Project of the end for the master

TRANSPORT, MOBILITY and SUPPLY CHAIN

Models of sales assignment to maximize the profits from an economic point of view in FMCG

Report

Author: PEIQIN HU
Director: DOMÉNECH LÉGA, BRUNO

Call: April 2022

ETSEIB

Escola Tècnica Superior
d'Enginyeria Industrial de Barcelona

UPC

ETSEIB

Abstract

The sales assignment by manufacturers is an important part of the supply chain at the micro level. It is the most obvious manifestation of dynamism. Also, it has a significant impact on improving the efficiency of the entire supply chain. However, market demand is often uncertain. It makes it more difficult to allocate orders. A typical example of this situation always appears in FMCG (Fast Moving Consumer Goods). Customers are often willing to pay more time to wait with advanced payments compared to other products, such as mobiles, luxury goods and cars. In response, manufacturers often use marketing strategies such as pre-ordering and creating waiting list to gather information. It is a good way of alleviating the information mismatch between demand and production in the supply chain. However, it is not the same situation with cosmetics, daily necessities, and food. They are characterized by fierce competition between manufacturers, high replaceability and relatively open market price information. Therefore, in Fast Moving Consumer Goods industry, manufacturers usually use proportional allocation as the main principle to ensure that resources are maximised at each link in the supply chain.

In this project, how managers make centralised decisions through a model if they have all the information will be discussed. They will not only decide how to allocate products quickly, but also get a theoretical maximum value of supply chain profits. Based on the mass nature of the goods in this industry, the sensitivity analysis will be also mentioned to validate its reasonableness.

Summary

1. Glossary

-**CPG.** Consumer-packaged goods. They are products that are sold quickly and at a relatively low cost. Examples include non-durable household goods such as packaged foods, beverages, toiletries, and other consumables.

-**FCST**. Abbreviation of forecast. It is always applied in sales estimation in the financial area of a FMCG company. It should be the closest figure to the actual sales and proposed by distributors or retailers theoretically.

-**FG**. Finish goods. Refers to the products which have been completely manufactured. They can be sold in the market with a certain retail price.

-**FMCG**. Fast moving consumer goods. Also known as consumer-packaged goods (CPG). They are products that are sold quickly and at a relatively low cost. The most typical products are household goods such as packaged foods, cosmetics, and personal care products.

-**GWP.** Gift with purchasing. They are bundled with some specific products as a combination to be given as a gift to consumers.

-**Launch cost**. A type of cost related to each order which should pay by distributor.

-**Nash equilibrium**. It is an idealised situation in game theory. Each participant in the allocation process cannot maximise the profit by changing itself individually. Until all parties make a choice there is an overall optimum. This state is called a “Nash equilibrium”.

-**Newsvendor model**. A mathematical model that was first defined in 1951. It was used to solve the problem of calculating the optimal order quantity in cases where the retailer had a penalty for not completing the sales.

-**OAT**. One at a time. It is a common method of sensitivity analysis. It means moving one input variable, keeping others at their baseline values, then returning the variable to its nominal value, then repeating for each of the other inputs in the same way.

-**OOS**. Out of stock. The quantity of goods in the warehouse is below the normal range of stock levels.

-**Opportunity sales loss**. It is a concept in microeconomics. It means the loss of revenue incurred when another alternative option is chosen. Here this refers not only to the value of the goods, but also to other measurement factors such as brand impacts, customer value, etc.

-**OS**. Over stock. The number of goods in the warehouse exceeds the normal range of stock levels.

-**PA**. Promotion allowance. It is a price reduction or discount granted by a manufacturer to a member of the marketing channel in return for some form of special promotion of some products.

-**Pareto distribution**. It is the way the Law of Two & Eight expressed in economics. In the following description it refers to the allocation rules that satisfy key account needs first. A small number of distributions are allocated the majority of FG.

-**POS**. Point of sales. It means a place in a shop where a product is passed from the seller to the customer. They are shops, counters etc.

-**Purchasing price**. Price of one unit FG purchased for a distributor from a manufacturer.

-**Retail price**. Price of one unit FG for a consumer bought form a POS.

-**SC**. Supply chain. It is an abbreviation.

-**SCM**. Supply chain management. It is an abbreviation.

-**Sell in.** A concept of retail management. A manufacturer always sells large quantity of goods to distributors. This behaviour is called sell-in.

-**Sell out**. It refers to the process that a unit of product sold from a POS finally to a consumer. It also can be called as “final sales”.

-**SKU**. Stock-keeping unit. It refers to a distinct type of item for sale in the field of inventory management.

-**Trade marketing.** It is a discipline of marketing that relates to increasing the demand at wholesalers, retailers, or distributors level rather than at the consumer level. It is an important medium between the marketing department and consumers.

-u. m. Unit of money.

-u. p. Unit of product.

2. Preface

Based on my more than three years of working experience in FMCG (Fast Moving Consuming Goods) industry trade marketing management, a manufacturer branding company doesn't just care about the final sales, but also the overall profit. Due to the highly competitive nature of the industry, each company will enhance its competitiveness and increase its profits from all aspects of the supply chain. For example, in the upstream, product development departments refine people into various target consumers. They develop corresponding product to expand their customer base. In the middle of the supply chain, manufacturers increase their efficiency to ensure maximum capacity. And at the end of the supply chain, POS (Point of Sales) attracts customers through various promotions and GWP (Gift with Purchasing) to increase the sales.

However, the link of products allocation sometimes would be ignored by managers. In the flow of FG (Finish Goods) from the manufacturer to the market, they need to be assigned to distributors first. If FG can be distributed more rationally in the process, goods will be purchased by the consumer with faster and a higher price. Meanwhile, it creates more profits for the whole supply chain.

In this segment, three players are involved: the manufacturer, distributors, and consumers. The manufacturer sells the products in bulk to distributors with a certain price. This process is called sell in. Then the distributors deliver goods to POS. FG will be sold from the shelves, counters, boutiques, and other forms of POS to customers. This process is known as sell out. As mentioned above, a proper sell in can facilitate a quick turnaround of FG. From a short-term perspective, quicker turnaround of products can generate more profits in SC. In the long term, a fair allocation of products can increase the turnover rate of goods and capture market share. It helps the manufacturer to have a healthy, virtuous cycle of business.

The flow of goods from the manufacturer finally to consumers is shown in Fig 2 .1. as below:

Fig. 2.1 The flow of FG from the manufacturer to consumers

The question of how to rationalise the assignment of goods to distributors is an issue worth exploring. In fact, one of the current approaches adopted by many enterprises is complex. Distributors and the manufacturer first make decentralised decisions of FCST (forecast) without sharing information. Based on which they negotiate several times and eventually negotiate a common quantity. This method consumes long time. It could also lead to stock-outs or backlogs due to the lack of information sharing between the two participants. To improve these points, a faster and more rational model needs to be established.

Based on my observations and the reflections above, there are several changes to be considered in the new model compared to the current ones:

- The common destination is to reach the most profits in this segment instead of others.
- The process needs to be centralized. It allows decisions to be made more quickly and reduces unnecessary efforts.
- Both sides take different responsibilities. Although the allocation is made mainly by one of the sides, it also takes more risks at the same time.

The analysis and details will be presented in the following sections.

3. Introduction

In this chapter, the description of the problem, objectives and the scope of the project will be clarified.

3.1. Description of the problem

In the modern concept of supply chain management, the quest is for more rational, efficient between deeper upstream and downstream cooperation. The rational use of resources and the improvement of efficiency are also the topics of continuous optimization by researchers. Various supply chains can be divided into many distinct types by different criteria. The most common approach is to distinguish by the type of products. The nature of the product will determine how the supply chain is produced, how it is transported and even its operational strategy.

As described above, if the supply chain is differentiated by product type, it can be divided into food, chemicals, textiles, automotive, electronics etc. Two of these categories, food, and chemicals, are often grouped into a more specific category: the FMCG industry. Its products share several characteristics that distinguish them from other consumer goods. In general, they have four characters [21]:

- **Fast-moving consumer goods are used up and bought repeatedly in a short period of time and are in great demand.** It is vital for people to use them in daily life: food, shampoo, cleansing agent…
- **Impromptu purchasing decisions are dominant.** In other words, when products are out of stock, there is a greater risk of being substituted. The manufacturer is exposed to greater loss of opportunity sales.
- **Market factors have a greater influence on final sales, such as packaging, display, changes of competitors, etc.** The products are quite common everywhere. They are not irreplaceable. Thus, any brand can be replaced by another.
- **FG have a much shorter shelf life.** Their high demand, repeat purchase also dictate a shorter life cycle.

The supply chain for these products can be illustrated in Figure 3.1. In this chain, there are three key nodes that require cooperation between different companies upstream and downstream. These nodes are supply, manufacture, and distribution. These links provide a complete picture of how FG are transformed from raw materials into CPG (Consumer-packaged goods) and ultimately sold to consumers.

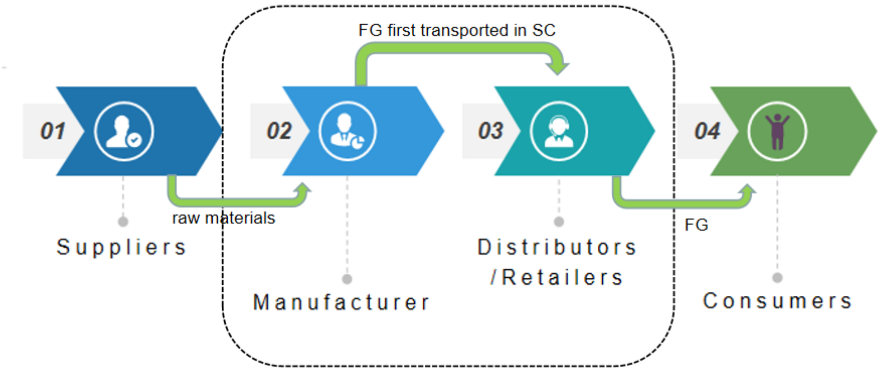

Fig. 3.1. The flow of logistics in FMCG supply chain

Of the three nodes that appear in Figure 3.1, efficiency between suppliers and manufacturers is the one that is most discussed. It is the productivity that is often mentioned in SCM (Supply Chain Management). This is because the manufacturer is in a strong position in the production process and has access to almost all the information. It includes different prices of suppliers, delivery, machine efficiency from etc. It shows how a high level of information sharing can lead to a good overall management of a certain segment. Therefore, the same approach will be used in this project.

Combined with the product characteristics mentioned above, it requires a shorter product cycle and a higher turnaround rate in FMCG industry. So, managers need to make faster and more precise decisions to distribute goods.

The most common method nowadays can be broken into a flow chart. Details are shown in Figure 3.2 below.

A normal flow of sales assignment is:

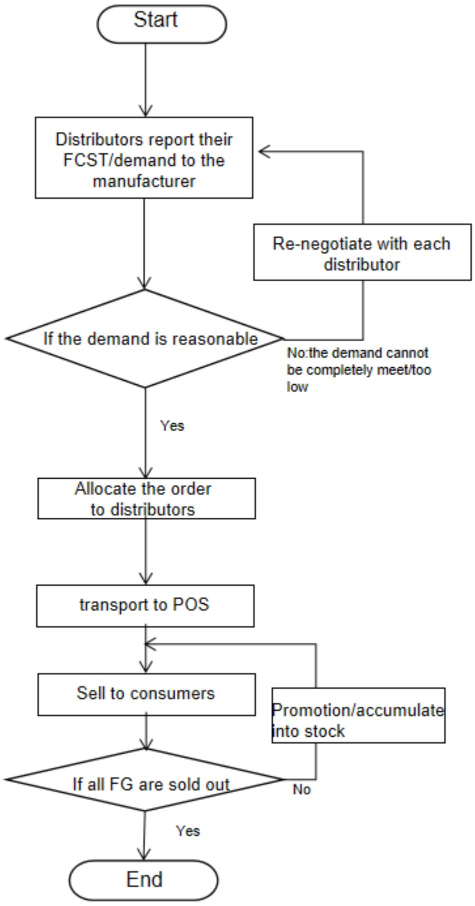

Fig. 3.2. The flow diagram of normal sales assignment

- Distributors report their FCST/demand to the manufacturer respectively.
- The manufacturer determines whether their initial requirements are justified. Distributors may over-report the demand to gain more FG or overly conservative estimates of sales.
- If the demand is reasonable, the manufacturer will meet it and allocate products. If no, they re-negotiate until reach a common quantity. Then the manufacturer launches goods also.
- Distributors transport products to different POS.
- POS try to sell all goods in a certain period.
- If the products are sold out, the process ends. If there are over-stock, the remaining quantity of goods is going to be sold again in next period with a promotion plan.

As we mentioned in section 2, managers spend a great deal of time in mutual speculation and negotiation. Instead of the current mode, enterprises need to focus on how to build a new mechanism for increasing efficiency and maximize total profit in this segment.

3.2. Objectives of the project

The general objective and the specific objectives are both included in following context.

3.2.1. General objective

The general objective of this project is to enhance the rational allocation of FG in FMCG industry. As it mentioned in 3.1, after the manufacturer finishes the production, there are still several stages that can be optimised to increase the profitability of the supply chain. During the flow of goods, they first need to be distributed to the various distributors. Once this objective has been achieved, the manufacturer can increase the turnover of goods. It also creates a good foundation for the processes that follow.

3.2.2. Specific objectives

There are five specific objectives of this project:

- Review similar topics from past studies. For example, what supply chain management has pursued in the past, etc.
- Simplify the process of allocating goods and help managers to make quicker decisions.
- Establish an effective mechanism based on the specificities of the sector. The aim is to urge partners to be more cautious about their prognosis.
- Build a prognosis model and explore whether it has a theoretical maximum. That is, the maximum value of profit.
- Explore the impacts of different parameter changes on the profit.

The points above lead to the conclusion of what models and corresponding trends we should base on to improve the efficiency of sales distribution more scientifically.

3.3. Scope of the project

This project aims to explore if there is a best solution of sales assignment between a manufacturer and its distributors to maximize the profit in this segment.

The research is set under some specific setting as below:

- **The model is discussed for individual SKU of one-time allocation in one certain sales period.** Multi SKU situation is not considered.
- **The decision is centralized making by the manufacturer**. Corresponding to what was mentioned in 3.1., the model can be discussed only if it is centralized, and the parameters are public information.
- **Data to be used in validation are not real**. Due to the limitation of data resource, we cannot use the real data for simulation.
- **Sensitivity analysis is considered to avoid serendipity.** The model involves several important parameters. However, due to the real data restriction, sensitivity analysis is included. It can also present the trend with changes.

4. State of art

Before carrying out the project, we will review what the researchers did in previous work with similar situations.

Cachon & Lariviere (1999) [1] presented a novel point of view: leading distributors to make order forecasts which exceed actual demand could lead to higher profits throughout the whole supply chain. In this report, the assumption they made at the outset was that N independent distributors under inventory pressure would under-report their estimates. The manufacturer incentivises them to inflate demand orders. As a result, the whole supply chain achieves better results in the profits. Meanwhile, the authors also raised several aspects that had not been considered, such as marginal effects and sales cycle. The utility that can be obtained from the part of the commodity near the limit of demand tends to consume more costs and can also significantly increase the time invested. Meanwhile, over-motivation can be "counter-manipulated" by a combination of distributors. And when prices are fixed, the only way to maximise supply chain profits is to drive more sales, which is difficult to maximise.

Based on this paper, Deshpande & Schwarz (2002) [2]. optimised the model. The authors made two very important points:

- When retailers' demand is under a "Pareto allocation". And the total profit of the supply chain is always higher under a centralised decision to allocate goods than that under a decentralised decision.

- The introduction of the newsvendor model allows the profit model to be linearised and the optimal value to exist in theory.

The existence of marginal utility is more rigorously demonstrated by “Pareto allocation”. At the same time, newsvendor model was also mentioned. It allows the model to become linear. There is also a theoretical maximum of profit.

However, the analysis is not analysed for a specific industry environment. The examples in the text are used in buy-side dominated industries such as chips and automobiles. The situation is usually one of insufficient "capacity" for the manufacturer. Similarly, the scenario set out in the text is one of privatisation of information. The difference is that the wholesale prices are different, making the parameters of the model more complex.

The concept of “newsvendor model” has been frequently applied in recent years in operations research and management science. Zhang et al. (2005) [3] described how to apply it in a one manufacturer – one distributor setting with centralized and decentralized decision. They also mentioned the term of “buy back”, which means return. It refers to the redistribution of goods by the manufacturer by means of returns and thus re-selling. This method is rarely used at FMCG due to the specific nature of the commodity. This model is often used in game theory. Dror et al. (2007) [4]. They analysed in detail how the “newsvendor model” should theoretically be used in the dynamic blogging of public opinion for centralised decision-making. Two situations when capacity and demand are not equal are both considered. Whereas this project focuses on the analysis of the FMCG industry, Wang & Webster (2010) [5] researched on the rules for the distribution of seasonal sales items and proposed a proportional allocation rule which will be used in this project.

In fact, the efficiency we seek in management can also be called "fairness". That is why fairness and collaboration are also important goals for us. Wu & Niederhoff (2014) [6] re-explored the way profits are distributed between upstream and downstream companies in the supply chain until almost both sides are comfortable with it and formally enter into a healthy cooperation. This is the result of fairness. They call such a situation a win-win. Take the above learning about the allocation rules together, we will flesh it out into a model in this project. We will use an important model: newsvendor model as mentioned above. Ulaş et al. (2011) [7] proved that the newsboy model is "convex" in nature. In other words, the newsvendor model has a maximum value theoretically. Doğru et al. (2012) [8] proposed a method for OS punishment to realize it. It is common in the case of one manufacturer to multi distributors.

The newsvendor model is designed to achieve a more rational distribution to ensure that every FG is sold as quickly as possible. The more profitable a unit of product is on this basis, the more profit it will bring to the entire chain. Niraj et al. (2001) [9] concluded it as the “profitability”. The POS of a unit of product at different distributors brings unequal profits to the supply chain. Therefore, allocating to the customers with the greatest demand first may not be the optimal approach.

To summarise, there are three broad types of programmes that can be used in the workplace. Karaesmen et al. (2011) [10] divided them as: easy to define, easy to achieve and close to optimal. Qin et al. (2010) [11] provided a complete review of the application of the newsboy model in a variety of previous literature, analysing the influence of various parameters on the model. And they suggested future directions for development.

The "newsvendor model" focuses on reducing losses due to OS. We also need to consider the potential loss of OOS. This is an important part of microeconomics that cannot be ignored. This is especially true for products that are highly competitive and substitutable in the market. Fitzsimons (2000) [13] provided an analysis of the various possibilities that consumers have for out-of-stock. The conclusion is that OOS can have a negative impact on sales. It will reduce the chances of customers returning. Chen et al. (2010) [12] found the impact on fresh produce to be very significant. Haws (2010) [14] marked in the literature that according to previous real statistics, OOS would result in an annual loss of up to 3% of sales even for large chains of distributors.

We have therefore taken this part into account in this project. There have been different ways to measure this loss before. Levy et al. (2004) [15] recommended its inclusion in the pricing strategy in their previous study. In this project, we focus more on the allocation rule and the model instead of others. And so, we take the same method to quantify the loss same with OS.

In recent years, the rapid growth of the consumer goods industry has made the market more competitive. In some industries, the concept of supply chain management has become more modern. An example is the bullwhip effect, which has been mentioned several times. Jaggi et al. (2018) [16] carefully describes the losses and distress caused by the bullwhip effect on the decisions of all parties in the supply chain and introduces a new algorithm to increase the total profit of all retailers.

In addition to this, information sharing, and deep collaboration is one of the directions often mentioned by researchers. Okoumba & Mafini C (2018) [17] used the FMCG industry as an example to verify that close collaboration between firms in the supply chain has a positive impact on performance improvement. Putra et al. (2020) [18] also In their article, they show that information sharing can enhance the bond between distributors and retailers. Song et al. (2021) [19] also used a decentralised decision-making approach for a new allocation mechanism. They paid attention to the points noted in the industry: increasing cooperation, increasing overall profit, etc. Jouida et al. (2021) [20] used three methods: egalitarian allocation, proportional allocation, and Shapley value to control costs and maximise profits. All three methods require a certain level of cooperation between the two parties.

The researchers above have all had their own focus in conducting similar studies to achieve a particular goal in supply chain management. They each have their own strengths and weaknesses. There are some studies that are very quantitative in focus but tend to be too complex to set. This can prevent managers from making quick decisions. Some of them focus a lot on market analysis. However, they do not have a quantitative approach and do not fit in with the research direction of the project.

Their strengths and weaknesses of literature [1] to [9] are illustrated in Table 4.1. And the strengths and weaknesses of literature [10] to [17] in Table 4. 2. and literature [18] to [20] in Table 4. 3.. They are shown in the following pages.

Table 4.1. Advantages and disadvantages of from literature [1] to [9]

No.	Title	Year	Authors	Advantages	Disadvantages
[1]	Capacity Choice and Allocation: Strategic Behavior and Supply Chain Performance	1999	Cachon Lariviere	Optimise the distribution mechanisms from the overall profitability of the supply chain.The conclusion was also reached.	Marginal effects and sales cycles were not taken into account.Incentives can be easily counter-manipulated by a combination of multiple distributors.
[2]	Optimal Capacity Choice and Allocation In Decentralized supply chains	2002	Deshpande Schwarz	They conclude that : 1. When retailers' demand is under a "Pareto distribution". And the total profit of the supply chain is always higher under a centralised decision to allocate goods than that under a decentralised decision. 2. The introduction of the newsboy model allows the profit model to be linearised and the optimal value to exist in theory.	They are not analysed for a specific industry environment. The examples in the text are used in buy-side dominated industries such as chips and automobiles. The situation is usually one of insufficient "capacity" for the manufacturer. Similarly, the scenario set out in the text is one of privatisation of information. The difference is that the wholesale prices are different, making the parameters of the model more complex.
[3]	Supply Chain Coordination of Loss-Averse Newsvendor with Contract	2005	Zhang Song Wu	It describes in detail how the model can be applied in practice in the case of one manufacture to one distribuitor.	The term "buy back" is mentioned, which is the concept of “return”. It is rarely used in the FMCG industry.
[4]	Dynamic Realization Games in Newsvendor Inventory Centralization	2007	Dror Guardiola Meca Puerto	The various scenarios in dynamic game theory are described in great detail, and the two cases of ordering demand > capacity and ordering demand < capacity are considered and described separately for each of them.	Too many scenarios are set and conditions are too specific, resulting in them not being applied well.The bilateral dynamic of the model leaves managers with no way to make quick decisions.
[5]	The loss-averse newsvendor problem	2010	Wang Webster	All models are in seasonal sales conditions and the goods are perishable. It can be used as a comparison for FMCG. The "proportional distribution" rule is also used.	The model is non-linear and ultimately no sensitivity analysis is done from a profit perspective.
[6]	Fairness in Selling to the Newsvendor	2014	Wu Niederhoff	The key words are "fairness" and "coordination". It is more in line with current supply chain management concepts and aims to achieve a "win-win" situation.	If different models had to be set up taking into account the preferences of each dealer, the decision-making process would become too lengthy.
[7]	On the convexity of newsvendor games	2011	Ulaş Norde Slikker	The “convex” nature of the newsboy model and its “single peak” is proved. This is also demonstrated by the normal and uniform distributions.	It does not use specific values to make the results more visual.
[8]	Newsvendor characterizations for one-warehouse multi retailer inventory systems with descrete demand under the balance assumption	2012	Doğru Kok Houtum	The concept of "block penalties" is explicitly mentioned in the article. It does not use too many mathematical concepts to explain it, but rather organises the logic of how the model is applied through practical work. It sets out one manufacture - multi distributors as the most common.	As this is literature in MBA, it does not contain sufficient data and analysis to prove the conclusion.
[9]	Customer Profitability in a Supply Chain	2001	Niraj Gupta Narasimhan	The concept of "profitability" is introduced in the article and refers to the fact that the profitability of the same product varies from one distributor to another, an important concept that we will use in the following section. The article also refers to "core customers". The allocation is divided into under-capacity and over-capacity, and the provision of additional services is considered, sharing the risk with the distributor. The text also mentions the incentives and compensation that were previously common.	The assessment of profitability should be multifaceted. The authors do not fully consider, for example, the potential loss of sales.

ETSEIB

Table 4.2 Advantages and disadvantages of from literature [10] to [17]

No.	Title	Year	Authors	Advantages	Disadvantages
[10]	Managing Perishable and Aging Inventories: Review and Future Research Directions	2011	Karaesmen Scheller Deniz	It concentrates on a review of research on shelf-life products and mentions the single-cycle treatment of slow-moving products, one method being discounting. It also mentions the costs commonly associated with ordering products by distributors, including "shortage costs" and, as we shall see in this article, "opportunity losses". The best cost solution is not always the best solution. All solutions can be divided into three categories: easy to define, easy to achieve and close to optimal.	The main study in the paper is discrete. And the whole model is optimised from a cost point of view.
[11]	The Newsvendor Problem: Review and Directions for Future Research	2010	Qin Wang Vakharia Chen Seref	A complete review of the newsboy model in its various previous applications in the literature is presented, analysing the influence of various parameters on the model. And future directions are also suggested.	The demand for simulation remains random. This can lead to problems that become complex.
[12]	The study of a forecasting sales model for fresh food	2010	Chen Lee Kuo Chen Chen	It analyses the sales model for fresh produce in different ways. It not only deals with actual sales, but also with the concept of "lost opportunities".	There is not enough detail in the article. The process of model building is not described in great detail.
[13]	Consumer response to stockouts	2000	Fitzsimons	The article analyses the reaction of consumers to out-of-stocks. It is clearly stated that out of stock not only loses sales at the moment, but also reduces the likelihood that the consumer will choose again next time. This value would be as high as 50%.	The article is mainly a descriptive analysis, with no numerical substitution and no prediction of greater losses due to stock-outs.
[14]	Driving Retail Sales Through Effective Supply Chain Management Technology	2010	Haws	The article focuses on the positive impact that RFID technology can have on POS stock-outs. The article clearly mentions that according to Accenture, for consumer goods, losses due to out-of-stock are up to 3% per year. This is an important parameter for our measurement model.	It does not concentrate on the building and analysis of the model.
[15]	Emerging trends in retail pricing practice: implications for research	2004	Levy Grewal Kopalle Hess	The article goes into detail about pricing strategies for shelf items, which mentions the need to take potential out-of-stock losses into account in the pricing strategy.	It does not describe in detail how to quantify the loss of out-of-stocks. And, one of the aims of supply chain management is not to run out of stock, and this loss should be considered within the management of wastage.
[16]	Quantitative Analysis for Measuring and Suppressing Bullwhip Effect	2018	Jaggi Verma Jain	The article carefully describes the losses and distress caused by the bullwhip effect on the decisions of all parties in the supply chain, and introduces a new algorithm to improve the total profit of all retailers.	The models introduced and other new concepts such as product fill rates make the models somewhat complex. Decision makers are unable to make quick decisions.
[17]	Buyer-supplier relationships and firm performance in the fast moving consumer goods retail industry	2018	Okoumba Mafini	The article illustrates in great detail the positive impact that increased cooperation and trust between buyers and sellers in the FMCG industry can have on improving performance.	In the article, the authors make quantitative assumptions to test the conjecture that close upstream and downstream partnerships can influence company performance. However, there is no mention of how this conclusion can be more fully exploited at a particular point in the process.

Table 4.3. Advantages and disadvantages of from literature [18] to [20]

No.	Title	Year	Authors	Advantages	Disadvantages
[18]	Influence of Information Quality on Retailer Satisfaction through Supply Chain Flexibility and Supplier Relationship Management in the Retail Industry	2020	Putra Jiwa Siagian	The article clearly identifies the advantages and disadvantages that information contribution brings to the supply chain. More complete information sharing can enhance the connection between distributors and retailers. It can also increase satisfaction.	The article focuses on the relationship between the upstream and downstream of the supply chain and does not address the issue of model allocation of products.
[19]	Research on Supplier Collaboration of Daily Consumer Goods under Uncertainty of Supply and Demand	2021	Song Zhang Ran Ran	The author does a good job of focusing on a number of points of current concern within the industry, such as horizontal cooperation and increasing overall profits. New methods of distribution are explored on this basis.	The model uses a decentralised decision-making approach.
[20]	Profit maximizing coalitions with shared capacities in distribution networks	2021	Jouida Guajardo Klibi Krichen	The paper explores all three of the most common allocation methods currently used in supply chains. In addition to maximising profits, deep cooperation between companies is pursued at the same time. The concept of modern supply chain management is well represented.	The main aim of the project is to maximise profits by controlling costs.

Overall, in all of the literatures above, researchers have spent a lot of time trying to prove or optimise one aspect of the allocation mechanism. For example, the importance of incentives, the advantages and disadvantages of punishment and the importance of complete information sharing. However, there is not a quantitative allocation model that would allow managers to make quick decisions. It must consider the trends and characteristics of the supply chain in recent years. There is also a need for clarity of purpose.

Compared with previous research, the model in this project is simpler and easier to see the impacts of different parameters and to quantify and include previously different dimensions in one way.

5. Methodology

This project is accomplished through these following steps.

- **Review materials.** To define what to do exactly with the project, I reviewed two types of materials. The first is the previous work of business models in FMCG supply chain. The second are the slides and notes during the whole master course. When I read them, I also wrote some important thinking which may be used in next steps about the topic.

- **Choose two optional basic models as reference.** From the previous step, a summary of state of the art could be done. Therefore, what the project is going to finish was clearer. Based on previous literatures and new thinking, I used 2 basic logical to build new models. Both of them are only basic models. They had not been validated at all.

- **Decide to use one logical to develop.** After talking with my supervisor several times, one of the basic models cannot be develop. Because it is too complex and covers content that goes beyond the master's programme. So, the other basic model was finally used to develop. Also, during this period, some explanation of the details in the model had been written as context.

- **Convert all written work and idea into the software.** As you can see in the following sections, this project is mainly calculated by excel. The model should be validated by the solver function until it works. At this step, I transferred all work before into a sheet. It is the basic before a mathematical model.

- **Adjust the mathematical model until it runs correctly**. In previous steps, there was only a basic model which has not been linearised. Also, it cannot be automatically solved by computer. Therefore, it must be adjusted. The details are going to be explained in the following section 6. A correct mathematical model should be able to be solved for all reasonable ranges of values. This process took a lot of time. The software was constantly making errors. It always indicated that it could not find a solution or provided very strange figures. This was not what I had expected at the beginning. There were various problems with the process, such as several terms in the model were not being linearised, there was a loop in the run and not being solved. Or the computer would run for more than 10 minutes. A solution appeared that did not make sense at all. It finally ran successfully.

- **Write steps and the result of building the mathematical model as a text.** After the software ran correctly, the writing of this part of the report should be done first. Because the work that follows will require a lot of repetition. So, before that step, previous work of basic paperwork and software need to be written as an official report. This part of report also serves as a cross-reference when questions arise about subsequent work.

- **Validate the model**. To validate a mathematical model, it requires passing a large number of validations. This step is one of the most time-consuming steps of the entire project. For commercial reasons, some of the actual figures could not be used directly. So, I kept trying to find references to adjust the numbers for validating the model and to interpret them as much as possible. The results of the validation were also reasonable. Sensitivity analysis is also required in this process. The calculation steps are repeated to analyse the impact of different parameter changes on the model. I probably repeated the calculation steps several hundred times throughout this process. I recorded these results for better presentation in the report.

- **Fulfil the report**. This was a very long process. As it mentioned in previous steps,I started by writing the two most important sections, section 6 and section 7 into report form first. Then I slowly tried to write from scratch, including the important sections of preface, introduction, and state of the art. Finally, I left some of the summaries for later. Finally, the initial report is completed. It needs to be revised several more times until every word is appropriate. Except this, the format is also something that needs to be considered.

After going through all these steps, the whole project is finally completed.

Details can be illustrated in Fig.5.1. as a Gantt chart.

No	Task/week	Inicial	Final	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23	Week 24	Week 25
1	Research work	2021/2/22	2021/3/19																									
2	Review notes about quantitative models in supply chain management	2021/2/22	2021/3/15																									
3	Research previous papers of similar topics	2021/2/22	2021/3/19																									
4	Define the title of the project	2021/3/15	2021/3/19																									
5	Building the model	2021/8/2	2022/2/14																									
6	Choose two optional of basic models as reference	2021/8/2	2021/8/13																									
7	Explore the possibilities of different models to finalise a logic to develop	2021/8/16	2021/8/27																									
8	Define the basic model	2022/1/17	2022/1/28																									
9	Linerise the basic model	2022/2/1	2022/2/10																									
10	Define the mathmatical model	2022/2/7	2022/2/14																									
11	Numerical study	2022/2/21	2022/3/24																									
12	Determine parameter values	2022/2/21	2022/2/18																									
13	Validate the model in different situations	2022/2/18	2022/3/4																									
14	Repeat the software to complete the sensitivity analysis section by varying the parameters	2022/3/4	2022/3/24																									
15	Fulfil the report	2022/2/14	2022/4/28																									
16	Write sections on the process of building the basic and mathematical model	2022/2/14	2022/2/18																									
17	Write up the sensitivity analysis as a report	2022/3/14	2022/3/25																									
18	Modify important issues in sections of building models and validation	2022/3/28	2022/4/8																									
19	Write other parts of the report	2022/4/8	2022/4/15																									
20	Restructure of the entire report	2022/4/18	2022/4/22																									
21	Modify details, including fonts, formatting, graphics, images, etc.	2022/4/18	2022/4/28																									

Fig. 5. 1. Gantt chart of the project

6. Model Building

In this chapter, the process of mathematical model building is presented. In 6.1., a basic model will be built. Items in the basic model will also be explained. It includes the profit of distributors, the profit of the manufacturer and total profit of this segment. In 6.2., some items in 6.1. will be linearized. In 6.3, a linear mathematical model is defined which includes the data, variables, the objective function, and constraints.

6.1. Basic model

6.1.1. Profit of distributors

Based on the literature [5], the basic allocation rule is determined. According to the regular process, before the manufacture makes the assignment, each distributor first proposes its FCST. The distributors are named as D. There are n distributors. Therefore distributor i is named as $D_i(i = 1, \ldots\ldots, n)$.

Corresponding to the process, before the allocation starts, each distributor reports its FCST to the manufacturer. FCST of D_i $(i = 1, \ldots\ldots, n)$ is F_i $(i = 1, \ldots\ldots, n)$. Each distributor can propose any estimated amount according to their own method. The minimum value is 0. Because the estimated sales of a SKU must be a non-negative number. And it can have no maximum value.

To observe the sales dashboard better, the manufacturer transforms the group of D_i $(i = 1, \ldots\ldots, n)$ into a group of data within a certain range. When it has all FCST value, there is the sum. At this point each distributor has a proportion of its own estimated sales to the total which is within the closed interval [0,1]. This proportion is known as β_i $(i = 1, \ldots\ldots, n)$. β_i $(\mathrm{i} = 1, \ldots\ldots, n)$ is calculated as follows:

$$\beta_i = F_i / \sum_{i=1}^{n} F_i \ (i = 1, \ldots\ldots, n) \qquad (1)$$

According to the formula (1), β_i $(i = 1, \ldots\ldots, n)$ could be any value higher or equal than 0 and lower or equal than 1. For better programming in the model, we use β_i $(i = 1, \ldots\ldots, n)$ instead of F_i $(i = 1, \ldots\ldots, n)$ as variables. It means the final allocated ratio of one certain FG for D_i $(i = 1, \ldots\ldots, n)$ by the manufacturer.

The manufacturer has its production plan in a period. The productivity for one SKU in one period is defined as q in the model. Based on the ratios and the productivity, we can obtain each distributor's actual allocated quantity of FG.

It equals to $\beta_i \cdot q\ (i = 1, \ldots\ldots, n)$. It may not be an integer. It will be linearized in 6.3..

In addition to the rule, the model introduces a parameter u which means the unit unfinished sales penalty for distributor $i\ (i = 1, \ldots\ldots, n)$ to restrict distributors compares with its actual FG sales capacity. It is determined as $q_i\ (i = 1, \ldots\ldots, n)$ for distributor $i\ (i = 1, \ldots\ldots, n)$

There are two scenarios that this item exists as below.

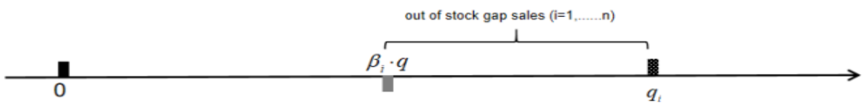

Fig.6.1. gap sales when q_i is more than $\beta_i \cdot q\,(i = 1, \ldots\ldots, n)$

As it shows in Fig.6.1., when $q_i\ (i = 1, \ldots\ldots, n)$ is more than $\beta_i \cdot q\ (i = 1, \ldots\ldots, n)$, the POS would appear some days of OOS (Out of Stock) condition. Under this situation, the final sales from distributor$i\ (i = 1, \ldots\ldots, n)$ to consumers is $\beta_i \cdot q\ (i = 1, \ldots\ldots, n)$. And the gaps sales are $q_i - \beta_i \cdot q\ (i = 1, \ldots\ldots, n)$.

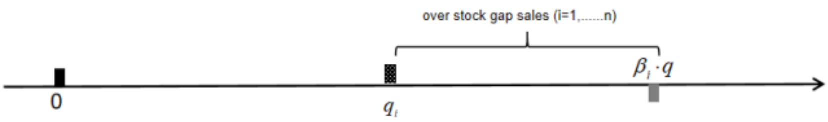

Fig.6.2. gap sales when q_i is less than $\beta_i \cdot q\,(i = 1, \ldots\ldots, n)$

Similarly, as it shows in Fig.6.2., when $\beta_i \cdot q(i = 1, \ldots\ldots, n)$ is more than $q_i\ (i = 1, \ldots\ldots, n)$, the sales quantity to consumers is $q_i(i = 1, \ldots\ldots, n)$. And the gap sales here is $\beta_i \cdot q - q_i\ (i = 1, \ldots\ldots, n)$.

To put it more simply in the model, the final sales of distributor i in a certain period can be combined as $\min(\beta_i \cdot q, q_i)\ (i = 1, \ldots\ldots, n)$. Meanwhile, the gaps can be combined as $|\beta_i \cdot q - q_i|\ (i = 1, \ldots\ldots, n)$.

The unit retail price is determined as R. So, the revenue for distributor i is unit retail price multiplied by its actual sales. It equals $R \cdot \min(\beta_i \cdot q, q_i)(i = 1, \ldots\ldots, n)$. Also, the penalty based on the gap sales is $u \cdot |\beta_i \cdot q - q_i|\ (i = 1, \ldots\ldots, n)$. They also need to be linearized later.

ETSEIB

Except the penalty, there are some other costs for distributor $i\ (i = 1,\ldots\ldots,n)$.

- **Purchasing cost of FG for distributor i $\beta_i \cdot q \cdot p\ (i = 1,\ldots\ldots,n)$.** Distributors purchase large amount of FG from the manufacturer with a price p.It is lower than the unit retail price. When it multiplied by the allocated quantity, we can obtain the total purchasing cost for distributor $i\ (i = 1,\ldots\ldots,n)$.

- **Total unit cost for distributor i $\beta_i \cdot q \cdot C_i\ (i = 1,\ldots\ldots,n)$.** C_i is the expense of unit FG such as stock cost, etc. The total unit cost is allocated quantity multiplied by unit cost.

- **Fixed cost for distributor i $FC_i\ (i = 1,\ldots\ldots,n)$.** It includes some fixed cost. For example, the rent fee and human resource salary, etc.

- **Launch cost CL.** It is an expense with each order paid by distributors. Each distributor pays once in the formula.

Combined all items above, the profit Π of distributor $i\ (i = 1,\ldots\ldots,n)$ Π_{D_i} can be written as:

$$\Pi_{D_i} = R \cdot min(\beta_i \cdot q, q_i) - \beta_i \cdot q \cdot p - \beta_i \cdot q \cdot C_i - u \cdot |q_i - \beta_i \cdot q| - FC_i - CL \quad (2)$$

6.1.2. Profit of the manufacturer

Corresponding to the situation in Fig. 6.2. above in 6.1.3, when the actual sale of POS is more than the allocated amount, not only the distributors will face the cost of gap sales, but the manufacturer will also take a cost of opportunity sales loss. Since in the process, the manufacturer stands a stronger position, it should also take the responsibility. Another parameter O is necessary. It is a unit cost when an FG could be sold but actually not. Due to lack of stock. For distributor $i\ (i = 1,\ldots\ldots,n)$, its opportunity sales loss amount is $max(q_i - \beta_i \cdot q, 0)\ (i = 1,\ldots\ldots,n)$.It means when all allocated FG are not sold out, the penalty is 0. Because at this time distributor $i\ (i = 1,\ldots\ldots,n)$ does not have any potential sales. In contrast, when it sells all commodities in advance, there would be some days that faced with OOS. At this point in the process, the number of potential sales it lost is its sales capacity minus its actual sales.

The accumulated amount of all distributors can be simplified to $\sum_{i=1}^{n} max(q_i - \beta_i \cdot q, 0)\ (i = 1,\ldots\ldots,n)$. When it multiplied by the unit expense, we can obtain the total opportunity sales loss for the manufacturer. It is $O \cdot \sum_{i=1}^{n} max(q_i - \beta_i \cdot q, 0)\ (i = 1,\ldots\ldots,n)$.

Likewise, we list the income and other expenses for the manufacturer.

- **Sell in revenue $q \cdot p$.** According to the principal allocation rule above, the manufacturer sold all FG to different distributors. The purchasing price is equal to wholesale price which is p. When it multiplied by total amount q, there is the whole sale revenue $q \cdot p$ of all distributors in this period.

- **Total manufacturer expense $q \cdot CM$.** There is a unit manufacturer cost CM which includes the raw material fee, electricity and so on. It should be multiplied by total manufacture quantity q. The result is the manufacturer's expense.
- **Fixed cost FCM**. It includes depreciation fee of equipment, rent fee of a factory, etc.

Combined with the items above, the profit for the manufacturer M Π_M is:

$$\Pi_M = q \cdot p - q \cdot CM - FCM - O \cdot \sum_{i=1}^{n} max(\, q_i - \beta_i \cdot q, 0) \qquad (3)$$

6.1.3. Basic model of distributors and the manufacturer

Based on formula (2) and (3), there is the profit total Π is sum of Π_{D_i} $(i = 1, \ldots\ldots, n)$ and Π_M. It is

$$\Pi = \Pi_M + \sum_{i=1}^{n} \Pi_{D_i} \qquad (4)$$

The data, variables, objective function, and constraints are as below. After it has been simplified, there is:

- **Data**

n number of distributors

D_i distributor i $(i = 1, \ldots\ldots, n)$

R unit retail price of FG from a shop to consumers

q total market demand of FG in one period

p unit purchasing price of FG for all distributors from the manufacturer

M the manufacturer

q_i actual sales of distributor i $(i = 1, \ldots\ldots, n)$

C_i unit cost of distributor i $(i = 1, \ldots\ldots, n)$

u unit penalty of unfinished sales between a_i and q_i $(i = 1, \ldots\ldots, n)$

FC_i fixed cost of distributor i $(i = 1, \ldots\ldots, n)$

CL launch cost of each order paid by distributors

CM unit cost of FG for manufacturer

FCM fixed cost of the manufacturer in a certain period

O unit opportunity sales loss for the manufacturer

- **Variables**

β_i FCST proportion of distributor i $(i = 1, \ldots\ldots, n)$

- **Objective function**

$$[MAX]\Pi = q \cdot (p - C_M) - FCM - O \cdot \sum_{i=1}^{n} max(q_i - \beta_i \cdot q, 0) + R \cdot \sum_{i=1}^{n} min(\beta_i \cdot q, q_i) - \sum_{i=1}^{n} \beta_i \cdot q \cdot (p + C_i) - u \cdot \sum_{i=1}^{n} |q_i - \beta_i \cdot q| - \sum_{i=1}^{n} FC_i - n \cdot CL \tag{5}$$

- **Constraints**

$\sum_{i=1}^{n} \beta_i = 1 \quad (i = 1, \ldots\ldots, n)$

$0 \leq \beta_i \leq 1 \quad (i = 1, \ldots\ldots, n)$ (LM1)

6.2. Linearization of the model

As it mentioned in 6.1., some items in the basic model need to be linearized.

- $\beta_i \cdot q \ (i = 1, \ldots\ldots, n)$

Depends on the description in 6.1.1, $\beta_i \ (i = 1, \ldots\ldots, n)$ can be any value between [0,1]. When there are many decimal places after the decimal point, the $\beta_i \cdot q \ (i = 1, \ldots\ldots, n)$ would also not be an integer. However, the product can only appear as a whole number. Therefore, it needs to be transformed first.

Set a new variable $a_i \ (i = 1, \ldots\ldots, n)$. It has the same with $\beta_i \cdot q \ (i = 1, \ldots\ldots, n)$: the actual allocated amount of distributor $i \ (i = 1, \ldots\ldots, n)$. There are some constraints for $a_i \ (i = 1, \ldots\ldots, n)$:

$a_i \leq \beta_i \cdot q + 0.5 \qquad (i = 1, \ldots\ldots, n)$

$a_i \geq \beta_i \cdot q - 0.5 + \varepsilon \qquad (i = 1, \ldots\ldots, n)$

a_i, int $(i = 1, \ldots\ldots, n)$ (LM2)

- $min(\beta_i \cdot q, q_i)$ $(i = 1, \ldots\ldots, n)$

The function max should also be linearized. Before it is transformed, it can be changed as $min(a_i, q_i)$ $(i = 1, \ldots\ldots, n)$ first. Set a new variable S_i $(i = 1, \ldots\ldots, n)$ which means sales quantity of distributor i $(i = 1, \ldots\ldots, n)$ final to consumers. There are the constraints for it as below:

$S_i \leq a_i$ $(i = 1, \ldots\ldots, n)$

$S_i \leq q_i$ $(i = 1, \ldots\ldots, n)$ (LM3)

- $[MAX] \ldots\ldots -|q_i - \beta_i \cdot q| \ldots\ldots$ $(i = 1, \ldots\ldots, n)$

The item of absolute value can be changed as $\max(q_i - a_i, a_i - q_i)$ $(i = 1, \ldots\ldots, n)$ first. It can be transformed as a new variable X_i $(i = 1, \ldots\ldots, n)$. Its constraints are:

$X_i \geq a_i$ $(i = 1, \ldots\ldots, n)$

$X_i \geq q_i$ $(i = 1, \ldots\ldots, n)$ (LM4)

- $[MAX]$.......-$\max(q_i - \beta_i \cdot q, 0) \ldots \ldots$ $(i = 1, \ldots\ldots, n)$

The objective function is to maximize the total profit. For easier programming, we set it as z_i $(i = 1, \ldots\ldots, n)$. Similarly,

$z_i \geq q_i - a_i$ $(i = 1, \ldots\ldots, n)$

$z_i \geq 0$ $(i = 1, \ldots\ldots, n)$ (LM5)

6.3. Mathematical model

Based on all propose above, there is the mathematical model as below.

- **Data**

n number of distributors

D_i distributor i $(i = 1, \ldots\ldots, n)$

R (u. m / u. p) unit retail price of FG from a shop to consumers

q (u. p) total market demand of FG in one period

p (u. m / u. p) unit purchasing price of FG for all distributors from the manufacturer

M the manufacturer

q_i (u. p) actual sales of distributor i $(i = 1, \dots\dots, n)$

C_i (u. m / u. p) unit cost of distributor i $(i = 1, \dots\dots, n)$

u (u. m / u. p) unit penalty of unfinished sales between a_i and q_i $(i = 1, \dots\dots, n)$

FC_i (u. m / u. p) fixed cost of distributor i $(i = 1, \dots\dots, n)$

CL (u. m) launch cost of each order paid by distributors

CM (u. m) unit cost of FG for manufacturer

FCM (u. m) fixed cost of the manufacturer in a certain period

O (u. m / u. p) unit opportunity sales loss for the manufacturer

- **Variables**

β_i FCST proportion of distributor i $(i = 1, \dots\dots, n)$

a_i (u. p) actual allocated amount of FG for distributor i based on its proportion $(i = 1, \dots\dots, n)$

S_i (u. p) sales quantity from the shop to customers for distributor i $(i = 1, \dots\dots, n)$

X_i (u. p) quantity of gap sales for distributor i between a_i and q_i i $(i = 1, \dots\dots, n)$

z_i (u. p) opportunity sales loss quantity of distributor i $(i = 1, \dots\dots, n)$

- **Objective function**

$$[MAX]\Pi = R \cdot \sum_{i=1}^{n} a_i - u \cdot \sum_{i=1}^{n} X_i - \sum_{i=1}^{n} a_i \cdot (p + C_i) - \sum_{i=1}^{n} FC_i - n \cdot CL + q \cdot p - q \cdot CM - FCM - O \cdot \sum_{i=1}^{n} z_i \quad (6)$$

- **Constraints**

$$\sum_{i=1}^{n} \beta_i = 1 \qquad (i = 1, \dots\dots, n)$$

$\beta_i \geq 0 \qquad (i = 1, \ldots\ldots, n)$

$\beta_i \leq 1 \qquad (i = 1, \ldots\ldots, n)$ (LM1)

$a_i \leq \beta_i \cdot q + 0.5 \qquad (i = 1, \ldots\ldots, n)$

$a_i \geq \beta_i \cdot q - 0.5 + \varepsilon \qquad (i = 1, \ldots\ldots, n)$

$a_i, int \qquad (i = 1, \ldots\ldots, n)$ (LM2)

$S_i \leq a_i \qquad (i = 1, \ldots\ldots, n)$

$S_i \leq q_i \qquad (i = 1, \ldots\ldots, n)$ (LM3)

$X_i \geq q_i - a_i \qquad (i = 1, \ldots\ldots, n)$

$X_i \geq a_i - q_i \qquad (i = 1, \ldots\ldots, n)$ (LM4)

$z_i \geq q_i - a_i \qquad (i = 1, \ldots\ldots, n)$

$z_i \geq 0 \qquad (i = 1, \ldots\ldots, n)$ (LM5)

7. Validation

In this section, we use some data to validate if there is a best solution of the model theoretically under three scenarios as below:

- $\sum_{i=1}^{n} q_i = q \ (i = 1, \ldots\ldots, n)$. It means sum of all distributors' sales capacity equals the manufacturer's production.
- $\sum_{i=1}^{n} q_i < q \ (i = 1, \ldots\ldots, n)$. It means sum of all distributors' sales capacity less than the manufacturer's production.
- $\sum_{i=1}^{n} q_i > q \ (i = 1, \ldots\ldots, n)$. It means sum of all distributors' sales capacity more than the manufacturer's production.

The number of distributors n can be any integer higher than or equal to 2. The allocation problem only makes sense if it is higher than 1. In this section, the solver function in Excel will be used for simulation. Its maximum parameters and constraints are 100. Therefore, n will be validated separately by taking a lower and a higher value. For better observation, n = 2 will be the lower one. It is also the lowest value for n. For the higher value, it is a higher value that can satisfy less than 100 constraints. Here we take n = 15.

As opposed to section 2 and section 6. Some parameters are subjected to sensitivity analysis:

- Sales capacity. In the model distributors' sales capacity are $q_i \ (i = 1 \ldots, n)$.
- Profitability. A same unit FG at different distributors brings different profits to the supply chain. In the mathematical model, the profitability relates to $C_i \ (i = 1 \ldots, n)$.
- Penalty of OS. Over stock FG represents a SKU does not flow quickly in the market. In the model it is u.
- Opportunity sales loss of OOS. As it mentioned above, unit opportunity sales loss is also important. In the model, it is O.

The data in the follow numerical simulation is not market figure due to commercial privacy protection. It is only for theoretical proof.

7.1. When $n = 2$

The number of distributors n can be very small. Let it be equal to 2 first.

7.1.1. Input parameters

We take a product as a reference to determine the values of some parameters.

As mentioned in section 3, FMCG products are generally common products with low unit cost and fast consumption. Let it to be a lipstick for an example. Its retail price of 20 (u. p). Meanwhile, the sell in price of a typical cosmetic product is about 70% of its retail price. So, its sell in price is 14 (u. p). And the unit cost price is about 30-40% of the retail price. In the validation below, it is defined as 35% of it. This means that the unit cost of production per unit of FG is 7 (u. p).

The unit costs of the two distributors are defined by them respectively. We set a range for it. It is greater than 0 and not higher than the net profit per unit of product. Within this range we take two random numbers.

Similarly, the specific unit penalty for sales gap and lost opportunity sales are defined by the manufacturer. They are greater than 0 and do not exceed the actual profit per unit of the product. Here, we take two random numbers also.

In addition to this, the value of the launch cost is set to a smaller value: 100 (u. m / launch). This cost is paid for by the distributor. The fixed cost of the manufacturer and two distributors are defined by themselves.

For observation purposes, we take a simple but larger integer for the manufacturer's capacity q. In fact, it can be any positive integer.

The exact values of some parameters are shown in Table 7. 1..

Table 7.1. Value of some parameters when $n = 2$

q	10,000 *(u. p)*		
R	20 *(u. m / u. p)*		
p	14 *(u. m / u. p)*		
CM	7 *(u. m / u. p)*		
O	2.93 *(u. m / u. p)*		
FCM	5,000 *(u. p)*		
CL	100 *(u. m / launch)*		
n	2		
u	1.56 *(u. m / u. p)*		
C_1	2.2 *(u. m / u. p)*	C_2	1.9 *(u. m / u. p)*
FC_1	1,000 *(u. m)*	FC_2	1,500 *(u. m)*

There still exists some missing data. As it described above, the sales capacities of two distributors are discussed in three cases. The solver function in Excel software will be applied in this section. It is used to calculate the optimal solution of the linear programming automatically.

Put all the parameters, variables and equations that appear in section 6 in a collated format in an Excel table, as shown in Figure 7.1 below.

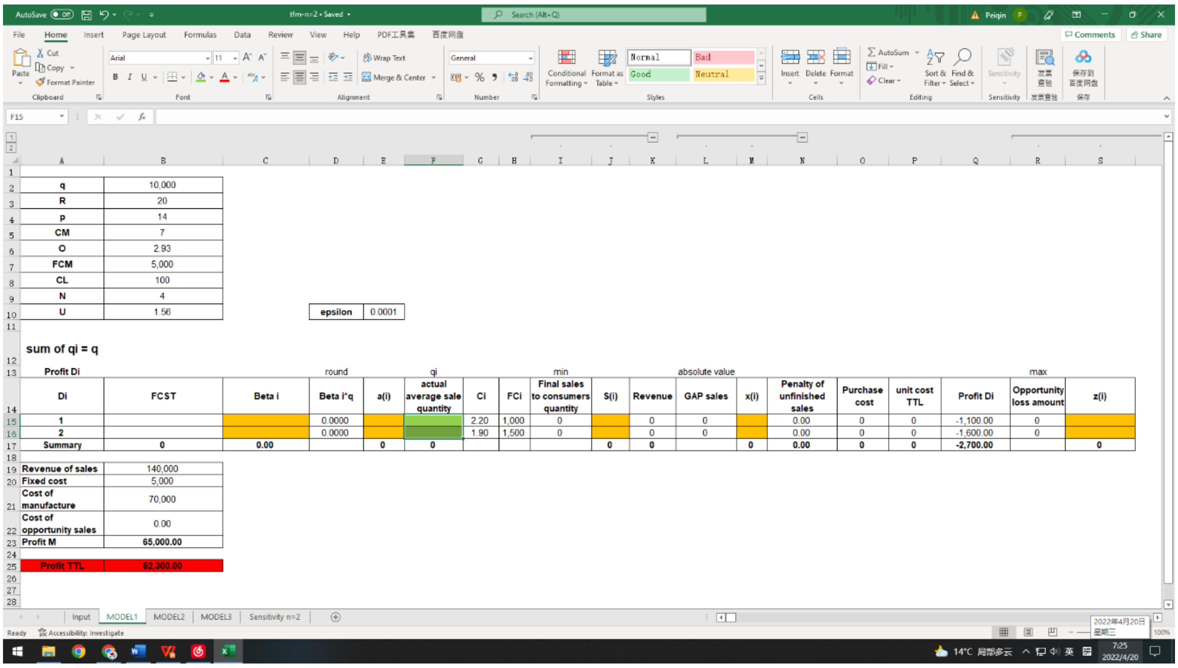

Fig. 7. 1. When $n = 2$ Excel screenshot

In the diagram, the yellow cells are variables. Column C is β_i $(i = 1 \ldots, n)$. Column E is the actual amount of each distributor allocated after rounding values in column C. Column J is the final amount of each distributor's sales. Column M is the number of each distributor's sales gap. Column S is the number of opportunity sales loss by each of them.

Column F, marked green in the graph, is each distributor's sales capacity which is not quantified above in Figure 7. 1.. It will be discussed in the following sections with details.

The target cell is B25. It's the sum of distributors and manufacturer's profit.

Constraints are also necessary. The screenshot is shown in Figure 7.2. as below.

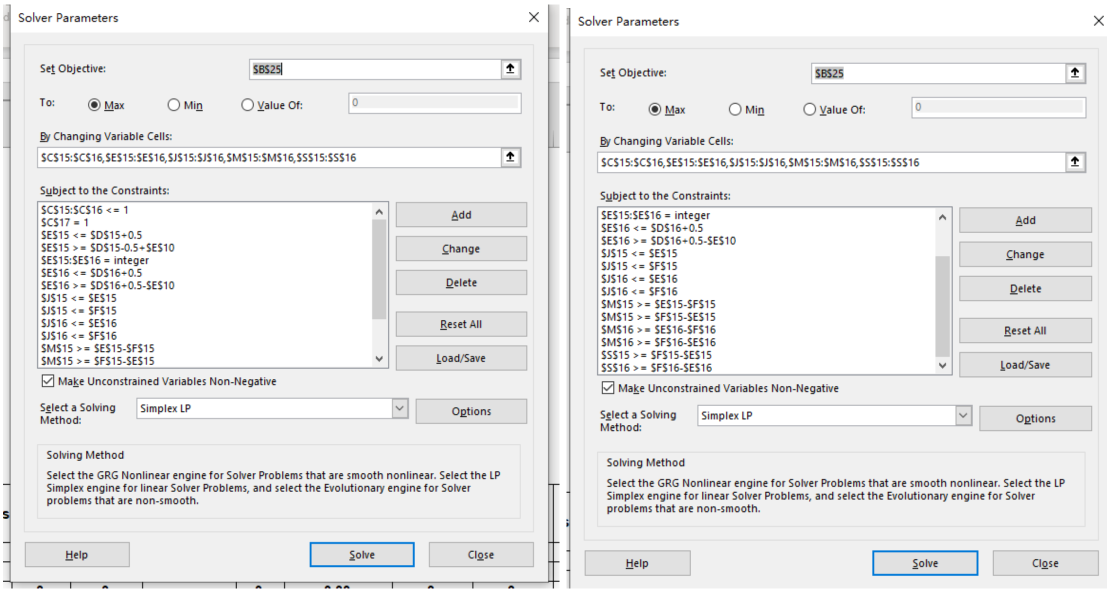

Fig. 7. 2. When $n = 2$ constraints screenshot

The software needs to calculate whether there has a maximum value and what is it.

When $n = 2$ there are 10 variables and 17 constraints. The system takes about 1 second to calculate the solution.

7.1.2. Results

- Scenario 1: $q_1 + q_2 = q$

The manufacturer has a production q of 10,000 (u. p). Under this condition that the sum of the sales capacity is equal to the production, q_1, q_2 can be any positive integer. Here, we randomly take $q_1 = 6{,}500$ (u. p), $q_2 = 3{,}500$ (u. p).

After software calculations, there is only one solution. It is:

$\beta_1 = 0.65005, \beta_2$ =0.34995

$a_1 = 6500, a_2 = 3500$

$S_1 = 6500, S_2 = 3500$

$X_1 = 0, X_2 = 0$

$z_1 = 0, z_2 = 0$

The solution means that in this scenario of sum of all distributors' sales capacity equals the manufacturer's production, there is an only optimal solution. The best allocation quota for D_1 is 0.65005, for D_2 is 0.34995. After rounding calculations based on the system's multiplication of the quota by the productivity, amounts of products allocated to the two distributors are 6,500 (u. p) and 3,500 (u. p). Currently, final sales to consumers are 6,500 (u. p), 3,500 (u. p) respectively. There is no gap sales or opportunity sales loss at this point.

The profit for D_1 is 23,600 (u. m), for D_2 is 12,750 (u. m) and for the manufacturer is 65,000 (u. m). Sum of them equals 101,350 (u. m).

This solution is the most profitable.

- Scenario 2: $q_1 + q_2 < q$

In the same way as in the above case, most of the parameter values are retained. Sales capacity for D_1 is 5250 (u. p), for D_2 is 3500 (u. p). These two parameters can also be any positive integer that adds up to lower than 10,000.

Change the two parameters setting in the table. Repeat same operations in the software. At this point, there is still a best solution. It is

$\beta_1 = 0.52505$, β_2 =0.47495

$a_1 = 5250, a_2 = 4750$

$S_1 = 5250, S_2 = 3500$

$X_1 = 0, X_2 = 1250$

$z_1 = 0, z_2 = 0$

The solution means that when the sum of sales capacity lower than the production capacity, the best allocation quota for D_1 is 0.65005, for D_2 is 0.34995. After rounding calculations based on the system's multiplication of the quota by the productivity, amounts of products allocated to the two distributors are 5,250 (u. p) and 4,750 (u. p). At this time, final sales to consumers are 5,250 (u. p), 3,500 (u. p) respectively.

Differs from scenario 1, there are 1,250 (u. p) FG left for D_2. They are OS (Over stock) of this sales period. D_2 need to bear the appropriate penalties. It is 1,948.44 (u. m).

In fact, the OS part can be allocated to any of the distributors. But the result of the objective function would not be changed in this scenario. Therefore, this state can be described as a Nash equilibrium.

Profit of distributors equals 9,792.46 (u. m). That of the manufacturer equals 65,000 (u. m). Sum of them which is the total should be reduced by the OS penalty 1,948.44 (u. m). The result is 74,792.46 (u. m).

- Scenario 3: $q_1 + q_2 > q$

Another scenario is $q_1 + q_2 > q$. As in both cases above, $q_1$and q_2 can also be any positive integer that adds up to higher than 10,000. We set $q_1 = 5780$ (u. p), $q_2 = 5720$ (u. p).

Repeat the operations, there is only one best solution. It is:

$\beta_1 = 0.42805$, β_2 =0.57195

$a_1 = 4280, a_2 = 5720$

$S_1 = 4280, S_2 = 5720$

$X_1 = 1500, X_2 = 0$

$z_1 = 1500, z_2 = 0$

The solution means that when the sum of sales capacity lower than the production capacity, the best allocation quota for D_1 is 0.42805, for D_2 is 0.57195. After rounding calculations based on the system's multiplication of the quota by the productivity, amounts of products allocated to the two distributors are 4,280 (u. p) and 5,720 (u. p). Currently, final sales to consumers are 4,280 (u. p) and 5,720 (u. p) respectively. All allocated sales can be finally sold to customers.

However, a part of the market demand cannot be met. In the situation of OOS (Out of Stock), both the distributors and the manufacturer should bear the corresponding penalties. In this scenario, D_1 pays 2,338.44 (u. m) for the gap sales. And the manufacturer pays 1,798.80 (u. m) for opportunity sale loss.

The final profit is 97,882.56 (u. m).

Put three solutions under different scenarios in table 7. 2..

Table 7.2. Results in different scenarios

	$q_1 + q_2 = q$ $q_1 = 6{,}500$ $q_2 = 3{,}500$	$q_1 + q_2 < q$ $q_1 = 5{,}250$ $q_2 = 4{,}750$	$q_1 + q_2 > q$ $q_1 = 5780$ $q_2 = 5720$
β_1	0.65005	0.52505	0.428050
β_2	0.34995	0.47495	0.571950
a_1 (u. p)	6,500	5,250	4,280
a_2 (u. p)	3,500	4,750	5,720
S_1 (u. p)	6,500	5,250	4,280
S_2 (u. p)	3,500	3,500	5,720
X_1 (u. p)	0	0	1,500
X_2 (u. p)	0	1,250	0
z_1 (u. p)	0	0	1,500
z_2 (u. p)	0	0	0
Profit D_1 (u. m)	23,600.00	18,850.00	12,829.36
Profit D_2 (u. m)	12,750.00	-9,057.54	21,852.00
Profit manufacturer (u. m)	65,000.00	65,000.00	65,000.00
Profit Total (u. m)	101,350.00	74,792.46	97,882.56

From the table we can obtain when $n = 2$:

- There is a best solution whether sales capacity is high or low.
- When sum of sales capacity equals productivity, both the manufacturer and distributors do not need to pay for OS or OOS. Meanwhile, the final profit is the highest.
- When there is an OS situation, the loss for profit is higher. This is because both the final sale of distributors is reduced and there are additional expenses.
- The profit of the manufacturer would not be influenced.

The details of which relate to sensitivity analysis. It will be explained at the end of this section.

7.2. When $n = 15$

To further prove the results in 7.1, n will be changed to a larger number in this section. At this point n = 15. It can avoid the serendipity that may occur in 7.1.

7.2.1. Input parameters

The exact values of the parameters are shown in Table 7. 3. as below.

Table 7.3. Value of parameters when $n = 15$

q		150,000 (u. p)	
R		20 (u. m / u. p)	
p		14 (u. m / u. p)	
CM		7 (u. m / u. p)	
o		2.93 (u. m / u. p)	
FCM		5,000 (u. m)	
CL		100 (u. m / launch)	
n		15	
u		1.56 (u. m / u. p)	
C_1	1.05 (u. m / u. p)	FC_1	2,919 (u. m)
C_2	3.20 (u. m / u. p)	FC_2	4,064 (u. m)
C_3	3.36 (u. m / u. p)	FC_3	2,551 (u. m)
C_4	3.21 (u. m / u. p)	FC_4	4,654 (u. m)
C_5	0.01 (u. m / u. p)	FC_5	2,941 (u. m)
C_6	0.99 (u. m / u. p)	FC_6	3,263 (u. m)
C_7	2.74 (u. m / u. p)	FC_7	2,303 (u. m)
C_8	2.00 (u. m / u. p)	FC_8	4,635 (u. m)
C_9	0.97 (u. m / u. p)	FC_9	3,664 (u. m)
C_{10}	2.54 (u. m / u. p)	FC_{10}	2,749 (u. m)
C_{11}	2.24 (u. m / u. p)	FC_{11}	1,424 (u. m)
C_{12}	1.15 (u. m / u. p)	FC_{12}	4,748 (u. m)
C_{13}	0.63 (u. m / u. p)	FC_{13}	936 (u. m)
C_{14}	2.76 (u. m / u. p)	FC_{14}	2,910 (u. m)
C_{15}	0.56 (u. m / u. p)	FC_{15}	1,634 (u. m)

Most of them are the same with those in Table 7. 1.. The manufacturer's productivity needs to be raised to a higher value for better simulation. It is 50,000 (u. p). Unit cost of each distributor and their fixed cost are random numbers.

Put all the variables, parameters, objective function, and constraints into Excel. The screen shot is shown in Figure 7. 3..

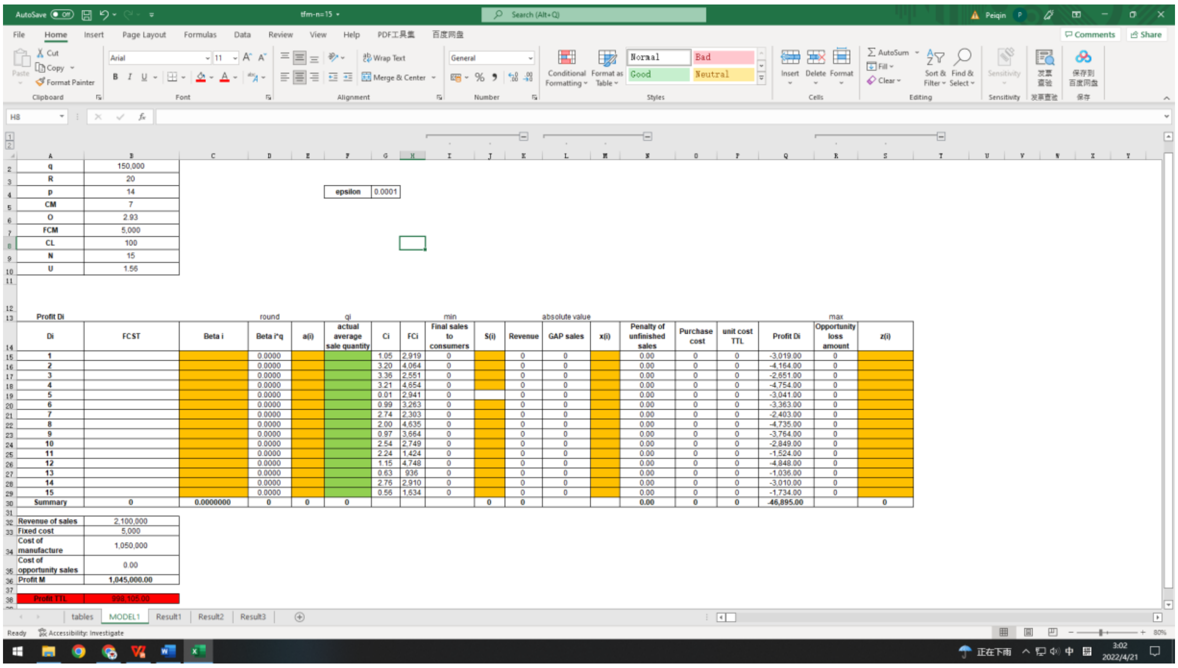

Fig. 7. 3. When n = 15 Excel screenshot

In the diagram, the yellow cells are variables. Column C is β_i $(i = 1 \ldots \ldots, 15)$. Column E is the actual amount of each distributor allocated after rounding values in column C. Column J is the final amount of each distributor's sales. Column M is the number of each distributor's sales gap. Column S is the number of opportunity sales loss by each of them.

Column F, marked green in the graph, is each distributor's sales capacity which is not quantified. It will be discussed in the following section.

The target cell is B38.

Due to significant increase numbers of variables, parameters, and constraints than that of $n = 2$, the system takes about 2 seconds each time to solve the problem.

With the above settings, the results will also be discussed in three different cases.

7.2.2. Results

- Scenario 1:$\sum_{i=1}^{n} q_i = q \ (i = 1 \ldots \ldots, 15)$

When sum of sales capacity equal to FG amount of the manufacturer. The random values of $q_i(i = 1 \ldots \ldots, 15)$ are as below in Table 7. 4..

Table 7.4. Sales capacity total equal to the productivity

(u. p)			
q_1	11,579	q_2	7,716
q_3	9,401	q_4	11,370
q_5	7,484	q_6	10,417
q_7	11,025	q_8	11,724
q_9	11,594	q_{10}	8,973
q_{11}	11,779	q_{12}	9,283
q_{13}	7,712	q_{14}	8,316
q_{15}	11,627		

After the solver function calculating, there is a unique optimal solution is as follows in Table 7. 5..

Table 7.5. The optimal solution when $\sum_{i=1}^{n} q_i = q \ (i = 1 \ldots \ldots, 15)$

β_1	0.07720	a_1	11,579	s_1	11,579	x_1	0	z_1	0
β_2	0.05144	a_2	7,716	s_2	7,716	x_2	0	z_2	0
β_3	0.06268	a_3	9,401	s_3	9,401	x_3	0	z_3	0
β_4	0.07580	a_4	11,370	s_4	11,370	x_4	0	z_4	0
β_5	0.04990	a_5	7,484	s_5	7,484	x_5	0	z_5	0
β_6	0.06945	a_6	10,417	s_6	10,417	x_6	0	z_6	0
β_7	0.07350	a_7	11,025	s_7	11,025	x_7	0	z_7	0
β_8	0.07816	a_8	11,724	s_8	11,724	x_8	0	z_8	0
β_9	0.07729	a_9	11,594	s_9	11,594	x_9	0	z_9	0
β_{10}	0.05982	a_{10}	8,973	s_{10}	8,973	x_{10}	0	z_{10}	0
β_{11}	0.07852	a_{11}	11,779	s_{11}	11,779	x_{11}	0	z_{11}	0
β_{12}	0.06188	a_{12}	9,283	s_{12}	9,283	x_{12}	0	z_{12}	0
β_{13}	0.05141	a_{13}	7,712	s_{13}	7,712	x_{13}	0	z_{13}	0
β_{14}	0.05544	a_{14}	8,316	s_{14}	8,316	x_{14}	0	z_{14}	0
β_{15}	0.07751	a_{15}	11,627	s_{15}	11,627	x_{15}	0	z_{15}	0

Profit of distributors and the manufacturer is 1,623,706.77 (u. m).

- Scenario 2: $\sum_{i=1}^{n} q_i < q \ (i = 1 \ldots \ldots, 15)$

The scenario of which total sales capacity of distributors is lower than manufacturer's production is also considered. Their specific values are shown below in Table 7. 6..

Table 7.6. Sales capacity when $\sum_{i=1}^{n} q_i < q \ (i = 1 \ldots \ldots, 15)$

(u. p)			
q_1	5,706	q_2	8,745
q_3	7,455	q_4	5,710
q_5	8,641	q_6	5,752
q_7	11,740	q_8	5,631
q_9	7,941	q_{10}	5,870
q_{11}	9,489	q_{12}	5,250
q_{13}	8,299	q_{14}	9,412
q_{15}	10,508		

Repeat the operation. The solution is shown as below in Table 7. 7.:

Table 7.7. The optimal solution when $\sum_{i=1}^{n} q_i < q \ (i = 1 \ldots \ldots, 15)$

β_1	0.03804	a_1	5,706	s_1	5,706	x_1	0	z_1	0
β_2	0.05830	a_2	8,745	s_2	8,745	x_2	0	z_2	0
β_3	0.04970	a_3	7,455	s_3	7,455	x_3	0	z_3	0
β_4	0.03807	a_4	5,710	s_4	5,710	x_4	0	z_4	0
β_5	0.28323	a_5	42,485	s_5	8,641	x_5	33,844	z_5	0
β_6	0.03835	a_6	5,752	s_6	5,752	x_6	0	z_6	0
β_7	0.07827	a_7	11,740	s_7	11,740	x_7	0	z_7	0
β_8	0.03754	a_8	5,631	s_8	5,631	x_8	0	z_8	0
β_9	0.05294	a_9	7,941	s_9	7,941	x_9	0	z_9	0
β_{10}	0.03914	a_{10}	5,870	s_{10}	5,870	x_{10}	0	z_{10}	0
β_{11}	0.06326	a_{11}	9,489	s_{11}	9,489	x_{11}	0	z_{11}	0
β_{12}	0.03500	a_{12}	5,250	s_{12}	5,250	x_{12}	0	z_{12}	0
β_{13}	0.05533	a_{13}	8,299	s_{13}	8,299	x_{13}	0	z_{13}	0
β_{14}	0.06275	a_{14}	9,412	s_{14}	9,412	x_{14}	0	z_{14}	0
β_{15}	0.07006	a_{15}	10,508	s_{15}	10,508	x_{15}	0	z_{15}	0

At this time, distributor 5 is allocated 42,485 (u. p). At the end of this sales period, there is

33,844 (u. p) left. So, it must pay for the OS. The profit at this point is 954,488.83 (u. m). In this case, the OS generated by the excess sales capacity is the same regardless of the distribution to any of them. Now the supply chain has reached a "Nash equilibrium" again.

- Scenario 3: $\sum_{i=1}^{n} q_i > q \quad (i = 1 \ldots, 15)$

There is another scenario. The sum of the distributor's sales capacity exceeds the manufacturer's capacity. A new variation occurs as a result. The values will be reset in Table 7.8.

Table 7.8. Sales capacity when $\sum_{i=1}^{n} q_i > q \quad (i = 1 \ldots, 15)$

(u. p)			
q_1	8,327	q_2	13,531
q_3	11,056	q_4	8,232
q_5	12,847	q_6	9,005
q_7	13,547	q_8	8,527
q_9	8,806	q_{10}	13,710
q_{11}	9,773	q_{12}	14,374
q_{13}	10,805	q_{14}	12,627
q_{15}	11,341		

After they are automatically calculated again, we can obtain the following solution in Table 7. 9..

Table 7.9. The optimal solution when $\sum_{i=1}^{n} q_i > q \quad (i = 1 \ldots, 15)$

β_1	0.05551	a_1	8,327	s_1	8,327	x_1	0	z_1	0
β_2	0.09020	a_2	13,531	s_2	13,531	x_2	0	z_2	0
β_3	0.00000	a_3	0	s_3	0	x_3	11,056	z_3	11,056
β_4	0.01858	a_4	2,787	s_4	2,787	x_4	5,445	z_4	5,445
β_5	0.08564	a_5	12,847	s_5	12,847	x_5	0	z_5	0
β_6	0.06003	a_6	9,005	s_6	9,005	x_6	0	z_6	0
β_7	0.09031	a_7	13,547	s_7	13,547	x_7	0	z_7	0
β_8	0.05684	a_8	8,527	s_8	8,527	x_8	0	z_8	0
β_9	0.05870	a_9	8,806	s_9	8,806	x_9	0	z_9	0
β_{10}	0.09140	a_{10}	13,710	s_{10}	13,710	x_{10}	0	z_{10}	0
β_{11}	0.06515	a_{11}	9,773	s_{11}	9,773	x_{11}	0	z_{11}	0
β_{12}	0.09582	a_{12}	14,374	s_{12}	14,374	x_{12}	0	z_{12}	0
β_{13}	0.07203	a_{13}	10,805	s_{13}	10,805	x_{13}	0	z_{13}	0
β_{14}	0.08418	a_{14}	12,627	s_{14}	12,627	x_{14}	0	z_{14}	0
β_{15}	0.07560	a_{15}	11,341	s_{15}	11,341	x_{15}	0	z_{15}	0

The solution of this scenario is the only optimal solution. The profit was 1,570,057.02 (u. m). There are two distributors who incur losses due to OOS.

Based on the three scenarios above, we can learn that when $n = 15$, same with the validation when $n = 2$:

- There is a best solution whether sales capacity is high or low.
- When sum of sales capacity equals productivity, both the manufacturer and distributors do not need to pay for OS or OOS. Meanwhile, the final profit is the highest.
- When there is an OS situation, the loss for profit is higher. This is because both the final sale of distributors is reduced and there are additional expenses.
- The profit of the manufacturer would not be influenced.

7.3. Sensitivity analysis

According to the conclusions we obtained in 7.1 and 7.2, there is always an optimal solution that maximises the profit, regardless of the value of n. So, in the following analysis, we will only use n = 2 for the purpose of a more intuitive presentation.

There are four main parameters to be analysed. In the description of 7.1., D_1 and D_2 are separate and identical in nature to each other. To better observe how a parameter effects on the results, we select only one of them to be changed. This method is also called OAT (one at a time) method.

- Sales capacity

The importance of sales capacity is evident in the validation above. However, only three changes were made to one of them in the discussion for each n. It still made some impacts on the results. Therefore, to get a better view of the change in sales capacity on the final result, we select one of the two parameters of the same nature to change the value multiple times. In this way, the importance it has on the results can be more easily observed.

We gradually increased q_1 from 5,250 (u. p) to 8,100 (u. p) and keep q_2 constant. Repeat the operation of solver function several times, the results are as below in Table 7. 10.:

Table 7.10. Profits changes by q_1

<table>
<tr><th></th><th>q_1</th><th>Profit TTL</th></tr>
<tr><td rowspan="9">$\sum_{i=1}^{n} q_i < q$
$(i = 1,2)$</td><td>5,250</td><td>74,775.00</td></tr>
<tr><td>5,400</td><td>77,964.00</td></tr>
<tr><td>5,550</td><td>81,153.00</td></tr>
<tr><td>5,700</td><td>84,342.00</td></tr>
<tr><td>5,850</td><td>87,531.00</td></tr>
<tr><td>6,000</td><td>90,720.00</td></tr>
<tr><td>6,150</td><td>93,909.00</td></tr>
<tr><td>6,300</td><td>97,098.00</td></tr>
<tr><td>6,450</td><td>100,287.00</td></tr>
<tr><td>$\sum_{i=1}^{n} q_i = q(i = 1,2)$</td><td>6,500</td><td>101,350.00</td></tr>
<tr><td rowspan="11">$\sum_{i=1}^{n} q_i > q$
$(i = 1,2)$</td><td>6,600</td><td>100,909.29</td></tr>
<tr><td>6,750</td><td>100,235.79</td></tr>
<tr><td>6,900</td><td>99,562.29</td></tr>
<tr><td>7,050</td><td>98,888.79</td></tr>
<tr><td>7,200</td><td>98,215.29</td></tr>
<tr><td>7,350</td><td>97,541.79</td></tr>
<tr><td>7,500</td><td>96,868.29</td></tr>
<tr><td>7,650</td><td>96,194.79</td></tr>
<tr><td>7,800</td><td>95,521.29</td></tr>
<tr><td>7,950</td><td>94,847.79</td></tr>
<tr><td>8,100</td><td>94,174.29</td></tr>
</table>

The results can be transferred in a diagram in 7. 4..

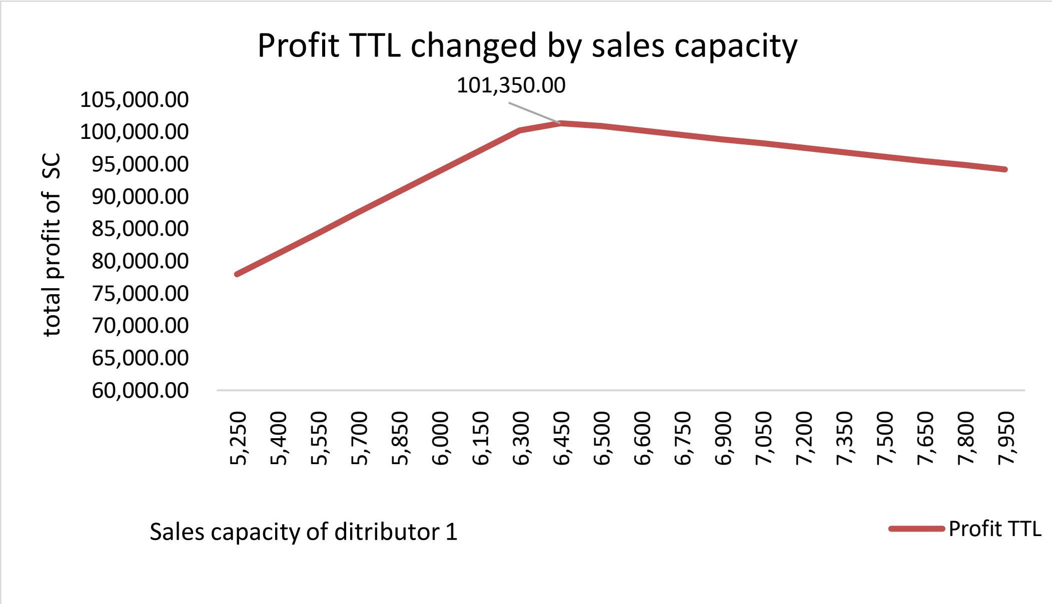

Fig. 7. 4. Profit changes by sales capacity

From Table 7.10. and Figure 7.4, we can observe some changes. With the individual increase of q_1 , sum of distributors sales capacity also raises. When it equals the manufacturer's productivity, the profit of SC reaches the peak. Prior to this, SC needs to suffer the OS penalty due to over-allocation and under-selling capacity. But this value is gradually decreasing. Finally, it becomes zero.

When the OS stock reaches 0, at this point, there is not any OS or OOS. Meanwhile, all of the products can be perfectly allocated to distributors and sold to consumers by POS finally. The profit of SC is maximum. The perfect allocation solution in this case is the one described as scenario 1 in 7.1.2.

After the apex, there is no more OS, but the total sales capacity of distributors is still increasing as q_1 increases. This is when POS may sell everything out in advance. But the sales period is not over, and at this point SC again suffers losses from OOS.

From the variation above we can see that the sales capacity of distributors has a correlated effect on supply chain profits. And it is convex.

- Unit cost

The profitability of the product is important, too. In the quantitative validation above, although the numbers are taken randomly, with open information, we can see that the same SKU brings different profits to the supply chain from different distributors. The retail price of the product, the sell in price, and the fixed expenses cannot usually be changed. In addition to this, there is the related parameter of the distributor's expenditure per unit.

Also with the OAT method, we changed the unit cost of D_1 with an increasing numerical series.

The results under three different scenarios are in table 7. 11. As below.

Table 7.11. Profits changes by C_1

C_1	$\sum_{i=1}^{n} q_i = q(i = 1,2)$	$\sum_{i=1}^{n} q_i < q\ (i = 1,2)$	$\sum_{i=1}^{n} q_i > q(i = 1,2)$
2.0	102,650.00	70,452.46	96,145.49
2.1	102,000.00	69,927.46	95,717.39
2.2	101,350.00	69,402.46	95,289.29
2.3	100,700.00	68,877.46	94,861.19
2.4	100,050.00	68,352.46	94,433.09
2.5	99,400.00	67,827.46	94,004.99
2.6	98,750.00	67,302.46	93,576.89
2.7	98,100.00	66,777.46	93,148.79
2.8	97,450.00	66,252.46	92,720.69
2.9	96,800.00	65,727.46	92,292.59
3.0	96,150.00	65,202.46	91,864.49
3.1	95,500.00	64,677.46	91,436.39
3.2	94,850.00	64,152.46	91,008.29
3.3	94,200.00	63,627.46	90,580.19
3.4	93,550.00	63,102.46	90,152.09
3.5	92,900.00	62,577.46	89,723.99
3.6	92,250.00	62,052.46	89,295.89
3.7	91,600.00	61,527.46	88,867.79
3.8	90,950.00	61,002.46	88,439.69
3.9	90,300.00	60,477.46	88,011.59
4.0	89,650.00	59,952.46	87,583.49

We also draw them as a graph to see their trends in Fig. 7. 5.

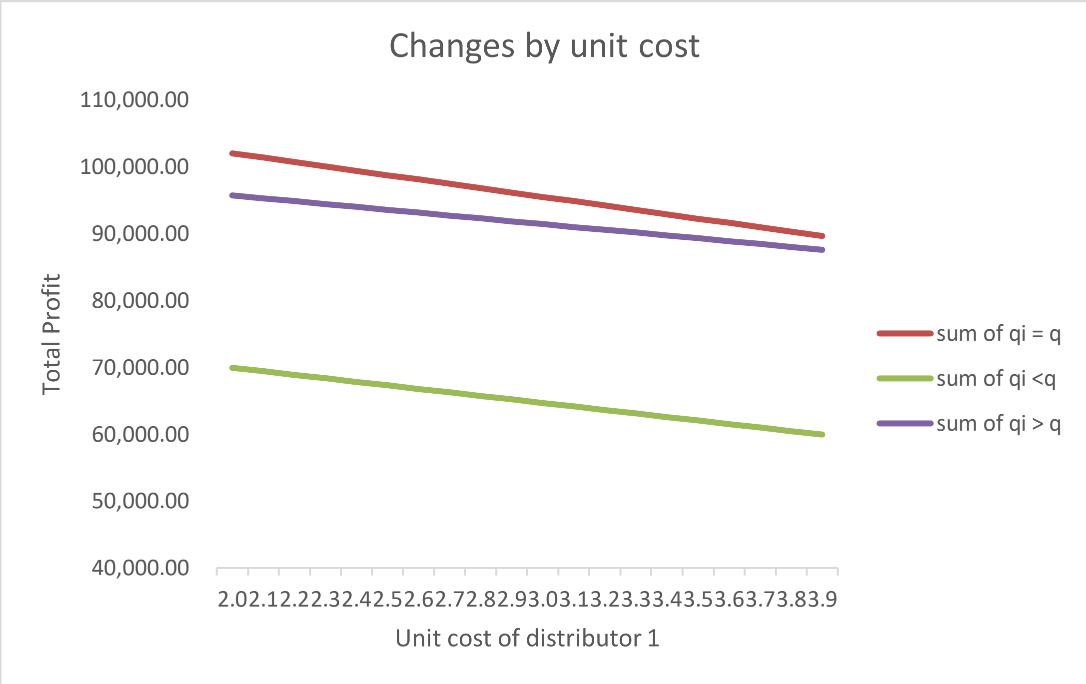

Fig. 7. 5. Profit change by unit cost

Unlike what happened above, even though we have split the situation into three like what we did in section 6, all of them show similar trends. Regardless of the manufacturer's capacity and the distributor's ability to sell, when other parameters are fixed, the overall profitability of the supply chain declines with the distributor's unit costs rise.

Unit costs also represent its profitability. It means that when the manufacturer allocates products by this model, it should not only take the sales capacity of individual distributors into account. Profitability is also important in terms of the supply chain. When the manufacturer has insufficient capacity, distributors with low unit costs and high profitability should be fulfilled first. Because they can bring more profits to the supply chain. Planners should not just meet large orders with large quantities of products.

- Unit penalty of gap sales

When we analyse the first series of parameter, we can see that the supply chain losses due to gap sales do not always exist. The amount of gap sales changes all the time as other parameters change. Therefore, the supply chain losses due to it should also be analysed.

Based on the process above, we set it with a group of data. Meanwhile keep other parameters with the same value.

The changed results are in the follow table 7. 12.. They can be shown in Fig. 7. 6.

Table 7.12. Profits changes by u

u	$\sum_{i=1}^{n} q_i = q(i = 1,2)$	$\sum_{i=1}^{n} q_i > q(i = 1,2)$	$\sum_{i=1}^{n} q_i < q\ (i = 1,2)$
1.08	101,350.00	96,008.81	75,391.98
1.14	101,350.00	95,918.87	75,317.04
1.20	101,350.00	95,828.93	75,242.10
1.26	101,350.00	95,738.99	75,167.16
1.32	101,350.00	95,649.05	75,092.22
1.38	101,350.00	95,559.11	75,017.28
1.44	101,350.00	95,469.17	74,942.34
1.50	101,350.00	95,379.23	74,867.40
1.56	101,350.00	95,289.29	74,792.46
1.62	101,350.00	95,199.35	74,717.52
1.68	101,350.00	95,109.41	74,642.58
1.74	101,350.00	95,019.47	74,567.64
1.80	101,350.00	94,929.53	74,492.70
1.86	101,350.00	94,839.59	74,417.76
1.92	101,350.00	94,749.65	74,342.82
1.98	101,350.00	94,659.71	74,267.88
2.04	101,350.00	94,569.77	74,192.94
2.10	101,350.00	94,479.83	74,118.00
2.16	101,350.00	94,389.89	74,043.06
2.22	101,350.00	94,299.95	73,968.12
2.28	101,350.00	94,210.01	73,893.18

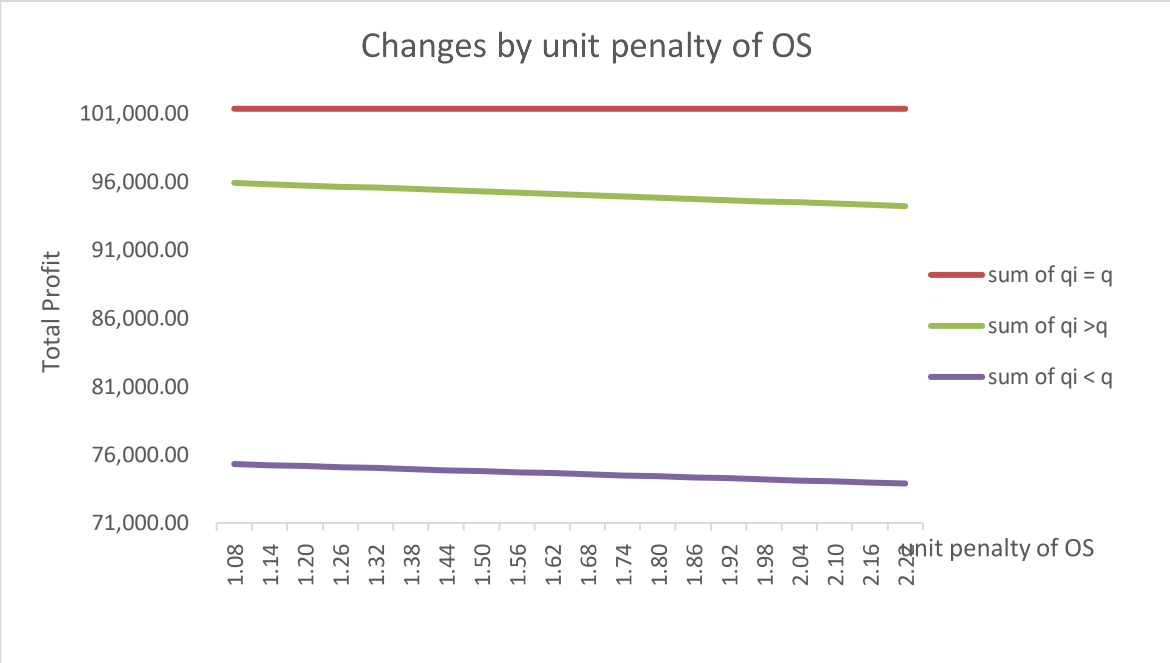

Fig. 7. 6. Profit change by unit penalty of OS

When the results are plotted on a graph, as in the previous set of parameters, the total profit of supply chain decreases with the increase in the gap sales unit penalty, regardless of the scenario. However, unlike what happens above, all three lines in Fig 7.6. have a very gentle downward trend. As mentioned above, there is a limit to the value of this parameter. It cannot exceed the net profit of a product.

Therefore, we can conclude that the total profit of the supply chain decreases as the unit penalty of gap sales increases, when other parameters are held constant. However, as there is a range of values, its change will not have a significant impact on the supply chain.

- Unit opportunity sales loss of OOS

Similar to the previous parameter, the penalty generated by OOS is also not always present. However, it has an impact on the total profit in some cases. As we analysed in section 3, FMCG is highly competitive industry. Therefore, this parameter also needs to be subjected to a sensitivity analysis.

As we mentioned in the sate of art, the total opportunity sales loss per year can be 3% of total sales. It can also reduce till 50% sales in the future. Therefore, we set a variable range [0.6, 1.9] to observe the trend of profit changes in three different scenarios.

The results are as below in table 7. 13. and Fig. 7. 7.

Table 7.13. Profits changes by O

O	$\sum_{i=1}^{n} q_i = q(i=1,2)$	$\sum_{i=1}^{n} q_i > q(i=1,2)$	$\sum_{i=1}^{n} q_i > q(i=1,2)$
0.60	101,350.00	98,781.96	74,792.46
1.20	101,350.00	97,882.56	74,792.46
1.80	101,350.00	96,983.16	74,792.46
2.40	101,350.00	96,083.76	74,792.46
2.93	101,350.00	95,184.36	74,792.46
3.00	101,350.00	94,284.96	74,792.46
3.60	101,350.00	93,385.56	74,792.46
4.20	101,350.00	92,486.16	74,792.46
4.80	101,350.00	91,586.76	74,792.46
5.40	101,350.00	90,687.36	74,792.46
6.00	101,350.00	89,787.96	74,792.46
6.60	101,350.00	88,888.56	74,792.46
7.20	101,350.00	87,989.16	74,792.46
7.80	101,350.00	87,089.76	74,792.46
8.40	101,350.00	86,190.36	74,792.46
9.00	101,350.00	85,290.96	74,792.46
9.60	101,350.00	84,391.56	74,792.46

Apply the numbers in a graphic, we can obtain the figure 7.7. as below.

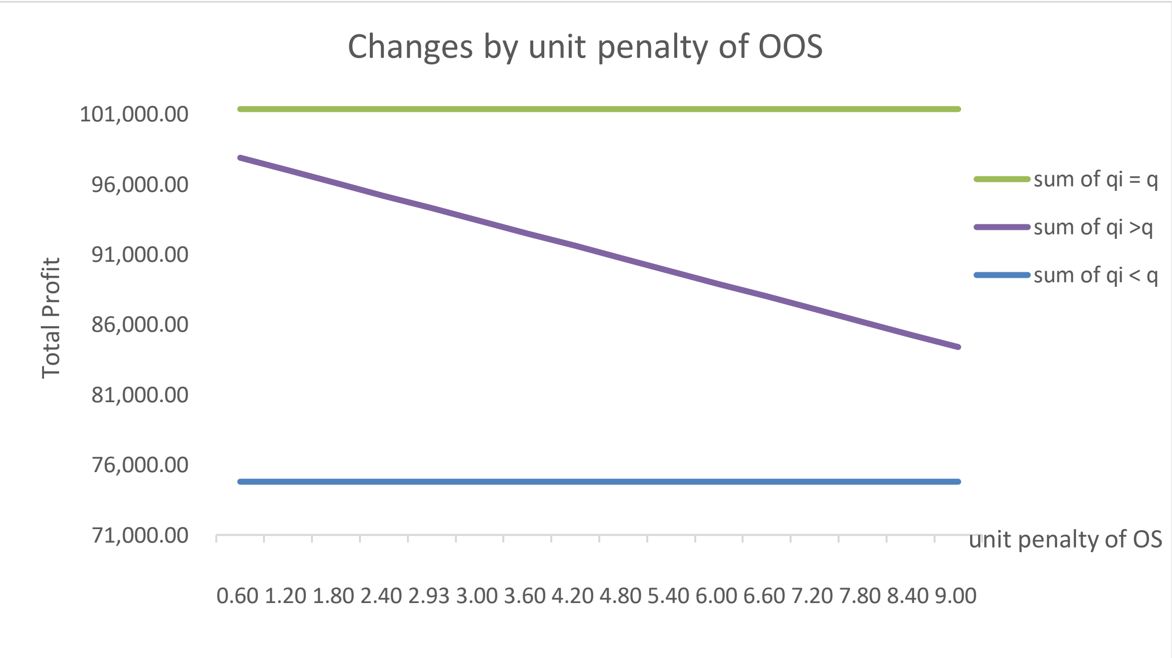

Fig. 7. 7. Profit change by unit penalty of OOS

Unlike all the analyses above, the change in O presents a completely different change in different scenarios. When the manufacturer's productivity is higher than or equal to the distributors’ sales capacity, the supply chain never runs out of stock. Therefore, the total profit of the supply chain remains the same, regardless of the change in unit penalties of OOS.

Conversely, when the manufacturer's capacity is insufficient, the supply chain is bound to run out of stock. The total profit of the supply chain is negatively related to the cost per unit of the shortage penalty. The higher the loss per unit of opportunity sales, the higher the total loss and the lower the total profit.

In general, from the sensitivity analysis we can obtain:

- Although the values are invented, after many changes in the individual parameters it still works as that in 7.1 and 7.2. There is always an optimal solution and a theoretical maximum profit. The model is valid.
- Changes of distributor's sales capacity, unit costs and unit gap sales penalty always have an impact on the results. Distributors’ sales capacity and their unit cost also affect the number of final allocation options.
- Changes of unit opportunity loss cost do not necessarily affect the outcome. Only when the manufacturer has insufficient capacity, its change will have an impact. But only on the SC profit, not on the allocation.

8. Budget of the project

The project is a personal project which is a master thesis. During the research period, details of the budget is in Table 8.1. as below:

Table 8.1. Budget of the project

Budget		
Staff member	600h*10 €/h	6,000 €
Google academic account for downloading literature	20€/literature * 50	1,000.00 €
Laptop	437€/piece	437.00 €
Desktop	699€/piece	499.00 €
Register fee	1732.89/project	1,732.89 €
Internet	20€/month *10 months	200.00 €
Electronic	15€/month *10 months	150.00 €
Budget without IVA		10,019 €
IVA(21%)		2,103.99 €
Budget total		12,122.99 €

Of these, a laptop and a desktop are necessary. Their costs are 437 € and 499 € respectively. At the beginning of the project, I read many literatures by Google academic account. Each of them costs about 20€ to read the full text. Also, the register fee for the project for ETSEIB is 1732. 89€.It includes the first register fee and extend fee.

Except these, this project actually starts from June,2021 to April 2022.The total period is about 10 months. It totally cost me about 600 hours working hours. Depends on the average salary in Spain, it is about 10€ per hour. Total staff member fee is 6,000€.

During this time, monthly average electronic fee and Internet fee are 15€ and 20€ respectively. They should be multiplied by 10. The results are 200€ and 150€.

Add up all the above costs, budget of the project is 10,019 €. There is a 21% value added tax which equals 2,103.99 €. Total budget of the project including tax is 12,122.99€.

9. Impacts of the project

In this section, both the environmental impacts and socioeconomic impacts are discussed.

9.1. Environmental impacts

The vast majority of the work in this project is finished via a computer. Only few papers were used with the collation and recording of some important notes and meetings. The project was done remotely from home. Therefore, some electricity was consumed. However, most of my official time is between 9:00 a.m.-14:00 p.m. am and 16:00 a.m.-19:00 p.m. Both are not peak hours for electricity consumption.

In summary, the Project is an environmentally neutral that does not have too many bad impacts on the environment or greatly contribute to environmental improvement.

9.2. Socioeconomic impact

In contrast to the environment impacts above, impacts generated by the project are also mainly of socioeconomic.

Channel management is part of the theoretical management of the supply chain. The management of distributors and retailers is moreover an important part of company management. A large partner is not only able to carry multi-brand products of the same category but can even carry cross-category goods. A change in the way how a manufacturer manages them could have an impact on the overall market environment. For example, although there is a theoretical unit penalty value which could maximises the profit, it should base on the premise that it's acceptable to both parties. If a partner rejected to accept what we set, otherwise a healthy relationship may deteriorate if the approach is not changed in time. The distributor invests more energy in the competitor's product operator and the resulting negative impact.

The external impact of the project is also positive if the approach is correct.

Conclusions

This project discussed how managers can follow a certain allocation rule with full information to make a sales assignment to distributors more efficiently. The aim is to maximise the profitability of the entire supply chain. The following points can be summarised from the project:

- If a manufacturer has complete information about its supply chain, it can calculate the best solution for the allocation of goods to its distributors based on the model above. Regardless of the relationship between its capacity and the sales capacity of distributors, at least one optimal allocation solution exists. At this point the profitability of the supply chain profit is maximum.

- When the revenue and other costs of the supply chain are fixed, the profit curve of supply chain varies with the sales capacity of distributors. It is "convex". It has a maximum value when the sum of manufacturer's production and the distributor's sales capacity is equal.

- Total profitability of supply chain decreases with the increase in unit cost of the distributor. When it rises, it represents a reduction in the profitability of individual products. The total profit of the supply chain also decreases.

- When distributors' sales capacity and production capacity are equal, the unit penalties for OS and OOS do not affect the solution or the outcome.

- When distributors' sales capacity and production capacity are not equal, elevated OS and OOS both reduce total profitability.

Also, there are some derived conclusions：

- More complete information sharing helps to centralised decision makers to make faster decisions. As it mentioned in section 5, given the uncertainty of information, some models have dynamic parameters in their models. It would complicate the situation. In FMCG industry, the supply chain needs to be fast moving and responsive. In this case, information sharing can solve this problem.

- If companies upstream and downstream are going to reach deep cooperation, they must share profits as well as risks. In the thinking of the construction with the basic model, distributors accept the centralised decisions from the manufacturer. They bear the risk of penalties for sales gap. At the same time, the manufacturer also takes the loss of opportunity sales for the situation of OOS. It is also a prerequisite for information sharing.

A healthy supply chain is one in which all participants work together to "make a bigger cake" and distribute profits more rationally rather than taking responsibility and risk for the convenience. In general, the model developed above still have a variety of limitations. In practice, there would be some flexibility in the maximum sales capacity of the distributor. However, these decision methods can still be applied in practical situations, such as the management of boutiques by manufacturers and seasonal products. If there is a basis for cooperation between the parties, it can be infinitely close to a sufficient condition of full information, minimising misleading information due to inaccuracies.

The model can be used as a reference in negotiations with supply chain partners to achieve better business management and a win-win situation.

Acknowledgments

First of all, I would like to sincerely thank my thesis supervisor Professor DOMÉNECH LÉGA, BRUNO. His meticulous academic attitude has benefited me a lot, and I have made great progress both in theoretical research and in practical work. In the whole process of opening the topic, structure, practice, writing, revision, and finalization. Bruno gave me a lot of careful guidance and detailed revision opinions, which enabled me to successfully complete the graduation thesis. Thanks again to Professor Bruno for his selflessness guidance and teaching.

Finally, I would like to express my heartfelt gratitude and respect to the experts who have patiently reviewed this thesis during the busy schedule and the teachers of the defense team!

ETSEIB

Bibliography

Bibliographic references

[1] Cachon, G., Lariviere, M. , (1999) Capacity Choice and Allocation: Strategic Behavior and Supply Chain Performance. Management Science Vol. 45-8

[2] Deshpande, V. Schwarz, L. (2002) Optimal capacity choice and allocation in decentralized supply chains. Working Paper.

[3] Zhang, L., Song, S., Wu, C., (2005) Supply chain coordination of loss-averse newsvendor with contract. Tsinghua Science and Technology Vol.102-2

[4] Dror, M., Guardiola, L., Meca, A., Puerto, J. (2007) Dynamic realization games in newsvendor inventory centralization. International Journal of Games Theory. Vol. 37-1.

[5] Wang, C., Webster, S. (2010) The loss-averse newsvendor problem. Omega, Vol.37-1

[6] Wu, X., Niederhoff, J. (2014) Fairness in selling to the newsvendor. Production and Operations Management Vol. 23-11

[7] Ulaş, Ö., Norde, H., Slikker, M., (2011) On the convexity of newsvendor games. International Journal of Production Economics Vol.133-1

[8] Doğru, M., Kok, A., Houtum, G. (2012) Newsvendor characterizations for one-warehouse multi-retailer inventory systems with discrete demand under the balance assumption. Central European Journal of Operations Research Vol. 21-3

[9] Niraj, R., Gupta, M., Narasimhan, C. (2001) Customer profitability in a supply chain. Journal of marketing Vol. 65-3

[10] Karaesmen, I., Scheller, A., Deniz, B. (2011) Managing perishable and aging inventories: review and future research directions. Planning production and inventories in the extended enterprise Pages 393-436

[11] Qin, Y., Wang, R., Vakharia, A., Chen, Y., Seref, M. (2011) The newsvendor problem: Review and directions for future research. European Journal of Operational Research Vol. 213-2

[12] Chen, C., Lee, W., Kuo, H., Chen, C., Chen, K. (2010) The study of a forecasting sales model for fresh food. Expert Systems with Applications Vol. 37-12

[13] Fitzsimons, G. (2000) Consumer response to stockouts. Journal of consumer research Vol. 27-2

[14] Haws, J. (2010) Driving Retail Sales Through Effective Supply Chain Management Technology. Regis University Student Publications

[15] Levy, M., Grewal, D., Kopalle, P., Hess, J. (2004) Emerging trends in retail pricing practice: implications for research. Journal of Retailing Vol. 80-3

[16] Jaggi, C., Verma, M., Jain, R. (2018) Quantitative Analysis for Measuring and Suppressing Bullwhip Effect. *Yugoslav Journal of Operations Research* Vol. 28

[17] Okoumba, W., Mafini, C. (2018) Buyer-supplier relationships and firm performance in the fast-moving consumer goods retail industry. Journal of Contemporary Management Vol. 15-1

[18] Putra, A., Tarigan, Z., Siagian, H. (2020) Influence of Information Quality on Retailer Satisfaction through Supply Chain Flexibility and Supplier Relationship Management in the Retail Industry. Jurnal Teknik Industri Vol. 22-2

[19] Song, T., Zhang, Q., Ran, J., Ran, W. (2021) Research on Supplier Collaboration of Daily Consumer Goods under Uncertainty of Supply and Demand. Sustainability, MDPI Vol. 13-10

[20] Jouida, s., Guajardo, M., Klibi, M., Krichen, S. (2021) Profit maximizing coalitions with shared capacities in distribution networks. European Journal of Operational Research, Elsevier Vol. 288-2

[21] Bartłomiej, S. (2018) MARKETING MANAGEMENT IN FMCG INDUSTRY. Acta Universitatis Nicolai Copernici. Zarządzanie Vol. 45-3