

**SUPPLY CHAIN OPTIMIZATION FOR SINGLE VENDOR MULTI-BUYER AND
MULTI-ITEMS WITH IMPERFECT PRODUCTION**

UNDERGRADUATE THESIS

**Submitted to the International Undergraduate Program in Industrial Engineering
in Partial Fulfilment of Requirement for the Degree of Sarjana Teknik at the
Faculty of Industrial Technology
Universitas Islam Indonesia**



Name : Andini Rakhmah Dwitia

Student Number : 19522400

UNDERGRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

FACULTY OF INDUSTRIAL TECHNOLOGY

UNIVERSITAS ISLAM INDONESIA

YOGYAKARTA

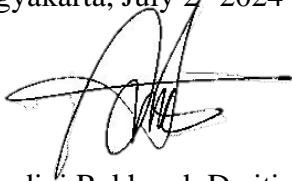
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Yogyakarta, July 2th 2024




Andini Rakhmah Dwitia
19522400

RESEARCH COMPLETION LETTER



FAKULTAS
TEKNOLOGI INDUSTRI

Gedung KH. Mas Mansur
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext. 4100, 4101
F. (0274) 895007
E. fti@uii.ac.id
W. fti.uui.ac.id

SURAT KETERANGAN PENELITIAN

Nomor: 009/Ka.Lab.Datmin/70/Lab.Datmin/VII/2024

Assalamu'alaikum Warahmatullahi Wabarakatuh

Kami yang bertanda tangan dibawah ini, menerangkan bahwa mahasiswa dengan keterangan sebagai berikut :

Nama : Andini Rakhmah Dwitia
No. Mhs : 19522400
Dosen Pembimbing : Ir. Muhammad Ridwan Andi Purnomo, S.T., M.Sc., Ph.D.,
IPM.

Telah selesai melaksanakan penelitian yang berjudul " SUPPLY CHAIN OPTIMIZATION FOR SINGLE VENDOR MULTY BUYER AND MULTY ITEMS WITH IMPERFECT PRODUCTION" di Laboratorium Data Mining, Program Studi Teknik Industri, Fakultas Teknologi Industri, Universitas Islam Indonesia tercatat mulai tanggal 09 Oktober 2023 sampai dengan tanggal 13 November 2023

Demikian surat keterangan kami keluarkan, agar dapat dipergunakan sebagaimana mestinya.

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Yogyakarta, 15 Juli 2024

Kepala Laboratorium
Data Mining

Annisa Uswatun Khasanah, ST., M.B.A., M.Sc.

SUPERVISOR APPROVAL SHEET

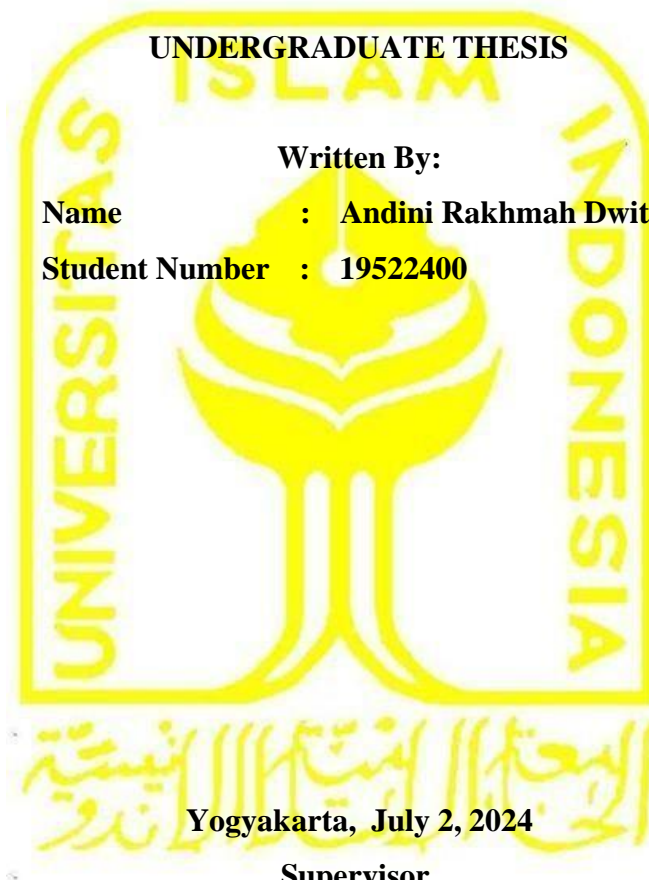
**SUPPLY CHAIN OPTIMIZATION FOR SINGLE VENDOR MULTI-BUYER AND
MULTI-ITEMS WITH IMPERFECT PRODUCTION
(CASE STUDY: PT. BATIK X YOGYAKARTA)**

UNDERGRADUATE THESIS

Written By:

Name : Andini Rakhmah Dwitia

Student Number : 19522400



Yogyakarta, July 2, 2024

Supervisor,

A handwritten signature in blue ink, appearing to be 'Muhammad Ridwan Andi Purpono', is written over the supervisor's name.

Ir. Muhammad Ridwan Andi Purpono, S.T., M.Sc., Ph.D., IPM.

EXAMINERS' APPROVAL PAGE**SUPPLY CHAIN OPTIMIZATION FOR SINGLE VENDOR MULTI-BUYER AND
MULTI-ITEMS WITH IMPERFECT PRODUCTION****UNDERGRADUATE THESIS****Written By:****Name : Andini Rakhmah Dwitia**
Student Number : 19522400**Has been defended before the board of examiners in Partial Fulfillment of the
requirement for Bachelor Degree in Teknik Industri at the Faculty of Industrial****Technology Universitas Islam Indonesia****Yogyakarta, July 23rd 2024****Board of Examiners****Ir. Muhammad Ridwan Andi Purnomo, S.T., M.Sc., Ph.D., IPM.**

Chairman

Dr. Agus Mansur, S.T., M.Eng.Sc.

Member I

Dr. Drs. Imam Djati Widodo, M.Eng.Sc.

Member II

Acknowledged by,**Head of Undergraduate Program in Industrial Engineering****Faculty of Industrial Technology****Universitas Islam Indonesia****Ir. Muhammad Ridwan Andi Purnomo, S.T., M.Sc., Ph.D., IPM.****015220101**

DEDICATION PAGE

Alhamdulillahirabbil'alamin

For my positive intentions and thoughts always to Allah SWT who is always with me, I'm always praying to Allah SWT to make this undergraduate thesis easier.

Also, this undergraduate thesis is filled with sincerity I present to my beloved:

My two beloved parents Mr. Untung Priyono (Papa) and Mrs. Suprpti (Mama). Your prayers are the strength for my life, there is always a word of forgiveness and love from you, what am I offering right now, is not enough to repay every sacrifice that you have given for my future.

MOTTO

“Ask for help patiently and pray. Indeed, Allah is with those who are patient”

(Q.S. Al-baqarah, 153)

“Ya Allah, this is more than what I prayed for, Alhamdulillah.”

“Not once Allah say: “worry about it” or “Stress over it” Allah said, “Trust me” .”

(Q.S. 33:48)

PREFACE

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Praise and gratitude go to the presence of Allah SWT, who has given His mercy, grace, and guidance. *Shalawat* and greetings always to our lord Rasulullah Muhammad SAW as a role model for Muslims who keep us away from the era of ignorance.

With the permission of Allah SWT, the author was able to complete the undergraduate thesis with the title “**Supply Chain Optimization for Single Vendor Multi Buyer and Multi-Item with Imperfect Production (Case Study: PT. Batik X Yogyakarta)**”. Therefore, the author would like to express gratitude and gratitude to all parties involved in the making of this undergraduate Thesis, namely:

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The author realizes this undergraduate thesis still has many shortcomings, so the author expects constructive criticism and suggestions from various parties for future improvements. This undergraduate thesis was prepared to fulfill one of the requirements for completing a bachelor's degree in the International Undergraduate Program in Industrial Engineering at the Faculty of Industrial Technology, Universitas Islam Indonesia.

Wassalamu'alaikum Warahmatullahi Wabarakatuh.

Yogyakarta, July 2th 2024



(Andini Rakhmah Dwitia)

19522400

ABSTRACT

This study explores the optimization of supply chain management for a single vendor serving multiple buyers with various items under conditions of imperfect production. Focusing on PT. Batik X Yogyakarta as a case study, the research aims to develop a mathematical model that minimizes the joint total cost for both the vendor and the buyers. The model integrates aspects of defective products and the coordination of orders among buyers to enhance overall efficiency. By applying a solution-solving evolutionary algorithm, the study validates the model's effectiveness through comparative analysis with and without coordination. Key components include a joint total cost (JTC) model and a joint economic lot sizing (JELS) approach. The findings demonstrate that coordinated strategies significantly reduce costs and improve the supply chain's performance, providing valuable insights for practical applications in industrial engineering and supply chain management.

Keywords: Supply Chain Optimization, Single Vendor, Multiple Buyers, Multiple Items, Imperfect Production, Joint Total Cost (JTC) Model, Joint Economic Lot Sizing (JELS), Evolutionary Algorithm, Cost Minimization.

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CHAPTER I

INTRODUCTION

1.1 Research Background

MSMEs in Indonesia have an important contribution to supporting the economy. Law no. 20 of 2008 concerning Micro, Small, and Medium Enterprises in Article 3 states that Micro, Small, and Medium Enterprises aim to grow and their efforts to develop the national economy based on just economic democracy. Growth and development The MSME sector is often interpreted as an indicator of development success, especially for countries that have low per capita income (Wibowo et al., 2015). As an illustration, in 2021 based on data The Ministry of Cooperatives and MSMEs (2022) stated that the contribution of the MSME sector to gross domestic product (GDP) was 61.97%, apart from MSMEs has a role in improving the Indonesian economy by successfully absorbing 97% of the workforce.

The city of Yogyakarta is one of the cities where batik grows and develops (Putra, 2019). Until now, there are many batik MSMEs spread across many points in the city of Yogyakarta. Therefore, the city of Yogyakarta has the potential to become a center for the promotion and development of batik.

On September 28, 2009, UNESCO declared that Batik is one of Indonesia's original cultural heritages. Since October 2, 2009, the United Nations Educational Scientific and Cultural Organization (UNESCO) has determined that batik is one of the world's cultural heritages produced by the Indonesian nation (Herawati, 2010: 12). Then the World Craft Council (WCC) designated the Special Region of Yogyakarta as the World Batik City on the 50th anniversary of the organization in Dongyang, Zhejiang Province, China on 18-23 October 2014 (Pradito, 2014).

With the opportunities from international integration, the current global economy is turning into a supply chain versus supply chain relationship. Hence, the need to integrate and develop related business functions is urged. More recently, digital technology advancement is transforming the economy in several ways, bringing about both opportunities and new challenges. Digitization has become a strategic priority for businesses. It offers game-changing tools for businesses to upgrade their supply chain, innovate, scale up faster, increase

employment, and boost output growth. The digitalized supply chain, for example, enables companies to identify and keep up with the emerging demand of the customers, streamline the supply side, and enhance efficiency improvement.

In facing business competition, companies must make efforts to search for the right and profitable strategy for the company to survive. One way is to improve management properly and improve the performance of existing business processes in the company. According to Zuraidah et al. (2021) to improve this business process, companies can maximize their supply chain management. Supply Chain Management is the management of activities that include activities to obtain raw materials to become an input in a company, carrying out the production process and then the product is sent until it reaches the consumer's hands (Pujotomo et al., 2016). Objective The main thing about SCM is delivering products on time, minimizing time as well as costs in the process of fulfilling demand, centralizing planning activities and distribution, as well as good inventory management between vendors and buyers (Pujawan & ER, 2010).

According to Amalesh & Jayanta (2014), the Imperfect production inventory model considers product reliability and reworking of imperfect items in the three-layer supply chain under a fuzzy rough environment. In the model, the supplier receives the raw materials, all are not of perfect quality, in a lot and delivers the items of superior quality to the manufacturer and the inferior quality items are sold at a reduced price in a single batch by the end of the cent percent screening process. The manufacturer produces a mixture of perfect and imperfect quality items. A portion of the imperfect items is transformed into perfect quality items after rework. Another portion of imperfect items, termed as 'less perfect quality items,' is sold at a reduced price to the retailer, and the portion that cannot be either transformed into perfect quality items or sold at a reduced price is rejected. Here, the retailer purchases both the perfect and imperfect quality items from the manufacturer to sell the items to the customers through his/her respective showrooms of finite capacities. A secondary warehouse of infinite capacity is hired by the retailer on a rental basis to store the excess quantity of perfect-quality items. This model considers the impact of business strategies such as optimal order size of raw materials, production rate, and unit production cost in different sectors in a collaborating marketing system that can be used in the industry, like textile, footwear, and electronics goods. An analytical method has been used to optimize the production rate and raw material order

size for maximization of the average profit of the integrated model. Finally, a numerical example is given to illustrate the model. (Amalesh, Jayanta, & Shyamal, 2014)

Inventory control models such as Joint Economic Lot Size (JELS) in Supply chain systems have been widely developed in previous research. JELS model can result in significant savings solutions on total inventory costs combined compared with independent and without inventory models coordination between supply chain members. Independent supplies usually only benefit one party, for example, the buyer, but do not consider other parties such as suppliers. This causes inventory costs to suppliers to become high and the total combined costs also become higher. Hence the model Integration like JELS is important to optimize all parties in the supply chain in this case suppliers and buyers. The JELS model allows suppliers to carry out production lot size optimization while buyers carry out optimization of order lot size so that the total combined cost is minimal.

The models for the JELS case develop according to the complexity of the problem. Research belonging to Anshori et al. (2011) developed models for single manufacturers and multi-buyers by request probabilistic. Gharaei et al. (2020) developed the JELS model at the supply level of multi-echelon chains using mathematical models with deterministic demand. In Yuniar & Wangsaputra's (2018) research, they created a model for cases where suppliers and sole producers use mathematical models with assumptions of probabilistic demand. The advantage of mathematical models according to (Ekoanindiyo, 2011) is a mathematical model that can provide easy answers to a system that simply, and fairly represents the actual system. Mathematical models also can provide optimal value results and do not require large costs compared to simulation; in addition, the mathematical model requires little data because it aims to provide an easy explanation of the system. This research focuses on managing inventory to a minimum total combined costs by integrating between single and multi-supplier buyers with transshipment cases.

PT. Batik X Yogyakarta is a batik producer in Yogyakarta whose products are highly favored by customers due to their quality. However, the company is still struggling to maintain the quality of the products it produces, as there are still defects in these batik products. Defects frequently occur during the production process, leading to increased costs and resulting in losses for the vendor. Therefore, the researcher is interested in studying how to maintain product quality to minimize defects that significantly losses impact the vendor. This research uses the evolutionary algorithm method to minimize product defects and

proposes improvements to reduce these defects. The researcher hopes that the final results will provide valuable insights for the company to improve quality and minimize defective products. The method used is the analytical method which is mathematical modelling because it can provide an optimum solution for the batik supply chain system under consideration. The optimization tool to solve the mathematical model is an evolutionary algorithm due to a large number of decision variables.

In the production process of PT. Batik X Yogyakarta there is a company problem, one of which is problems with quality control. When it reaches a certain production point, defective products are found in production. A comparison of production quantity, number of defective products, and decent amount is shown in Figure 1.1 based on the company's historical data in 1 period.

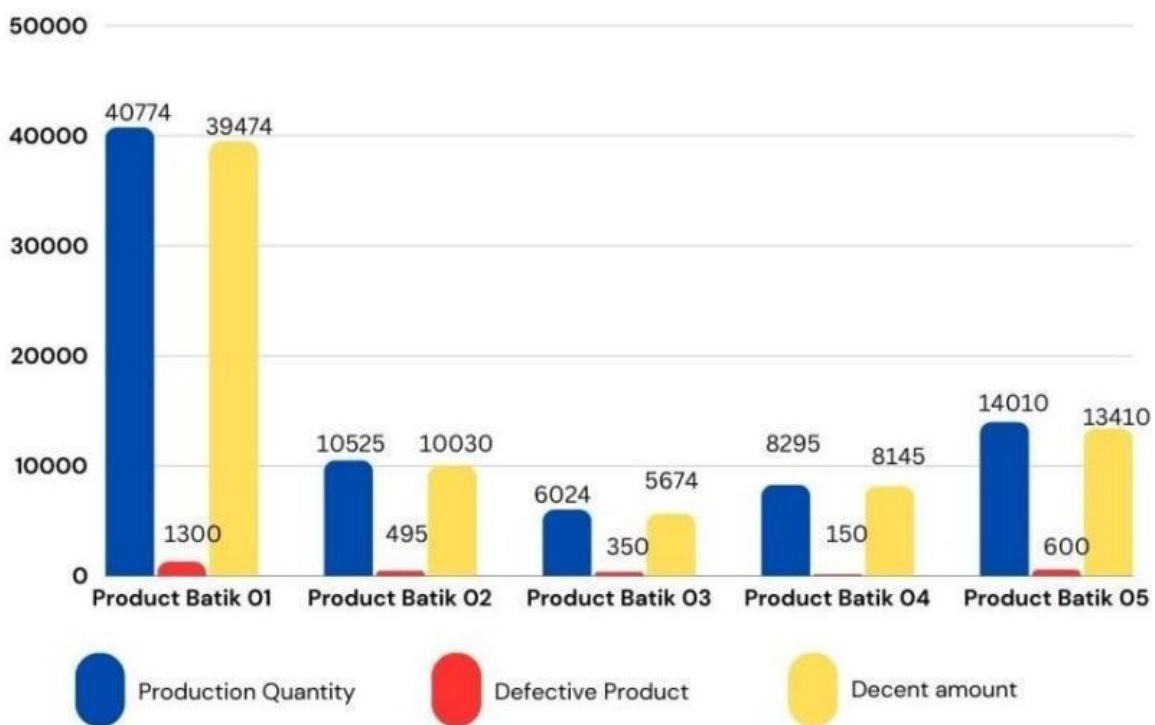


Figure 1. 1 Comparison of production quantity

In Figure 1.1, it is noticed that the largest defective product is found in batik product 1, namely 1300 pieces and the lowest defective product is in batik product 4, amounting to 150 pieces. The number of defective products increases and decreases in each period. The

defective product in question is a product that does not pass the inspection because it does not comply with the standards or specifications determined by the company.

This time delay in product delivery to the finishing department is a rework process that has to be done to achieve production targets. The rework process can be detrimental to the company because it requires additional costs for the re-production process of defective products. Apart from that, the company needs more time for production and of course, it will lead to delays in the process of sending products to customers.

Therefore, companies need to maintain product quality so that it complies with predetermined requirements or criteria in order to reduce the number of defective products. By carrying out quality control, product defects can be prevented. The defective products focused on in this research were carried out to evaluate defective products so that they would be better in the future.

1.2 Problem Formulation

From the description of the background above, the company fails to evaluate employee performance optimally which has an impact on the company's operational performance. Therefore, obtained several formulations of the problem, namely:

1. What is the optimization model for the batik supply chain under consideration?
2. Joint Total Cost (JTC) of the entire supply chain is still high due to overstock and shortage.
3. Improvement in the batik supply chain will significantly reduce the JTC and increase the profit of the entire chain for the long term. Will it also increase the competitive advantage of the batik products?

1.3 Research Objective

From the problem formulation above below are the objectives of this study are as follows:

1. Optimizing mathematical models to solve imperfect production to minimize the total supply chain cost.
2. Find the optimal method (JTC) with the evolutionary algorithm for managing the stock of finished products.
3. Determine the difference in JTC from company data to minimization using an evolutionary algorithm. so that can optimize production results and minimize production.

1.4 Benefit of Research

The results of this study are expected to provide benefits to the following:

1. Can be an input for companies in managing inventory.
2. This research can be a reference source for further research related to Joint Total Cost (JTC).

1.5 Research Limitations

Research limitations are used to be more focused on the research objectives. The limitations of this study are as follows:

1. All of the data are assumed not to change during the research.
2. The model is suitable for the condition when the model is developed.
3. The products produced by the vendor in this research are multi-product which consists of 5 batik products.

1.6 Systematic Writing

This Undergraduate research will be organized into several chapters, which will be explained below:

CHAPTER I INTRODUCTION

This chapter contains an explanation of the context of the subject matter discuss the topic of this research. In addition, this chapter discusses problem formulation based on the presentation of the research context and research objectives to determine the research direction, the benefits of research for various parties, limitations problems and research systematization briefly.

CHAPTER II LITERATURE REVIEW

Chapter II summarizes the result of previous studies and studies related to this research. After reviewing previous research and conducting extensive research, they will be a reference for the researcher to solve existing problems.

CHAPTER III METHODOLOGY

This section describes the framework for solving the problem and an

explanation of the research steps to be carried out using the method that has been determined. This chapter also contains the subject and object of research, data sources research, research tools and materials, data collection techniques, data processing, data analysis and research flow chart.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter contains the data obtained during the research, data processing with the method chosen according to the description in the previous chapter. Result of data processing then displayed in the form of picture, table or graphs.

CHAPTER V DISCUSSION

This chapter contains the discussion and analysis of the result of the collection and data processing. The discussion of the result adjusted to the background, formulation of the problem and the purpose of the research so that it will produce conclusions of the research conducted.

CHAPTER VI CONCLUSION AND SUGGESTION

Chapter 6 is a closing that contains conclusions and includes suggestions given based on experience as a reference for further research. Conclusions made based on the result and discussion, must also answer the research objective.

CHAPTER II

LITERATURE REVIEW

2.1 Deductive Review

2.1.1 *Defective Product*

There are several definitions regarding defective products, according to (Bustami & Nurlela, 2007) defective products are products produced in the process of production, where the product produced does not comply with the quality standards fixed, but it can still be repaired at a cost According to (Kholmi & Yuningsih, 2009), a defective product is a product that is produced but cannot meet the standards set by the company, but it can still be repaired. So, it can be concluded that the product is defective if a product is produced through a process and does not follow specifications or standards, that the manufacturer of the product has set, but it can still be repaired by removing certain burdens or costs.

Defective products are goods or services created in the production process but have deficiencies that cause the quality value to be less than good or less than perfect. According to Hansen and Mowen (2001), defective products are products that do not meet specifications. In other words, they are considered as failing to meet the quality standards. The effect of defective products on the company has an impact on quality costs, company image, and consumer satisfaction. There are more and more defective products produced, the greater the quality costs incurred, this is based on the greater. The high-quality costs incurred on defective products will result in inspection, rework actions, etc. The occurrence of defective products can actually be prevented by companies producing correctly from the start. This prevention can be done by increasing the inspection of raw materials for processing. A large number of defective products can hinder the smooth running of production processes caused by external conditions. Irregular machine processes will cause problems and disturbances in the flow of employee movements who have to be forced to use a manual system which carries more risk large compared to using machine technology. This can cause an increase in products that experience defects resulting in decreased quality.

In every production process flow, it cannot be denied that the process does not entirely produce the perfect products. The defective product will exist with a certain probability. The

probability of defective products will have an impact on the company's profit loss because of increased repair costs and other costs associated with loss of profits (Rizky et al., 2022). In order to return to having resale value, the defective product is required to be reworked at a certain cost (Sarkar & Giri, 2020).

2.1.2 Supply Chain

According to Beamon (1998), Supply Chain (SC) is a structured manufacturing process wherein raw materials are transformed into finished goods and then delivered to end customers. Similarly, Pienaar & Vogt (2009) define SC as a general description of the process integration involving organizations to transform raw materials into finished goods and to transport them to the end-user. Most SC definitions orbit in the same sphere as the abovementioned definitions, while others include an extended view of the SC and its integration with additional relevant activities. For example, Chow & Heaver (1999) define SC as the group of manufacturers, suppliers, distributors, retailers, and transportation, information, and other logistics management service providers that are engaged in providing goods to consumers, whereby novel synchro modality definitions, under the DSCR domain, creating the perfect match in time and space for the building blocks of the SC (Giusti et al., 2021; Y. Zhang et al., 2022).

2.1.3 Supply Chain Management

The next evolution of the SC field is the emergence of SCM. According to Kundu et al. (2015), the creation of the SCM term is credited to a Booz Allen consultant, Keith Oliver, who mentioned it during an interview with the Financial Times in 1982. SCM is defined as the discipline where organizations and stakeholders involve themselves in a supply chain intending to manage its complex network in the most efficient manner. SCM has been theorized over the last forty years (Chopra & Meindl, 2016); such management involves different and interdependent approaches for inter-organizational interplay, namely cooperation, coordination, and collaboration. Finkenstadt & Handfield (2021) explained that SCM is the active management of supply chain activities with the objective to maximize customer value and achieve a sustainable competitive advantage. For the author, SCM represents a conscious effort made by supply chain firms to develop and run supply chains toward the optimal level of service at a minimal cost. In other words, SCM is a set of

interdependent processes that manage information, material, and financial flows among stakeholders of the SC network, effectively and efficiently.

Supply Chain Management is a supply chain, supply chain, logistics network, or supply network is a coordinated system consisting of organizations, human resources, activities, information, and other day-to-day resources that are involved together in moving in terms of products or services in either physical or virtual form from a supplier to a customer. According to Schroeder (2003), Supply Chain Management is the planning, design, and control of the flow of information and goods along the supply chain which aims to meet customer requirements efficiently for the present and the future. SCM (Supply chain management) is a concept or mechanism for increasing a company's total productivity in the supply chain by optimizing the time, location, and quantity flow of materials. Supply Chain Management (Supply chain management) is a comprehensive process by which products are created and delivered to consumers from a structural standpoint. A supply chain refers to the complex network of relationships that an organization maintains with its business partners to obtain production resources to deliver to consumers. The goal to be achieved in each supply chain is to maximize the overall value produced. An integrated supply chain will increase the overall value generated by the supply chain.

In facing business competition, companies must make efforts to search for the right and profitable strategy for the company to survive. One way is to improve management properly and improve the performance of existing business processes in the company. According to Zuraidah et al. (2021) to improve this business process, companies can maximize supply chain management. Supply Chain Management is the management of activities that include activities to obtain raw materials to become an input in a company, carrying out the production process and then the product is sent until it reaches the consumer's hands (Pujotomo et al., 2016). The main objectives of SCM are delivering products on time, minimizing time as well as costs in the process of fulfilling demand, centralizing planning activities and distribution, as well as good inventory management between vendors and buyers (Pujawan & ER, 2010).

Based on Table 2.1, there are three types of components, which are upstream supply chain, downstream supply chain, and internal supply chain:

Table 2. 1 Type of Supply Chain

Upstream Supply Chain	The first component is the upstream supply chain. This component is a product movement management activity. This activity is usually carried out by companies with vendors providing raw materials.
Downstream Supply Chain	Next there is the downstream supply chain component. It is defined as works to distribute the company's products to customers. This activity is generally carried out directly by the company to the costumer without employing a vendor who supplies the goods.
Internal Supply Chain	The final component is the internal supply chain, which has the task of managing the availability of raw materials, supplies, and the production process. This component is carried out by the management system.

2.1.4 Total Cost

Total cost is the total of fixed costs and also variable costs that must be incurred to produce a good, in a period certain time. The value in total cost is a combination of variable costs and fixed costs. Both are included in the total cost type, plus marginal cost, which means in total there will be 3 types of total costs.

Knowing the total costs in a business can provide various benefits as well benefits for the business being run, especially in determining profit or profit from Total cost can be used as a reference in making comparisons evaluation in determining the position of the product in market competition. The method is through a review of the cost of production. If the review finds that the total cost could be cheaper compared to competitors, the price of the product can be adjusted so that it remains viable to survive and compete in the market. Apart from that, this comparison can also be used as a reference as to whether the company needs to increase sales to get more profit or not. In addition, total cost can also be used as an indicator of product range or performance of the company or business. That way, companies can speed up the process of production and negotiating with vendors, if necessary.

2.1.5 *Model Joint Total Cost (JTC)*

Joint Product, Joint Cost, By Product For many industrial companies, a process can produce two or more products simultaneously in different proportions. If a production process can produce two or more products, then they can be considered joint products (joint-product), main products, or by-products, Charles T. Horngren and Endah Susilaningtyas, (2004:361).

2.1.6 *Model Joint Economic Lot Sizing (JELS)*

The idea of the joint optimization between vendor and manufacturer costs was first introduced by Goyal in 1976. However, the term joint economic lot sizing (JELS) was introduced by Banerjee (1986), who developed the concept for a special case where a supplier produces to order for a manufacturer on a lot-for-lot basis. The relationship between supplier and manufacturer has been defined by Muckstadt et al (2001) into four categories. First, firms as communicators, the manufacturer will give the orders to the supplier based on the manufacturer's needs. Since there's no agreement between the supplier and manufacturer, the inventory problems have been solved separately. Therefore, the inventory policy of the supplier doesn't depend on the inventory policy of the manufacturer and vice versa. The second level is firms as coordinators, where the supplier and the manufacturer share the information in more detail. Moreover, when the interaction requires suitable information for supporting the business process, such as increased demand in the manufacturer or decreased production capacity in suppliers, then the firms will communicate the types of cooperators. Finally, the highest level of relationship between both firms will be considered collaborators, if their strategic and tactical plans are to achieve the maximum system effectiveness. Originally, the JELS had the assumption that all items produced were conforming items with the perfect quality. The other research has been done with reduced setup under the perfect environment (Saraswati et al, 2006).

However, in a real condition, the product quality is not always perfect, non-conforming items are being produced due to imperfect production processes. The non-conforming items have been detected by the manufacturer through 100% inspection. It must be rejected and sent to the vendor as the rework items. Therefore, the JELS inventory model from Banerjee might not be appropriate in this environment. The objective of this paper is to minimize the joint total relevant cost between supplier and manufacturer at level cooperators. Since this relationship has considered the capacity of the supplier and the needs of the manufacturer. In

presenting the study, this paper will be organized as follows; in section 2, model descriptions with notations and assumptions are provided. Section 3 describes the JELS model with imperfect production systems, for a single vendor and a single buyer with a single delivery and multiple deliveries.

2.1.7 Inventory

Inventory is a significant asset for retailers and represents what a store has to offer its customers for instant purchase; at the same time, considerable costs are associated with holding inventory. In this study, we use inventory turnover as a measure of inventory performance. We build upon previous research and use firm-specific measures to untangle the link between inventory performance and chain affiliation as well as time trends for SMEs (Jorgen Breivik, 2019). Inventory is goods stored for use or sale in the future or period (Ristono, 2008).

According to Rangkuti (2007), Raw material supplies are:

“Raw material vendors have an important position in the company because the supply of raw materials has a very large influence on the smooth production process.”

According to Eddy Herjanto (2007), Raw material supplies are:

“Inventory is stored materials or goods that will be used to fulfill a specific purpose, for example for use in a process production or assembly, for resale, or spare parts of equipment or machines.”

Based on the definitions above, inventory is material that can be raw goods, semi-finished goods, or managed finished goods and used to support the production process

2.1.8 Functions of Inventory

Inventory can provide functions to the company to increase flexibility for operational activities. Based on Heizer & Render (2014) four functions inventory for the company:

1. To provide a choice of goods to meet the anticipated requirements and aggregate consumer demand company from fluctuations in demand. Stock-ups like this are generally used in retail companies.
2. To separate several stages of the production process. If a company's inventory fluctuates, additional inventory may be necessary in order to separate the production process from the vendor.

3. Take advantage of placing orders with the system of quantity discounts, due to making internal purchases in large quantities that can reduce shipping costs.
4. Protect the company against inflation and price increases.

2.1.9 Type of Inventory

To accommodate inventory functions, according to Heizer and Render (2014) based on the production process, inventory is divided into four types, namely:

1. Raw material inventory is materials that have been purchased but have not yet been processed. Available ingredients are processed from natural sources or purchased from suppliers (producers).
2. Inventory of semi-finished goods (work in process) or goods in the process are components or raw materials that have been through a production process/have gone through several process changes but have not yet been completed or will be processed again to become finished goods.
3. Maintenance/repair/operation supplies (maintenance, repair, operating) namely the supplies provided for necessary maintenance, repairs, and operations to keep machines and processes running smoothly and productively.
4. Finished goods inventory (finished goods inventory), namely products that have been produced or processed and are ready for sale.

2.1.10 Inventory Cost

According to Rangkuti (2007), inventory is a working capital item that is considered quite important because most of the company's business capital comes from supply. Inventory costs are costs that arise due to the existence of supply. According to Heizer and Render (2014), costs arise from supplies are as follows:

1. Holding Costs

Storage costs are costs associated with storage for a certain period of time. Storage fees also concern obsolete goods in the warehouse or costs related to storage. Related costs storage costs include housing costs (rent or depreciation building, taxes, and insurance) raw material handling costs (lease or depreciation of equipment and power), labor costs (receiving, warehousing, security), investment costs (lending costs, taxes,

and insurance on inventory), costs spoilage, scrap, and obsolete goods (the higher if the product resulting quickly changes, such as computers or cellphones).

2. Ordering Costs

Ordering costs are all costs that include supplies, forms, administration, and so on covering the ordering process.

3. Setup Costs

Installation costs are costs incurred for preparing machines or processes to produce orders. These costs also include time and labor for cleaning and replacing equipment.

2.1.11 Inventory Model

Heizer and Render (2014), explained the inventory of material properties or goods, whether the material is of free demand (independent) or as a dependent request. Free request (independent) is influenced by market conditions beyond the control of the operating function; therefore, it is free (independent) from operating functions. According to Heizer and Render (2014). The independent demand-supply model is divided into:

1. Economic order quantity (EOQ) model

The EOQ model is the most frequently used control technique for supplies, easy techniques to use by knowing the assumptions about the amount of demand known, waiting time/lead time is constant, no discounts available quantity, variable costs are only ordering costs, and holding costs, and stockouts can be completely avoided.

2. Production order quantity model

The production order quantity model can only be applied to two situations, namely when supplies flow or accumulate randomly ongoing for a period of time after an order is placed or in situations where units are produced and sold individually simultaneously.

3. Quantity discount model

The quantity discount model is a price reduction for an item's goods if purchased in large quantities. The inventory models above assume that demand for a product is constant and definite.

If this assumption is ignored and considers real-world conditions directly, the probabilistic model can be employed where demand and waiting times are not always known and are

constant. Apart from that, according to Heizer and Render (2014) explained several models, namely:

1. Single Period Model (single period inventory model)

This model explains the situation where one order is placed for one product. This model is used to order goods with little or no value at the end of the period of sale. For example, goods in bakeries, newspapers, or magazines.

2. Fixed Period System (fixed quantity)

This inventory model is an ordering system by quantity the same order every time. This model assumes that the only relevant costs are booking fees and costs of storage, known and constant lead times, and goods–goods are mutually independent.

2.1.12 Model Transshipment

The transshipment model is a model that allows for indirect delivery of commodities, where goods from one source can be at another source or another destination before reaching the final destination. So in this transshipment model, a source can also act as a destination and vice versa, a destination can also act as a source (Ayudina Puji Er, Mirna Widayanti, 2002).

2.1.13 Optimization Evolutionary Algorithm

According to Pradnya A. Vikhar (2016), the Evolutionary algorithm (EA) has emerged as an important optimization and search technique in the last decade. EA is a subset of Evolutionary Computations (EC) and belongs to a set of modern heuristics-based search methods. Due to the flexible nature and robust behavior inherited from Evolutionary Computation, it becomes an efficient means of problem-solving method for widely used global optimization problems. It can be used successfully in many applications of high complexity. This paper presents a critical overview of Evolutionary algorithms and their generic procedure for implementation. It further discusses the various practical advantages of using evolutionary algorithms over classical methods of optimization. It also includes the unusual study of various invariants of EA like Genetic Programming (GP), Genetic Algorithm (GA), Evolutionary Programming (EP), and Evolution Strategies (ES). Extensions of EAs in the form of Memetic algorithms (MA) and distributed EA are also discussed. Further, the paper focuses on various refinements done in the area of EA to solve real-life problems.

According to Hillier and Lieberman in research conducted by Yulianto et al (2020) stated that the evolutionary algorithm has several advantages compared to other metaheuristic algorithm methods, namely:

1. The complexity of the objective function does not affect the evolutionary algorithm, as long as the function can be evaluated for a given test problem.
2. The complexity of the existing constraints does not affect the evolutionary algorithm substantially.
3. The evolutionary solver itself is not trapped in the local optimum for a result and will continue to work randomly to find even more optimal results. Evolutionary algorithms can also find global optimum results. If the process is carried out continuously, this method is very suitable for problems that tend to be small.

2.2 Inductive Review

Inductive studies are conducted to find out about previous studies relating to research conducted by researchers. Inductive studies in this research will be related to problems in inventory control by using relevant methods. The following are studies previously that will be a reference for researchers in carrying out research this time.

According to research conducted by Kohlmann and Sahling (2024) “A flexible planning approach for integrated lot sizing and rework planning with random proportion of defective products” This paper addresses a stochastic capacitated lot sizing problem with in-line rework, where both defective and defect-free products can occur due to uncertainties in the production process. Reworking defective products is considered due to their significant value and for economic and environmental reasons. The paper proposes a nonlinear model formulation for integrated lot sizing and rework planning. To handle the uncertainty in the proportion of defective products, a sample average approach is utilized to approximate the nonlinear model. A flexible planning approach is applied to adjust production and rework quantities. The paper conducts thorough numerical investigations to assess the effectiveness of the proposed planning approach.

Based on research conducted by Jauhari, Sianipar, Rosyidi, Dwicahyani, & Peng (2018) “A vendor–buyer inventory model with imperfect production considering investment to reduce lead time variability” This study presents a valuable contribution to inventory management systems, benefiting both researchers and practitioners. The proposed model

offers insights for decision-makers in efficiently managing inventories across supply chains, optimizing factors such as order quantity, safety factor, number of deliveries, and lead time variance. The supply chain system under consideration involves a single vendor and a single buyer, where the vendor produces and delivers items, accounting for defective items due to imperfections in their production process. The buyer faces stochastic demand and employs a continuous review policy for inventory management. To address lead time variance, the study introduces an investment model formulated with a logarithmic function. Through iterative procedures, two models are developed and solved, demonstrating that allowing the vendor to invest in reducing lead time variance can lead to benefits such as a reduction in joint total cost. This research offers practical implications for enhancing supply chain efficiency and reducing costs associated with inventory management.

According to research conducted by Shib Sankar Sana (2010) “A production–inventory model in an imperfect production process” The paper develops a model to determine the optimal product reliability and production rate that achieves the biggest total integrated profit for an imperfect manufacturing process. The basic assumption of the classical Economic Manufacturing Quantity (EMQ) model is that all manufacturing items are of perfect quality. The assumption is not true in practice. Most of the production system produces perfect and imperfect quality items. In some cases, the imperfect quality (non-conforming) items are reworked at a cost to restore their quality to the original one. Rework cost may be reduced by improvements in product reliability (i.e., decreasing in product reliability parameter). The lower value of the product reliability parameter results in an increased development cost of production and also a smaller quantity of non-conforming products.

Based on research conducted by Hoque (2011) “An optimal solution technique to the single-vendor multi-buyer integrated inventory supply chain by incorporating some realistic factors” To minimize the total cost of set up, ordering, inventory holding and transportation, the production flow is synchronized by transferring the lot with equal and/or unequal (either all are equal or all are unequal or a combination of equal and unequal) sized batches (sub-lots), each of which incurs a transportation cost. For easy implementation of the models, we relax some unrealistic assumptions in the existing models such as unlimited capacities of the transport equipment and buyers’ storage, insignificant setup and transportation times, unlimited lead time, and batch sizes. A common optimal solution technique for the models is derived and their performances are analyzed. Potential significances of the solution method

are highlighted with solutions to some numerical problems. The importance of the relaxed factors and the limitations of the models are discussed.

Based on research conducted by Abolfazl, Mostafa, and Seyed (2019) "An integrated multi-product, multi-buyer supply chain under penalty, green, and quality control policies and a vendor managed inventory with consignment stock agreement: The outer approximation with equality relaxation and augmented penalty algorithm" The objective is to determine the optimal batch-sizing policy with the minimum TC in the integrated SC that finds both the number of the vendor's batches for each of the transported products and the volume of the batches transported to the buyers so as to minimize the TC of the integrated SC while the stochastic constraints are satisfied. Because of the complexity of the optimization model and mathematical formulations, an outer approximation with equality relaxation and augmented penalty algorithm is presented to determine the optimal batch-sizing policy.

Based on research conducted by Elaheh, Nadia, and Mikael (2024) "A multi-level production-inventory-distribution system under mixed make to stock, make to order, and vendor managed inventory strategies: An application in the pulp and paper industry" The objective is to optimize the total cost while the (vendor managed inventory) VMI customers are timely satisfied and the target service level for (make to order) MTO customers is respected. Furthermore, the purchase acceptance rate for (make-to-stock) MTS customers can be controlled to enhance capacity utilization.

According to research conducted by Mohd Nizam, Raden Achmad, Fairul, etc (2016) "Incorporating logistic costs into a single vendor-buyer JELS model" The economic benefits to calculating the logistic costs decrease as the shipped weight increases. This paper modifies the logistic function by adding the distance parameter. The modified function does not change the essence of the previous logistic function but increases the economic benefits. Based on the sensitivity analysis, results imply that total costs decline as distance falls. Hence, shorter distances do not only provide benefits in lowering logistic costs but also help the company practice frequent, smaller deliveries to reduce holding costs and delays; thus, increasing SC management flexibility.

According to research conducted by Agustian & Dahda (2022) "Pengembangan Model Persediaan Single Vendor Multi Buyer Dengan Kebijakan Rework" The objective to determine the size of the production lot and minimize the total inventory costs. This research uses a model for determining production size in a single vendor and multi buyer supply chain

system with Economic Production Quantity (EPQ) taking into account product defects. This research uses a simple algorithm and sensitivity analysis to determine total costs minimal inventory. From the results of the numerical calculation examples obtained shows that the lower the percentage of product defects X and the higher A decrease in demand will cause total inventory costs to decrease so that minimum total inventory costs will be obtained.

According to research conducted by Wakhid Ahmad Jauhari (2008) "Model Joint Economic Lot Size (JELS) pada Kasus Pemanufaktur-Pembeli dengan Permintaan Probabilistik dan Lead Time Variable" consider a two-layer supply chain model consisting of a vendor and a buyer. The buyer observes a probabilistic demand and orders lots from the vendor. Numerical results show that the integrated inventory model will always result in savings in the total joint cost, buyer cost and vendor cost.

According to research conducted by Rahmanto & Dahda (2022) "Integrated Inventory Model for Single Vendor Single Buyer Considering the Level of Product Defects" aims to propose a single buyer single producer inventory model with consideration of the presence of defective products in order to minimize the total combined inventory costs. In this research, demand is assumed to be normally distributed while the defect rate is stochastic. The model used in the research is the JELS model with an iterative algorithm to obtain a minimum total combined inventory cost by determining the optimal value of delivery frequency and cycle length. This research shows that the higher the percentage of defective products in each shipment from the manufacturer to the buyer, the total combined inventory costs will decrease or be at a minimum. In addition, if defective products are assumed to be fixed, the total combined inventory costs will also increase.

According to research conducted by Andini (2024) "Supply Chain Optimization for Single Vendor Multi Buyer and Multi Item with Imperfect Production" the research aims to develop a mathematical model that minimizes the joint total cost for both the vendor and the buyers. The model integrates aspects of defective products and the coordination of orders among buyers to enhance overall efficiency. By applying a solution-solving evolutionary algorithm, the study validates the model's effectiveness through comparative analysis with and without coordination. Key components include a joint total cost (JTC) model and a joint economic lot sizing (JELS) approach. The findings demonstrate that coordinated strategies significantly reduce costs and improve the supply chain's performance, providing valuable insights for practical applications in industrial engineering and supply chain management.

Table 2. 2 Inductive Review

No	Research Conducted	Model	Consider Defective Products	Reactive Lateral Transshipment	Request Type
1.	Kohlmann, P., & Sahling, F. (2024)	JELS	Yes	No	Stochastic
2.	Jauhari, Sianipar, Rosyidi, Dwicahyani, & Peng (2018)	Optimal solution	Yes	No	Stochastic
3.	Shib sankar sana (2010)	EMQ, EOQ	Yes	No	Numerical
4.	Hoque (2011)	JELS	No	Yes	Numerical
5.	Abolfazl, Mostafa, and Seyed (2019)	Multiproduct, multi-buyer	Yes	No	Stochastic
6.	Elaheh, Nadia, and Mikael (2024)	mixed-integer linear programming (MILP)	No	No	Deterministic
7.	Mohd Nizam, Raden Achmad, Fairul, etc. (2016)	JELS	No	No	Heuristic
8.	Agustian & Dahda (2022)	EOQ/EPQ	Yes	No	Diskrit
9.	Wakhid Ahmad Jauhari (2008)	EPQ, JELS	No	No	Numerical
10.	Rahmanto & Dahda (2022)	JELS	Yes	No	Deterministic
11.	Andini (2024)	JELS, Evolutionary Algorithm	Yes	Yes	Stochastic

BAB III

RESEARCH METHOD

3.1 Research Subject and Object Design

The object of this research is the optimal product inventory for vendors and buyers to fulfill the unpredictability of customer demand. The subject of this research is the UMKM Batik X in Yogyakarta, which in this supply chain is a single vendor or buyer of batik products that produces several batik products and distributes them to 5 buyers as resellers. This research focuses on finding the optimal solution for the size of the ordering lot, production lot and reorder point by considering the transshipment system and the probability of defective products.

3.2 Data Collection Method

At this stage, researchers collect the data needed for research, which will then be processed at the next stage. In this research, this data collection method was carried out using several methods, such as interviews, and observation. The required data are the number of products and the number of buyers that will be collected through direct interviews with the vendor. This literature study was also carried out to strengthen the basis of the research conducted.

Then Setup, shortage, and holding costs at the vendor will be collected through direct interviews and observation at the vendor. In addition, Ordering, holding, and shortage costs at the buyers will be collected through direct interviews and observation of the buyers.

3.3 Research Flow

This research is conducted by following a research flow chart as shown in Figure 3.1

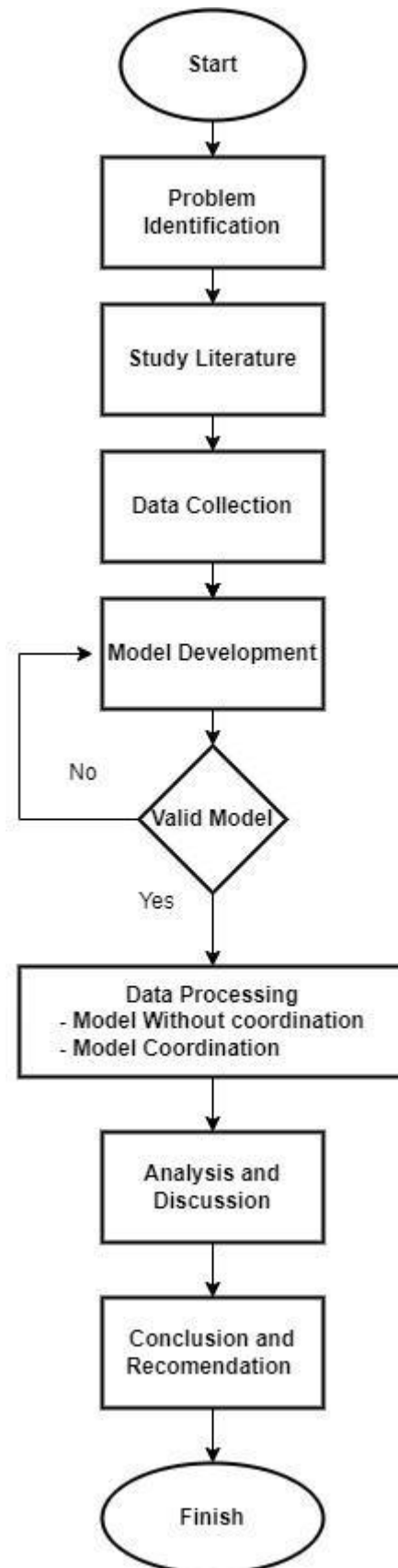


Figure 3. 1 Research Flow

3.4 Problem Identification

At this stage, an analysis of existing problems in the company is carried out which will become the background and basis for conducting this research.

3.4.1 Problem Identification and Problem Formulation

At this stage, an analysis is carried out regarding the problems that exist in the company, which will be the background and basis of this research. The problem formation phase is done after identifying the problems that exist in the company. This step identifies the issues to be investigated to determine the research direction. The problem is defined as a question that the search results will be the answer. Research that is stated in the relationship between the vendor and the buyer for the determination of lot sizes ordering Q , lots of production P , and optimal reorder point.

3.4.2 Literature Study

The Literature Study Stage is carried out to find supporting data in research. In this case, the researcher explores information from previous research as comparative material, both regarding existing deficiencies and advantages. The data used as references include journals and previous research with similar methods. Literature studies were also carried out to determine research methods, design questionnaires, and prepare research background.

3.4.3 Data Collection

The data obtained in this research is in the form of interviews and observation. In this research, the data required consists of vendor data and buyer data, as for the data required include:

1. Order Quantity (Q)
2. Reorder point (r)
3. Setup cost
4. Inventory
5. Lost sales cost
6. Probability data of defective products and defect cost

Meanwhile, the data needs of Buyers 1, 2, 3, 4, and 5 are as follows:

1. Demand distribution data

2. Ordering costs to the vendor
3. Ordering costs between buyers
4. Storage costs
5. Lost Sales Costs

3.4.4 Data Processing Method

After obtaining the necessary data from each company, then Numerical calculations are carried out using models that have been developed in stages previously. After obtaining the necessary data from each company, then Numerical calculations are carried out using models that have been developed in stages previously. In this research, two models were built, namely the model without coordination and the model with coordination. Models to be developed:

1. The model without coordination is a model that is a model that is optimized individually between vendor and buyers using Evolutionary solver, minimization of the buyer's total cost, and minimization of total vendor cost
2. The model with coordination is a model by calculating joint optimization between vendors and buyers using the Evolutionary solver, using data that has been obtained at the processing stage of the model without coordination so that the costs can be directly calculated which are used to obtain the Join total combined costs, then optimize the order lot size and production lot size using the Evolutionary solver with predetermined constraints to find out the Join total combined cost the optimal one.

3.4.5 Result and Discussion

In this stage, discussions and comparisons of the results are carried out Numerical analysis has been carried out at the next stage. The analysis is carried out by comparing decision variables and research performance criteria in the form of total combined costs between the model without coordination and the model with coordination.

3.4.6 Conclusion and Recommendation

In the end, the core of the results of this research will be presented. The conclusion contains the core points that answer the objectives of this study. At the same time, suggestions will include initiatives or things that can be done for further research or companies.

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collecting

Data collection was carried out with the aim of meeting all needs research to be carried out. In this research, the data needed is interviews and observation data from UMKM Batik X Yogyakarta, the following is the data used in this research.

Table 4. 1 Data on vendor and buyer cost

Type of Cost	Types of Batik Products					Dimension
	Batik 1	Batik 2	Batik 3	Batik 4	Batik 5	
Vendor						
Setup Cost (sc)	5.700	5.700	5.700	5.700	5.700	/unit/Setup
Holding cost (h)	3.500	3.500	3.500	3.500	3.500	/unit/month
Lost Sales Cost (πv)	5.500	6.500	4.000	7.000	4.000	/Unit
Buyer 1						
Ordering Cost	13.000	13.000	13.000	13.000	13.000	
Holding cost (h)	2.000	2.000	2.000	2.000	2.000	/unit/month
Lost Sales Cost (πb)	20.000	25.000	20.000	20.000	25.000	/Unit
Buyer 2						
Ordering Cost	8.000	8.000	8.000	8.000	8.000	
Holding cost (h)	2.000	2.000	2.000	2.000	2.000	/unit/month
Lost Sales Cost (πb)	25.000	25.000	25.000	25.000	25.000	/Unit
Buyer 3						
Ordering Cost	10.000	10.000	10.000	10.000	10.000	
Holding cost (h)	2.000	2.000	2.000	2.000	2.000	/unit/month
Lost Sales Cost (πb)	25.000	30.000	25.000	30.000	25.000	/Unit
Buyer 4						
Ordering Cost	8.000	8.000	8.000	8.000	8.000	
Holding cost (h)	2.000	2.000	2.000	2.000	2.000	/unit/month
Lost Sales Cost (πb)	35.000	25.000	25.000	25.000	25.000	/Unit
Buyer 5						
Ordering Cost	13.000	13.000	13.000	13.000	13.000	
Holding cost (h)	2.000	2.000	2.000	2.000	2.000	/unit/month
Lost Sales Cost (πb)	25.000	25.000	25.000	35.000	30.000	/Unit

And in the transshipment or ordering process between buyers, there is an ordering fee between buyers as follows:

Table 4. 2 Data on the cost of ordering between buyers

Connection	Total Order Cost	Dimension
Buyer 1 to buyer 5	13.000	IDR/4 Unit
Buyer 2 to buyer 1	8.000	IDR/4 Unit
Buyer 3 to buyer 1	8.000	IDR/4 Unit
Buyer 3 to buyer 2	8.000	IDR/4 Unit
Buyer 5 to buyer 2	8.000	IDR/4 Unit

4.2 System Description

This research uses a model supply chain between a single vendor, multi buyers / 5 buyers and multi 5 products. The subject of this research is a manufacturing company engaged in making batik products. In this research, the company Manufacturers have the role of vendors and retailers as buyers. This research also considers the lateral transshipment system between buyers, which is a situation where buyers make it possible to send products to other buyers in an effort to supply demand.

The supply chain process that occurs begins when 5 buyers (referred to as Buyer 1, Buyer 2, Buyer 3, Buyer 4, and Buyer 5) receive several requests from consumers. Then check the availability of product stock in the buyer's warehouse. If the product stock is at the reorder point, the buyer will order Q amount of product from the vendor at a cost of A. Next the vendor will receive the order information from the buyer, and start performing several production lot sizes of P with a set up cost of S

In this study, demand is stochastic with normal distribution with a mean of D and a standard deviation of σ or uniformly distributed. Delivery requests buyers distributed uniforms while the lead time in this study was constant. Stochastic demand also causes the risk of shortages inventory (shortage) in the form of Lost Sales whose costs are borne by the buyer.

PT. Batik X Yogyakarta as a vendor sells 5 types of products to buyers as retail companies that sell their products directly to end customers. Besides transactions are carried out between buyers and vendors, in this research buyers can also buy products from other buyers so that quantity information is exchanged Requests are also made between buyers. The correlation between buyers and vendor in ordering products can be seen in the Figure below:

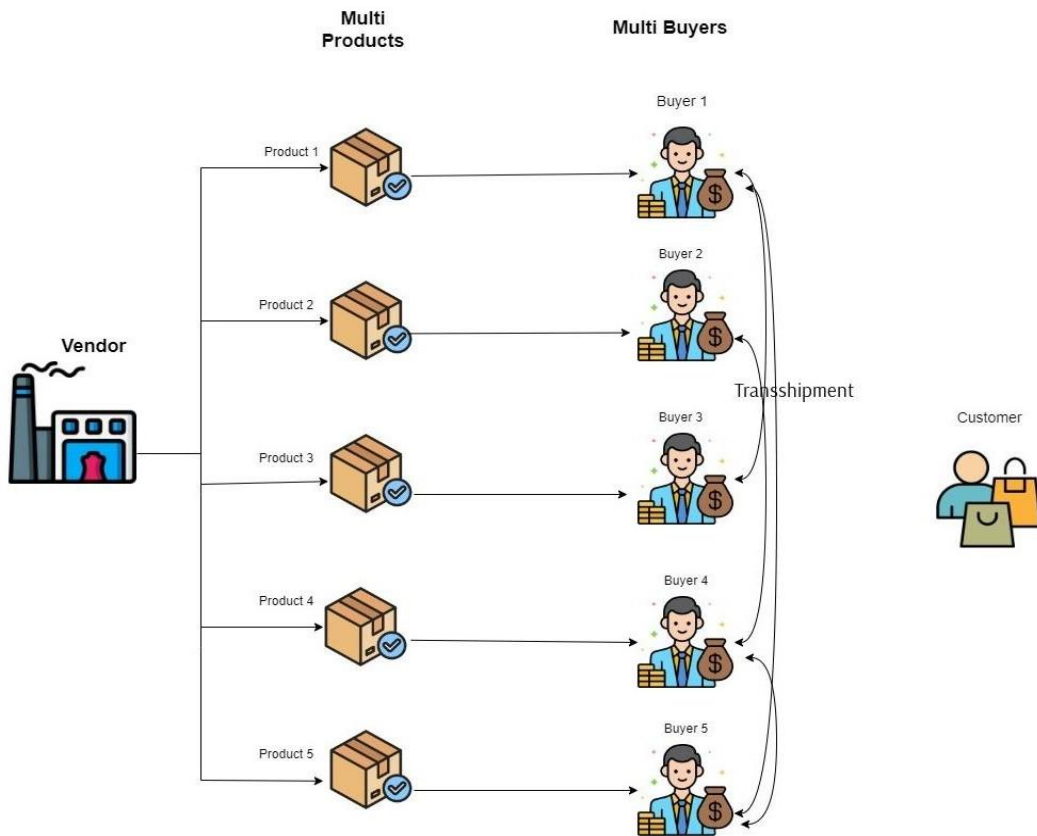


Figure 4. 1 Correlation Between Vendor and Buyer

The environment in this paper follows Affisco, Paknejad, and Nasri (2002), JELS with an imperfect production process. The 100% inspection is done by the manufacturer before it delivers to the warehouse at the factory plants. Any discovery of non-conforming items is reworked by the vendor. See Figure 4. 2 It assumes that the inspection is done with no errors and that the items are repairable.

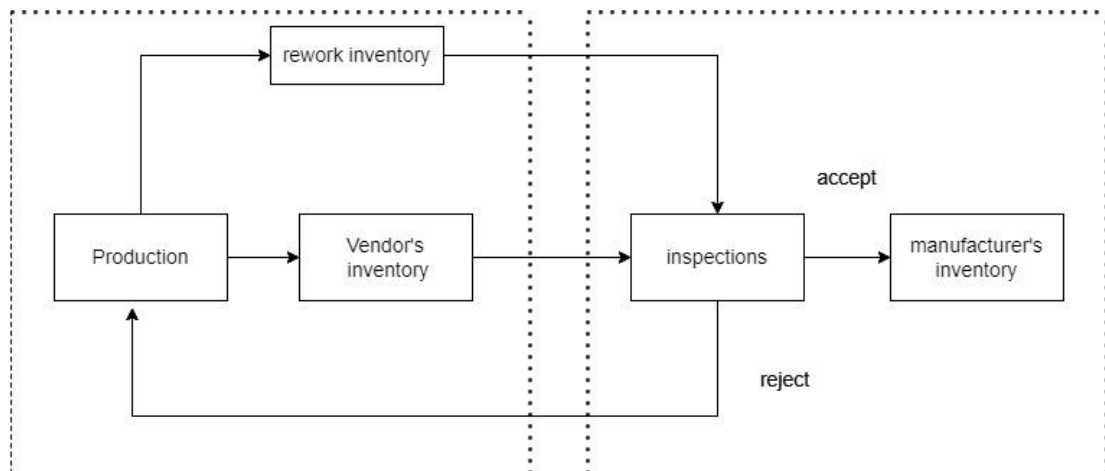


Figure 4. 2 Defect production process with 100% inspection and rework

Since the vendor still has an imperfect production process that is where if a machine has reached a certain amount of production, it will experience a performance decrease, so that sometimes there are defective products with probability.

4.3 Component Model

4.3.1 Notation

The objective is to minimize the joint total cost from the vendor and the manufacturer. The vendor's total costs consist of setup cost, inventory costs, defect costs, inventory costs for rework items and transportation costs. The manufacturer's total cost includes order costs, and inventory costs. The following are the notations used in this study, namely:

General Indexes:

- v : Vendor index
 b : Buyer index
 p : Product index
 t : Period index

Parameters

- D : demand from buyers of product to vendor (unit)
 d : demand between buyers and other buyers (unit)
 dfc : number of defective products (unit)
 σ : demand standard deviation of buyer (unit/month)
 P : vendor production lot size (unit/month)
 A_{bv} : buyer's ordering costs to vendor (IDR/4pcs)
 A_{bb} : ordering costs between buyers (IDR/4pcs)
 S : set-up costs per production (IDR/unit/month)
 h_v : vendor inventory cost per unit per year (IDR/unit/month)
 h_b : buyer's inventory costs per unit per year (IDR/unit/month)
 r_v : vendor's re-production point (unit)
 r_b : buyer's reorder point (unit)
 π_v : lost sales cost of vendor (IDR/unit)
 π_b : lost sales cost of buyers (IDR/unit)
 L : lead time (month)
 Q_b : buyer's order lot size (unit)
 JTC : joint total cost of the supply chain system (IDR)

4.3.2 Decision Variables and Performance Criteria

The decision variables used are as follows:

Q^*	: buyer's optimal ordering lot size	(units)
P^*	: vendor optimal production lot size	(units)
r_b^*	: optimal reorder points	(units)
r_v^*	: vendor optimal reproduction point	(unit)

The following are the performance criteria used:

JTC_b	: total cost from the buyer
JTC_v	: total costs from the vendor
JTC	: join total cost

4.3.3 Assumption and Model Limitations

The assumptions used in this research are as follows:

1. This model is limited to a single vendor inventory system, multiple products, and multiple buyers.
2. Transportation costs per unit from a vendor to buyer or buyer to buyer are constant and independent of the order quantity, thus transportation costs can be ignored.
3. Lead-time is constant.
4. Production level is greater than total demand ($P \geq D$).
5. Considering safety stock but not considering damaged goods.
6. There is no quantity discount.
7. The costs in this research are constant and are not influenced by inflation and others.
8. The vendor still has an imperfect production system, because the production machine is not optimal to meet needs so that when production reaches 5000 production units, there is a lack of performance on the production machine so it often experiences defects in the following period.

4.4 Mathematical Model Formulation

4.4.1 Objective Function

The objective function of the model developed is to determine the total costs of buyers and storage costs between vendors and buyers. These total costs include lost sales costs for buyers,

lost sales vendors, inventory costs for buyers, inventory costs for vendors, order costs buyers, setup costs for vendors, and order costs for buyer to buyer. The decision variables of this model are the number of product orders to vendors, and the reorder point.

The objective function of this model is as follows:

$$\text{Minimization JTC} = \text{TC}_b + \text{TC}_v \quad (4.1)$$

4.4.2 Joint Total Cost of The Buyer (TC_b)

1. Inventory Cost

Inventory costs are costs incurred by internal buyers handle product storage. Inventory costs are a product of the sum of inventories during a certain period, in this research, namely as much as 60 months or 5 years which is then multiplied by the buyer's holding costs per unit. The following is the equation for the buyer's total inventory:

$$\text{HC}_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b \quad \dots(4.2)$$

Therefore:

I_{btp} = Inventory owned by buyer b , period t , and product p

h_{bp} = Buyer b to storage costs per unit on product p

2. Lost Sales Cost

Shortage costs are divided into two parts, namely expectations back-order costs and Lost Sales costs. Shortage costs arise when there is unavailability of the product at the required time or when there is inventory in the warehouse. In this study inventory shortages were considered as Lost Sales, and it is assumed that the buyer does not place a back-order or sudden reordering. The following is the equation for inventory experiencing Lost Sales:

$$\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b \quad \dots(4.3)$$

Therefore:

X_{btp} = Lost sales that occur to buyer b , period t , and product p

π_b = Cost of lost sales per unit borne by buyer b , and product p

3. Ordering Cost to Vendors

Ordering costs are the costs incurred by buyer b on when placing an order with a vendor. The following is the ordering cost formula for vendor:

$$OC_{bv} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv} \quad \dots(4.4)$$

Therefore:

Q_{btp} = Number of orders placed by buyer b , period t , product p to vendor

A_{bv} = Buyer b to ordering costs to the vendor

4. Ordering Cost between Buyers

Ordering costs between buyers are costs incurred by the buyer ordering products from other buyers. Data on demand between buyers was obtained from random generation results based on uniform distribution data using Microsoft Excel. The following is the delivery order cost formula buyer:

$$OC_{bb} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb} \quad (4.5)$$

Therefore:

d_{btp} = Orders placed between buyers for product b , period t , buyer p

A_{bb} = Ordering costs between buyers

4.4.3 Joint Total Cost of the Vendors (TC_v)

1. Inventory Cost

The storage cost is the multiplication of the sum of the inventory over a certain period, in this study, the period that occurs is 60 months or 5 years which is then multiplied by the vendor storage cost per unit. The following is the total cost formula vendor inventory:

$$HC_v = \sum_{p=1}^p \sum_{t=1}^t I_{vtp} \times h_v \quad \dots(4.6)$$

Therefore:

I_{vtp} = Inventory owned by the vendor in period t and product p

h_v = Holding costs on product p owned by the vendor

2. Lost Sales Cost

Vendor lost sales costs occur if the vendor cannot fulfill demand from the buyer resulting in lost sales which are borne by the vendor, in the research these defective products that cannot be reworked are considered lost sales. Following is the vendor's lost sales cost formula:

$$\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vtp} \times \pi_v \quad \dots(4.7)$$

Therefore:

X_{vtp} = Lost sales that occurred for buyer b , period t , and product p

π_v = Cost of lost sales per unit borne by buyer b , and product p

3. Setup Cost

Setup costs are costs obtained from multiplying the production quantity in one setup multiplied by the setup costs that must be incurred for each production times. The following is the formula for the total setup costs that must be incurred by vendors:

$$SC = \sum_{p=1}^p \sum_{t=1}^t P \times S \quad \dots(4.8)$$

4. Defect Cost

Defect costs are costs obtained due to product defects that are needed by the company. The total defect costs are obtained by multiplying the number of defective products by the defect costs. The following is the formula for the total defect costs that must be incurred by the vendor:

$$DC = \sum_{p=1}^p \sum_{t=1}^t dfc \times df_v \quad \dots(4.9)$$

Therefore:

dfc = number of defective products at vendor, period t , and product p

df_v = the cost of defective products borne by the vendor on product p

4.4.4 Joint Total Cost (JTC)

The combined total cost can be obtained from the sum of the total costs between the buyer and vendor. So, the total combined costs can be obtained using a mathematical model formulated as follows:

$$JTC = HC_b + \pi_b + OC_v + OC_{bb} + HC_v + \pi_v + SC + DC \quad \dots(4.10)$$

However:

- HC_b = total inventory costs of buyers
- π_b = total lost sales costs of the buyer
- OC_v = total cost of ordering buyers to vendor
- OC_{bb} = total cost of ordering from buyer to buyer
- HC_v = total vendor inventory costs
- π_v = total lost sales costs of the vendor
- SC = total vendor setup costs
- DC = total defect cost

4.5 Solution Solving Algorithm

The model solution that will be carried out in this research is divided into two, namely real condition model solutions without coordination and model solutions with coordination.

1. Model Without Coordination

A model without coordination model is one where decision-making is randomized between vendors and buyers, respectively. Buyers optimize the Q and r values itself and vendors also do the same thing, namely optimizing the P value and r respectively. The following are the steps for calculating the model without coordination.

Table 4. 3 Steps to Model Calculation Without Buyer Coordination

Buyer	
No	Step by step
1	Generate demand data for each buyer for each batik product by using the Ms. Excel for normal distribution with function: =INT (NORMNIV(RAND();D;σ;)), while for uniform distribution you can use the function:

Buyer	
No	Step by step
	<p>=RANDBETWEEN(Top;Bottom)</p> <p>or we can use the Data Analysis (Data - Data Analysis - Random Number Generation - Ok - Normal - (mean, standard deviation) - Output range) then make a integer number, after that copy as value in excel.</p>
2	<p>Create a calculation simulation model using an Excel table consisting of table of calculation of total requests from customers and other buyers, total ending inventory, number of lost sales, and total orders.</p> <p>The formula is as following:</p> <p>Total Demand = Customer Demand + Buyer Demand</p> <p>Ending Inventory = Beginning Inventory – Total Demand</p> <p>Lost sales occur when there is demand that is greater than supply existing or conditions where ending inventory is less than 0 or has a negative value. This can be seen to mean that customer requests cannot be fulfilled.</p>
3	<p>Order Q occurs when ending inventory is less than value reorder point and not placing orders in the previous period. The values of Q and r_b at the beginning of the calculation are assumed to not exist or uses random numbers to then optimize using Microsoft Excel solver with evolutionary algorithm. The objective function is the minimization of the total costs of each buyer for each product, with modifying variables Q and r_b as well certain limitations.</p>
4	<p>Calculate the buyer's total inventory costs with the equation following:</p> $HC_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b$
5	<p>Calculate the total cost of lost sales for buyers using the formula:</p> $\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b$
6	<p>Calculate the total cost of ordering from vendor and the cost of ordering between buyers with the following equation:</p> $OC_{bv} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv}$

Buyer	
No	Step by step
	$OC_{bb} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb}$
7	<p>Calculating the total cost for the buyer by adding up the cost of inventory, cost of lost sales, and cost of buyer's orders to vendors and inter-buyer orders.</p> $JTC_b = HC_b + \pi_b + OC_{bv} + OC_{bb}$

Table 4. 4 Model Calculation Steps Without Vendor Coordination

Vendor	
No	Step by step
1	<p>The vendor demand data is obtained from the total number of orders placed by buyers for each product during period t. The equation for vendor demand is formulated as follows.</p> $D = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_b$ <p>However:</p> <p>Q_b = Number of orders from buyer b.</p>
2	<p>Create a calculation simulation model using the Ms. Excel, there is The table required to carry out calculations is the total calculation demand, total ending inventory, number of lost sales and total production. The following is the calculation formula:</p> <p>Total Demand = Total Buyer Orders</p> <p>Ending Inventory = Beginning Inventory – Demand</p> <p>Lost sales occur when demand is greater than existing supply or ending inventory is less than 0 or negative. This can be known means customer requests cannot be met.</p>
3	<p>Vendors carry out production if ending inventory is less than return production value. The optimal P and r_v values were calculated using the</p>

Vendor	
No	Step by step
	Microsoft Excel Evolutionary optimization solver. The objective function is Minimize total vendor costs for each product, with variables P and r_v modifiers and certain limitations.
4	Calculate the total vendor inventory costs for each product from all buyers with the following equation: $HC_v = \sum_{p=1}^p \sum_{t=1}^t I_{vtp} \times h_v$
5	Calculate the vendor's total Lost Sales costs with the equation following: $\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vtp} \times \pi_v$
6	Calculate the total vendor set-up costs with the following equation: $SC = \sum_{p=1}^p \sum_{t=1}^t P \times S$
7	Calculation of Total Defect Cost with the following: $DC = \sum_{p=1}^p \sum_{t=1}^t P \times D$
8	Calculate total vendor costs by adding up costs inventory, Lost Sales costs and setup costs. $JTC_v = HC_v + \pi_v + SC + DC$

2. Model With Coordination

Models with coordination are decisions made by vendors and buyers in an integrated way. If the model is without buyer coordination carry out cost optimization individually, in a model with cost coordination which is calculated as the total combined costs of vendor and buyers. The following are:

Table 4. 5 Steps of Model Calculation with Coordination

No	Step by step
1	Using the initial model that already exists in the calculation previously.

No	Step by step
2	<p>Carry out optimization using the Ms. Excel solver Evolutionary with the choice of objective function is the total cost cell a combination of all buyers and vendors. Modifying variables are the values of Q_b and r_b as well as the values of P and r_v in the calculation previously. The existing limitations are as follows:</p> <p>A. The values Q_b, r_b, P, and r_v are integer numbers</p> <p>B. There is a bottom the Q_b and r_v values, namely ≥ 0 or positive value</p> <p>C. Meanwhile, the top on the Q_b and r_v values is ≤ 10000</p> <p>D. The P and r_v values are positive</p> <p>E. The larger P value is the same as the largest demand value ($P \geq D$)</p>
3	<p>Calculate the total ending inventory of buyers, total lost sales of buyers, total buyer's orders, vendor's total ending inventory, vendor's total lost sales, Vendor defect cost and total vendor production.</p>
4	<p>Calculate the buyer's total inventory costs using the equation following:</p>
$HC_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b$	
5	<p>Calculate the total lost sales costs of buyers using the following equation:</p>
$\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b$	
6	<p>Calculate the total cost of orders to vendor and between buyers the following equation:</p>
$OC_{bv} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv}$ $OC_{bb} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb}$	
7	<p>Calculate the total Vendor inventory costs for each product from all buyers with the following equation:</p>
$HC_v = \sum_{p=1}^p \sum_{t=1}^t I_{vtp} \times h_v$	
8	<p>Calculate the vendor's total Lost Sales costs using the equation following:</p>

No	Step by step
	$\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vtp} \times \pi_v$
9	Calculate the total vendor setup costs with the following equation: $SC = \sum_{p=1}^p \sum_{t=1}^t P \times S$
10	Calculating Total defect Cost using the equation following: $DC = \sum_{p=1}^p \sum_{t=1}^t dfc \times df_v$
11	Calculate the total costs of buyers and vendor by adding up the costs following: $JTC = HC_b + \pi_b + OC_v + OC_{bb} + HC_v + \pi_v + SC + DC$

4.6 Valid Model

Equation	Unit Inspection	Status
Buyer's holding costs	$HC_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b$ $HC_b = \text{unit} \times \frac{D}{\text{unit}}$ $HC_b = \text{IDR}$	Valid
Lost Sales Costs buyer	$\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b$ $\pi_b = \text{unit} \times \frac{D}{\text{unit}}$ $\pi_b = \text{IDR}$	Valid
Ordering Cost of buyer to vendor.	$OC_{bv} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv}$ $OC_{bv} = \text{unit} \times \frac{D}{\text{unit}}$ $OC_{bv} = \text{IDR}$	Valid
Ordering cost buyer to the buyer.	$OC_{bb} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb}$	Valid

Equation	Unit Inspection	Status
	$OC_{bb} = \text{unit} \times \frac{D}{nt}$	
	$OC_{bb} = IDR$	
Vendor Holding Cost	$HC_v = \sum_{p=1}^p \sum_{t=1}^t l_{vip} \times h_v$ $HC_v = \frac{nt}{onth} \times \frac{D/n}{onth}$	Valid
	$HC_v = IDR$	
Lost Sales cost Vendor	$\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vip} \times \pi_v$ $\pi_v = \text{unit} \times \frac{D}{nt}$	Valid
	$\pi_v = IDR$	
Set-up Cost Vendor	$SC = \sum_{p=1}^p \sum_{t=1}^t P \times S$ $SC = \frac{nt}{onth} \times \frac{D/n}{onth}$	Valid
	$SC = IDR$	
Total Defect Cost Vendor	$DC = \sum_{p=1}^p \sum_{t=1}^t dfc \times df_v$ $\text{unit} \times \frac{D}{nt}$	Valid
	$DC =$	
	$DC = IDR$	

4.6.1 Validation of the Assumption of the Probability of Defective Products

In this research, the vendor, namely UMKM Batik =INT(RANDBETWEEN(0;40/100)*Number of Production). Then from the number of defective products produced, only 40% of the number of defective products can be increased in production capacity, so that from the number of defective products obtained, the function =ROUND(Number of Defective Products*0.4, 0) is used to obtain the number of defective products produced. Production capacity can be increased, where the remaining 60% of the defective products obtained will be increased to the production quantity so that the overall demand from buyers is met. To find out when the production will experience the potential to produce defective products, that is by

doing a cumulative sum of the number of productions that have been carried out in the previous period if the amount of production in several periods has reached a multiple of 5000 units, then the production activity in that period will have the potential for defective products.

To know when the production will experience potential producing defective products by doing a cumulative sum of the amount of production that has been carried out in the previous period, if the amount of production in some periods has reached multiples of 5000 units, hence on activity Production of such periods will have the potential for defective products. The following is an example of validating the probability assumption for Batik Product 1 between trial results and real data.

t	Init.Inv	Total Demand	End.Inv	Prod. Qty	cum. product qty	Total defect	Lost Sales	Abs. Inv
1	1405	1405	0	1406	1406	0	0	0
2	1406	0	1406	0	1406		0	1406
3	1406	1405	1	1406	2812	0	0	1
4	1407	0	1407	0	2812	0	0	1407
5	1407	1405	2	1406	4218	0	0	2
6	1408	0	1408	0	4218	0	0	1408
7	1408	1405	3	1406	5624	100	0	3
8	1409	0	1409	0	5624	0	0	1409
9	1409	1405	4	1406	7030	0	0	4
10	1410	0	1410	0	7030	0	0	1410
11	1410	1405	5	1406	8436	0	0	5
12	1411	0	1411	0	8436	0	0	1411
13	1411	1405	6	1406	9842	0	0	6
14	1412	0	1412	0	9842	0	0	1412
15	1412	1123	289	0	9842	0	0	289
16	289	282	7	1406	11248	250	0	7
17	1413	1123	290	0	11248	0	0	290
18	290	282	8	1406	12654	0	0	8
19	1414	1123	291	0	12654	0	0	291
20	291	282	9	1406	14060	0	0	9
21	1415	1123	292	0	14060	0	0	292
22	292	282	10	1406	15466	50	0	10
23	1416	1123	293	0	15466	0	0	293
24	293	282	11	1406	16872	0	0	11
25	1417	1123	294	0	16872	0	0	294
26	294	282	12	1406	18278	0	0	12
27	1418	1123	295	0	18278	0	0	295
28	295	282	13	1406	19684	0	0	13
29	1419	1123	296	0	19684	0	0	296
30	296	282	14	1406	21090	650	0	14
31	1420	1123	297	0	21090	0	0	297
32	297	282	15	1406	22496	0	0	15
33	1421	1123	298	0	22496	0	0	298
34	298	282	16	1406	23902	0	0	16
35	1422	1123	299	0	23902	0	0	299
36	299	282	17	1406	25308	100	0	17
37	1423	1123	300	0	25308	0	0	300
38	300	282	18	1406	26714	0	0	18
39	1424	1123	301	0	26714	0	0	301
40	301	282	19	1406	28120	0	0	19
41	1425	1123	302	0	28120	0	0	302
42	302	282	20	1406	29526	0	0	20
43	1426	1123	303	0	29526	0	0	303
44	303	282	21	1406	30932	0	0	21
45	1427	1123	304	0	30932	0	0	304
46	304	282	22	1406	32338	0	0	22
47	1428	1123	305	0	32338	0	0	305
48	305	282	23	1406	33744	0	0	23
49	1429	1123	306	0	33744	0	0	306
50	306	282	24	1406	35150	100	0	24
51	1430	1123	307	0	35150	0	0	307
52	307	282	25	1406	36556	0	0	25
53	1431	1123	308	0	36556	0	0	308
54	308	282	26	1406	37962	0	0	26
55	1432	1123	309	0	37962	0	0	309
56	309	282	27	1406	39368	0	0	27
57	1433	1123	310	0	39368	0	0	310
58	310	282	28	1406	40774	50	0	28
59	1434	1123	311	0	40774	0	0	311
60	311	282	29	0	40774	0	0	29
				40774		1300	0	17198

Figure 4. 3 Validation of results on batik products 1

4.7 Data Processing

At this stage, researchers calculate models without coordination and models with coordination to know the most optimal model.

4.7.1 Example of Model Calculation Without Coordination

1. Buyer

Step 1: Generate Buyer Request Data

The demand data in this research is stochastic in nature where the data can be normally or uniformly distributed with the number of requests varying each month. The demand data here represents requests received by Buyer 1 for Batik Product 1 during 60- months. The average distribution of demand for Buyer 1 for Batik Product 1 is 300 units with a standard deviation of 35 units. The following are the results of generating consumer demand data for Buyer 1 of Batik Product 1 over 60 months:

Table 4. 6 Consumer Demand Data

Normal distribution, Product 1 Buyer 1. (300,35)							
Period (month)	Demand (unit)	Period (month)	Demand (unit)	Period (month)	Demand (unit)	Period (month)	Demand (unit)
1	340	16	329	31	342	46	279
2	286	17	338	32	296	47	306
3	296	18	326	33	281	48	334
4	260	19	262	34	358	49	285
5	282	20	261	35	312	50	331
6	234	21	327	36	313	51	310
7	264	22	312	37	291	52	291
8	306	23	313	38	285	53	274
9	264	24	271	39	300	54	374
10	259	25	322	40	330	55	276
11	344	26	224	41	246	56	318
12	306	27	283	42	308	57	300
13	345	28	289	43	316	58	274
14	311	29	303	44	216	59	281
15	366	30	234	45	394	60	297

In addition to receiving requests from consumers, Buyer 1 also receives requests from Buyer 2 and Buyer 3 as part of the lateral transshipment concept where buyers can fulfill each other's requests. The demand pattern from other buyers is uniformly distributed, with buyer 2 having a lower limit of 2 and an upper limit of 10, while

buyer 3 has a lower limit of 2 and an upper limit of 15. The following is the result of generating requests from buyer 2 to buyer 1:

Table 4. 7 Buyer 2 Demand Data to Buyer 1

Period (unit)	Demand (unit)	Period (unit)	Demand (unit)	Period (unit)	Demand (unit)
1	3	21	6	41	5
2	0	22	0	42	0
3	5	23	0	43	0
4	0	24	10	44	2
5	3	25	0	45	0
6	2	26	0	46	10
7	7	27	0	47	7
8	5	28	0	48	0
9	7	29	6	49	4
10	0	30	8	50	0
11	3	31	0	51	4
12	6	32	4	52	9
13	0	33	0	53	0
14	0	34	7	54	0
15	0	35	9	55	0
16	8	36	0	56	4
17	7	37	8	57	0
18	8	38	0	58	3
19	7	39	0	59	5
20	8	40	0	60	8

The following is the result of generating a request for product 1 from buyer 3 to buyer 1.

Table 4. 8 Buyer 3 Demand Data to Buyer 1

Period (unit)	Demand (unit)	Period (unit)	Demand (unit)	Period (unit)	Demand (unit)
1	4	21	0	41	0
2	12	22	0	42	2
3	0	23	11	43	3
4	14	24	0	44	4
5	4	25	0	45	6
6	15	26	0	46	0
7	5	27	0	47	12
8	0	28	14	48	6
9	12	29	0	49	0

Period (unit)	Demand (unit)	Period (unit)	Demand (unit)	Period (unit)	Demand (unit)
10	11	30	0	50	6
11	0	31	14	51	0
12	0	32	5	52	8
13	13	33	4	53	11
14	4	34	13	54	4
15	6	35	0	55	0
16	12	36	0	56	5
17	0	37	12	57	7
18	10	38	0	58	0
19	10	39	0	59	0
20	0	40	9	60	9

Step 2: Calculation Model for Total Demand, Total Inventory, and Lost Sales.

In this stage, an example calculation of the model will be conducted for Buyer 1 on Product 1. The complete calculation for each buyer and product will be displayed in the appendix.

The ordering policy used for Buyer 1 on Product 1 is based on the results of optimization using Solver Evolutionary and is as follows:

Table 4. 9 Buyer 1 Data on Batik Product 1

Initial inventory (unit)	Order quantity Q (unit)	Reorder point r (unit)	Lead time (month)
300	609	1605	1

Table 4. 10 Examples of Inventory Models for Buyer 1 for Batik Product 1

t	Init. Inv	Demand	End. Inv	Order to Vendor	Order to Buyer 5	Lost Sales	Abs Inv
1	300	264	29	609	5	0	29
2	638	261	365	0	5	0	365
3	365	309	51	609	0	0	51
4	660	334	312	0	0	0	312
5	312	252	53	609	4	0	53
6	662	301	344	0	4	0	344
7	344	332	0	609	2	0	0
8	609	310	294	0	0	0	294

t	Init. Inv	Demand	End. Inv	Order to Vendor	Order to Buyer 5	Lost Sales	Abs Inv
9	294	336	-61	609	2	61	0
10	609	288	310	0	0	0	310
11	310	288	19	609	0	0	19
12	628	276	346	0	0	0	346
13	346	287	46	609	2	0	46
14	655	291	360	0	5	0	360
15	360	309	45	609	3	0	45
16	654	300	334	0	3	0	334
17	334	355	-28	609	0	28	0
18	609	346	245	0	0	0	245
19	245	247	-19	609	0	19	0
20	609	252	349	0	5	0	349
21	349	265	78	609	5	0	78
22	687	299	388	0	3	0	388
23	388	332	45	609	0	0	45
24	654	343	301	0	3	0	301
25	301	325	-24	609	4	24	0
26	609	253	356	0	0	0	356
27	356	311	45	609	0	0	45
28	654	269	371	0	3	0	371
29	371	242	123	609	0	0	123
30	732	325	399	0	2	0	399
31	399	239	146	609	0	0	146
32	755	272	474	0	0	0	474
33	474	335	135	609	0	0	135
34	744	363	361	0	0	0	361
35	361	274	78	609	0	0	78
36	687	333	354	0	0	0	354
37	354	315	19	609	0	0	19
38	628	256	372	0	0	0	372
39	372	332	40	609	0	0	40
40	649	304	336	0	3	0	336
41	336	270	61	609	0	0	61
42	670	311	357	0	5	0	357
43	357	267	87	609	5	0	87
44	696	339	351	0	3	0	351
45	351	280	65	609	5	0	65
46	674	319	345	0	0	0	345

t	Init. Inv	Demand	End. Inv	Order to Vendor	Order to Buyer 5	Lost Sales	Abs Inv
47	345	293	33	609	0	0	33
48	642	328	308	0	5	0	308
49	308	227	77	609	0	0	77
50	686	352	328	0	0	0	328
51	328	304	20	609	2	0	20
52	629	292	320	0	0	0	320
53	320	324	-15	609	0	15	0
54	609	277	328	0	3	0	328
55	328	270	58	609	3	0	58
56	667	358	300	0	0	0	300
57	300	368	-75	609	0	75	0
58	609	263	343	0	4	0	343
59	343	290	48	609	0	0	48
60	657	331	309	0	0	0	309
Total				18270	98	222	11661

Based on the calculation in the table above, the number of orders to a vendor, the number of orders to other buyers, the number of lost sales, and the final inventory level are obtained. After obtaining these data, cost calculations can be carried out for the buyer

Step 3: Perform Q_b and r_b optimization

Q_b and r_b optimization was carried out using Ms. Excel with algorithms evolutionary. The objective function chosen is total buyer costs with variables. modifiers are Q_b and r_b with restrictions such as:

- Q_b and r_b are more than equal to 0 which is positive
- Q_b and r_b are integer numbers

The results of optimizing the optimum Q_b and r_b on Buyer 1 for product 1 values are as follows:

Table 4. 11 Optimization Results of Buyer 1 on Batik Product 1

<u>Order quantity Q (unit)</u>	<u>Reorder point r (unit)</u>
---	--

Order quantity Q (unit)	Reorder point r (unit)
609	1605

Step 4: Calculation of Buyer's Inventory Cost

The buyer's inventory cost can be obtained by multiplying the total inventory with the holding cost of buyer 1 for product 1. The calculation is as follows:

$$HC_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b$$

$$HC_{11} = 11.661 \times 2000$$

$$HC_{11} = \text{IDR } 23.322.000$$

Step 5: Calculation of Buyer Lost Sales Costs

The buyer's lost sales costs can be obtained by multiplying the total lost sales with lost sales costs to Buyer 1 for product 1. There is a calculation as follows:

$$\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b$$

$$\pi_{11} = 222 \times 20.000$$

$$\pi_{11} = \text{IDR } 4.440.000$$

Step 6: Calculation of Buyer Order Costs to vendor and other Buyers

Buyer ordering costs are divided into two, namely ordering costs to vendors and ordering costs to other buyers, in this example, such as Buyer 1 places an order for product 1 from the vendor, and also Buyer 1 places an order to Buyer 5.

There is a calculation of the buyer's ordering costs to the vendor as follows:

$$OC_{bv} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv}$$

$$OC_{V11} = 18.270 \times 3.250$$

$$OC_{V11} = \text{IDR } 59.377.500$$

Meanwhile, the ordering cost to Buyer 5 can be calculated as follows:

$$OC_{bb} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb}$$

$$OC_{b11} = 98 \times 3.250$$

$$OC_{b11} = \text{IDR } 318.500$$

Step 7: Calculation of Total Buyer Costs

The total buyer costs can be obtained by adding up the total inventory costs, total lost sales costs, and total order costs to buyers and vendors. There are calculations as follows:

$$JTC_b = HC_b + \pi_b + OC_{bv} + OC_{bb}$$

$$JTC_b = 23.322.000 + 4.440.000 + 59.377.500 + 318.500$$

$$JTC_b = \text{IDR } 87.458.000$$

2. Vendor

Step 1: Calculating total demand, ending inventory, and Lost Sales

The vendor's model calculation is done for each product with demand being the accumulation of the number of orders from each buyer. The simulation model below is the vendor's model with demand data coming from the number of orders from buyer 1 to buyer 5, complete calculations are attached in the appendix. The production policy for Batik Product 1 is obtained from optimization results using evolutionary algorithms using Microsoft Excel.

Table 4. 12 Vendor Data for Product 1

Initial inventory I0 (unit)	Product Quantity (unit)	Reorder point r_v (unit)	Lead time (month)
1405	1406	28	1

The following is a simulation model owned by the vendor for Batik Product 1.

Table 4. 13 Example Simulation Model of Batik Product Vendor 1

t	Init.Inv	Total Demand	End.Inv	Prod. Qty	cum. product qty	Total defect	Lost Sales	Abs. Inv
1	1405	1405	0	1406	1406	0	0	0
2	1406	0	1406	0	1406	0	0	1406
3	1406	1405	1	1406	2812	0	0	1
4	1407	0	1407	0	2812	0	0	1407
5	1407	1405	2	1406	4218	0	0	2

t	Init.Inv	Total Demand	End.Inv	Prod. Qty	cum. product qty	Total defect	Lost Sales	Abs. Inv
6	1408	0	1408	0	4218	0	0	1408
7	1408	1405	3	1406	5624	100	0	3
8	1409	0	1409	0	5624	0	0	1409
9	1409	1405	4	1406	7030	0	0	4
10	1410	0	1410	0	7030	0	0	1410
11	1410	1405	5	1406	8436	0	0	5
12	1411	0	1411	0	8436	0	0	1411
13	1411	1405	6	1406	9842	0	0	6
14	1412	0	1412	0	9842	0	0	1412
15	1412	1123	289	0	9842	0	0	289
16	289	282	7	1406	11248	250	0	7
17	1413	1123	290	0	11248	0	0	290
18	290	282	8	1406	12654	0	0	8
19	1414	1123	291	0	12654	0	0	291
20	291	282	9	1406	14060	0	0	9
21	1415	1123	292	0	14060	0	0	292
22	292	282	10	1406	15466	50	0	10
23	1416	1123	293	0	15466	0	0	293
24	293	282	11	1406	16872	0	0	11
25	1417	1123	294	0	16872	0	0	294
26	294	282	12	1406	18278	0	0	12
27	1418	1123	295	0	18278	0	0	295
28	295	282	13	1406	19684	0	0	13
29	1419	1123	296	0	19684	0	0	296
30	296	282	14	1406	21090	650	0	14
31	1420	1123	297	0	21090	0	0	297
32	297	282	15	1406	22496	0	0	15
33	1421	1123	298	0	22496	0	0	298
34	298	282	16	1406	23902	0	0	16
35	1422	1123	299	0	23902	0	0	299
36	299	282	17	1406	25308	100	0	17
37	1423	1123	300	0	25308	0	0	300
38	300	282	18	1406	26714	0	0	18
39	1424	1123	301	0	26714	0	0	301
40	301	282	19	1406	28120	0	0	19
41	1425	1123	302	0	28120	0	0	302
42	302	282	20	1406	29526	0	0	20
43	1426	1123	303	0	29526	0	0	303
44	303	282	21	1406	30932	0	0	21

t	Init.Inv	Total Demand	End.Inv	Prod. Qty	cum. product qty	Total defect	Lost Sales	Abs. Inv
45	1427	1123	304	0	30932	0	0	304
46	304	282	22	1406	32338	0	0	22
47	1428	1123	305	0	32338	0	0	305
48	305	282	23	1406	33744	0	0	23
49	1429	1123	306	0	33744	0	0	306
50	306	282	24	1406	35150	100	0	24
51	1430	1123	307	0	35150	0	0	307
52	307	282	25	1406	36556	0	0	25
53	1431	1123	308	0	36556	0	0	308
54	308	282	26	1406	37962	0	0	26
55	1432	1123	309	0	37962	0	0	309
56	309	282	27	1406	39368	0	0	27
57	1433	1123	310	0	39368	0	0	310
58	310	282	28	1406	40774	50	0	28
59	1434	1123	311	0	40774	0	0	311
60	311	282	29	0	40774	0	0	29
		Total		40774	1273836	1300	0	17198

Step 2: Optimizing the values of P and r_v

P and r_v optimization using Ms. Excel solver with the Evolutionary algorithm. The selected objective function is the total vendor cost with the variables being P and r_v with constraints such as:

- The values of P and r_v are integer numbers.
- The value of P is greater than or equal to the maximum value of D .
- The value of P and r_v is greater than or equal to 0, which is a positive value.

The optimization results of the optimum P value and r_v for Batik Product 1 are as follows:

Table 4. 14 Vendor Optimization Results on Batik Products 1

Production quantity P (unit)	Reorder point r_v (unit)
1406	28

Step 3: Calculation of Vendor Inventory Costs

$$HC_v = \sum_{p=1}^p \sum_{t=1}^t I_{vtp} \times h_v$$

$$HC_v = 17.198 \times 3.500$$

$$HC_v = \text{IDR } 60.193.000$$

Step 4: Calculation of Vendor Lost Sales Cost

$$\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vtp} \times \pi_v$$

$$\pi_v = 0 \times 5.500$$

$$\pi_v = \text{IDR } 0$$

Step 5: Calculation Set-up Costs

$$SC = \sum_{p=1}^p \sum_{t=1}^t P \times S$$

$$SC = 40.774 \times 5.700$$

$$SC = \text{IDR } 232.411.800$$

Step 6: Calculation of Total Defect Cost

$$DC = \sum_{p=1}^p \sum_{t=1}^t dfc \times df_v$$

$$DC = 1.300 \times 4.000$$

$$DC = 5.200.000$$

Step 7: Calculation of the Total Vendor Cost

$$JTC_v = HC_v + SC_v + SC + DC$$

$$JTC_v = 60.193.000 + 0 + 232.411.800 + 5.200.000$$

$$JTC_v = \text{IDR } 297.804.800$$

4.7.2 Example of Model Calculation with Coordination

Step 1: Carry out optimization Q_b , r_b , P , and r_v

The data used in the model calculation with coordination is obtained from the model calculation without coordination, both from the buyer and vendor. Then, the data is optimized using Ms. Excel solver, namely the Evolutionary algorithm, with constraints such as:

1. The values of Q , r_b , P , and r_v are integers.
2. There is a lower limit on the values of Q_b and r_v , which is ≥ 0 or positive.
3. The upper limit on the values of Q_b and r_v is ≤ 10000 .
4. The values of P and r_v are positive.
5. The value of P is greater than or equal to the largest demand ($P \geq D$).

The following is the result of optimizing Q_b , r_b , P , and r_v for each buyer and vendor for Batik Product 1 using the above constraints.

Table 4. 15 Buyer Optimization Results Using Models with Coordination

Buyer	Quantity order (Q) unit	Reorder point (r) unit
Buyer 1	609	1605
Buyer 2	306	2536
Buyer 3	96	533
Buyer 4	282	112
Buyer 5	112	387

Table 4. 16 Vendor Optimization Results Using Coordination Models

Production Quantity	Production Point
1406	28

Step 2: Buyer's Inventory Cost Calculation

The buyer's inventory costs can be obtained by multiplying the total inventory with holding costs at buyer 1 for product 1. There is a calculation as follows:

$$HC_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p I_{btp} \times h_b$$

$$HC_{11} = 10.818 \times 2000$$

$$HC_{11} = 21.636.000$$

Step 3: Calculation of Buyer Lost Sales Costs

The buyer's lost sales costs can be obtained by multiplying the total lost sales with lost sales costs to buyer 1 for product 1. There is a calculation as follows:

$$\pi_b = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p X_{btp} \times \pi_b$$

$$\pi_{11} = 290 \times 20.000$$

$$\pi_{11} = 5.800.000$$

Step 4: Calculation of Buyer Order Costs to vendor and other Buyers

Buyer ordering costs are divided into two, namely ordering costs to vendors and ordering costs to other buyers, in this example that is what buyer 1 did ordering product 1 to the vendor and also buyer 1 placing an order to buyer 5. There is a calculation of the buyer's ordering costs to the vendor as follows:

$$OC_{bvp} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p Q_{btp} \times A_{bv}$$

$$OC_{v11} = 18270 \times 3.250$$

$$OC_{v11} = 59.377.500$$

There is also a calculation of ordering costs from buyer to buyer as follows:

$$OC_{bbp} = \sum_{b=1}^b \sum_{t=1}^t \sum_{p=1}^p d_{btp} \times A_{bb}$$

$$OC_{151} = 219 \times 3.250$$

$$OC_{151} = 711.750$$

Step 5: Vendor Inventory Cost Calculation

Vendor inventory costs can be obtained by multiplying the total inventory with holding costs at vendors for product 1. There is a calculation as follows:

$$HC_v = \sum_{p=1}^p \sum_{t=1}^t I_{vtp} \times h_v$$

$$HC_v = 16979 \times 3500$$

$$HC_v = 59.426.500$$

Step 6: Calculation of Vendor Lost Sales Costs

The vendor's lost sales costs can be obtained by multiplying the total lost sales with lost sales costs to vendors for product 1. There is a calculation as follows:

$$\pi_v = \sum_{p=1}^p \sum_{t=1}^t X_{vtp} \times \pi_v$$

$$\pi_v = 0 \times 5.500$$

$$\pi_v = 0$$

Step 7: Vendor Setup Cost Calculation

Vendor setup costs can be obtained by multiplying the total production amount with setup costs at vendors for product 1. There are calculations as follows:

$$SC = \sum_{p=1}^p \sum_{t=1}^t P \times S$$

$$SC = 40.774 \times 5.700$$

$$SC = 232.411.800$$

Step 8: Calculation of total defect product

The total defect costs are obtained by multiplying the number of defective products by the defect costs. The following is the formula for the total defect costs that must be incurred by the vendor:

$$DC = \sum_{p=1}^p \sum_{t=1}^t dfc \times df_v$$

$$DC = 1.149 \times 4.000$$

$$DC = 4.596.000$$

Step 9: Calculate total combined costs

The total combined cost can be obtained by adding up all costs across all buyers and vendors.

There are calculations as follows:

$$\begin{aligned}
 JTC &= HC_b + \pi_b + OC_{bvp} + OC_{bbp} + HC_v + \pi_v + SC + DC \\
 JTC &= 21.636.000 + 5.800.000 + 59.377.500 + 711.750 + 59.426.500 + 0 \\
 &\quad + 232.411.800 + 4.596.000 \\
 JTC &= 492.628.550
 \end{aligned}$$

4.7.3 Summary of Model Calculation from Model Without Coordination

1. Product Batik 1

a. The cost of the buyer

The result of the total inventory cost calculation based on the total inventory multiplied by the inventory cost per unit for Batik Product 1 is as follows:

Table 4. 17 Calculation of Inventory Costs for Buyers of Batik Products 1

Buyer	Abs Inv (unit)	Inventory Cost (IDR/ Unit)	Total Cost Inventory (IDR)
Buyer 1	11.661	2.000	23.322.000
Buyer 2	5.820	2.000	11.640.000
Buyer 3	2.687	2.000	5.374.000
Buyer 4	6.262	2.000	12.524.000
Buyer 5	4.527	2.000	9.054.000

The following is the result of the calculation of Lost Sales buyer costs for Batik Product 1.

Table 4. 18 Calculation of Lost Sales Costs for Buyers of Batik Product 1

Buyer	Total lost sales	Lost Sales Cost/unit (SHORTAGE)	Total Lost Sales Cost
Buyer 1	222	20.000	4.440.000
Buyer 2	258	25.000	6.450.000
Buyer 3	38	25.000	950.000
Buyer 4	15	35.000	525.000
Buyer 5	107	25.000	2.675.000

The following is the result of the calculation of ordering costs from the buyer to the vendor for Batik Product 1.

Table 4. 19 Calculation of Ordering Costs to Vendor of Batik Product 1

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1	18.270	13.000	59.377.500
Buyer 2	9.180	8.000	18.360.000
Buyer 3	2.880	10.000	7.200.000
Buyer 4	8.460	8.000	16.920.000
Buyer 5	3.360	13.000	10.920.000

The following is the result of the calculation of ordering costs in transshipment between buyers for Batik Product 1.

Table 4. 20 Calculation of Delivery Costs for Buyers of Batik Product 1

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1 to 5	98	13.000	318.500
Buyer 2 to 1	198	8.000	396.000
Buyer 3 to 1	297	8.000	594.000
Buyer 4 to 2	372	8.000	744.000

The summary for calculating the optimal order quantity and costs incurred by buyers on Batik Product 1 can be seen in the following table.

Table 4. 21 Summary of Costs for Buyers of Batik Products 1

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	609	1605	23.322.000	4.444.000	59.377.500	318.500	87.458.000
Buyer 2	306	2536	11.640.000	6.450.000	18.360.000	396.000	36.846.000
Buyer 3	96	533	5.374.000	950.000	7.200.000	594.000	14.118.000
Buyer 4	282	112	12.524.000	525.000	16.920.000	744.000	30.713.000
Buyer 5	112	387	9.054.000	2.675.000	10.920.00	-	22.649.000

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Total							191.784.000

b. The Cost of the Vendor

The following is the result of the vendor cost calculation for Batik Product 1 using an evolutionary solver in the model without coordination.

Table 4. 22 Calculation of Inventory Costs for Vendor of Batik Products 1

Total Inventory	Inventory Cost	Total Inventory Cost
17198	3.500	60.193.00

Table 4. 23 Total Cost of Lost Sales Vendor on Batik Product 1

Total Lost Sales	Lost Sales Cost IDR/unit	Total Lost Sales Cost
0	55.00	0

Table 4. 24 Total vendor Setup Costs for Batik Product 1

Total Prod. Qty	Setup Cost IDR/unit	Total Setup Cost IDR/unit
40.774	5.700	232.411.800

Table 4. 25 Total vendor Defect Costs on Batik Product 1

Total product defect	Defect Cost	Total Defect Cost (IDR)
1.300	4.000	5.200.000

Table 4. 26 Total Overall Costs of Vendor on Batik Product 1

P (unit)	r_v (unit)	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost IDR/unit	Total Defect Cost	Total Cost Vendor
1406	28	60.193.000	0	232.411.800	5.200.000	297.804.800

2. Product Batik 2

a. The Cost of the Buyer

The result of the total inventory cost calculation based on the total inventory multiplied by the inventory cost per unit for Batik Product 2 is as follows:

Table 4. 27 Calculation of Inventory Costs for Buyers of Batik Products 2

Buyer	Abs Inv (unit)	Inventory Cost (IDR/ Unit)	Total Cost Inventory (IDR)
Buyer 1	1.039	2.000	2.078.000
Buyer 2	2.865	2.000	5.730.000
Buyer 3	2.137	2.000	4.274.000
Buyer 4	2.425	2.000	4.850.000
Buyer 5	1.598	2.000	3.196.000

The following is the result of the calculation of Lost Sales buyer costs for Batik Product 2.

Table 4. 28 Calculation of Lost Sales Costs for Buyers of Batik Product 2

Buyer	Total lost sales	Lost Sales Cost/unit (SHORTAGE)	Total Lost Sales Cost
Buyer 1	69	25.000	1.725.000
Buyer 2	63	25.000	1.575.000
Buyer 3	31	30.000	930.000
Buyer 4	14	25.000	350.000
Buyer 5	15	25.000	375.000

The following is the result of the calculation of ordering costs from the buyer to the vendor for Batik Product 2.

Table 4. 29 Calculation of Ordering Costs to Vendor of Batik Product 2

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1	920	13.000	2.990.000
Buyer 2	3.016	8.000	6.032.000
Buyer 3	2.352	10.000	5.880.000
Buyer 4	2.808	8.000	5.616.000

Buyer 5	1.792	13.000	5.824.000
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The following is the result of the calculation of ordering costs in transshipment between buyers for Batik Product 2.

Table 4. 30 Calculation Order Cost Buyer to Buyer of Batik Product 2

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost between buyer
Buyer 1 to 5	123	13.000	399.750
Buyer 2 to 1	158	8.000	316.000
Buyer 3 to 1	228	8.000	456.000
Buyer 4 to 2	119	8.000	238.000

The summary for calculating the optimal order quantity and costs incurred by buyers on Batik Product 2 can be seen in the following table.

Table 4. 31 Summary of Costs for Buyers of Batik Products 2

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	40	13	2078000	1725000	2990000	399750	7.192.750
Buyer 2	116	42	5730000	1575000	6032000	316000	13.653.000
Buyer 3	84	40	4274000	930000	5880000	456000	11.540.000
Buyer 4	104	35	4850000	350000	5616000	238000	11.054.000
Buyer 5	64	21	3196000	375000	5824000	-	9.395.000

b. The Cost of the Vendor

The following is the result of the vendor cost calculation for Batik Product 2 using an evolutionary solver in the model without coordination.

Table 4. 32 Calculation of Inventory Costs for Vendor of Batik Products 2

Total Inventory	Inventory Cost	Total Inventory Cost
4969	3500	17.391.500

Table 4. 33 Total Cost of Lost Sales Vendor on Batik Product 2

Total Lost Sales	Lost Sales Cost IDR/unit	Total Lost Sales Cost
1390	6.500	9.035.000

Table 4. 34 Total vendor Setup Costs for Batik Product 2

Total Prod. Qty	Setup Cost IDR/unit	Total Setup Cost IDR/unit
10525	5700	59.992.500

Table 4. 35 Total vendor Defect Costs on Batik Product 2

Total product defect	Defect Cost	Total Defect Cost (IDR)
495	4.000	1.980.000

Table 4. 36 Total Overall Costs of Vendor on Batik Product 2

<i>P</i> (unit)	<i>r_v</i> (unit)	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost IDR/unit	Total Defect Cost	Total Cost Vendor
421	32	17.391.500	9.035.000	59.992.500	1.980.000	88.399.000

3. Product Batik 3

a. The Cost of the Buyer

The result of the total inventory cost calculation based on the total inventory multiplied by the inventory cost per unit for Batik Product 3 is as follows:

Table 4. 37 Calculation of Inventory Costs for Buyers of Batik Products 3

Buyer	Abs Inv (unit)	Inventory Cost (IDR/ Unit)	Total Cost Inventory (IDR)
Buyer 1	2.408	2.000	4.816.000
Buyer 2	6.703	2.000	13.406.000
Buyer 3	2.820	2.000	5.640.000
Buyer 4	2.885	2.000	5.770.000
Buyer 5	3.144	2.000	6.288.000

The following is the result of the calculation of Lost Sales buyer costs for Batik Product 3.

Table 4. 38 Calculation of Lost Sales Costs for Buyers of Batik Product 3

Buyer	Total lost sales	Lost Sales Cost/unit (SHORTAGE)	Total Lost Sales Cost
Buyer 1	36	20.000	720.000
Buyer 2	21	25.000	525.000
Buyer 3	54	25.000	1.350.000
Buyer 4	20	25.000	500.000
Buyer 5	96	25.000	2.400.000

The following is the result of the calculation of ordering costs from the buyer to the vendor for Batik Product 3.

Table 4. 39 Calculation of Ordering Costs to Vendor of Batik Product 3

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1	2.640	13.000	8.580.000
Buyer 2	7.050	8.000	14.100.000
Buyer 3	3.780	10.000	9.450.000
Buyer 4	2.900	8.000	5.800.000
Buyer 5	5.640	13.000	18.330.000

The following is the result of the calculation of ordering costs in transshipment between buyers for Batik Product 3.

Table 4. 40 Calculation Order Cost Buyer to Buyer of Batik Product 3

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1 to 5	100	13.000	325.000
Buyer 2 to 1	289	8.000	578.000
Buyer 3 to 1	265	8.000	530.000
Buyer 4 to 2	220	8.000	440.000

The summary for calculating the optimal order quantity and costs incurred by buyers on Batik Product 3 can be seen in the following table.

Table 4. 41 Summary of Costs for Buyers of Batik Products 3

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	88	306	4.816.000	720.000	8.580.000	325.000	14.441.000
Buyer 2	235	907	13.406.000	525.000	14.100.000	578.000	28.609.000
Buyer 3	126	1783	5.640.000	1.350.000	9.450.000	530.000	16.970.000
Buyer 4	116	31	5.770.000	500.000	5.800.000	440.000	12.510.000
Buyer 5	188	806	6.288.000	2.400.000	18.330.000	-	27.018.000

b. The Cost of the Vendor

The following is the result of the vendor cost calculation for Batik Product 3 using an evolutionary solver in the model without coordination.

Table 4. 42 Calculation of Inventory Costs for Vendor of Batik Products 3

Total Inventory	Inventory Cost	Total Inventory Cost
18.946	3.500	66.311.000

Table 4. 43 Total Cost of Lost Sales Vendor on Batik Product 3

Total Lost Sales	Lost Sales Cost IDR/unit	Total Lost Sales Cost
1.309	4.000	5.236.000

Table 4. 44 Total vendor Setup Costs for Batik Product 3

Total Prod. Qty	Setup Cost IDR/unit	Total Setup Cost IDR/unit
6.024	5.700	34.336.800

Table 4. 45 Total vendor Defect Costs on Batik Product 3

Total product defect	Defect Cost	Total Defect Cost (IDR)
350	4.000	1.400.000

Table 4. 46 Total Overall Costs of Vendor on Batik Product 3

P (unit)	r_v (unit)	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost IDR/unit	Total Defect Cost	Total Cost Vendor
753	0	66.311.000	5.236.000	34.336.800	1.400.000	107.283.800

4. Product Batik 4

a. The Cost of the Buyer

The result of the total inventory cost calculation based on the total inventory multiplied by the inventory cost per unit for Batik Product 4 is as follows:

Table 4. 47 Calculation of Inventory Costs for Buyers of Batik Products 4

Buyer	Abs Inv (unit)	Inventory Cost (IDR/ Unit)	Total Cost Inventory (IDR)
Buyer 1	597	2.000	1.194.000
Buyer 2	1161	2.000	2.322.000
Buyer 3	3557	2.000	7.114.000
Buyer 4	1332	2.000	2.664.000
Buyer 5	3527	2.000	7.054.000

The following is the result of the calculation of Lost Sales buyer costs for Batik Product 4.

Table 4. 48 Calculation of Lost Sales Costs for Buyers of Batik Product 4

Buyer	Total lost sales	Lost Sales Cost/unit (SHORTAGE)	Total Lost Sales Cost
Buyer 1	128	20.000	2.560.000
Buyer 2	71	25.000	1.775.000
Buyer 3	19	30.000	570.000
Buyer 4	22	25.000	550.000
Buyer 5	70	35.000	2.450.000

The following is the result of the calculation of ordering costs from the buyer to the vendor for Batik Product 4.

Table 4. 49 Calculation of Ordering Costs Buyer to the vendor of Batik Product 4

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1	806	13.000	2.619.500
Buyer 2	1.320	8.000	2.640.000
Buyer 3	3.900	10.000	9.750.000
Buyer 4	1.392	8.000	2.784.000
Buyer 5	2.961	13.000	9.623.250

The following is the result of the calculation of ordering costs in transshipment between buyers for Batik Product 4.

Table 4. 50 Calculation Order Cost Buyer to Buyer of Batik Product 4

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1 to 5	151	13.000	490.750
Buyer 2 to 1	154	8.000	308.000
Buyer 3 to 1	202	8.000	404.000
Buyer 4 to 2	190	8.000	380.000

The summary for calculating the optimal order quantity and costs incurred by buyers on Batik Product 4 can be seen in the following table.

Table 4. 51 Summary of Costs for Buyers of Batik Products 4

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	31	9	1.194.000	2.560.000	2.619.500	490.750	6.864.250
Buyer 2	44	3661	2.322.000	1.775.000	2.640.000	308.000	7.045.000
Buyer 3	130	82	7.114.000	570.000	9.750.000	404.000	17.838.000
Buyer 4	48	22	2.664.000	550.000	2.784.000	380.000	6.378.000
Buyer 5	141	42	7.054.000	2.450.000	9.623.250	-	19.127.250

b. The Cost of the Vendor

The following is the result of the vendor cost calculation for Batik Product 4 using an evolutionary solver in the model without coordination.

Table 4. 52 Calculation of Inventory Costs for Vendor of Batik Products 4

Total Inventory	Inventory Cost	Total Inventory Cost
7.469	3.500	261.415.000

Table 4. 53 Total Cost of Lost Sales Vendor on Batik Product 4

Total Lost Sales	Lost Sales Cost IDR/unit	Total Lost Sales Cost
1722	7000	12.054.000

Table 4. 54 Total vendor Setup Costs for Batik Product 4

Total Prod. Qty	Setup Cost IDR/unit	Total Setup Cost IDR/unit
8.295	5.700	47.281.500

Table 4. 55 Total vendor Defect Costs on Batik Product 4

Total product defect	Defect Cost	Total Defect Cost (IDR)
150	4.000	600.000

Table 4. 56 Total Overall Costs of Vendor on Batik Product 4

<i>P</i> (unit)	<i>r_v</i> (unit)	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost IDR/unit	Total Defect Cost	Total Cost Vendor
395	1	261.415.000	12.054.000	47.281.500	600.000	86.077.000

5. Product Batik 5

a. The Cost of the Buyer

The result of the total inventory cost calculation based on the total inventory multiplied by the inventory cost per unit for Batik Product 5 is as follows:

Table 4. 57 Calculation of Inventory Costs for Buyers of Batik Products 5

Buyer	Abs Inv (unit)	Inventory Cost (IDR/ Unit)	Total Cost Inventory (IDR)
Buyer 1	4438	2.000	8.876.000
Buyer 2	3174	2.000	6.348.000
Buyer 3	1235	2.000	2.470.000
Buyer 4	904	2.000	1.808.000
Buyer 5	3952	2.000	7.904.000

The following is the result of the calculation of Lost Sales buyer costs for Batik Product 5.

Table 4. 58 Calculation of Lost Sales Costs for Buyers of Batik Product 5

Buyer	Total lost sales	Lost Sales Cost/unit (SHORTAGE)	Total Lost Sales Cost
Buyer 1	76	25.000	1.900.000
Buyer 2	73	25.000	1.825.000
Buyer 3	29	25.000	725.000
Buyer 4	65	25.000	1.625.000
Buyer 5	105	30.000	5.150.000

The following is the result of the calculation of ordering costs from the buyer to the vendor for Batik Product 5.

Table 4. 59 Calculation of Ordering Costs Vendor of Batik Product 5

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1	5.430	13.000	17.647.500
Buyer 2	4.620	8.000	9.240.000
Buyer 3	1.320	10.000	3.300.000
Buyer 4	1.146	8.000	2.292.000
Buyer 5	5.654	13.000	18.375.500

The following is the result of the calculation of ordering costs in transshipment between buyers for Batik Product 5.

Table 4. 60 Calculation Order Cost Buyer to Buyer of Batik Product 5

Buyer	Total order (unit)	Order Cost/4pcs	Total Order Cost
Buyer 1 to 5	215	13.000	698.750
Buyer 2 to 1	157	8.000	314.000
Buyer 3 to 1	135	8.000	270.000
Buyer 3 to 5	156	8.000	312.000
Buyer 4 to 2	55	8.000	110.000

The summary for calculating the optimal order quantity and costs incurred by buyers on Batik Product 5 can be seen in the following table.

Table 4. 61 Summary of Costs for Buyers of Batik Products 5

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	181	788	8.876.000	1.900.000	17.647.500	698.750	29.122.250
Buyer 2	154	798	6.348.000	1.825.000	9.240.000	314.000	17.727.000
Buyer 3	44	737	2.470.000	725.000	3.300.000	270.000	7.077.000
Buyer 4	38	148	1.808.000	1.625.000	2.292.000	312.000	5.835.000
Buyer 5	187	307	7.904.000	5.150.000	18.375.500	110.000	29.429.500

b. The Cost of the Vendor

The following is the result of the vendor cost calculation for Batik Product 5 using an evolutionary solver in the model without coordination.

Table 4. 62 Calculation of Inventory Costs for Vendor of Batik Products 5

Total Inventory	Inventory Cost	Total Inventory Cost
1.450	3.500	5.075.000

Table 4. 63 Total Cost of Lost Sales Vendor on Batik Product 5

Total Lost Sales	Lost Sales Cost IDR/unit	Total Lost Sales Cost
4160	4.000	16.640.000

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Batik Product or Product Batik, please be consistent. If you prefer Batik Product x....then make them all uniform in writing, vice versa

Table 4. 64 Total vendor Setup Costs for Batik Product 5

Total Prod. Qty	Setup Cost IDR/unit	Total Setup Cost IDR/unit
14.010	5.700	79.857.000

Table 4. 65 Total vendor Defect Costs on Batik Product 5

Total product defect	Defect Cost	Total Defect Cost (IDR)
600	4.000	2.400.000

Table 4. 66 Total Overall Costs of Vendor on Batik Product 5

P (unit)	r_v (unit)	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost IDR/unit	Total Defect Cost	Total Cost Vendor
467	0	5.075.000	16.640.000	79.857.000	2.400.000	103.927.000

4.7.4 Summary of Model Calculation from Model with Coordination

1. Product Batik 1

The following are the results of order optimization and buyer cost calculations on

Batik 1 products that use solvers evolutionary solvers in models with coordination:

Table 4. 67 Results of Total Buyer Cost on Model with Batik Product Coordination 1

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	609	1605	21.636.000	5.800.000	59.377.500	711.750	87.525.250
Buyer 2	306	2536	12.714.000	6.075.000	18.360.000	266.000	37.415.000
Buyer 3	96	533	3.966.000	2.750.000	7.200.000	594.000	14.510.000
Buyer 4	282	112	14.638.000	1.610.000	16.356.000	394.000	32.998.00
Buyer 5	112	387	8.676.000	4.150.000	10.920.000		23.746.00
Total							196.194.250

The following are the results of production optimization and cost calculation at the vendor:

Table 4. 68 Results of Total Vendor Cost on Model With Batik Product Coordination 1

p	r_v	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost	Total vendor Defect Costs	Total Vendor Cost
1406	28	59.426.500	0	232.411.800	4.596.000	296.434.300

Table 4. 69 Results of Join Total Combined Cost of Batik Products 1

Total Cost of All Buyer	Total Cost of all Vendor	Total Combined Cost
196.194.250	296.434.300	492.628.550

In the optimization results above, the optimal Q_b and r_b values can be explained, then the optimal P value is 1406 units with a reorder point of 28 units. There are costs from all buyers, which are 196.194.250 IDR and vendor costs are 296.434.300 IDR So it is known that the total combined costs for Batik Product 1 are equal to 492.628.550 IDR.

2. Product Batik 2

The following are the results of order optimization and buyer cost calculations on products Batik 2 uses evolutionary solvers in models with coordination:

Table 4. 70 Cost Summary of Batik Product Buyers 2

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	40	13	2.064.000	1.900.000	2.990.000	399.750	7.535.750
Buyer 2	116	42	5.730.000	1.575.000	6.032.000	316.000	13.653.000
Buyer 3	84	40	4.260.000	930.000	5.880.000	470.000	11.540.000
Buyer 4	104	35	5.378.000	1.675.000	4.992.000	238.000	12.283.000
Buyer 5	64	21	2.768.000	1.350.000	5.408.000	-	9.526.000
Total							54.355.750

The following are the results of production optimization and cost calculation at the vendor:

Table 4. 71 Results of Total Vendor Cost on Model with Batik Product Coordination 2

p	r_v	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost	Total vendor Defect Costs	Total Vendor Cost
421	32	19.834.500	14.781.000	59.992.500	1.160.000	94.608.000

Table 4. 72 Results of Join Total Combined Cost of Batik Products 2

Total Cost of All Buyer	Total Cost of all Vendor	Total Combined Cost
54.355.750	94.608.000	150.123.750

In the optimization results above, the optimal Q_b^* and r_b^* values can be explained, then the optimal P value is 421 units with a reorder point of 32 units. There are costs from all buyers, which are 54.355.750 IDR and vendor costs are 94.608.000 IDR So it is known that the total combined costs for Batik Product 2 are equal to 150.123.750 IDR

3. Product Batik 3

The following are the results of order optimization and buyer cost calculations on products Batik 3 uses evolutionary solvers in models with coordination:

Table 4. 73 Cost Summary of Batik Product Buyers 3

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	88	306	5.602.000	560.000	8.580.000	370.500	15.112.000
Buyer 2	235	907	13.510.000	250.000	14.100.000	586.000	28.446.000
Buyer 3	126	1783	5.528.000	1.750.000	9.450.000	498.000	17.226.000
Buyer 4	116	31	5.628.000	2.125.000	5.568.000	440.000	13.761.000

Buyer 5	188	806	6.202.000	4.275.000	18.330.000	-	28.807.000
Total							103.352.500

The following are the results of production optimization and cost calculation at the vendor:

Table 4. 74 Results of Total Vendor Cost on Model with Batik Product Coordination 3

p	r_v	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost	Total vendor Defect Costs	Total Vendor Cost
753	0	63.497.000	4.168.000	34.336.800	436.000	102.437.800

Table 4. 75 Results of Join Total Combined Cost of Batik Products 3

Total Cost of All Buyer	Total Cost of all Vendor	Total Combined Cost
103.352.500	102.437.800	205.790.300

In the optimization results above, the optimal Q_b^* and r_b^* values can be explained, then the optimal P value is 753 units with a reorder point of 0 units. There are costs from all buyers, which are 103.352.500 IDR and vendor costs are 102.437.800 IDR So it is known that the total combined costs for Batik Product 3 are equal to 205.790.300 IDR

4. Product Batik 4

The following are the results of order optimization and buyer cost calculations on Products Batik 3 use evolutionary solvers in models with coordination:

Table 4. 76 Cost Summary of Batik Product Buyers 4

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
Buyer 1	31	9	1.204.000	2.000.000	2.619.500	464.750	6.288.250
Buyer 2	44	3661	2.246.000	2.375.000	2.640.000	312.000	7.573.000

Buyer 3	130	82	6.024.000	2.130.000	9.425.000	432.000	18.011.000	
Buyer 4	48	22	2.190.000	1.675.000	2.784.000	414.000	7.063.000	
Buyer 5	141	42	21.900.000	2.345.000	7.790.250	-	12.325.250	
Total								51.260.500

The following are the results of production optimization and cost calculation at the vendor:

Table 4. 77 Results of Total Vendor Cost on Model with Batik Product Coordination 4

p	r_v	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost	Total vendor Defect Costs	Total Vendor Cost
395	1	20.9335.500	10.640.000	247.665.500	4.000.00	56.340.000

Table 4. 78 Results of Join Total Combined Cost of Batik Products 4

Total Cost of All Buyer	Total Cost of all Vendor	Total Combined Cost
51.260.500	60.340.000	111.600.500

In the optimization results above, the optimal Q_b^* and r_b^* values can be explained, then the optimal P value is 395 units with a reorder point of 1 unit. There are costs from all buyers, which are 51.260.500 IDR and vendor costs are 60.340.000 IDR So it is known that the total combined costs for Batik Product 4 are equal to 111.600.500 IDR

5. Product Batik 5

The following are the results of order optimization and buyer cost calculations on Products Batik 3 use evolutionary solvers in models with coordination:

Table 4. 79 Cost Summary of Batik Product Buyers 5

Buyer	Q_b	r_b	Total Inventory Cost	Total Lost Sales Cost	Total Order Cost (to vendor)	Total Order Cost (to buyer)	Total Cost Buyer
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Buyer 1	181	788	7.848.000	2.625.000	17.647.500	546.000	22.443.500	
Buyer 2	154	798	13.442.000	0	9.240.000	454.000	11.694.000	
Buyer 3	44	737	2.972.000	1.000.000	3.300.000	272.000	6.940.000	
Buyer 4	38	148	2.260.000	1.425.000	2.292.000	296.000	4.824.000	
Buyer 5	187	307	9.302.000	2.940.000	18.375.500	72.000	19.455.500	
Total								65.347.000

The following are the results of production optimization and cost calculation at the vendor:

Table 4. 80 Results of Total Vendor Cost on Model with Batik Product Coordination 5

<i>p</i>	<i>r_v</i>	Total Inventory Cost	Total Lost Sales Cost	Total Setup Cost	Total vendor Defect Costs	Total Vendor Cost
467	0	4.900.000	9.200.000	2.850.000	852.000	102.905.000

Table 4. 81 Results of Join Total Combined Cost of Batik Products 5

Total Cost of All Buyer	Total Cost of all Vendor	Total Combined Cost
65.347.000	43.452.000	108.799.000

In the optimization results above, the optimal Q_b^* and r_b^* values can be explained, then the optimal P value is 467 units with a reorder point of 0 units. There are costs from all buyers, which are 65.347.000 IDR and vendor costs are 43.452.000 IDR So it is known that the total combined costs for Batik Product 5 are equal to 108.799.000 IDR.

CHAPTER V

ANALYSIS AND DISCUSSION

5.1 Analysis of Decision Variables

Based on the calculation results obtained in the previous chapter, this chapter will explain the results of the calculation analysis to find out the models as suggested by the result. The model is generated from a condition in which both parties, namely buyers and vendors, optimize each other, while the second model, namely the **model with coordination**, is a condition in which buyers and vendors are optimized altogether by considering the total combined costs generated. Below is the result of a lot size optimal ordering at vendor using models with coordination.

Table 5. 1 Result of Buyer Decision Variables

Type of Product	Part	Model With Coordination	
		$Q_b^*(\text{unit})$	$r_b^*(\text{unit})$
Batik 1	Buyer 1	609	1605
	Buyer 2	306	2536
	Buyer 3	96	533
	Buyer 4	282	112
	Buyer 5	112	387
Batik 2	Buyer 1	40	13
	Buyer 2	116	42
	Buyer 3	84	40
	Buyer 4	104	35
	Buyer 5	64	21
Batik 3	Buyer 1	88	306
	Buyer 2	235	907
	Buyer 3	126	1783
	Buyer 4	116	31
	Buyer 5	188	806
Batik 4	Buyer 1	31	9

Type of Product	Part	Model With Coordination	
		$Q_b^*(\text{unit})$	$r_b^*(\text{unit})$
	Buyer 2	44	3661
	Buyer 3	130	82
	Buyer 4	48	22
	Buyer 5	141	42
	Buyer 1	181	788
Batik 5	Buyer 2	154	798
	Buyer 3	44	737
	Buyer 4	38	148
	Buyer 5	187	307

In Table 5.1 variables for vendor in the research, namely the optimal order lot size (Q_b) and the optimal reorder point (r_b). Based on Table 5.1, there is an optimal ordering lot size (Q_b), where for Batik Products there is an optimal ordering (Q_b) in the model with coordination, there is an optimal ordering lot size (Q_b) which still has the optimal ordering lot size (Q_b)

Then the optimal reorder point decision variable (r_b) obtained in Table 5.1 Based on the optimization results using Solver Evolutionary, especially on variables of The reorder point decision (r_b), can be seen in Table 5.1 which shows the values (r_b) and (Q_b) the evolutionary solver, it happens because the Evolutionary Solver continues to search for various possibilities to find the most optimal value for minimize a cost within a predetermined time and limits, then if the Solver Evolutionary has found the most optimal value, the Solver Evolutionary will automatically stop by providing the optimal value to minimize a cost.

Table 5. 2 Result of Vendor Decision Variables

Type of Product	Part	Model With Coordination	
		$P^*(\text{unit})$	$r_v^*(\text{unit})$
Batik 1		1406	28
Batik 2		421	32
Batik 3		753	0
Batik 4	Vendor	395	1
Batik 5		467	0

Table 5.2 shows the results of the optimal production amount (P) and the return production point (r_v). Optimization results using the Evolutionary solver show the optimal production amount (P) in the model with coordination, as in Batik Product 1 optimal production amount (P), namely 1406 units. In Batik Product 2, the optimal production quantity (P), namely 421 units, as in Batik Product 3, the optimal production quantity (P), namely 753 units, in Batik Product 4, 395 units and in Batik Product 5, 467 units on optimization.

Then at the re-production point (r_v) which was optimized using the Evolutionary solver, we obtained the value at the re-production point (r_v), namely for Batik Product 1 is 28 units, Batik Product 2 is 32 units, and Batik Product 3 is 0 units. Batik Products 4 is 1 unit and Batik Products 5 is 0 units.

The stability of the lot size that needs to be produced by the vendor directly will minimize production setup costs, because the more production there is, the more setup costs incurred will also increase. In addition, an increase in production lot size affects the number of products that need to be stored, which results in inventory costs that must be spent also increase.

5.2 Comparative Analysis of Total Cost of Buyers

The following are the results of the comparison of the total costs that buyers need to pay in the two models obtained from the results of the order lot size optimization and the reorder point of optimization.

Table 5. 3 Comparison Results of Total Cost of Buyers

Types of Products	Part	Model Without Coordination	Model With Coordination
Batik 1	Buyer 1	87.458.000	87.525.250
	Buyer 2	36.846.000	37.415.000
	Buyer 3	14.118.000	14.510.000
	Buyer 4	30.713.000	32.998.00
	Buyer 5	22.649.000	23.746.00
Batik 2	Buyer 1	7.192.750	7.535.750
	Buyer 2	13.653.000	13.653.000
	Buyer 3	11.540.000	11.540.000
	Buyer 4	11.054.000	12.283.000

Types of Products	Part	Model Without Coordination	Model With Coordination
	Buyer 5	9.395.000	9.526.000
	Buyer 1	14.441.000	15.112.000
	Buyer 2	28.609.000	28.446.000
Batik 3	Buyer 3	16.970.000	17.226.000
	Buyer 4	12.510.000	13.761.000
	Buyer 5	27.018.000	28.807.000
	Buyer 1	6.864.250	6.288.250
	Buyer 2	7.045.000	7.573.000
Batik 4	Buyer 3	17.838.000	18.011.000
	Buyer 4	6.378.000	7.063.000
	Buyer 5	19.127.250	12.325.250
	Buyer 1	29.122.250	22.443.500
	Buyer 2	17.727.00	11.694.000
Batik 5	Buyer 3	7.077.000	6.940.000
	Buyer 4	5.835.000	4.824.000
	Buyer 5	29.429.500	19.455.500

Table 5. 4 Total Results of Summing Buyer Costs on Each Batik Product

Types of Products	Part	Model Without Coordination	Model With Coordination
Batik 1		191.784.000	196.194.250
Batik 2		52.834.750	54.355.750
Batik 3	All Buyer	99.548.000	103.352.500
Batik 4		57.252.500	51.260.500
Batik 5		89.190.750	65.347.000

In Table 5.4 there are total costs that need to be incurred by buyers in both models using Evolutionary solver optimization. The total costs of the model with coordination show that total costs tend to increase for Batik Product 1, namely that overall Buyers have increased

when optimization is done. Also, Batik Product 2 and Batik Product 3 have increased, but for Buyer 4, namely from IDR 57,252,500 to IDR 51,260,500, and Buyer 5, namely from IDR 89,190,750 to IDR 65,347,000. The increase and decrease in total cost were caused by changing the order lot and reorder point that occurred in the results of model optimization with coordination.

5.3 Comparative Analysis of Total Vendor Costs

The following is a comparison of the total costs that need to be covered by the vendor in the two models obtained from the results of the optimization of production lot size and optimal production points.

Table 5. 5 Results of Comparison of Total Vendor Costs

Types of Products	Part	Model Without Coordination	Model With Coordination
Batik 1		297.804.800	296.434.300
Batik 2		88.399.000	94.608.000
Batik 3	Vendor	107.283.800	102.437.800
Batik 4		86.077.000	60.340.000
Batik 5		103.972.000	43.452.000

Table 5.5 shows the total costs that must be paid by vendors in two models using Evolutionary solver optimization. In the total cost model with coordination, it shows that total costs tend to decrease for Batik Product 1 from IDR 297,804,800 to IDR 296,434,300 for Batik Product 3 from 107,283,800 IDR to 102,437,800 IDR batik products 4 from 86,077,000 IDR to 60,340,000 IDR batik products 5 from 103,972,000 IDR to 43,452,000 IDR while batik products 2 increases 88,399,000 IDR 94,608,000 IDR.

Table 5. 6 Results of Comparison of Total Defect Costs

Types of Products	Part	Model Without Coordination	Model With Coordination
Batik 1		5.200.000	4.596.000
Batik 2		1.980.000	1.160.000
Batik 3	Vendor	1.400.000	436.000
Batik 4		600.000	4.000.000

Types of Products	Part	Model Without Coordination	Model With Coordination
Batik 5		2.400.000	852.000

Table 5.6 shows the total cost of defective products that must be paid by vendors in both models using Evolutionary solver optimization. The total cost model with coordination shows that the total cost tends to decrease for Batik Product 1 from IDR 5,200,000 to IDR 4,596,000 for Batik Product 2 from 1,980,000 IDR to 1,160,000 IDR Batik Product 3 from 1,400,000 IDR to 436,000 IDR Batik Product 5 from 2,400,000 IDR to 852,000 IDR Meanwhile, batik product 4 increased by 600,000 IDR to 4,000,000 IDR.

5.4 Comparative Analysis of Total Combined Costs

Based on the results of the decision variables generated in the model as shown in Table 5.1 and Table 5.2, at this stage of the analysis, a comparison of the total combined costs of the two models and the savings generated by the model with coordination will be carried out. The calculation is used to determine the savings obtained in the model with coordination.

$$\text{Total saving} = \text{Model Without Coordination} - \text{Model with Coordination} : \text{Model Without Coordination} \times 100\%$$

Table 5. 7 Results of Comparison of Total Combined Costs

Variable	Type of Product	Model Without Coordination	Model With Coordination	Total Savings Combined Costs	
		(IDR)	(IDR)	IDR	Percentage %
	Batik 1	489.588.800	492.628.550	-3.039.750	-0.62%
Total	Batik 2	141.233.750	150.123.750	-8.890.000	-6.29%
Combined	Batik 3	206.831.800	205.790.300	1.041.500	0.50%
Cost	Batik 4	143.329.500	111.600.500	31.729.000	2.21%
	Batik 5	193.162.750	108.799.000	84.363.750	43.67%
Total		1.174.146.600	1.068.942.100	105.204.500	9,84%

Based on Table 5.7, it can be seen that there are savings in total combined costs for Batik Product 3, Batik Product 4, and Batik Product 5, while there are no savings for Batik Product 1 and Batik Product 2. Comparison of the total combined costs between the model without

coordination and the model with coordination, which is where can be seen in Batik Product 1, namely in the initial model it is IDR 489,588,800 per 5 years, while in the combined model it is IDR 492,628,550 per 5 years, in the two model total costs there is a cost difference of -3,039,750 IDR or equal to -0.62%. Then for Batik Product 2, namely in the initial model, it is IDR 150,123,750 per 5 years, while in the combined model it is IDR 150,123,750 per 5 years, in the two models' total costs there is a cost difference of -8,890,000 IDR or -6.29 %. Then for Batik Product 4, namely the initial model, which is IDR 143,329,500 per 5 years, while in the combined model it is IDR 111,600,500 per 5 years, in the two models' total costs, there is a cost difference of IDR 31,729,000 or 2.21%. Meanwhile, for Batik Product 5, the initial model is IDR 193,162,750 per 5 years, while for the combined model it is IDR 108,799,000 per 5 years, for the two total costs there is a cost difference of IDR 84,363,750 or 43.67%.

It can be seen that based on calculations, the model with coordination can provide much greater savings, namely IDR 105,204,500 or 9.84% than the model without coordination. In the coordination model, the vendor benefits more because Batik Product 3, Batik Product 4, and Batik Product 5 have a decrease in total costs from the initial model, this is reversed by the total cost of buyers who have increased total costs when optimizing the model with coordination, namely Batik Product 1 and Batik Product 2. There are calculations used to determine the savings obtained in the model with coordination.

5.4.1 Example Comparison initial data from the company between optimizations

Table 5. 8 Comparison of Initial Data from the Company between optimizations

<i>Product Batik 3 Of buyer</i>		
Initial Data	Model Without Coordination	Model With Coordination
95.015.500	99.548.000	103.352.500
<i>Product Batik 3 of Vendor</i>		
105.883.800	107.283.800	102.437.800

It can be seen that based on the comparison of initial data from the company between optimization, without the exposure of the Coordination Model, the model is built based on the calculation of costs, tailored for the total cost between vendor and buyers. Using an Evolutionary solver for optimization. Steps include creating demand patterns through Excel and using the Evolutionary Solver. In the model with coordination, the model is built by calculating the joint optimization between vendor and buyers using the Evolutionary solver,

Diana Keuangan FTI

I cannot understand the line, please text regarding this..08112500781. "masi" atau setelah optimisasi? Example for comparison of initial data before and after optimization?

with data that has been obtained at the processing stage of the model without coordination so that the costs can be directly calculated to obtain the total combined cost.

CHAPTER VI

CONCLUSIONS AND SUGGESTIONS

6.1 Conclusion

The following are the conclusions obtained from the research results to answer the formulation of the problem in this research:

1. An optimization model considered to minimize the Joint Total Cost (JTC), By applying a solution-solving evolutionary algorithm
2. Coordination between vendors and buyers results in optimal lot sizing and reorder points, minimizing overall costs. To solve no coordination often results in overstock and shortages, vendors should forecast demand for buyers to customize production needs. By knowing the forecasting and knowing that every amount of production reaches 5000 units, then in that period, there will be a decrease in machine performance on the machine which causes the potential production of defective products, it can be concluded that the vendor will calculate production based on forecasting and the risk of defective products. so that overstock is minimized, and shortages can be eliminated.
3. JTC optimization Advantage calculations show a considerable decrease in total combined costs compared to without coordination models. The model with coordination can provide much greater savings, therefore IDR 105,204,500 or 9.84% than the model without coordination

6.2 Suggestion

Based on the results of the research and the conclusions that have been obtained, the researcher provides:

1. In the next study, it can be considered related to the cost of transportation or shipping costs of the product.
2. The model can then be developed by considering other variables such as back-orders, safety stock, and quantity discounts every time the order is made in a certain amount so that it can still be profitable for the buyer.

3. **Monitoring Production Quantity:** Keep an eye on the production quantity, especially when it reaches high levels such as 5000 units, as this can lead to decreased machine performance and increased defective products. This will help in planning and reducing the risk of defective products.

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APPENDIX

Appendix. 1 Demand Pattern Distribution Data

Example in the following normal distribution: Normal (300,35) the number 300 indicates the magnitude of the average and the number 35 indicates the standard deviation. Example in the following Uniform distribution: Uniform (30,70) the number 30 indicates the magnitude of the limit of the upper and 70 numbers indicate the magnitude of the lower boundary.

Product 1:

Order Buyer to Vendor

		Buyer				
		1	2	3	4	5
Vendor		Normal(300, 35)	Normal(150, 20)	Uniform(30, 70)	Uniform(120, 155)	Normal(60, 25)

Orders between Buyers

		PEMBELI				
		1	2	3	4	5
Buyer	1		Uniform(2, 10)	Uniform(2, 15)		
	2				Uniform(7, 13)	
	3					
	4					
	5	Uniform(2, 5)				

Product 2:

Order Buyer to vendor

		Buyer				
		1	2	3	4	5
Vendor		Normal(10, 7)	Normal(50, 13)	Normal(40, 10)	Uniform(30, 65)	Uniform(20, 35)

Orders Between Buyers

		Buyer				
Buyer	1	2	3	4	5	
1		Uniform(5, 8)	Uniform(5, 7)			
2				Uniform(2, 5)		
3						
4						
5	Uniform(2, 5)					

Product 3:

Order Buyer to vendor

		Buyer				
		1	2	3	4	5
Vendor	Uniform(22, 47)	Uniform(100, 130)	Uniform(44, 83)	Uniform(20, 75)	Uniform(80, 110)	

Orders Between Buyers

		Buyer				
Buyer	1	2	3	4	5	
1		Uniform(5, 15)	Uniform(7, 9)			
2				Uniform(4, 11)		
3						
4						
5	Uniform(3, 4)					

Product 4:

Order Buyer to vendor

		Buyer				
		1	2	3	4	5
Vendor	Uniform(2, 17)	Uniform(10, 30)	Uniform(24, 93)	Uniform(10, 35)	Normal(50, 20)	

Orders Between Buyers

	Buyer				
Buyer	1	2	3	4	5
1		Uniform(4, 7)	Uniform(3, 11)		
2				Uniform(3, 9)	
3					
4					
5	Uniform(4, 5)				

Product 5:

Order Buyer to vendor

	Buyer				
	1	2	3	4	5
Vendor	Normal(87, 7)	Normal(80, 20)	Uniform(14, 33)	Uniform(10, 30)	Normal(90, 15)

Orders Between Buyers

	Buyer				
Buyer	1	2	3	4	5
1		Uniform(2, 10)	Uniform(2, 7)		
2				Uniform(1, 3)	
3					
4					
5	Uniform(5, 8)		Uniform(3,6)		