efficiency	- Convenience to handle	- Circular economy
	- Circular economy	- Unitization.

5.2 Limitations

This research does not include the designing of the packaging system. Prior to designing the packaging system, it is important to collect other requirements, such as product, co-packer/producer, marketing, waste handlers requirements. Developing the packaging with some information could lead to poor performance to some actors in the supply chain and it leads to further optimization in a later stage. Further optimization or sub-optimization requires higher cost and resources, and consumes a lot of time. Also, company X has not finalized the characteristics of a frozen meal such as type of product, product size, market volume, etc. So, this research focused to select the type of packaging system and different supply chain actors' requirements for developing sustainable packaging in the later stage.

6. Suggestions and Future Research

6.1 Suggestions

The first research question facilities to choose the type of packaging material and packaging system which is available in the market. The plastic and carton packaging systems are commonly used packaging for frozen meals in the market. Both the packaging systems have pros and cons to some extent. For example, production efficiency is better with plastic packaging system and packaging waste is better with the carton packaging system. The overall packaging performance was performed for both the packaging system in the supply chain based on the 15 packaging features. The result suggests the company X to choose the carton-based packaging system, because the carton packaging system performed better with most of the supply chain actors and with consumers. The plastic packaging performed better only with the producer of the frozen meal.

It is important to develop the sustainable packaging system, which aims to reduce the overall cost and environmental impact, and increase the value for the packed product in the supply chain. The research findings suggest the company X to include the requirements of producer, distributor, retailer and consumer while designing the packaging system. The features: product protection was ranked highest importance among all the supply chain actors for all level of packaging. The product protection includes a mechanical, thermal, barrier and sealing properties. Volume and weight efficiency (L3)were seen the highest importance for secondary and tertiary packaging, which suggests the company X to develop the primary packaging that fit well into the secondary and tertiary packaging. Circular economy of packaging was seen among all level of packaging system as well as among supply chain actors. The research suggests to include all the supply chain actors while developing the sustainable packaging system with the aim of sharing the benefits among all the actors. The research findings highlight the supply chain challenges, such as temperature control, lead time, etc. Finally, the research develops a specification table for each actor and for each packaging level, and that could help company X to point out the most important packaging features during the development process.

6.2 Future Research

This research analysed the frozen meal packaging system from the stage of production to consumption and found the above-mentioned result, i.e. carton packaging is performing better. The research recommends further study in these areas as mentioned below.

1. The packaging performance of product A and product B was conducted for producer, warehouse, retailer and consumer. Further, the research could be done in a similar way to find out the packaging performance with other actors, such as packaging material supplier and packaging waste handler.

2. This research analysed the environmental impact of packaging (product A and product B) to some extent. Further, the research could be done for detailed environmental analysis, for example, LCA, EEFP tool, etc.

3. This research finds out the producer, warehouse, retailer and consumer requirements in terms of the top five most important packaging features. Further, the research could be done to find out other requirements such as a) Product requirements, b) Marketing requirements, c) Co-packer/ Producer requirements/facilities, d) Packaging supplier requirements/demands d) Packaging waste handler requirements.

4. This research aimed to find out the different supply chain actor's requirements, and do not include the design thinking process. So, after gathering all the requirements, further research could be done for designing/developing the sustainable frozen meal packaging system.

7.References

Aitken, J., 1998. Supply chain integration within the context of a supplier association: case studies of four supplier associations.

Alwitt, L.F. and Pitts, R.E., 1996. Predicting purchase intentions for an environmentally sensitive product. *Journal of consumer psychology*, *5*(1), pp.49-64.

APS, 2017. How Packaging Helps in Successful Warehouse Management. [online]. Available at:https://www.apsfulfillment.com/warehouse-fulfillment/how packaging-helps-in-successful-warehouse-management/. [Accessed March 2019].

Ashok, A., Brison, M. and LeTallec, Y., 2017. Improving cold chain systems: challenges and solutions. *Vaccine*, *35*(17), pp.2217-2223.

Athukorala, N.A., 2011. An Empirical study of the critical success factors for business process re-engineering (BPR) in the employees' provident fund.

Azzi, A., Battini, D., Persona, A. and Sgarbossa, F., 2012. Packaging design: general framework and research agenda. Packaging Technology and Science, 25(8), pp.435-456.

Barbosa-Cánovas, G.V., Altunakar, B. and Mejía-Lorío, D.J., 2005. *Freezing of fruits and vegetables: An agribusiness alternative for rural and semi-rural reas* (Vol. 158). Food & Agriculture Org.

Beckeman, M. and Olsson, A., 2005. Driving forces for food packaging development in Sweden-a historical perspective. *World of Food Science*.

Blaikie, N., 2003. *Analyzing quantitative data: From description to explanation*. Sage.

Bluszcz, A., 2018. Conditions for maintaining the sustainable development level of EU member states. *Social indicators research*, *139*(2), pp.679-693.

Board bia, 2013. Consumer insight. [online]. Available at: https://www.bordbia.ie/industry/. [Accessed January 2019.

Bourlakis, M.A., Vlachos, I.P. and Zeimpekis, V. eds., 2011. *Intelligent agrifood chains and networks*. John Wiley & Sons.

Breakwell, G.M. (1995). Interviewing. In G.M. Breakwell, ed., S. Hammond, ed. and C. Fife-Schaw (Eds.), Research Methods in Psychology. London, UK: Sage Publications.

Brewerton, P.M. and Millward, L.J., 2001. *Organizational research methods: A guide for students and researchers*. Sage.

Broderick, M., Bouchier-Hayes, A. and Larkin, T., 2015. The average Irish consumer a packaged food profile. *British Food Journal*, *117*(11), pp.2801 2813.

Cai, X., Huang, W., Xu, B., Kaltenpoth, G. and Cheng, Z., 2002. A study of moisture diffusion in plastic packaging. *Journal of electronic materials*, *31*(5), pp.449-455.

Cambridge dictionary, 2019. Transportation. [online]. Available at: https://dictionary.cambridge.org/dictionary/english/transportation. [Accessed February 2019].

Chandrasekaran, M. (2013) *Valorization of food processing by-products. [Elektronisk resurs]*. Boca Raton, Fla. : CRC Press, 2013.

Cheng, J.-H., D.-W. Sun, and H. Pu. 2016. Combining the genetic algorithm and successive projection algorithm for the selection of feature wavelengths to evaluate exudative characteristics in frozen-thawed fish muscle. Food Chemistry 197:855–863

Christopher, M., 2016. *Logistics & supply chain management*. Pearson UK.

Dagnelie, P.C. and Mariotti, F., 2017. Vegetarian Diets: Definitions and Pitfalls in Interpreting literature on health effects of vegetarianism. In *Vegetarian and plant-based diets in health and disease prevention* (pp. 3-10). Academic Press.

Daniel, M., 1952. Variety Every Day with Frozen Foods. *Development*, 2nd Edition. Van Nostrand Reinhold Company, New York.

Diabat, A. and Govindan, K., 2011. An analysis of the drivers affecting the implementation of green supply chain management. *Resources, Conservation and Recycling*, *55*(6), pp.659-667.

Dias, K.T. and Braga Junior, S.S., 2016. The use of reverse logistics for waste management in a Brazilian grocery retailer. *Waste Management & Research*, *34*(1), pp.22-29.

Dobrucka, R. and Cierpiszewski, R., 2014. Active and intelligent packaging food–research and development–a review. *Polish Journal of Food and Nutrition Sciences*, *64*(1), pp.7-15.

Driscoll, D.L., 2011. Introduction to primary research: Observations, surveys, and interviews. *Writing spaces: Readings on writing*, *2*, pp.153-174.

Dubiel, M., 1996. Costing structures of reusable packaging systems. *Packaging Technology and Science*, *9*(5), pp.237-254.

EEA (European Environment Agency) (2014), "Resource-efficient Green Economy and EU policies'', Luxembourg: Publications Office of the European Union.

Eldesouky, A. and Mesias, F., 2014. An insight into the influence of packaging and presentation format on consumer purchasing attitudes towards cheese: a qualitative study. *Spanish Journal of Agricultural Research*, *12*(2), pp.305-312.

Eldesouky, A., Pulido, A.F. and Mesias, F.J., 2015. The role of packaging and presentation format in consumers' preferences for food: an application of projective techniques. *Journal of Sensory Studies*, *30*(5), pp.360-369.

Elkington J. (1997), Cannibals with Forks: The Triple Bottom Line of the 21st Century Business. Capstone Publishing, Oxford

Emas, R., 2015. The concept of sustainable development: definition and defining principles. *Brief for GSDR*, pp.1-3.

EmmersonPackaging. (2019). The Highest Quality Frozen Food Packaging. Retrieved March 11, 2019, from https://www.emmersonpackaging.com/markets/frozen-food

Esse R.L. (1989), Package development, manufacturing, and distribution strategy consideration. In: *Packaging Strategy Meeting the Challenge of Changing Times*. A.W. Harckham (ed.), Technomic Publishing AG Lancaster, Pennsylvania, pp. 107–116.

FAO, 2013. Food packaging. [online]. Available at http://www.fao.org/statistics/en/. [Accessed January 2019].

Fernie, J. and Sparks, L. eds., 2004. *Logistics and retail management: insights into current practice and trends from leading experts*. Kogan Page Publishers.

Footprint, F.W. and Food and Agriculture Organization of the United Nations, 2013. *Toolkit: Reducing the Food Wastage Footprint*. Food Agriculture Organization (FAO).

Frozen food europ, 2018. Scandinavia – A Leading Region. Available at https://www.frozenfoodeurope.com/scandinavia-a-leading-region/ [Accessed June 2019]

Frozen meals (2016). *Trends of frozen foods* [online]. Available at https://www.bordbia.ie/industry/insights [Accessed February 2019]

Gardner, J.T. and Cooper, M.C., 2003. Strategic supply chain mapping approaches. *Journal of Business Logistics*, *24*(2), pp.37-64.

Griffin R.C. Jr., Sacharow S. and Brody A.L. (1985), *Principles of Packaging*

Griffin, R.C., Sacharow, S. and Brody, A.L., 1985. Packaging Equipment. In *Principles of Package Development* (pp. 205-252). Springer, Dordrecht.

Grönman, K., Soukka, R., Järvi-Kääriäinen, T., Katajajuuri, J.M., Kuisma, M., Koivupuro, H.K., Ollila, M., Pitkänen, M., Miettinen, O., Silvenius, F. and Thun, R., 2013. Framework for sustainable food packaging design. *Packaging Technology and Science*, *26*(4), pp.187-200.

Gubrium, J.F. and Holstein, J.A., 2002. FROM THE INDIVIDUAL INTERVIEW TO THE INTERVIEW SOCIE^. *Handbook of interview research: Context and method*, p.3.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R. and Meybeck, A., 2011. *Global food losses and food waste* (pp. 1-38). Rome: FAO.

Hanssen O.J. (1998), Environmental impacts of product systems in a life cycle perspective: A survey of five product types based on life cycle assessments studies. *Journal of Cleaner Production*, 3–4, 299–311.

Heap, R.D., 2006. Cold chain performance issues now and in the future. *Bulletin of the IIR*, *4*.

Heldman, D.R., Lund, D.B. and Sabliov, C. eds., 2018. *Handbook of food engineering*. CRC press.

Hellström, D. and Nilsson, F., 2011. Logistics-driven packaging innovation: a case study at IKEA. *International Journal of Retail & Distribution Management*, *39*(9), pp.638-657.

Hellström, D. and Olsson, A., 2017. *Managing Packaging Design for Sustainable Development: A Compass for Strategic Directions*. John Wiley & Sons.

Hellström, D. and Saghir, M., 2007. Packaging and logistics interactions in retail supply chains. *Packaging Technology and Science: An International Journal*, *20*(3), pp.197-216.

Hensler, S., Herren, D.B. and Marks, M., 2015. New technical design of food packaging makes the opening process easier for patients with hand disorders. *Applied ergonomics*, *50*, pp.1-7.

Hexa research (2019). Food and beverages. Scandinavia Frozen Food Market Analysis, Market Size, Product Categories, Distribution Channel, Competitive Strategies and Forecasts, 2016 To 2024 [Online]. Available at https://www.hexaresearch.com/research-report/scandinavia-frozen-food market [Accessed June 2019].

Holdsworth, S. D. (1988). Freezing and refrigeration. In M. D. Ranken, R. C. Kill, & C. Baker (Eds.), *Food Industries Manual*. Chapman & Hall

Hotta, Y., 2014. 3R Policy Indicator Factsheets. *Asia Resource Circulation Policy Research Group*, pp.49-53.

Hui, Y.H., Legarretta, I.G., Lim, M.H., Murrell, K.D. and Nip, W.K. eds., 2004. *Handbook of frozen foods* (Vol. 133). CRC Press.

International Conference on Productivity and Quality Research (ISPQR), Miami, Florida.

Jahre, M. and Johan Hatteland, C., 2004. Packages and physical distribution: Implications for integration and standardisation. *International Journal of Physical Distribution & Logistics Management*, *34*(2), pp.123-139.

Janssen, AM, Nijenhuis, M, Boer, EPJ & Kremer, S 2017, 'Fresh, frozen, or ambient food equivalents and their impact on food waste generation in Dutch households', *Waste Management*, vol. 67, pp. 298 307. https://doi.org/10.1016/j.wasman.2017.05.010

Jarupan, L., Kamarthi, S.V. and Gupta, S.M., 2004, February. Evaluation of trade offs in costs and environmental impacts for returnable packaging implementation. In *Environmentally Conscious Manufacturing III* (Vol. 5262, pp. 6-15). International Society for Optics and Photonics.

Jayaratne, P., Styger, L. and Perera, N., 2012. Role of supply chain mapping in sustainable supply chain management.

Jenkins, W. (1991). *Packaging Food with Plastics*. Lancaster: Technomic.

Johnsson, M., 1998. Packaging logistics a value-added approach Engineering Logistics Lund.

Kennedy, C.J. ed., 2000. *Managing frozen foods*. Elsevier.

Khan, M.Y. and Mittal, A., 2017. Freezing of food products: A review. International Journal of Advance Research in Science and Engineering, Volume No. 06, Issue No. 09.

Klevås, J., and M. Saghir. 2004. Introducing the Concept of Design for Packaging Logistics. Proceedings of the International Conference on Productivity and Quality Research (ISPQR), Miami, Florida.

Kline, J. (1982). *No Title*. *Paper and Paperboard: Manufacturing and Converting Fundamentals* (Ed., 2nd). Miller Freeman Publications.

Labatt, S., 1997. Corporate response to environmental issues: packaging. *Growth and Change*, *28*(1), pp.67-92.

Lai, J., Harjati, A., McGinnis, L., Zhou, C. and Guldberg, T., 2008. An economic and environmental framework for analyzing globally sourced auto parts packaging system. *Journal of Cleaner Production*, *16*(15), pp.1632-1646.

Lancioni R. and Chandran R. (1990), The role of packaging in international logistics. *International Journal of Physical Distribution and Logistics Management*, 20(8), 41–43.

Lancioni, R.A. and Chandran, R., 1990. The role of packaging in international logistics. *International Journal of Physical Distribution & Logistics Management*, *20*(8), pp.41-43.

Lee, K. H. (2005). Plastic Packaging of Frozen Foods. In D.-W. Sun (Ed.), *Handbook of Frozen Food Processing and Packaging* (pp. 641–651). CRC Press Book.

Lindh, H., Olsson, A. and Williams, H., 2016. Consumer perceptions of food packaging: contributing to or counteracting environmentally sustainable development?. *Packaging Technology and Science*, *29*(1), pp.3-23.

Lindh, H., Williams, H., Olsson, A. and Wikström, F., 2016. Elucidating the indirect contributions of packaging to sustainable development: A terminology of packaging functions and features. *Packaging Technology and Science*, *29*(4-5), pp.225-246.

Livingstone, S. and Sparks, L., 1994. The new German packaging laws: effects on firms exporting to Germany. *International Journal of Physical Distribution & Logistics Management*, *24*(7), pp.15-25.

Lockamy III, A., 1995. A conceptual framework for assessing strategic packaging decisions. *The International Journal of Logistics Management*, *6*(1), pp.51 60.

Mallett, C.P. ed., 1993. *Frozen food technology*. Springer Science & Business Media.

Manalili, N.M., Dorado, M.A. and Van Otterdijk, R., 2014. Appropriate Food Packaging in Developing Countries. *Food and Agricultural Organization: Rome, Italy*.

Manay, N.S.O., 2001. *Food: facts and principles*. New Age International.

Market research, 2017. Ready Meals in Sweden. Euromonitor International. [Online] Available at https://www.marketresearch.com/Euromonitor

International-v746/Ready-Meals-Sweden-11328907/. [Accessed June 2019].

Marsh, K. and Bugusu, B., 2007. Food packaging—roles, materials, and environmental issues. *Journal of food science*, *72*(3), pp.R39-R55.

Mayor, M. ed., 2009. *Longman dictionary of contemporary English*. Pearson Education India.

Miracle, G.E., 1965. Product characteristics and marketing strategy. *The Journal of Marketing*, pp.18-24

Mitchell, M., Brunton, N.P. and Wilkinson, M.G., 2012. Sodium and ready meals: a survey of Irish consumer awareness. *International journal of consumer studies*, *36*(3), pp.317-326.

Molina-Besch, K. and Pålsson, H., 2016. A Supply Chain Perspective on Green Packaging Development-Theory Versus Practice. *Packaging Technology and Science*, *29*(1), pp.45-63.

Monteiro, C.A., Levy, R.B., Claro, R.M., Castro, I.R.R.D. and Cannon, G., 2010. A new classification of foods based on the extent and purpose of their processing. *Cadernos de saude publica*, *26*, pp.2039-2049.

Morawicki, R.O., 2011. *Handbook of sustainability for the food sciences*. John Wiley & Sons.

Murray, M, 2019. Efficient Packaging Methods in a Warehouse. [online]. Available at:https://www.thebalancesmb.com/packaging-in-the-warehouse-2221182. [Accessed March 2019].

Nilsson F., Olsson A. and Wikstrom F. (2011), Toward sustainable goods flows – a framework from a packaging perspective. *Conference Proceedings Nofoma.*

Noya, L.I., Vasilaki, V., Stojceska, V., Gonzalez-García, S., Kleynhans, C., Tassou, S., Moreira, M.T. and Katsou, E., 2018. An environmental evaluation of food supply chain using life cycle assessment: A case study on gluten free biscuit products. *Journal of Cleaner Production*, *170*, pp.451-461.

Ogba, I.E. and Johnson, R., 2010. How packaging affects the product preferences of children and the buyer behaviour of their parents in the food industry. *Young Consumers*, *11*(1), pp.77-89.

Oliver, R.K. and Webber, M.D., 1982. Supply-chain management: logistics catches up with strategy. *Outlook*, *5*(1), pp.42-47.

Olsson A. and Larsson A.C. (2009), *Value Creation in PSS Design through Product* Ono, K., 1990. Frozen food and oven-proof trays. *Food Packaging*, pp.253 268.

Pacha, A. (2019, March). A smart indicator to boost frozen food safety. *The Hindu*, p. 17. Bengaluru. Retrieved from https://www.thehindu.com/sci-tech/a smart-indicator-to-boost-frozen-food-safety/article26481239.ece

Pack, M., Lee, D., & Lee, K. (2002). *Food Packaging Science*. Seoul: Hyungseol.

Packaging world, 2008. Convenience drives frozen food packaging. [online]. Available at:https://www.packworld.com/article/food/bakery/convenience drives-frozen-food-packaging. [Accessed February 2019].

Paine F.A. (1981), *Fundamentals of Packaging*. Leicester: Brookside Press.

Paine, F. A., & Paine, H. Y. (1992). *A Handbook of Food Packaging* (Vol. 2 ed). SPRINGER-SCIENCE+BUSINESS MEDIA, BV.

Pålsson, H. and Hellström, D., 2016. Packaging logistics in supply chain practice current state, trade-offs and improvement potential. *International Journal of Logistics Research and Applications*, *19*(5), pp.351-368.

Pålsson, H., 2018. *Packaging Logistics: defining packaging logistics*. Kogan Page Publishers.

Parfitt, J., Barthel, M. and Macnaughton, S., 2010. Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical transactions of the royal society B: biological sciences*, *365*(1554), pp.3065-3081.

Phillips, S.D., Shakarji, C.M., Balsamo, A., Krystek, M. and Morse, E.P., 2016. The 2016 Revision of ISO 1–Standard Reference Temperature for the Specification of Geometrical and Dimensional Properties.

Prasad, P. and Kochhar, A., 2014. Active packaging in food industry: a review. *Journal of Environmental Science, Toxicology and Food Technology*, *8*(5), pp.1-7.

Pu, H., D.-W. Sun, Ma. Ji, and J.-H. Cheng. 2015. Classification of fresh and frozen thawed pork muscles using visible and near infrared hyperspectral imaging and textural analysis. Meat Science 99:81–88.

Pu, Y.-Y., and D.-W. Sun. 2016. Prediction of moisture content uniformity of microwave-vacuum dried mangoes as affected by different shapes using NIR hyperspectral imaging. Innovative Food Science and Emerging Technologies 33:348–356

Pu, Y.-Y., and D.-W. Sun. 2017. Combined hot-air and microwave-vacuum drying for improving drying uniformity of mango slices based on hyperspectral imaging visualisation of moisture content distribution. Biosystems Engineering 156:108–119

Radey, M., 2010. Secondary data analysis studies. *The handbook of social work research methods*, pp.163-182.

Research and Markets (10AD) 'Sustainable Packaging Market: Global Industry Analysis, Trends, Market Size and Forecasts up to 2024 ResearchAndMarkets.com', *Business Wire (English)*, 2018. Available at: http://search.ebscohost.com.ludwig.lub.lu.se/login.aspx?direct=true&dbwh&AN=bizwire.c86891362&site=eds-live&scope=site (Accessed: 4 May 2019).

Ribeiro, A.P.L., Carneiro, J.D.D.S., De Melo Ramos, T., Patterson, L. and Pinto, S.M., 2018. Determining how packaging and labeling of Requeijão cheese affects the purchase behavior of consumers of different age groups. *British Food Journal*, *120*(6), pp.1183-1194.

Rizos, V., Rizos, V., Tuokko, K., Tuokko, K., Behrens, A. and Behrens, A., 2017. *The Circular Economy: A review of definitions, processes and impacts. CEPS Research Report No 2017/8, April 2017*.

Robertson, G. L. (2013). *Food Packaging: Principles and Practice*. *CRC Press*. https://doi.org/10.1177/0340035206070163

Robertson, G.L., 1990. Good and bad packaging: who decides?. *International Journal of Physical Distribution & Logistics Management*, *20*(8), pp.37-40.

Robertson, G.L., 2009. *Food packaging and shelf life: a practical guide*. CRC Press.

Rokka, J. and Uusitalo, L., 2008. Preference for green packaging in consumer product choices–do consumers care?. *International Journal of Consumer Studies*, *32*(5), pp.516-525.

Rundh, B., 2005. The multi-faceted dimension of packaging: marketing logistic or marketing tool?. *British food journal*, *107*(9), pp.670-684.

Saghir, M., 2004. *A platform for Packaging Logistics Development: a systems approach*. Department of Design Sciences, Faculty of Engineering, Lund University.

Schwartzman, H.B., 1993. *Ethnography in organizations* (Vol. 27). Sage.

Selke, S.E., 2012. Green packaging. In *Green Technologies in Food Production and Processing* (pp. 443-468). Springer, Boston, MA.

Service-System Design, Sakao and Lindahl (eds), Springer, pp. 93–108.

Sohail, M., Sun, D.W. and Zhu, Z., 2018. Recent developments in intelligent packaging for enhancing food quality and safety. *Critical reviews in food science and nutrition*, *58*(15), pp.2650-2662.

Sun, D.W., 1999. Comparison and selection of EMC/ERH isotherm equations for rice. *Journal of Stored Products Research*, *35*(3), pp.249-264.

Sun, D.W., 2016. *Handbook of frozen food processing and packaging*. CRC press.

Sun, D.-W., and I. W. Eames. 1996. Performance characteristics of HCFC123 ejector refrigeration cycles. International Journal of Energy Research 20:871–885.

Sustainable Packaging Alliance, 2019. Defining sustainable packaging. [online]. Availableat: http://www.sustainablepack.org/research/subpage.aspx PageID=10&id=7. [Accessed March 2019].

Sustainable Packaging Coalition, 2019. Definition of sustainable packaging. [online]. Available at: http://www.sustainablepackaging.org/content/?type=5&id=definition of-sustainable-packaging. [Accessed March 2019].

Svanes, E., Vold, M., Møller, H., Pettersen, M.K., Larsen, H. and Hanssen, O.J., 2010. Sustainable packaging design: a holistic methodology for packaging design. *Packaging Technology and Science: An International Journal*, *23*(3), pp.161-175.

Sykes, C., 2018. Time-and Temperature-Controlled Transport: Supply Chain Challenges and Solutions. *Pharmacy and Therapeutics*, *43*(3), p.154.

Tanner, D., & Amos, N. (2006). Paper and Card Packaging of Frozen Foods. In D. W. Sun (Ed.), *Handbook of Frozen Food Processing and Packaging* (pp. 653–665). CRC Press Book.

The 10-R's of Sustainability (2014). Earth Mother [online]. Available: https://www.earth-month.org/the-10-r-s-of-sustainability/ [Accessed February 2019].

Twede, D., Clarke, R.H. and Tait, J.A., 2000. Packaging postponement: a global packaging strategy. *Packaging technology and science*, *13*(3), pp.105-115.

UN, Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2017 Revision: Key Findings and Advance Tables; Working Paper No. EDA/P/WP/248; United Nations: New York, NY, USA, 2017.

Valigra, L., 2012. Clarence Birdseye's Frozen Food Process Innovated an Industry. Food quality and safety. Retrieved on march 23, 2019, from https://www.foodqualityandsafety.com/article/clarence-birdseyes-frozen food-process-innovated-an-industry/

Verghese, K. and Lewis, H., 2007. Environmental innovation in industrial packaging: a supply chain approach. *International Journal of Production Research*, *45*(18-19), pp.4381-4401.

Vernuccio, M., Cozzolino, A. and Michelini, L., 2010. An exploratory study of marketing, logistics, and ethics in packaging innovation. *European Journal of Innovation Management*, *13*(3), pp.333-354.

Vinnari, M., Montonen, J., Härkänen, T. and Männistö, S., 2009. Identifying vegetarians and their food consumption according to self-identification and operationalized definition in Finland. *Public Health Nutrition*, *12*(4), pp.481-488.

Wang, L. J., and D. -W. Sun. 2001. Rapid cooling of porous and moisture foods by using vacuum cooling technology. Trends in Food Science and Technology 12:174–184.

Wang, S. (2012). Handbook of Frozen Food Processing and Packaging. *Trends in Food Science & Technology*, *29*(1), 80–81. https://doi.org/10.1016/j.tifs.2012.07.001

Wikström, F. and Williams, H., 2010. Potential environmental gains from reducing food losses through development of new packaging–a life-cycle model. *Packaging Technology and Science*, *23*(7), pp.403-411.

Williams, H., 2011. *Food packaging for sustainable development* (Doctoral dissertation, Karlstad University).

Wohner, B., Pauer, E., Heinrich, V. and Tacker, M., 2019. Packaging-Related Food Losses and Waste: An Overview of Drivers and Issues. *Sustainability*, *11*(1), p.264.

Yam, K. L., P. T. Takhistov, and J. Miltz. 2005. Intelligent packaging: concepts and applications. Journal of Food Science 70:1–10.

Ying, J.; Li-Jun, Z. Study on green supply chain management based on circular economy. *Phys. Procedia* 2012, *25*, 1682–1688.

Yoon, H.S. and Occeña, L.G., 2015. Influencing factors of trust in consumer-to consumer electronic commerce with gender and age. *International Journal of Information Management*, *35*(3), pp.352-363.

Zijm, H., Klumpp, M., Heragu, S. and Regattieri, A., 2019. Operations, Logistics and Supply Chain Management: Definitions and Objectives. In *Operations, Logistics and Supply Chain Management* (pp. 27-42). Springer, Cham

8. Appendix

8.1 Appendix A: 15 packaging features and their description

Area	No.	Packaging Feature	Description
Product waste	PW1	Protection and containment	Ability to protect the product from the physical, chemical and biological hazards.
	PW2	Right amount and size	Right size of the packaging
	PW3	Food Waste	Minimal amount of food waste
Logistics	L1	Unitisation	Right fit of different level of packaging
	L2	Stack ability	Ability to stack as many shipment units as possible at warehouse and during transport
	L3	Volume and weight	Ability to use all the available volume and load capacity
	L4	Track and trace capability	Capacity to trace the packaging/products in the supply chain
Value adding	VA1	Product information	Provide product information
	VA2	Convenience	Simplify the use of packaging
	VA3	Promotional attributes	Promote and sell the product
Packaging material	PM1	Packaging cost	The cost of the packaging
	PM2	Packaging waste	Minimal amount of packaging waste
	PM3	Circular economy	Maintain the packaging in closed loop.
	PM4	Safety and Security	Ability to protect the product from the thefts
	PM5	Production efficiency	Enable efficient processing in production

8.2 Appendix B: Interview Questions – Supply chain actors

A. Producer

1. Could you please tell me a bit about your background?
    a. Education
    b. Total experiences and the experience in this company
    c. Roles and responsibilities

Protection and containment & Right amount and size

2. Could you please tell me, do you face any product damages due to this packaging? If yes, could be please tell me in what way?
3. Does this package fit well into the packaging system? And do you give importance for right size and amount packaging? And for what reason? And how much do you satisfy with this packaging?

Material Handling & Convenience

4. Could you please tell me, how the packages are handled (for e.g. automatic or manual)? Do you use any special tools/equipment for handling the packaging?
5. Does all level of packaging is convenient to handle, do you face any trouble while handling the packaging?

Volume and weight efficiency & Stack ability

6. How do you fill the pallet (half or full pallet)? if half, what could be the reason? How do you stack the secondary packaging (for e.g. interlocking or normal align stacking)?

Track and Trace capability & Production Efficiency

7. What type of documents do you use for track and traceability? How often do you carry out the track and trace process?
8. Does this package fit well in the production line? Do you have any specific problem with the packaging machine? Are you satisfy with the production efficiency?

Packaging waste & Circular economy

9. What kind of packaging waste do you handle? And how do you manage the packaging waste (recycling, energy recovery, landfill)?
10. Does the packaging waste have a circular economy? How important is proper handling of packaging waste, and why? And how much do you satisfy with this packaging?

Unwrapping & Packaging cost

11. How do you do the wrapping process and do you face any issues with that? Do you have any product damages while wrapping process?

12. Do you think that the increase or decrease in packaging cost, will affect the product quality and the purchasing power of the consumer? and do you give importance to packaging cost and does it have an influence?

Other areas

13. What are the main challenges and risk you are facing with the packaging system? Where/at what stage you are facing those challenges and risk? Does this packaging system affect the work and time, if yes in what way?
14. Does the environmentally friendly packaging would increase the selling capacity of the product? What type of packaging do you like the most, and why so?
15. What are the three main things you like with the current packaging system? What are the three main things you like to change with the current packaging system?
16. What are the things need to consider while developing environmentally friendly packaging?
17. Do you give importance to environmentally friendly packaging? what type of packaging do you prefer? Plastic based or carton based for frozen meal?

<u>B. Warehouse</u>

1. Could you please tell me a bit about your background?

- Education
- Total experiences and the experience in this company
- Roles and responsibilities

Protection and containment & Right amount and size

2. Could you please tell me, do you have faced any product damages due to this packaging? Also, do you faced any product damages in the relevant packed product?
3. Why do you think that the product is getting damaged? Could you please give me 3 to 5 main reasons?
4. Does this package fit well into the packaging system and storage space? And do you give importance for right size and amount packaging? And for what reason? And how much do you satisfy with this packaging?

Material Handling & Convenience

5. Does all level of packaging is convenient to handle, do you face any trouble while handling the packaging?

Volume and weight efficiency & Stack ability

6. How do you receive the pallet (half or full) and do you have a problem with that? How the packages are stacked before and after? Does the package get damage, due to this type of stacking practices?

Track and Trace capability

7. What type of documents do you use for track and traceability? What information do you want to trace when something goes wrong? How often do you carry out the track and trace process?

Packaging waste & Circular economy

8. What kind of packaging waste do you handle? And how do you manage the packaging waste (recycling, energy recovery, landfill)?
9. Does the packaging (2º, 3º) have a circular economy? How important is proper handling of packaging waste, and why? And how much do you satisfy with this packaging?

Unwrapping & Security

10. How do you do an unwrapping process and do you face any issues with that? Do you have any product damage while unwrapping process?
11. Do you lose any packed product in the supply chain? if yes could you please tell me how and where?
12. Does the cold temperature have an effect on the package? do you face any problem to maintain the temperature throughout the process?

Other areas

13. What are the main challenges and risk you are facing with the packaging system? Where/at what stage you are facing those challenges and risk? Does this packaging system affect the work and time, if yes in what way?
14. What type of packaging do you like the most, and why so? And what type of packaging you don't like, and why so? Do you prefer returnable secondary packaging, if yes, why?
15. What are the three main things you like with the current packaging system? What are the three main things you like to change with the current packaging system?
16. What are the things need to consider while developing environmentally friendly packaging?
17. Do you give importance to environmentally friendly packaging? what type of packaging do you prefer? Plastic based or carton based for frozen meal?

C. Retailer

1. Could you please tell me a bit about your background?

- Education
- Total experiences and the experience in this company
- Roles and responsibilities

Protection and containment & Right amount and size

2. Could you please tell me, do you face any product damages, due to packaging? Also, do you faced any product damages in the relevant frozen meal packaging?
3. Why do you think that the product is getting damaged? Could you please give me 3 to 5 main reasons?
4. Does this package fit well in the packaging system and the shelf? And do you give importance for right size and amount packaging? And for what reason? And how much do you satisfy with this packaging?

Material Handling & Convenience

5. Does all level of packaging is convenient to handle, do you face any trouble while handling the packaging?

Volume and weight efficiency & Stack ability

6. How do you receive the roll container (half or full) and do you have a problem with that? How the packages are stacked, does the package get damage, due to this type of stacking practices?

Track and Trace capability & Promotional attributes

7. What type of documents do you use for track and traceability? What information do you want to trace when something goes wrong? How often do you carry out the track and trace process?
8. How do the packages help in information flow in the supply chain? What kind of promotional attributes influence the consumer buying behaviour?

Packaging waste & Circular economy

9. How do you manage packaging waste (recycling, energy recovery, landfill)? Does the packaging (2º, 3º) have a circular economy?
10. Do you think that the increase or decrease in packaging cost, will affect the product quality and the purchasing power of the consumers? And do you give importance to packaging cost and does it have an influence with selling capacity?

Unwrapping & Security

11. How do you do an unwrapping process and do you face any issues with that? Do you have any product damage while unwrapping process?
12. Do you lose any packed product in the supply chain? if yes could you please tell me how and where?
13. Does the cold temperature have an effect on the package? Do you face any problem to maintain the temperature throughout the process?

Other areas

14. What are the main challenges and risk you are facing with the packaging system? Where/at what stage you are facing those challenges and risk? Does this packaging system affect the work and time, if yes in what way?
15. Does the environmentally friendly packaging would increase the selling capacity of the product? What type of packaging do you like the most, and why so? And what type of packaging you don't like, and why so?
16. What are the three main things you like with the current packaging system? What are the three main things you like to change with the current packaging system?
17. What are the things need to consider while developing environmentally friendly packaging?
18. Do you give importance to environmentally friendly packaging? What type of packaging do you prefer? Plastic-based or carton-based for frozen meal?

8.3 Appendix C: Interview Questions – Consumers

1. Could you please tell me a bit about yourself?

Protection and containment & Right amount and size

2. Could you please tell me, do you face any product damages due to this packaging? If yes, could be please tell me in what way?
3. Does this package fit well into the storage place? And do you give importance to right size and amount of packaging? And for what reason? And how much do you satisfy with this packaging?

Convenience & Product Information

4. Does the packaging is convenient to handle, do you face any trouble while handling the packaging, for example easy to open?
5. Does the package is missing any sort of information, what you are looking for?
6. Do you have enough information to provide a consumer complaint, when you realise that the product is not safe to consume?

Promotional attributes & Packaging waste

7. Do the promotional attributes influence your buying behaviour? What kind of promotional attributes influence you the most?
8. Does the package is convenient to separate different materials? What are the challenges do you face? Does the package is easy to empty? And do you face any product waste in the package?
9. Do you have the sufficient information about the reuse or recycling process?

Circular economy

10. Does the packaging waste have a circular economy? How important is proper handling of packaging waste, and why? And how much do you satisfy with this packaging?

Other areas

11. What are the main challenges and risk you are facing with this packaging? Where/at what stage you are facing those challenges and risk?
12. What are the main things you like with the current packaging system? What are the main things you like to change with the current packaging system?
13. What are the things need to consider while developing environmentally friendly packaging?
14. Do you give importance to environmentally friendly packaging? what type of packaging do you prefer? Plastic based or carton based for frozen meal, for why?

Packaging Scorecard Table - producer
(Similar packaging scorecard table was developed for other supply chain actors)

8.4 Appendix D: Observations

Retailer warehouse

1. How the product is received from the producer/distributor warehouse, could you please explain me the overall process?
2. Also, could you please explain and show the following activities -> unloading activities -> document verification process -> storage activities -> internal movement -> repackaging process-> further loading to truck?
3. Could you please explain me the temperature monitoring process through the activities?
4. What are the main challenges and risk you are facing in this process? Where/at what stage you are facing those challenges and risk? If possible, could you compare with other produces (similar type) and show me the differences?

Check list:

Sl. No	Packaging features	How they are doing?	+	-
1	Protection and containment			
2	Right amount and size			
3	Material Handling			
4	Convenience			
5	Volume and weight efficiency			
6	Stack ability			
7	Track and Trace capability			

8	Packaging waste			
9	Circular economy			
10	Unwrapping			
11	Security			
Others				

Additional Questions

Additional comments

Retailer shop

1. How the product is received from the warehouse, could you please explain me the overall process?
2. Also, could you please explain and show the following activities -> unloading activities -> document verification process -> storage activities -> internal movement -> repackaging process -> further storage at shelf?
3. Could you please explain me the temperature monitoring process through the activities?
4. What are the main challenges and risk you are facing in this process? Where/at what stage you are facing those challenges and risk? If possible, could you compare with other produces (similar type) and show me the differences?

Check list:

Sl. No	Packaging features	How they are doing?	+	-
1	Protection and containment			

2	Right amount and size			
3	Material Handling			
4	Convenience			
5	Volume and weight efficiency			
6	Stack ability			
7	Track and Trace capability			
8	Promotional attributes			
9	Packaging waste			
10	Circular economy			
11	Unwrapping			
12	Security			
Others				

Additional Questions

Additional comments

8.5 Appendix E: Survey Questions – Consumers

Consumer – Survey

1. Could you please tell me, about your diet options?
2. Indicate your age group?

3. Could you please tell me, where do you live or work or study (for short or long period)?
4. How often do you purchase the frozen meal?
5. Which packaging do you like the most for the product - frozen meal? and could you please explain the reason? (as shown in the above picture)
6. According to you what are the two main criteria you consider when buying a new frozen meal?
    a) Price, b) Health/nutritional benefits, c) Right size (or quantity) of the product, d) Environmental concern
7. Does the type of packaging material and design influence you while purchasing the product?
8. What is important for you, when it comes to frozen meal packaging, Rank 1 (Less important) to 5 (Very important)
    a) Appearance, b) Convenient to handle and store, c) East to open, d) Easy to disposal, e) Environmentally friendly
9. What is important for you, when it comes to frozen meal packaging, Rank 1 (Less important) to 5 (Very important)
    a) Reuse the packaging material (tray) b) Recycle the packaging material (tray), c) Use of biodegradable packaging material
10. According to you, how important it is to use a circular economy in packaging?
11. Please choose the relevant sentence?
    a) I choose: A frozen meal which is packed in an echo friendly packaging, which is expensive
    b) I choose: A frozen meal which is packed in an echo friendly packaging, which is expensive
12. Do you face any challenges with frozen meal tray packaging, if yes, what are the three main challenges?
13. Is there anything else you would like to add or suggest?

8.6 Appendix F: Rationale of a packaging scorecard table

**Importance Score – How much importance do you give for this packaging, based on the packaging features.*

**Satisfaction Score – How much do you satisfied with this packaging, based on the packaging features.*

Producer:

Area	Packaging Feature	Description	Importance Score *(Kindly, give your score from 1 to 5, where 1 = less important and 5 = most important)*	Satisfaction Score *(Kindly, give your score from 1 to 5, where 1 = less satisfied and 5 = most satisfied)*	Comments
Product waste	Protection and containment	Ability to protect the product from the physical, chemical and biological hazards.			
	Right amount and size	Right fit of product into package			
Logistics	Unitisation	Modularization of the packaging levels			
	Material handling	Ability of efficient handling of packaging			
	Stack ability	Ability to stack as many shipment units as possible at warehouse and during transport			
	Volume and weight	Ability to use all the available volume and load capacity			
	Track and trace capability	Capacity to trace the packaging/products in the supply chain			
Value adding	Product information	Ability to display product information			
	Convenience	Simplify the use of packaging			
Packaging material	Packaging cost	The cost of the packaging			
	Packaging waste	Minimal amount of packaging waste			
	Production efficiency	Ability of packaging use in the production line			

Distributor warehouse:

Area	Packaging Feature	Description	Importance Score *(Kindly, give your score from 1 to 5, where 1 = less important and 5 = most important)*	Satisfaction Score *(Kindly, give your score from 1 to 5, where 1 = less satisfied and 5 = most satisfied)*	Comments / Insights
Product waste	Protection and containment	Ability to protect the product from the physical, chemical and biological hazards.			
	Right amount and size	Right size of the packaging material			
Logistics	Unitisation	Right fit of the packaging levels			
	Material handling	Ability of efficient handling of packaging			
	Stack ability	Ability to stack as many shipment units as possible at warehouse and during transport			
	Volume and weight	Ability to use all the available volume and load capacity			
	Track and trace capability	Capacity to trace the packaging/products in the supply chain			
Packaging material	Circular economy	It is an economic system, which aim to reuse the packaging material (Pallet) in the supply chain.			
	Security and safety	Ability to protect the product from the thefts			

Retailer warehouse:

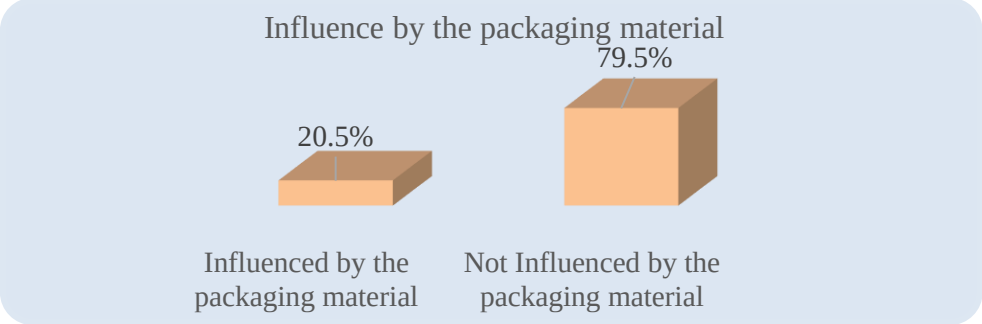
Area	Packaging Feature	Description	Tertiary Packaging – Pallet		Tertiary Packaging – Roll Container		Secondary Packaging – Carton Box	
			Importance Score	Satisfaction Score	Importance Score	Satisfaction Score	Importance Score	Satisfaction Score
Product waste	Protection and containment	Ability to protect the product from the physical, chemical and biological hazards.						
	Right amount and size	Right fit of product into package						
Logistics	Unitisation	Modularization of the packaging levels						
	Material handling	Ability of efficient handling of packaging						
	Stack ability	Ability to stack as many shipment units as possible at warehouse and during transport						
	Volume and weight	Ability to use all the available volume and load capacity						
	Track and trace capability	Capacity to trace the packaging/products in the supply chain						
	Convenience	Simplify the use of packaging						
Packaging material	Circular economy	It is an economic system, which aim to reuse the packaging material (Pallet) in the supply chain.						
	Security and safety	Ability to protect the product from the thefts						

Retailer store

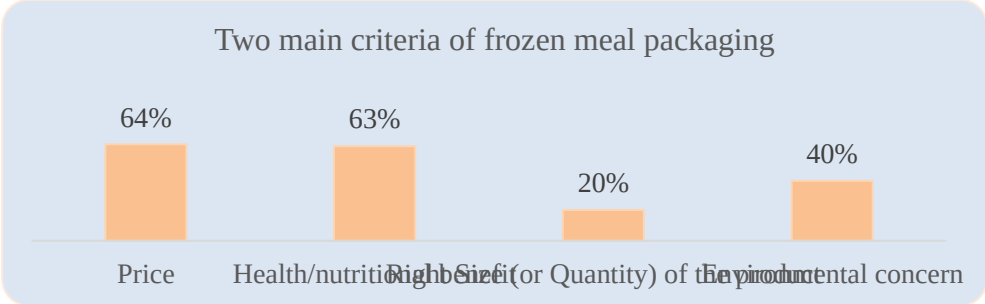
Area	Packaging Feature	Description	Primary Packaging		Secondary Packaging – Carton Box		Tertiary Packaging – Roll Container	
			Importance Score	Satisfaction Score	Importance Score	Satisfaction Score	Importance Score	Satisfaction Score
Product waste	Protection and containment	Ability to protect the product from the physical, chemical and biological hazards.						
	Right amount and size	Right size of the packaging						
Logistics	Unitisation	Right fit of different level of packaging						
	Material handling	Ability of efficient handling of packaging	x	x				
	Stackability	Ability to stack as many shipment units as possible at warehouse and during transport			x	x	x	x
	Volume and weight	Ability to use all the available volume and load capacity						
	Track and trace capability	Capacity to trace the packaging/products in the supply chain						
Value adding	Convenience	Simplify the use of packaging					x	x
	Product information	Ability to display product information			x	x	x	x
	Promotional attributes	Promote and sell the product			x	x	x	x
Packaging material	Packaging cost	The cost of the packaging			x	x	x	x
	Packaging waste	Minimal amount of packaging waste	x	x			x	x
	Circular economy	It is an economic system, which aim to reuse the packaging material (Pallet) in the supply chain.	x	x				
	Security and safety	Ability to protect the product from the thefts						

8.7 Appendix G: Survey Results

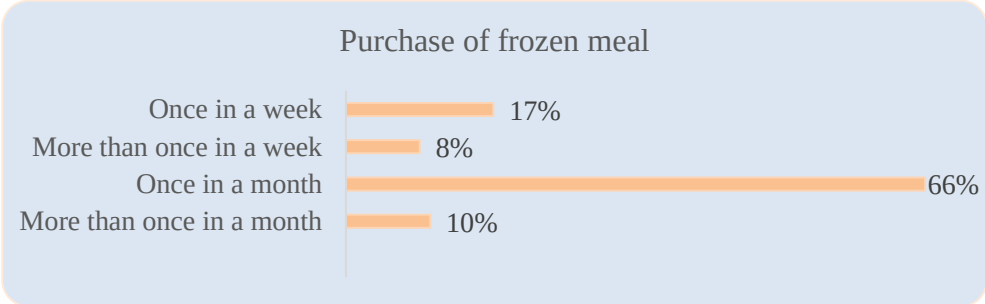
Influence by the packaging material



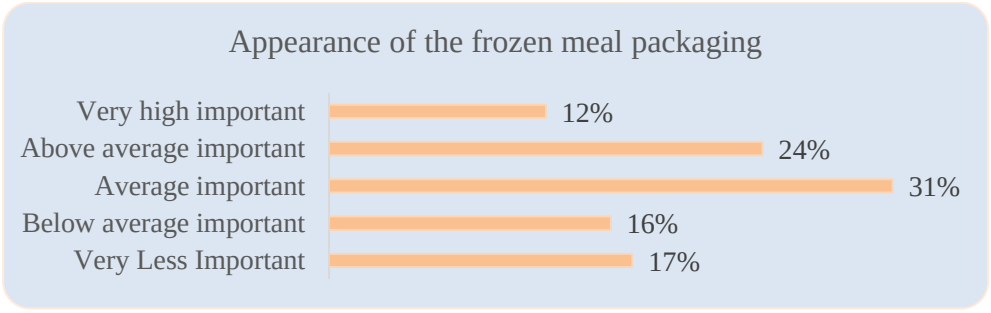
Two main criteria of frozen meal packaging



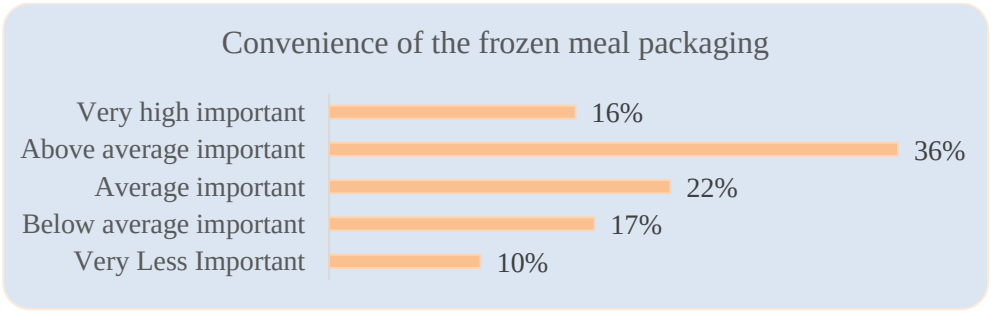
Purchase of frozen meal



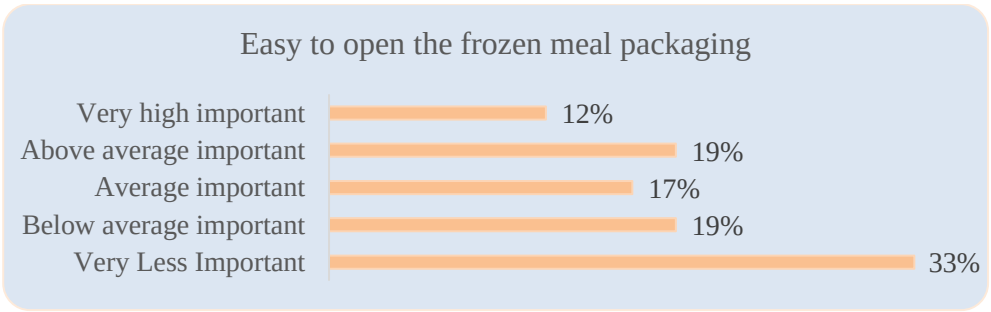
Appearance of the frozen meal packaging



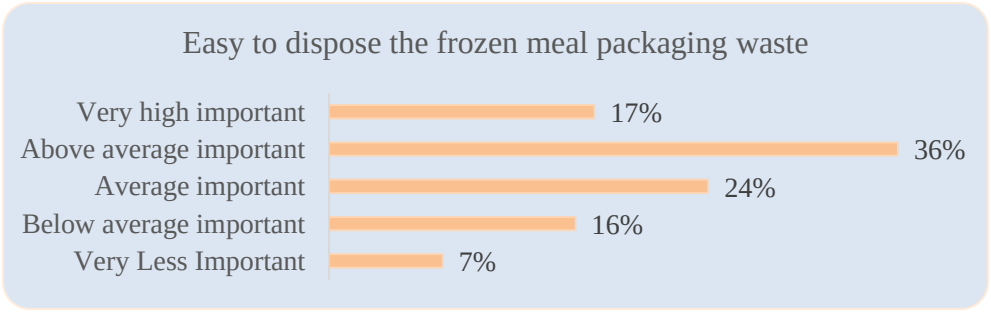
Convenience of the frozen meal packaging



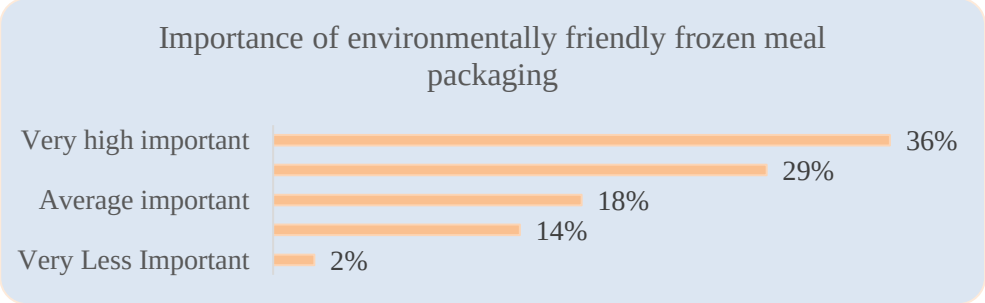
Easy to open the frozen meal packaging



Easy to dispose the frozen meal packaging waste

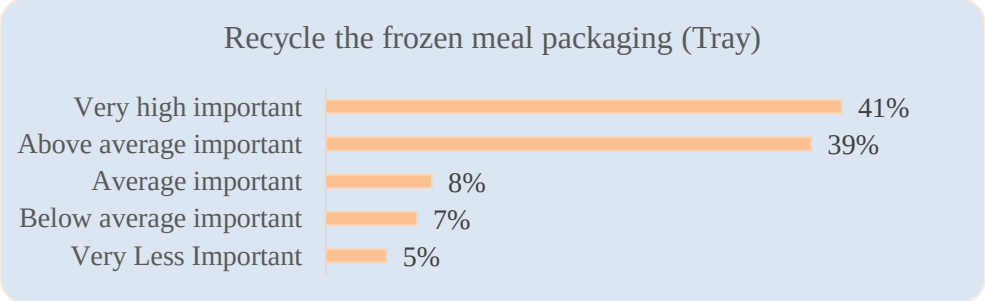


Importance of environmentally friendly frozen meal packaging

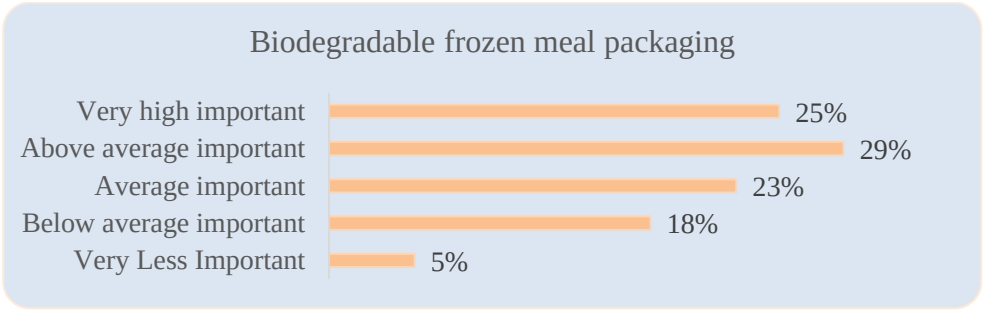


Reuse of frozen meal packaging (Tray)

Recycle the frozen meal packaging (Tray)



Biodegradable frozen meal packaging



Circular economy in frozen meal packaging