

**INTEGRATING SOCIAL COSTS INTO JOINT ECONOMIC LOT SIZING:
OPTIMIZING ORDER QUANTITY TO MINIMIZE INVENTORY AND
MENTAL HEALTH-RELATED COSTS IN A MULTI-BUYER BATIK
SUPPLY CHAIN**

UNDERGRADUATES THESIS

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



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AUTHENTICITY STATEMENT

I acknowledge that this thesis is entirely my own work, except for quotations and summaries for which I have clearly stated the sources. If it is later proven that this acknowledgement is untrue and violates valid regulations, I am willing to have the degree I have received revoked by the Universitas Islam Indonesia.

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Demikian surat keterangan penelitian ini kami buat. Atas perhatiannya dan kerja samanya kami mengucapkan terima kasih.

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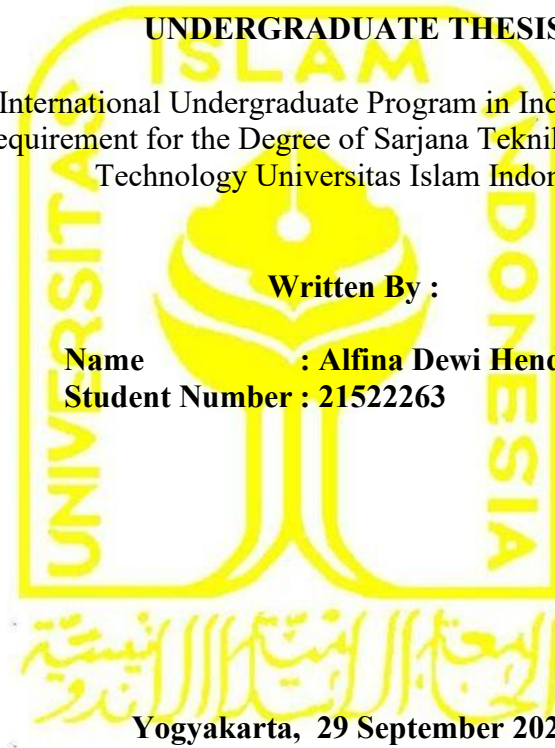
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DEDICATION PAGE

To ayah and ibu, who have always supported and prayed for me, I express my sincere gratitude for all that you have given me. May you always be blessed with good health and long life, so that you may continue to accompany and witness my journey toward success.

MOTTO

"Allah does not burden a soul beyond that it can bear."
(Surah Al-Baqarah: 286)

"And whoever fears Allah, Allah will make a way for us to escape (from every difficulty)."
(Q.S. At-Talaq (65:2-3))

"There is no gift more valuable that parents can give to their children than the education of noble character."
(HR. Bukhari)

PREFACE

Assalamu'alaikum Warahmatullahi Wabarakatuh

All praise and gratitude go to Allah SWT for His mercy, grace, and guidance, which enabled the author to successfully complete this undergraduate thesis titled "Integrating Social Costs Into Joint Economic Lot Sizing: Optimizing Order Quantity to Minimize Inventory and Mental Health-Related Costs in a Multi-Buyer Batik Supply Chain." This thesis is submitted as part of the requirements for getting a Bachelor's degree in Industrial Engineering from the Faculty of Industrial Technology, Universitas Islam Indonesia. The completion of this effort would not have been possible without the extraordinary assistance, direction, and encouragement of numerous individuals and organizations. As such, the author would like to express genuine appreciation and profound gratitude to the following:

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The author acknowledges that this thesis may still have some shortcomings. Constructive feedback and suggestions are greatly appreciated for improving future research. In conclusion, the author hopes that this thesis will offer valuable insights and contribute to the academic discussion in the field of Industrial Engineering.

Wassalamu'alaikum Warahmatullahi Wabarakatuh

Yogyakarta, September 19, 2025



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ABSTRACT

This research aims to develop an integrated model for optimizing order quantities within the batik supply chain, combining economic cost reduction with mental health considerations of the workforce. The study applies the Joint Economic Lot Size (JELS) model to minimize inventory costs (holding, ordering, and lost sales), while also addressing social costs, particularly the mental health challenges faced by workers in batik production. The focus is on balancing production efficiency and employee welfare by integrating mental health data (e.g., stress, burnout, and workload) into the traditional economic models. Data from a batik vendor in Yogyakarta serving multiple retailers was collected through surveys, interviews, and historical data, evaluating the impact of mental health on productivity and overall supply chain performance. The research incorporates evolutionary algorithms to optimize order cycles, reduce the Grand Total Cost (GTC), and improve both economic and social sustainability. The findings indicate that optimizing order quantities while considering worker mental health can significantly reduce operational costs, enhance employee well-being, and improve supply chain efficiency. This research provides valuable insights for industries, especially labor-intensive ones like batik, to adopt more sustainable and humane supply chain practices.

Keywords: Batik, Supply Chain, Social Costs, Mental Health, Joint Economic Lot Size, Optimization, Evolutionary Algorithm, Sustainability.

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CHAPTER I

INTRODUCTION

1.1 Background

The batik industry is a significant contributor to Indonesia's economy, as it combines its rich cultural heritage with industrial and commercial opportunities. This sector not only contributes significantly to economic growth and employment opportunities but also preserves traditional craftsmanship (Indonesian Ministry of Industry, 2024). The supply chain frequently comprises a single vendor that supplies multiple retailers, resulting in substantial fluctuations in demand as the demand for batik products increases. In order to guarantee seamless operations and meet market demands, it is imperative to implement effective inventory management in this dynamic environment. The primary objective of conventional inventory management methods is to reduce economic costs, including holding, procuring, and stockout costs. Nevertheless, these methodologies frequently fail to account for social costs, including worker health and well-being, which are essential for the sustainability of labor-intensive industries like batik (Fan, Zhang, & Wei, 2021).

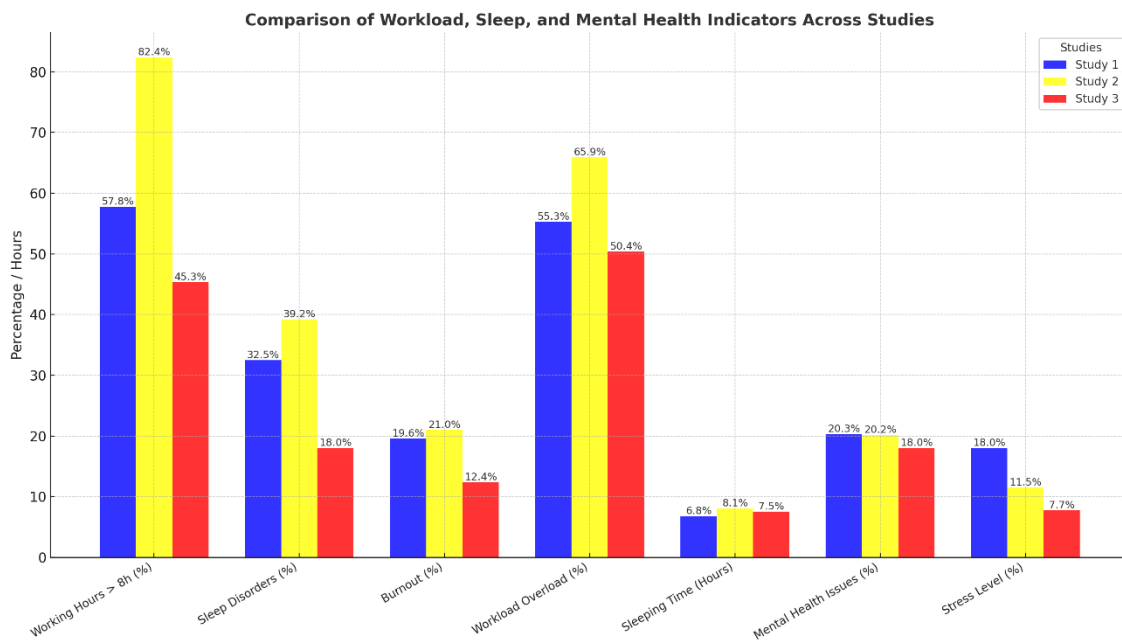


Figure 1. 1 Comparison of Workload, Sleep, and Mental Health Indicators

The urgent necessity for sustainable labor practices is underscored by the visual data in Figure 1.1, which emphasizes critical indicators such as sleeping time, stress levels, mental health issues,

burnout, workload, sleep disorders, and working hours exceeding 8 hours. The impact of high workloads on worker well-being is illustrated by the graph, which demonstrates significant variability in these indicators across studies. For example, a staggering 82.4% of individuals report working hours exceeding eight hours, which is associated with increased stress levels (18%) and mental health issues (20.3%). Additionally, the cumulative impact of extended duties on employee health and productivity is emphasized by sleep disorders and burnout, as evidenced by numerous studies. Györfy et al. (2016) emphasized the negative mental health consequences associated with burnout and workload, whereas Sobhani et al. (2023) underscored the inverse relationship between mental burden and workability, particularly among nurses in high-stress environments. Furthermore, Le Thi Ngoc et al. (2022) have emphasized the prevalence of melancholy, anxiety, and stress among frontline health workers during the COVID-19 pandemic, identifying long working hours as a significant risk factor. This evidence is consistent with the industry's urgent requirement to integrate social sustainability principles. The batik sector can achieve ethical and operational balance by incorporating social costs, such as tension and burnout, into inventory management systems like the JELS model. In addition to reducing concealed costs, such as delayed deliveries and rejected orders, improved practices will also enhance the productivity and resilience of the workforce. This dual approach guarantees that the industry can meet the increasing demands of the market while simultaneously protecting its most valuable asset its employees.

The batik supply chain consists of two main levels: the retailer, acting as the intermediary between batik items and consumers, and the vendor, tasked with making and supplying these products. Retailers satisfy client demand by ordering from vendors; However, vendors sometimes prioritize increasing order numbers without sufficiently addressing the working conditions and welfare of their employees. This neglect often results in mental health issues among employees, including stress, burnout, and weariness, which subsequently detrimentally affect vendor performance. These consequences result in concealed demand costs, such as rejected products and delayed delivery, which impede the vendor's capacity to fulfil retailer expectations efficiently. Setiawan and Prabowo (2020) underscored the significance of tackling these difficulties in their research on sustainable supply chain management within the batik industry, stressing that enhancing worker wellbeing can alleviate these concealed costs and improve overall operational sustainability. This research seeks to identify and quantify concealed costs while suggesting techniques to optimize store orders in accordance with customer demand and vendor production capabilities. The

study underscores the value of vendor relationship management, emphasizing both production optimization and the necessity of addressing workers' mental health to maintain sustainable supply chain operations. An evolutionary algorithm is proposed to enhance order management by reconciling consumer demand, production capacity, and employee welfare, thereby establishing a comprehensive foundation for sustainable and efficient supply chain performance.

Workers frequently experience increased responsibilities during periods of high demand. Mental health challenges, such as burnout, diminished sleep quality, and stress, can result from prolonged exposure to heavy workloads. The vendor's capacity to fulfill orders on time is also impacted by these issues, which also affect worker productivity. Financial penalties, unmet customer demand, and a loss of trust between vendors and consumers can result from production delays. Lee and Lee (2019) identified tension as a critical factor that diminishes operational efficiency and underscored the necessity of proactive strategies to promote employee well-being. Likewise, Karimi and Ardalan (2019) emphasized the importance of addressing physical and psychosocial vulnerabilities in supply chains to ensure operational stability and productivity.

It has become increasingly crucial to incorporate social sustainability principles into inventory management systems in order to establish a more ethical and resilient supply chain. Social sustainability emphasizes ethical labor practices, worker welfare, and equitable treatment. The batik industry, which significantly relies on manual labor for production, is particularly affected by these principles. Karimi and Ardalan (2019) assert that the integration of social factors into supply chain management is beneficial in mitigating operational instabilities that are a result of labor stress. In an industry where employees are the foundation of operations, it is imperative to prioritize employee well-being in order to maintain productivity and minimize disruptions.

The objective of this investigation is to improve the Joint Economic Lot Size (JELS) model, which has historically been concerned with optimizing order quantities in order to reduce economic expenses. Zhou, Wang, and Zhang (2022) suggested that the JELS model be modified to account for social costs by integrating variables such as worker workload, supervisor accessibility, and burnout levels. The updated model can establish order intervals that reduce the burden on workers while simultaneously ensuring cost efficiency and demand fulfillment by incorporating these factors. This method is consistent with contemporary sustainable supply chain management trends, which prioritize workforce welfare over operational success.

In order to facilitate this improvement, clustering algorithms will be implemented to categorize the mental health conditions of employees into two groups: those who are confronted with obstacles and those who are not. Kouki, Michalakidis, and Papageorgiou (2020) underscored the importance of adaptive techniques in dynamic supply chain environments, particularly when labor conditions are a critical factor. This research will provide practical insights for enhancing overall supply chain performance and increasing workforce conditions by examining factors such as workload, sleep duration, stress levels, and access to supervisor support.

The necessity of incorporating social sustainability into supply chain practices is strongly supported by empirical studies. Fan, Zhang, and Wei (2021) demonstrated that the integration of social considerations not only enhances the resilience of supply chains but also reduces systemic risks. Moreover, Zhou, Wang, and Zhang (2022) demonstrated that the operational efficiency and adaptability of inventory models are improved by incorporating social costs. These results are especially pertinent to labor-intensive industries, such as batik production, where operational outcomes are directly influenced by worker stability and well-being.

The significance of addressing concealed social costs, such as tension and burnout, is emphasized by the batik industry's dependence on manual production techniques. These factors frequently remain undetected, despite their substantial influence on operational outcomes. Lee and Lee (2019) contended that the prevention of exhaustion and the reduction of stress enhances worker productivity and decreases turnover rates, thereby contributing to long-term operational stability. In the same vein, reports such as *Batik Pekalongan: Significance Role in Economic* (Asia Climate Lab, 2019) underscore the economic significance of batik in regional development, while simultaneously confronting challenges such as the sustainability of the workforce and the growing demand for production.

In summary, this study serves to reconcile the disparity between operational efficacy and social responsibility within the batik supply chain. The objective of this study is to establish a comprehensive framework for sustainable decision-making by incorporating social costs into the Joint Economic Lot Size (JELS) model. This method protects the welfare of workers while simultaneously addressing inefficiencies in inventory management. The research endeavors to cultivate a more ethical, resilient, and productive batik sector that prioritizes the health and well-being of its workforce while meeting the increasing demands of the market, in accordance with global sustainability objectives.

1.2 Problem Formulation

Based on the research background, the problem formulations are as follows:

1. How can inventory costs (holding, ordering, and lost sales) be minimized by determining the optimal order quantity and reorder point, and how does this optimization affect the Joint Total Cost (JTC) in the batik industry when considering workers' mental health?
2. How can vendors create a more sustainable and worker-friendly inventory system by integrating employee well-being, and how many workers are predicted to face potential mental health problems after optimization?

1.3 Research Objectives

Based on the problem formulation, the research aims to achieve the following:

1. To develop an integrated inventory optimization model that combines the Q-system to determine the optimum ordering quantity for buyers to vendors.
2. To incorporate social and mental health considerations of vendor workers into the model, creating a more sustainable and worker-friendly inventory system.
3. To evaluate the cost savings and overall benefits of implementing the optimized model for both buyers and vendors.

1.4 Research Benefits

This research is projected to provide benefits for all stakeholders, including:

1. For Batik Suppliers: This research provides valuable insights into improving inventory management by incorporating social costs, helping to reduce inefficiencies and strengthen relationships between vendors and retailers.
2. For Workers: By addressing mental health issues and promoting balanced workloads, this study aims to create better workplace conditions, reduce stress and burnout, and ultimately improve the well-being of workers.
3. For Students: The research contributes to advancing knowledge in sustainable supply chain management by showcasing how social sustainability can be integrated into economic models like the JELS framework, paving the way for more responsible business practices.

1.5 Scope of Research

This undergraduate research operates within the following limitations:

1. The research methods focus on grouping workers into categories based on their mental health risks using clustering techniques, analyzing workload patterns through historical data, and enhancing the Joint Economic Lot Size (JELS) model by integrating social costs to improve inventory management.
2. The study is centered on the batik supply chain, specifically examining a vendor currently serving two retailers, with plans to expand to five retailers.
3. The focus of this study is to develop an optimized ordering strategy and inventory management framework that incorporates social factors, such as worker stress and well-being, alongside operational efficiency.
4. The data used in this research, including information on workers' sleeping habits, workload, stress levels, and access to supervisors, were collected during fieldwork. These data are confidential and will not be shared outside the research.

1.6 Systematic Research

CHAPTER I: INTRODUCTION

This chapter offers a comprehensive summary of the research, which encompasses the problem's context, problem formulation, limitations of the study, objectives, benefits, and report structure. It establishes the foundation for comprehending the research's significance and objective.

CHAPTER II: REVIEW OF THE LITERATURE

This chapter provides a thorough examination of the current body of literature, integrating both inductive and deductive methodologies. It functions as a theoretical framework, connecting the research queries to pertinent theories and previous studies.

CHAPTER III: RESEARCH METHODS

This section delineates the methodology, which incorporates the research design, instruments, and step-by-step procedures. The research object, data collection, and analysis stages employed to accomplish the study's objectives are all described.

CHAPTER IV: DATA COLLECTION AND PROCESSING

The data acquisition and processing phases are the primary focus of this chapter. It comprises preliminary analysis, tables, figures, and descriptions of the raw data, which will subsequently serve as the foundation for the discussion and interpretation in the subsequent chapter.

CHAPTER V: DISCUSSION

This chapter analyzes the results of the data processing and establishes a connection between them and the research objectives and queries. It encompasses a comprehensive examination of the findings and suggests potential enhancements to resolve the identified issues.

CHAPTER VI: CONCLUSION AND RECOMMENDATION

In this concluding chapter, the primary discoveries of the investigation are summarized, offering solutions to the problem formulation. It also contains practical suggestions for stakeholders and recommendations for future studies, which are derived from the insights obtained from the study.

CHAPTER II

LITERATURE REVIEW

2.1 Deductive Review

2.1.1 Mental Health

Mental health, as described by the World Health Organization (2013), is a condition of well-being wherein individuals recognize their potential, manage the typical stressors of life, engage in productive employment, and contribute to their community. It is a fundamental element of total health, affecting emotional, psychological, and social functioning.

Keyes (2002) characterizes mental health as a spectrum that spans from languishing to flourishing. Languishing denotes a condition of emotional stagnation, diminished motivation, and a sense of emptiness, whereas thriving signifies excellent mental health, characterized by positive emotions, resilience, and a robust sense of purpose. The Diagnostic and Statistical Manual of Mental Illnesses (DSM-5), published by the American Psychiatric Association in 2013, classifies mental health illnesses such as anxiety, depression, and stress-related ailments. These illnesses influence individuals' cognition, emotions, and behaviors, frequently hindering daily functioning and overall quality of life.

Kessler et al. (2005) emphasize the widespread occurrence of mental health issues, indicating their commonality across diverse age groups and demographics. Their findings underscore that prompt identification and intervention are crucial for the optimal management of mental health disorders. Galea, Nandi, and Vlahov (2005) elucidated those external influences, including exposure to traumatic experiences, occupational stress, and insufficient social support, can profoundly affect mental health. These pressures can result in disorders such as anxiety, depression, and post-traumatic stress disorder (PTSD), impacting both individuals and their communities.

Mental health concerns among workers are becoming increasingly pertinent inside the batik supply chain. When retailer demand surges, vendor-level employees encounter intensified workloads, diminished sleep, elevated stress, and burnout. Mental health disorders can lead to absenteeism, diminished productivity, manufacturing errors, and employee turnover. Vendors encountering such issues may find it difficult to adhere to delivery deadlines, leading to penalties from retailers and forfeited sales opportunities.

Mental health concerns among workers in the batik supply chain are becoming more prevalent. When retail demand rises, vendor workers face increased workloads, fewer sleeping hours, higher stress levels, and burnout. These mental health concerns can lead to absenteeism, decreased productivity, errors in production, and even turnover. Vendors encountering such issues may fail to satisfy delivery deadlines, resulting in retailer penalties and missed sales opportunities. Key Factors contributing to mental health challenges in this context include:

1. Sleeping Time

The physical and mental performance of employees can be significantly impacted by insufficient sleep. Proper sleep is essential for the maintenance of cognitive function, concentration, and productivity in the workplace, as well as for recuperation, as per Walker and McGowan (2018). The significance of sleep deprivation for the overall well-being of workers is underscored by its association with cognitive decline, psychological disturbances, and an elevated risk of errors.

2. Workload of Workers

Excessive workloads are a key source of stress and exhaustion in the job. According to Kahn and Byosiore (1992), when employees encounter expectations that exceed their capacity, they may experience feelings of pressure and inadequacy, which can harm their mental health. Managing workload is critical for a healthy work environment and avoiding burnout.

3. Stress Level of Workers

The efficiency and concentration of employees can be adversely affected by elevated tension levels. Lazarus and Folkman (1984) observe that prolonged tension impairs an individual's capacity to concentrate and make decisions, resulting in increased errors and decreased productivity. In order to improve workplace efficacy and employee well-being, it is essential to address stress levels.

4. Burnout

Burnout, defined by physical and emotional exhaustion, represents a critical consequence of extended stress exposure. Maslach and Leiter (2016) characterize burnout as encompassing fatigue, depersonalization, and a reduced sense of personal accomplishment. This condition significantly affects mental and physical health, leading to decreased motivation and job satisfaction among employees.

The mental health of those involved in the batik supply chain is a significant hidden cost issue, as stated in conclusion. Stakeholders have the ability to develop a supply chain system that is more sustainable and efficient if they acknowledge and address the difficulties that they face through data-driven analysis and smart order placement.

2.1.2 Supply Chain

Supply Chain (SC) is a structured system that encompasses a succession of integrated activities, including planning, procurement of raw materials, production, and the distribution of products to end customers, as per Chopra and Meindl (2010). SC's primary objective is to guarantee that products are delivered on time, cost-effectively, and efficiently, thereby satisfying customer needs and reducing operational inefficiencies. This process necessitates the seamless exchange of materials, information, and financing among numerous entities, such as suppliers, manufacturers, distributors, retailers, and end users. In the same vein, Kaminsky & Simchi-Levi (2003) define Supply Chain as a methodical approach that interconnects a variety of components in the production and distribution processes. They emphasize that supply chains must be strategically designed to reduce waste, enhance flexibility, and respond promptly to market changes. By optimizing resource utilization and adhering to production timelines, effective Supply Chain management enhances an organization's overall competitiveness.

Lukman (2021) elaborates on this by characterizing the supply chain as a cohesive network that connects suppliers, manufacturers, distributors, and retailers. The seamless operation of the entire system is contingent upon the critical function of each link in the chain. Lukman emphasizes that Supply Chain is not solely concerned with the movement of tangible products; it also involves the exchange of precise and timely information, which is essential for the development of strategies and decision-making. He underscores the significance of incorporating technology into Supply Chain processes to improve efficiency, traceability, and visibility.

Furthermore, O'Brien & Marakas (2011) underscore the significance of information systems in the facilitation of Supply Chain operations. They contend that contemporary Supply Chain significantly depends on robust Enterprise Resource Planning (ERP) systems and Supply Chain Management (SCM) software to monitor, control, and optimize processes. Real-time data sharing across the Supply Chain network is facilitated by information technology, which enables stakeholders to effectively predict demand, manage inventory levels, and prevent bottlenecks.

Utilizing these systems is also essential for mitigating the risks associated with fluctuations in demand and supply.

Stevenson (2018) emphasizes the importance of efficacy in the management of resources, production schedules, and logistics in order to achieve success, with a particular emphasis on the operational aspect of Supply Chain. In Supply Chain, operational excellence is achieved by optimizing transportation routes, reducing delay times, and ensuring that inventory levels are in accordance with market demands. Stevenson also emphasizes the significance of continuous improvement practices, including Just-In-Time (JIT) methodologies and Lean Manufacturing, in order to enhance productivity and reduce wastage within the Supply Chain ecosystem.

The majority of definitions of Supply Chain are centered on the fundamental principles of integration, efficiency, and collaboration; however, the interpretation may differ based on the specific challenges and objectives of the industry. For instance, in the manufacturing sector, Supply Chain may prioritize production efficiency and raw material procurement, whereas in the retail sector, the emphasis may transfer to inventory management, demand forecasting, and customer service.

2.1.3 Supply Chain Management

Supply Chain Management (SCM) is the process of coordinating and integrating critical activities, such as sourcing, production, and distribution, to ensure the efficient movement of products and services from suppliers to a final consumer. The primary goals of supply chain management (SCM) are to optimize operational efficiency, reduce costs, and improve customer satisfaction, all while promoting sustainability and mitigating risks (Chopra & Meindl, 2019). A Supply Chain Management (SCM) framework that is effective encourages collaboration among all stakeholders and ensures the optimal utilization of resources to attain overarching business objectives (Supply Chain Council, 2012).

In the past, supply chain management (SCM) strategies have prioritized operational objectives, including accurate demand forecasting, cost reduction, and inventory management. However, the well-being of laborers, particularly in vendor environments, has become a critical area of focus as supply chains become more complex. Stress, exhaustion, and other mental health issues are frequently the result of high workloads, extended working hours, and an imbalanced task distribution among employees (Karasek & Theorell, 1990). These challenges, which are frequently

referred to as "hidden costs," have a substantial impact on supply chain operations by resulting in an increase in absenteeism, a decrease in productivity, and a decrease in product quality (Wan & Toppinen, 2016). In order to establish supply chains that are resilient, sustainable, and ethical, it is imperative to confront these concealed expenses and their underlying causes.

In supply chains that are characterized by fluctuating demands, worker mental health is particularly pertinent, as it can result in an inconsistent allocation of tasks among vendors. Vendors frequently experience penalties, missed deadlines, and strained relationships with customers as a consequence of excessive demands. Furthermore, the overall efficacy of the supply chain may be further impacted by the compromise of product quality that may result from hurried production processes that are driven by high pressure. Despite the fact that these issues are not always immediately quantifiable, they make a substantial contribution to long-term risks and operational inefficiencies (Wan & Toppinen, 2016).

To remain competitive, businesses must adopt the most profitable and appropriate strategy. One option is to improve the performance of the company's current business operations and management. According to Zuraidah et al. (2021), businesses can improve supply chain management by optimizing it. Supply Chain Management refers to the management of activities that include acquiring fundamental resources to serve as inputs in a corporation, carrying out the manufacturing process, and distributing the product till it reaches the consumer. The primary goals of supply chain management (SCM) include timely product delivery, cost and time savings in meeting demand, centralization of planning and distribution, and effective inventory management between vendors and customers (Pujawan & ER, 2010). There are three categories of components: internal supply chain, downstream supply chain, and upstream supply chain.

1. Upstream Supply Chain

The activities associated with the sourcing and procurement of primary materials and components that are essential for production are referred to as the upstream supply chain. This component concentrates on the management of relationships with suppliers and vendors who supply critical inputs for manufacturing processes. In order to guarantee a consistent supply of high-quality materials, it is essential to effectively manage the upstream supply chain, as this directly affects production efficiency and cost (Monczka et al., 2015).

2. Downstream Supply Chain

The downstream supply chain includes the processes related to delivering completed products to consumers. This component encompasses processes including order fulfillment, warehousing, and transportation, usually overseen solely by the corporation without external vendor participation. The efficacy of the downstream supply chain is essential for customer satisfaction and can substantially impact a company's market competitiveness (Bowersox et al., 2013).

3. Internal Supply Chain

The internal supply chain is the organization's management of processes and resources that guarantee the availability of basic materials, supplies, and the production process. This element entails the coordination of numerous departments, including procurement, production, and inventory management, to optimize internal operations and guarantee the seamless operation of production (Heizer et al., 2017).

2.1.4 Model Joint Economic Lot Size

Goyal introduced the notion of cooperative cost optimization for vendors and manufacturers in 1976. Banerjee (1986) coined the term "joint economic lot sizing" (JELS) to describe a specific scenario in which a supplier manufactures to order for a manufacturer on a lot-by-lot basis. Muckstadt et al. (2001) divide the connection between supplier and manufacturer into four kinds. Initially, firms serve as communicators, with the manufacturer sending directives to the supplier based on its specifications. The lack of an agreement between the supplier and manufacturer leads to separate resolution of inventory issues, with each party's inventory policy acting independently of the other.

The second level involves firms acting as coordinators, in which the supplier and manufacturer communicate more detailed information. When interactions necessitate appropriate information to support the business process, such as increasing demand from the manufacturer or decreased production capacity from suppliers, businesses communicate efficiently. The highest level of relationship between the firms is collaborators, with strategic and tactical strategies aimed at maximizing system effectiveness. Originally, the JELS model assumed that all manufactured things were conforming and of flawless quality. Saraswati et al. (2006) extended this study by investigating reduced setups in a perfect environment.

However, in real-world circumstances, product quality is not always ideal, and non-conforming objects are produced due to flawed manufacturing procedures. These non-conforming components are identified by the manufacturer during a 100% inspection, rejected, and returned to the vendor for rework. As a result, Banerjee's typical JELS inventory model may not be suitable in certain circumstances.

This study applies the JELS model to a batik supply chain scenario with one seller and numerous retailers, initially two but expandable to five. Buyers and retailers typically place orders in response to fluctuating demand. The primary goal of this study is to reduce total inventory expenses, which include three major components: holding costs, ordering costs, and lost sales costs. However, this analysis adds a new dimension by considering social costs incurred at the vendor level.

2.1.5 Total Cost

The term "total cost" denotes the comprehensive expenses that a business incurs in the production of products or services, which encompass both direct and indirect costs. It functions as a critical financial metric for evaluating operational efficacy and profitability.

Suryani et al. (2021) in *Jurnal Ilmu Ekonomi (JIE)* define total cost as the sum of all expenditures associated with the production process, such as fixed costs (e.g., rent, salaries) and variable costs (e.g., raw materials, utilities). The sustainability and profitability of small-scale industries are guaranteed by the proper administration of these costs.

According to Oktaviani et al. (2024) in *Jurnal Ekonomi Pembangunan*, the total cost is a critical factor in the equilibrium of operational expenditures and revenue. Businesses can optimize production levels, manage resources efficiently, and accomplish long-term financial sustainability by analyzing total cost. In *Jurnal Aplikasi Manajemen* (2015), Satyanegara et al. (2015) underscore that the total cost encompasses not only production-related costs but also concealed costs, including workforce-related challenges, inefficiencies, and delays. Supply chain performance and overall profitability are frequently affected by these concealed expenses.

The total cost is the basis for the calculation of critical financial ratios, including the Benefit-Cost Ratio (B/C Ratio) and Return on Investment (ROI), as per Al Ubaidillah and Suparta (2024) in *Jurnal Ekonomi Bisnis dan Kewirausahaan*. These ratios assist businesses in evaluating the financial performance and feasibility of their operations. The total cost is defined as the sum of all production-related expenses, including both tangible and intangible costs, cost analysis, revenue,

and R/C of Tofu agroindustry. In order to guarantee sustainable operations and prevent financial losses, it is imperative that these expenses are meticulously managed.

The entire cost of the batik supply chain is not restricted to holding costs, ordering costs, and lost sales costs; it also includes social costs associated with the mental health of the workforce. These social costs encompass factors such as inadequate sleep, tension, excessive workloads, and worker burnout, all of which can disrupt production schedules and generate additional expenses.

2.1.6 Inventory

Inventory is a valuable asset for businesses since it symbolizes the things available for immediate purchase. However, the expenses of inventory management are enormous. Inventory turnover is used as an indication of inventory efficacy in this inquiry. We use firm-specific indicators and build on previous research to investigate the relationship between inventory performance, chain affiliation, and time trends for SMEs (Jorgen Breivik, 2019). Inventory refers to products that are kept for later use or sale (Ristono, 2008).

2.1.7 Type Of Inventory

In order to accommodate inventory functions that are based on the production process, Heizer and Render (2014) divide inventory into four categories:

1. Raw Material Inventory refers to the materials that have been acquired but have not yet undergone any processing. These materials can be sourced from natural origins or obtained from suppliers (producers).
2. Work in Process Inventory consists of components or raw materials that have undergone some stages of production but are not yet complete. These items have experienced various processing changes and may require further processing to become finished products.
3. Maintenance, Repair, and Operating Supplies are the materials designated for essential maintenance, repairs, and operations necessary to ensure that machinery and processes function efficiently and effectively.
4. Finished Goods Inventory includes products that have been manufactured or processed and are now ready for sale.

2.1.8 Inventory Cost

Inventory is a working capital item that is highly significant to the company, as the majority of its business capital is derived from supply, as per Ranguti (2007). Inventory costs are expenses that result from the presence of a supply. The following are the costs that result from supplies, as per Heizer and Render (2014):

1. Holding Cost

Storage costs are expenses that are associated with the storage of goods for a specific duration. Obsolete products in the warehouse or storage-related expenses are also included in storage fees. The costs associated with storage include housing costs (rent or depreciation of the 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), and costs for spoilage, scrap, and obsolete goods (the latter of which is more expensive if the product is subject to rapid change, such as computers or cellphones).

2. Ordering Cost

Supplies, forms, administration, and other expenses associated with the ordering process are collectively referred to as ordering costs.

3. Setup Cost

The costs associated with the preparation of devices or processes to fulfil orders are known as installation costs. Additionally, these expenses encompass the time and labor required to sanitize and replace equipment.

2.1.9 Inventory Model

The inventory of material properties or commodities, whether the material is of free demand (independent) or as a dependent request, was elucidated by Heizer and Render (2014). Market conditions beyond the operational function's control influence the free request (independent); consequently, it is free (independent) from operating functions. In accordance with Heizer and Render (2014). The independent demand-supply model is separated into the following categories:

1. Economic Order Quantity (EOQ) model

The EOQ model is the most frequently employed supply control technique. It is simple to implement by making assumptions about the amount of demand, and the waiting time/lead

time is constant. There are no discounts available for quantity, and the only variable costs are ordering and holding costs. Stockouts can be completely avoided under this model.

2. Production Order Quantity model

The production order quantity model is limited to two scenarios: situations in which supplies flow or accrue randomly for a period of time after an order is placed, and situations in which units are produced and sold individually simultaneously.

3. Quantity discount model

There is a price reduction for an item's products when purchased in large quantities under the quantity discount model. The inventory models mentioned above presuppose that the demand for a product is both definite and constant.

2.1.10 Optimization Evolutionary Algorithm (EA)

Rifqi Mulyawan (2023) states that the Evolutionary Algorithm (EA) is a prominent optimization and search technique that has developed in recent decades. Evolutionary Algorithms (EA) constitute a subset of Evolutionary Computations (EC) and are classified as a contemporary heuristic search technique. Owing to its adaptability and resilient characteristics derived from Evolutionary Computation, EA has emerged as an effective approach for addressing intricate global optimization challenges and is extensively employed in numerous high-complexity applications.

The algorithm functions by employing a population of candidate solutions that are assessed and altered by biologically-inspired processes, including mutation, crossover, and selection. The main aim is to generate optimal or near-optimal solutions within an extensive search space. In its execution, EA employs multiple methodologies, including Genetic Algorithm (GA), Evolution Strategies (ES), Genetic Programming (GP), Evolutionary Programming (EP), and Differential Evolution (DE). Each method presents distinct benefits, rendering EA appropriate for various problem-solving contexts.

Yulianto et al. (2020) cite Hillier and Lieberman, who emphasize the following advantages of EA in comparison to other metaheuristic methods:

1. Independence from the Complexity of the Objective Function: The EA is not influenced by the complexity of the objective function, as long as the function can be evaluated for a specific test problem.

2. Flexibility in the Face of Complex Constraints: The efficacy of the EA is not significantly impacted by the complexity of the existing constraints.
3. Ability to Avoid Local Optima: EA solvers are not ensnared in local optima. Rather, they persist in their efforts to identify more optimal outcomes through ad hoc methods. EA can identify global optima, particularly for small-scale problems that necessitate high-precision solutions, when the procedure is executed continuously.

EA has been utilized in the context of course scheduling, as JTIK UB (2023) has observed, illustrating its substantial potential for the management of intricate and constraint-based tasks. The Petra Journal also addresses the application of EA in industrial systems, with a particular emphasis on the improvement of operational processes' efficiency and productivity. Statistika Komputasi Blog emphasizes the theoretical underpinnings of EA, particularly the natural selection principles that are derived from Darwin's theory of evolution.

Furthermore, EA has been expanded to encompass other forms, including Distributed EA and Memetic Algorithms (MA). EA has become one of the most versatile tools in the optimization and decision-making fields because of recent research that concentrates on refining it to solve real-world problems.

2.2 Inductive Study

An inductive study entails examining existing literature to comprehend methodology, reveal significant discoveries, and pinpoint gaps that new research can address. This strategy enables academics to enhance current frameworks by incorporating novel viewpoints and methodologies. This document presents a summary of pertinent research concerning supply chain management, lot-sizing optimization, and sustainability.

In their paper "Healthier Construction: Conceptualizing Transformation of Mental Health Outcomes through an Integrated Supply Chain Model," London, Meade, and McLachlan (2022) investigated systemic mental health issues within the construction sector. They presented a revolutionary conceptual framework to enhance mental health outcomes throughout the supply chain by tackling stressors including job instability, excessive workloads, rushed schedules, and fragmented subcontracting systems. This research highlighted the significance of leadership responsibility, the incorporation of mental health measures into procurement procedures, and the promotion of work-life balance to enhance long-term well-being within the supply chain ecosystem.

The research highlights the importance of cooperative frameworks and policy measures for effectively tackling mental health issues.

Moch. Anshori, Nurul Hidayatul Isnaini, and Gusti Adriansyah (2021) utilized the Joint Economic Lot Sizing (JELS) model to enhance inventory cost efficiency within a two-tier food and beverage supply chain in their research titled "Joint Economic Lot Sizing at Two Levels of Supply Chain in Food and Beverage Industry." This study reduced procurement, holding, and ordering expenses by aligning order cycles between suppliers and distributors, resulting in a 21.03% decrease in overall expenditures. The study emphasized the essential role of collaborative planning and synchronization in improving inventory management efficiency and overall supply chain performance.

In their paper, "Improving Supply Chain Profit through Reverse Factoring: A New Multi-Suppliers Single-Vendor Joint Economic Lot Size Model," Beatrice Marchi, Simone Zanoni, and Mohamad Y. Jaber (2020) incorporated Reverse Factoring (RF) into the JELS framework. This study highlighted the financial partnership between vendors and financial institutions, facilitating suppliers' access to low-interest financing alternatives. The integration of RF resulted in significant cost reductions (up to 43.2%) for suppliers, higher profit margins, and increased operational efficiency via synchronized order cycles.

Kohlmann and Sahling (2024) introduced a dynamic lot-sizing model that incorporates defect management and rework planning in their research titled "Integrated Lot Sizing and Rework Planning with Random Proportion of Defective Products." The research concentrated on the management of defective products and rework processes in unpredictable production settings. The research revealed cost reductions, enhanced manufacturing efficiency, and environmental advantages through waste reduction by using real-time fault detection. This novel method emphasized the significance of adaptive modifications to enhance lot-sizing based on real-time information.

Asgari Sooran, Tayebi, and Ebrahimnejad (2023) examined financial collaboration frameworks inside supply chains in their research titled "A Joint Economic Lot-Size Model with Collaboration of Supply Chain Members." The study utilized mathematical optimization and collaborative financial investments to improve operational resilience and cash flow management while minimizing inventory expenses. The results indicated that supply chain stakeholders gained from

greater risk management, less financial liabilities, and improved profit allocation, underscoring the need of collaboration in attaining supply chain sustainability.

In their work, "A Supply Chain Model with Service Level Constraints and Strategies Under Uncertainty," Bhuniya, Pareek, and Sarkar (2021) created a stochastic supply chain model. This study optimized inventory expenses under fluctuating demand conditions by incorporating fuzzy demand assessment and service level limitations. The findings indicated substantial enhancements in customer happiness, lead time dependability, and cost-effectiveness, underscoring the importance of sophisticated modelling methods for managing uncertainty in supply chain activities.

In their study, Mohd Nizam, Raden Achmad, Fairul, and others (2016) investigated supplier-buyer coordination through the Joint Economic Lot Sizing (JELS) model. This research revealed that matching procurement and production decisions leads to cost savings and enhanced synchronization in supply chain operations, highlighting the significance of collaboration for achieving efficiency.

Ghaderi, Sadjadi, Niaki, and Hosseini (2016) utilized the Generalized Benders Decomposition (GBD) methodology in their research titled "Joint Economic Lot-Sizing in Multi-Product Multi-Level Integrated Supply Chains." This study tackled inventory synchronization issues across several goods and tiers, resulting in considerable cost reductions and improved scalability through optimized resource use. The results highlight the significance of sophisticated optimization methods for overseeing intricate supply chain networks.

Teterissa, Wijono, and Hunga (2023) investigated the psychological resilience of batik craftsmen in Indonesia during the pandemic in their paper titled "Psychological Resilience of Batik Artisans in Indonesia Based on 'Putting-Out System' During the Pandemic." The research revealed seven resilience qualities, including optimism, empathy, and emotional management, that assisted craftspeople in overcoming economic challenges. It emphasized the significance of community networks, governmental support, and product innovation in addressing difficulties. The results underscored the necessity for psychological support networks and training programs to bolster resilience in future crises.

In their work, "Optimization of Supply Chain Costs with Sustainability Considerations," Akbari, Mostafa, and Kordli, M. T. (2020) created a sustainability-oriented Economic Order Quantity (EOQ) model. This study integrated environmental sustainability criteria into

conventional EOQ models, highlighting the necessity of reconciling economic efficiency with environmental accountability.

Moussawi-Haidar and Jaber (2017) incorporated environmental factors into Economic Order Quantity models in their research titled, "Economic Production Quantity Models for Imperfect Production Systems with Environmental Considerations." The study revealed the potential for substantial cost reductions and environmental advantages by including sustainability into inventory optimization models.

Keita, Kimberly T. (2015) examined the influence of inventory optimization models on supply chain performance in her work, "The Impact of Inventory Optimization Models on Supply Chain Performance." The research emphasized the significance of utilizing EOQ models to rectify inefficiencies in inventory management, hence improving overall performance.

Bouchery, Yann; Ghaffari, Abbas; Jemai, Zied; and Dallery, Yves (2016) examined sustainability in lot-sizing in their research titled "Economic Lot-Sizing with Carbon Emission Constraints." This study incorporated carbon emission limitations into conventional lot-sizing models, emphasizing the balance between cost efficiency and environmental sustainability.

In their work, "A Multi-Objective Economic Order Quantity Model for Sustainable Supply Chains," Gürlü and Demirel (2019) created a Stochastic Lot Sizing Model incorporating carbon emission limitations. This study integrated environmental and social considerations into inventory optimization, resulting in substantial cost savings while tackling sustainability issues.

In their paper, "Sustainability in a Lot-Sizing and Scheduling Problem with Delivery Time Window and Sequence-Dependent Setup Cost Consideration," Flores-Abad, Framinan, and Perez-Gonzalez (2019) included sustainability into lot-sizing and scheduling. This study emphasized the significance of delivery timeframes and setup expenses in sustainable inventory management.

Wahyu Firmansyah, Didik Gunawan Tamtomo, and Pranoto (2020) utilized the Joint Economic Lot Size (JELS) model and quantity discounts in their research titled "Application of the Joint Economic Lot Size (JELS) Model and Quantity Discount in Collaborative Determination of Order Lots Between Producers and Consumers." This study illustrated cost reductions and enhanced collaboration between producers and consumers by synchronizing lot-sizing choices with quantity discount incentives.

Table 2. 1 Comparison with Previous Study

No.	Research Conducted	Year	Method		
			Joint Economic Lot Size (JELS)	Hidden Cost Analysis	Economic Order Quantity
1.	London, Meade, & McLachlan	2022		√	
2.	Moch. Anshori, Nurul Hidayatul Isnaini, & Gusti Adriansyah	2021	√		√
3.	Beatrice Marchi, Simone Zanoni, Mohamad Y. Jaber	2020	√		√
4.	Kohlmann, P., & Sahling, F.	2024		√	
5.	Asgari Sooran, Tayebi, & Ebrahimnejad	2023	√		√
6.	Bhuniya, Pareek, & Sarkar	2021		√	√
7.	Mohd Nizam, Raden Achmad, Fairul, et. al.	2016	√		
8.	Ghaderi, Sadjadi, Niaki, & Hosseini	2016		√	√
9.	Teterissa, Wijono, & Hunga	2023		√	
10.	Akbari, Mostafa & Kordli, M. T.	2020			√

No.	Research Conducted	Year	Method		
			Joint Economic Lot Size (JELS)	Hidden Cost Analysis	Economic Order Quantity
11.	Moussawi-Haidar, Louay & Jaber, Mohamad Y.	2017		√	√
12.	Keita, Kimberly T.	2015		√	√
13.	Bouchery, Yann; Ghaffari, Abbas; Jemai, Zied; Dallery, Yves	2016		√	√
14.	Flores-Abad, Leticia; Framinan, Jose M.; Perez-Gonzalez, Pedro	2019	√	√	
15	Wahyu Firmansyah, Didik Gunawan Tamtomo, Pranoto	2020	√		√
16.	Alfina	2024	√	√	√

Alfina's research, titled "Integrating Social Costs into Joint Economic Lot Sizing: Optimizing Order Quantity to Minimize Inventory and Mental Health-Related Costs in a Multi-Buyer Batik Supply Chain," presents an innovative framework that incorporates mental health-related social costs into the Joint Economic Lot Sizing (JELS) model. This methodology enhances conventional

supply chain optimization by incorporating both economic and social aspects. In contrast to Anshori et al. (2021), who concentrated on reducing procurement, holding, and ordering expenses in a two-tier food and beverage supply chain with JELS, Alfina's research highlights the concealed costs related to employee mental health, including stress, burnout, and absenteeism. Marchi et al. (2020) improved JELS through Reverse Factoring to enhance financial collaboration and supply chain profitability, whereas Alfina emphasizes social sustainability by measuring the effects of mental health issues on inventory performance and order fulfilment, especially in the labor-intensive and culturally important batik production sector.

Alfina's research extends beyond the conceptual frameworks established by London, Meade, and McLachlan (2022), who investigated systemic mental health issues within the construction sector. Although their work emphasized the significance of leadership responsibility and mental health interventions, it was deficient in practical optimization models. Conversely, Alfina integrates mental health expenses into a pragmatic mathematical model, allowing vendors and merchants to optimize order volumes while ensuring employee welfare. In contrast to Kohlmann and Sahling (2024), who concentrated on defective product management and rework planning, and Bhuniya et al. (2021), who examined stochastic demand and service level constraints, Alfina's research distinctly integrates mental health factors into the optimization process, reconciling conventional inventory costs with social sustainability.

Alfina's research, unlike previous studies such as Firmansyah et al. (2020) and Ghaderi et al. (2016), which emphasized economic cost reduction and supply chain synchronization, places a significant focus on the human impact of supply chain operations. By tackling the concealed expenses associated with employee mental health, including tardiness, declined orders, and absenteeism, Alfina develops a holistic methodology that incorporates both social and operational elements. Furthermore, drawing on the insights of Teterissa, Wijono, and Hunga (2023), who investigated psychological resilience among batik artisans during the pandemic, Alfina applies these findings within the JELS framework, offering a pragmatic approach to balancing inventory efficiency and worker welfare.

In conclusion, Alfina's research addresses a notable deficiency in current literature by presenting a comprehensive supply chain optimization model that combines economic efficiency with social sustainability. This method is especially crucial in the batik supply chain, where labor-intensive processes and several buyer encounters heighten the necessity for equitable decision-

making. By integrating mental health-related social costs into JELS, Alfina establishes a new standard for sustainable and inclusive supply chain management, providing actionable insights for industries where human well-being is essential to operational performance.

CHAPTER III

RESEARCH METHOD

3.1 Research Subject and Object

This study concentrates on a batik supply chain that is comprised of a single vendor who supplies numerous retailers. The study commences by examining the interaction between the vendor and two retailers, and it subsequently expands to five retailers in order to conduct a more thorough analysis. The vendor serves as the central production center in this supply chain, while retailers function as distribution channels for end consumers.

The primary goal of this research is to reduce the total costs, which encompass both inventory costs (holding, ordering, and lost sales costs) and social costs that result from mental health-related concealed expenses within the vendor's workforce. These concealed costs, which are frequently disregarded in conventional supply chain models, have a substantial impact on operational efficiency and production reliability.

The study establishes a Joint Economic Lot Size (JELS) model as a foundation to accomplish this objective. The model is subsequently improved by incorporating mental health costs associated with the vendor's workforce. This incorporates issues such as burnout, tension, diminished sleep, and worker turnover, which are exacerbated by fluctuating order quantities from retailers in the marketplace. The critical need for sustainable solutions is underscored by the potential consequences of these mental health challenges, including financial penalties, unmet orders, and delayed deliveries.

The evolutionary algorithm is employed to solve the improved JELS model, which optimizes order quantities while simultaneously balancing inventory efficiency and labor well-being. This method guarantees that the social and economic aspects of the supply chain are addressed, thereby enhancing the performance of vendors and the stability of production.

3.2 Problem Identification

This step involves observing problems in the field and analyzing the results to determine the major concerns that require additional inquiry. The goal of this step is to determine the difference between the ideal and real conditions. Currently taking place. To acquire a comprehensive grasp of the

difficulties that are occurring collectively, the problem identification procedure must be completed prior to determining the research's emphasis.

3.3 Problem Formulation

Following an intensive identification of the problem, the researcher must develop the research problem that will serve as the principal focus of the study. The conclusion will address the specific concerns raised in this formulation. This study focuses on two research questions: joint total cost and workers' mental health. Both of these concerns can be systematically examined and researched.

3.4 Review of the Literature

At this step, a literature review is carried out to get a better knowledge of the theoretical foundations and earlier findings relevant to the research issue. This technique is essential for identifying research gaps that can serve as the basis for a new study. Researchers might develop a study topic with a specific strategy by reviewing a number of scientific materials, such as journals and prior publications.

3.5 Description of the Supply Chain System

The focus of this study is the supply chain system for batik products in Yogyakarta, involving a single vendor supplying five batik products to five customers (retailers). The research models the supply chain as a single-vendor, multi-buyer, multi-product system, where the manufacturer acts as the vendor and the retailers serve as buyers. To manage uncertain demand and enable faster replenishment with lower procurement costs, this study also incorporates a lateral transshipment system among buyers, allowing products to be shared between retailers when necessary. Figure 3.1 illustrates the configuration of this supply chain system.

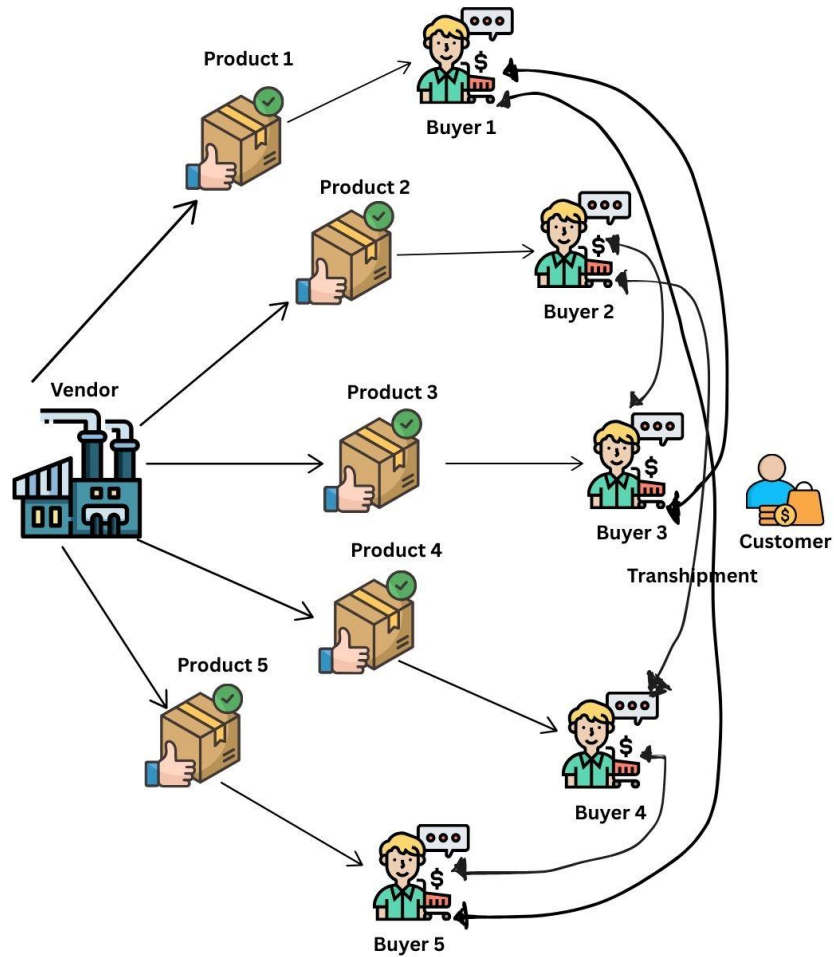


Figure 3. 1 The Supply Chain System Diagram

3.6 Development of Mathematical Models

a. Variables and Parameters Definition

The calculation procedure in this study involves the use of numerous variables. There are two variables: the parameter and the decision variable. The variables and parameters of this investigation are explicated in the following lists:

Parameters

A : Ordering Cost

H : Holding Cost

π : Profit Loss
 I_0 : Beginning Inventory
 P : Period of order/ Lead Time

Decision Variable

r : Reorder Point
 Q : Quantity
 P_Q : Production Quantity

Variables

SL : Stress Level
 WL : Workload of Employee
 SH : Sleep Hours
 BS : Burnout Score
 Ag : Ages of Employee
 Ey : Experience Year in Working
 D : Dependent on company board
 I : Interaction

b. Mathematical Model

Mathematical Model Development is a mathematical representation in the form of an equation or model system that is intended to achieve logical and quantitative outcomes. This experiment used the mathematical model formula shown below. The buyer's desire is compatible with the statistical distribution, which is normal and uniform, as demonstrated by past data. Equations 1 and 2 are used to mimic the normal and uniform distributions, respectively.

$$\text{Demand (Normal)} = \text{round}(\text{norm.inv} \left(\text{rand} (), \frac{\text{mean}}{\text{days}}, \frac{\text{deviation}}{\text{days}} \right), 0) \quad (1)$$

$$\text{Demand (Uniform)} = \text{round} \left(\text{randbetween}(), \frac{\text{mean,deviation}}{\text{days}}, 0 \right) \quad (2)$$

Buyer Demand

$$\begin{aligned}
&= \text{round}(\text{if}(\text{mod}(t_n, 7) \\
&= 6, \text{if} \left(\text{rand}(\) > 0.5, \frac{\text{randbetween}(20, 100)}{30, 0} \right), \text{if} \left(\text{and}(\text{demand}_{n-1} = 0, (\text{mod}(t_n, 7) = \right. \\
&0), \text{randbetween} \left(20, \frac{100}{30, 0} \right) \right), 0)
\end{aligned} \tag{3}$$

Ending Inventory

$$\begin{aligned}
&= \max(0, (\text{beginning inv} + \text{vendor ord} + \text{buyer ord}) \\
&- \text{sum}(\text{demand} + \text{buyer demand})
\end{aligned} \tag{4}$$

Lot Sales

$$\begin{aligned}
&= \max(0, \text{sum}(\text{demand} + \text{buyer demand}) \\
&- (\text{beginning inv} + \text{vendor ord} + \text{buyer ord})
\end{aligned} \tag{5}$$

Order Status

$$\begin{aligned}
&= \text{if}(\text{ending inventory}_n \leq r; 1; 0) \\
&= \text{if}(\text{and}((\text{order status}_n = 0; \text{ending inventory}_n \leq r); 1; 0) \\
&= \text{if}(\text{and}(\text{sum}(\text{order status}_n) = 0; \text{ending inventory}_n \leq r); 1; 0)
\end{aligned} \tag{6}$$

Vendor Order

$$= \text{if}(\text{order status}_n = 1; Q; 0) \tag{7}$$

Ordering Cost (A)

$$= \text{Order status}_n \times A \times \text{roundup} \left(\frac{Q}{4}; 0 \right) \tag{8}$$

$$\text{Holding Cost (H)} = h \times \text{ending inventory}_n \tag{9}$$

$$\text{Lost Sales Cost } (\pi) = \pi \times \text{ending inventory}_n \tag{10}$$

$$\text{Joint Total Cost (JTC)} = A + H + \pi \tag{11}$$

$$\textbf{Grand Total Cost (GTC)} = JTC_{p1} + JTC_{p2} + JTC_{p3} + JTC_{p4} + JTC_{p5} + JTC_{vendor} \quad (12)$$

$$\textbf{Product Workload (PW)} = \text{round} \left(\frac{\text{employee}_n}{\sum \text{employee}_{n1 \sim 12}} \right) \times ((PQ \times 5), 0) \quad (13)$$

Weekly Workload (WW)

$$= ((PW_1 \times \text{process time}) + (PW_2 \times \text{process time}) + (PW_3 \times \text{process time}) + (PW_4 \times \text{process time}) + (PW_5 \times \text{process time})) \quad (14)$$

$$\textbf{Stress Level (SL)} = \frac{(SL_n - \min(SL_{n1 \sim 12}))}{\max(SL_{n1 \sim 12}) - \min(SL_{n1 \sim 12})} \quad (15)$$

$$\textbf{Weekly Workload (WW)} = \frac{(WW_n - \min(WW_{n1 \sim 12}))}{\max(WW_{n1 \sim 12}) - \min(WW_{n1 \sim 12})} \quad (16)$$

$$\textbf{Sleep Hour (SH)} = \frac{SH_n - \min(SH_{n1 \sim 12})}{\max(SH_{n1 \sim 12}) - \min(SH_{n1 \sim 12})} \quad (17)$$

$$\textbf{Burnout (B)} = \frac{(B_n - \min(B_{n1 \sim 12}))}{\max(B_{n1 \sim 12}) - \min(B_{n1 \sim 12})} \quad (18)$$

$$\textbf{Ages (As)} = \frac{(Ag_n - \min(Ag_{n1 \sim 12}))}{\max(Ag_{n1 \sim 12}) - \min(Ag_{n1 \sim 12})} \quad (19)$$

$$\textbf{Experience Years (Ey)} = \frac{(EY_n - \min(EY_{n1 \sim 12}))}{\max(EY_{n1 \sim 12}) - \min(EY_{n1 \sim 12})} \quad (20)$$

$$\textbf{Dependents (D)} = \frac{(D_n - \min(D_{n1 \sim 12}))}{\max(D_{n1 \sim 12}) - \min(D_{n1 \sim 12})} \quad (21)$$

$$\textbf{Interaction and Sleep (IS)} = \frac{(IS_n - \min(IS_{n1 \sim 12}))}{\max(IS_{n1 \sim 12}) - \min(IS_{n1 \sim 12})} \quad (22)$$

Prediction

$$= if \left(\frac{1}{1 + \exp(-(b_0 + b_1 \times SL_n + b_2 \times WW_n + b_3 \times SH_n + b_4 \times B_n + b_5 \times Ag_n + b_6 \times EY_n + b_7 \times D_n + b_8 \times IS_n))} \right) \geq 0.5, 1, 0 \quad (23)$$

Optimize GTC

$$= \text{Optimize Objective Function} \times (1 + \text{sum of value of Mental Health}) \quad (24)$$

3.7 Data Collection Method

Several methods of information collection were employed by the author in this investigation. Following is the methodology that was employed.

3.2.1 Primary Data

Primary data will be obtained directly from the vendor and its workforce through a combination of surveys, structured interviews, and direct observations. We will concentrate on the collection of data regarding critical mental health indicators and workload-related variables. Data elements that are considered primary include:

1. Sleeping Time: Monitoring the average number of hours spent in bed during periods of high and low demand.
2. Workload per Worker: Calculating the daily and weekly workload, which includes overtime hours.
3. Stress Level Assessment: Utilizing standardized stress level questionnaires or scales to evaluate psychological duress.
4. Burnout Symptoms: Identifying the signs of burnout, which include mental and physical fatigue, decreased efficiency, and persistent sickness.
5. Accessibility to Supervisor Assistant: Assessing the ease with which employees can seek assistance and direction from supervisors during difficult workloads.

In order to capture demand fluctuations, surveys and interviews will be carried out throughout various production cycles.

3.2.2 Secondary Data

Existing academic journals, research articles, industry reports, and vendor records will serve as the primary sources of secondary data. Included in the secondary data are:

1. Data on historical production and inventory.

2. The records of workforce attendance and turnover.
3. Data on financial losses and penalties resulting from delayed or defective orders.
4. Prior research findings regarding the incorporation of social costs into supply chain models.
5. In order to compare and validate findings, benchmark data from comparable industries would be utilized.

3.8 Data Processing

The data processing process was initiated by the integration of databases from a variety of participating retailers and vendors. This data was used to conduct a simulation of the supply chain inventory using predefined probability distributions. The purpose of this process was to provide a thorough comprehension of the supply chain relationships that are involved in the transshipment process. As a result, a model was developed to optimize the Joint Total Cost (JTC) while also considering the mental health conditions of workers, utilizing Excel Solver. The optimization results suggested that the Joint Total Cost was reduced and that the allocation of duties was optimized.

3.9 Discussion and Analysis

During this phase, the data processing results acquired in the previous phase are the basis for discussion and analysis. The objective of this phase is to acquire a thorough comprehension of the research findings and to ensure that they are consistent with the pertinent theoretical framework. The findings offer answers to the fundamental research question and provide valuable insights into the optimization of the Joint Total Cost (JTC) in a multi-echelon supply chain relationship within the batik industry.

3.10 Conclusion and Recommendations

At this stage, the researcher presents several conclusions that align with the problem formulation established as the core issue of the study. The findings serve as the basis for addressing the research objectives previously defined. In addition, recommendations are provided as an effort to improve and resolve potential issues in the future.

3.11 Research Flow

The research flow and techniques used in the current study are described below:

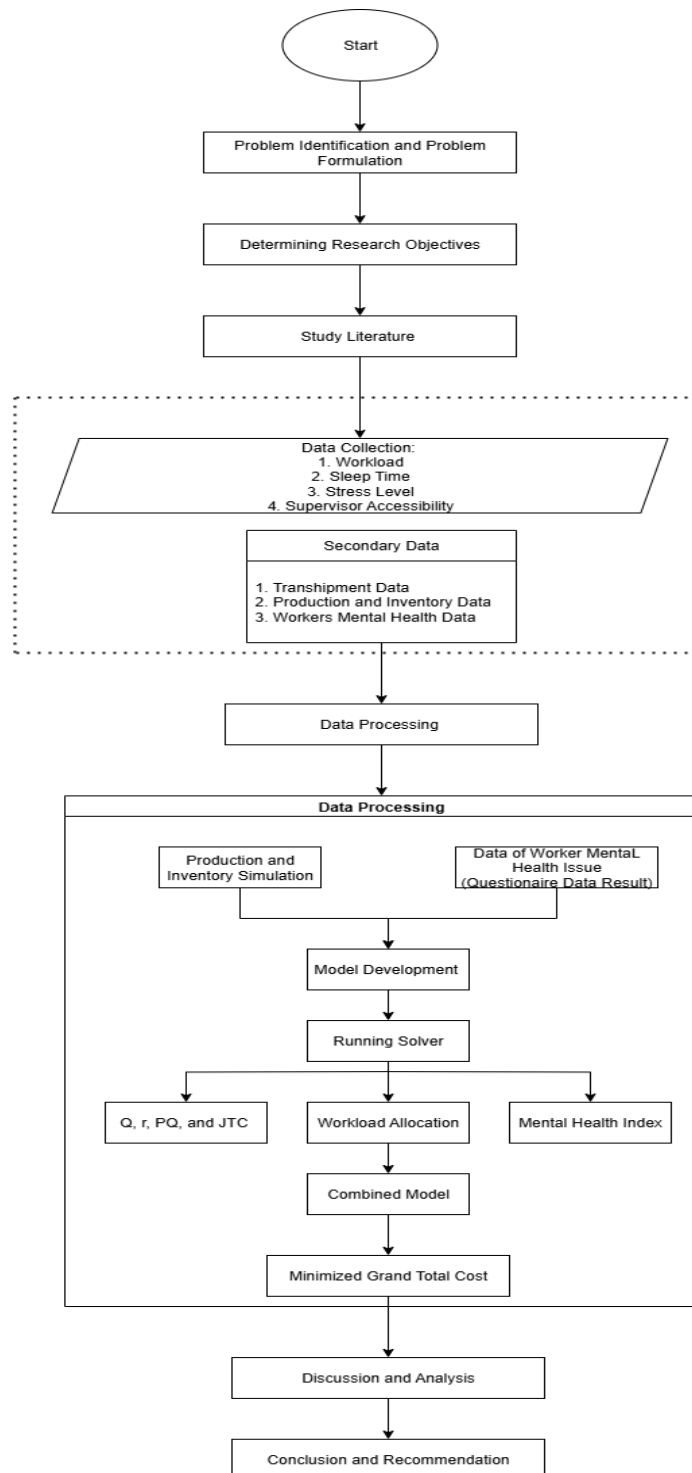


Figure 3. 2 Research Flow

At this point, an examination of the Batik Supply Chain existing challenges is conducted, which will serve as the background and foundation for this research.

1. Start

2. Problem Identification and Problem Formulation

During this phase, the issue to be investigated is identified through the process of problem identification. Subsequently, problem formulation is implemented to generate pertinent solutions and results.

3. Determining Research Objectives

The purpose of this phase is to ensure that the research objectives are clearly and systematically established. The research objectives are defined to guarantee that the study has a specific focus and can generate pertinent results.

4. Study Literature

The purpose of the study literature is to comprehend the prior research that has been conducted on the respective research topic. This is accomplished through the utilization of a logistic regression approach to identify reference sources from journals or books that address predictive mental health in the supply chain. Exploring the literature can provide the researcher with a deeper understanding of the progression of research on this subject.

5. Data Collection

In Data Collection, secondary data is gathered from the company's database at this juncture, which has been previously collected by other researchers. These data are comprised of mental health data, production and inventory data, and transshipment data, which are collected through the questionnaire. Furthermore, the researcher accumulates numerous articles or research

journals that are pertinent to the current research topic. These sources will serve as reference materials for the completion of the study.

6. Data Processing

During this phase, a particular approach is implemented to analyze the data. This is being done to guarantee that the results can be further analyzed and yield valid findings. Inventory data and mental health data comprise the data utilized during the processing phase. The following are the steps of data processing:

a. Simulation of production and Inventories

The distribution processes between vendors and retailers are simulated using this data. The simulation encompasses both normal and uniform distribution types, which are implemented to comprehend demand patterns and the quantity of products that must be manufactured.

b. Mental Health Issue of Worker

Questionnaires were distributed to 12 employees in order to gather mental health data. To evaluate their present mental health status, all employees were requested to respond to the queries that were provided. A coefficient, denoted as value B, was employed to normalize this data. This coefficient was obtained through an optimization procedure that employed a solver. The value of B is obtained from the solver's results, which are then utilized in the optimization model to forecast mental health conditions.

c. Model Development

The Solver tool in Microsoft Excel was used to generate the model. During this process, the objective cell, or Joint Total Cost (JTC) to be minimized, is developed. To meet the specifications of product-related variables such as Q, r, PQ, and task allocation, certain cells were set aside for adjustment. Then, constraints were added to limit the value ranges, including upper and lower boundaries, as well as specify integer data types.

d. Running Solver

This phase comprises using Solver to run the model that was established in order to attain the best possible result in terms of lowering the JTC value.

e. Q,r,PQ, and Cost Parameter

The optimization technique was carried out in conjunction with the obtained variables and cost parameters.

f. Workload Allocation

The Solver distributes the workload according to the aptitude of each worker. The findings were normalized in accordance with the study's objective by applying a specific formula: a single product burden is equivalent to PQ multiplied by 5 workdays.

g. Mental Health

This phase offers a comparative analysis of the extant conditions before and after optimization, with a particular emphasis on the processing time or cycle time for each employee.

h. Optimization Result

The results are analyzed across all relevant variables and parameters upon the completion of the optimization process. In addition, a comparison is made to ascertain whether there has been any development, particularly in the reduction of the number of employees affected by mental health issues.

i. Minimized Grand Total Cost (GTC)

The primary objective of this study is to minimize the GTC, particularly in the context of transshipment within supply chain relationships between retailers and vendors, as indicated by the overall results.

7. Discussion and Analysis

The processed data from the previous phase is the subject of analysis and discussion at this stage. The results of the analysis are also connected to the theoretical underpinnings of previously reviewed reference sources in order to derive valid conclusions.

8. Recommendation and Conclusion

This stage includes a complete review of the study findings as well as recommendations for achieving the intended research objectives.

9. End

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collecting

The data collected in this study includes historical order data between the retailer and the vendor, as well as mental health condition data of the involved workers. The outcome will be determined in the form of Joint Total Cost optimization, considering the mental health issues experienced by the workers, after all collected data has been processed and analyzed. The optimization process will be executed by substituting these data into the mathematical model that was devised in this study. An integrated optimization approach is employed to process the data utilized in this investigation. The objective is to mitigate the expenses associated with the production process and the management of mental health issues.

4.1.1 Retailer and Vendor Data

Historical supply chain data from the store and vendor includes a number of variables such as starting inventory, lead time, reorder point, production amount, and profit loss. Tables 4.1 and 4.2 show the operational cost statistics for vendors and retailers.

Table 4. 1 Vendor Data

Item	Cost	Dimension
Setup	5700	/setup
H1	3500	/unit/month
π 1	5500	/unit
H2	3500	/unit/month
π 2	6500	/unit
H3	3500	/unit/month
π 3	4000	/unit
H4	3500	/unit/month
π 4	7000	/unit
H5	3500	/unit/month
π 5	4000	/unit

Table 4. 2 Retailer Data

Item	Cost					Dimension
	Buyer 1	Buyer 2	Buyer 3	Buyer 4	Buyer 5	
Ordering	13000	8000	10000	8000	13000	/4 pcs
h1	2000	2000	2000	2000	2000	IDR//unit/month
π 1	20000	25000	25000	35000	25000	IDR/unit
h2	2000	2000	2000	2000	2000	IDR//unit/month
π 2	25000	25000	30000	25000	25000	IDR/unit
h3	2000	2000	2000	2000	2000	IDR//unit/month
π 3	20000	25000	25000	25000	25000	IDR/unit
h4	2000	2000	2000	2000	2000	IDR//unit/month
π 4	20000	25000	30000	25000	35000	IDR/unit
h5	2000	2000	2000	2000	2000	IDR//unit/month
π 5	25000	25000	25000	25000	30000	IDR/unit

There is a supply chain cycle that connects retailers and vendors, integrating multiple business operations. The supply chain is critical for good enterprise management since it coordinates crucial factors such as facilities, labor, and operating expenditures. These components are essential for ensuring seamless collaboration among all parties. In terms of expenses, this study uses the terms Grand Total Cost and Joint Total Cost, which indicate the sum of all cost components taken into account during financial analysis. Finally, both retailers and vendors want to save money while increasing revenues by making the best use of the resources they have.

4.1.2 Mental Health Data

In order to identify the psychological challenges that employees encounter, mental health information is implemented. In order to ascertain the extent to which each employee may be enduring critical mental health challenges, the mental well-being of each employee is assessed through surveys and interviews.

The dataset was collected from 12 individuals who are involved in the supply chain activities of the batik industry. Structured questionnaires were implemented during the collection

process to identify indicators of stress and exhaustion. Subsequently, these responses were collected and analyzed to offer a deeper understanding of the workers' psychological state.

The results of the scoring procedure, which were derived from a variety of questionnaire items, are presented in Tables 4.3 and 4.4. These findings establish the groundwork for the development of stress and burn out variables, which are subsequently employed to anticipate potential mental health issues in the workforce.

Table 4. 3 Raw Data of Stress Variable

No.	Interview Question	Scoring Guide	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Q1	How often do you feel overwhelmed with your workload?	1 (Never) to 5 (Very Often)	5	2	5	2	4	1	5	3	4	2	5	2
Q2	Do you feel that you have control over your tasks and decisions at work?	1 (Always) to 5 (Never)	3	2	4	1	3	2	5	2	3	3	4	1
Q3	How frequently do you receive conflicting demands from different people?	1 (Rarely) to 5 (Very Frequently)	4	3	4	2	4	2	5	3	4	2	5	3
Q4	How supported do you feel by your supervisor or team?	1 (Very Supported) to 5 (Not at All)	3	2	4	2	3	2	4	3	3	3	3	2

No.	Interview Question	Scoring Guide	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Q5	How concerned are you about losing your job or not meeting performance targets?	1 (Not Concerned) to 5 (Very Concerned)	4	2	5	2	3	2	4	2	4	2	5	2
Q6	How often does work interfere with your personal life (family, rest, hobbies)?	1 (Rarely) to 5 (Very Often)	4	3	3	2	4	1	5	3	4	3	3	2
Total			23	14	25	11	21	10	28	16	22	15	25	12
Stress Level			7	3	8	2	6	2	9	4	7	4	8	3

Table 4. 4 Raw Data of Burn Out Variable

No.	Interview Question	Dimension	Notes	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Q1	How often do you feel emotionally exhausted at work?	EE	Classic burnout signal	5	2	5	2	4	1	5	3	5	3	5	2
Q2	How often do you feel you can't face another day at work?	EE	Chronic emotional fatigue	4	3	5	2	4	2	5	3	4	3	5	2
Q3	How often do you feel physically drained by the end of the workday?	EE	Physical + emotional fatigue	5	2	4	2	4	2	5	3	4	3	5	2
Q4	How often do you feel disconnected or distant from your work tasks?	DP	Depersonalization	4	2	5	2	3	1	5	3	4	2	5	2
Q5	How often do you feel cynical or	DP	Negative attitudes	4	2	4	2	3	2	4	3	4	3	5	1

No.	Interview Question	Dimension	Notes	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
	negative about your job?														
Q6	How often do you find it difficult to care about your job performance?	DP	Motivation decline	4	2	4	1	3	2	4	3	4	2	4	2
Q7	How often do you feel proud of the work you accomplish? (reverse scored)	PA	More pride = less burnout	4	2	5	2	3	2	5	3	4	3	5	2
Q8	How often do you feel effective and productive at work? (reverse scored)	PA	Competence = lower burnout	3	2	4	2	4	1	4	3	4	3	5	2
Q9	How often do you feel you're making a meaningful	PA	Purpose reduces burnout	4	3	4	3	4	3	5	3	4	3	5	3

No.	Interview Question	Dimension	Notes	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Q10	impact at work? (reverse scored) How often do you feel confident in your ability to do your job well? (reverse scored)	PA	Confidence = less burnout	4	3	4	3	4	3	5	3	4	3	5	3
Total				41	23	44	21	36	19	47	30	41	28	49	21
Burnout				8	3	9	3	7	2	9	5	8	5	10	3

Notes

EE : Emotional Exhaustion

DP : Depersonalization

PA : Reduced Personal Accomplishment

Furthermore, questionnaires were administered to collect general demographic and lifestyle information, including age, sleep duration, employment experience, number of dependents, and social connections. The mental health data obtained from this investigation are presented in Table 4.5. It should be noted that in Table 4.5, the workload data are still represented using arbitrary values.

Table 4. 5 Raw Data Mental Health Data

Employee	Stress Level (1-10)	Workload (hours/week)	Sleep (hours/night)	Burnout Score (1-10)	Age (years)	Experience (years)	Dependents	Interaction (Sleep × Stress)	Severe	Mental Health Status
									Mental	
									Health Issue (Yes/No)	
E1	7	50	6	8	35	10	2	42	Yes	1
E2	3	40	7	3	28	4	1	21	No	0
E3	8	55	5	9	42	20	3	40	Yes	1
E4	2	38	8	3	30	5	1	16	No	0
E5	6	48	6	7	38	15	2	36	Yes	1
E6	2	36	7	2	25	3	0	14	No	0
E7	9	60	5	9	45	22	4	45	Yes	1
E8	4	42	7	5	32	8	2	28	No	0
E9	7	52	6	8	40	18	3	42	Yes	1
E10	4	40	7	5	29	6	1	28	No	0
E11	8	55	5	10	47	25	5	40	Yes	1
E12	3	38	8	3	27	3	1	24	No	0
									Sum	6

4.2 Data Processing

4.2.1 Retailer and Vendor Data

The reciprocal relationship between the merchant and seller, developed via purchase transactions, facilitates the interchange of items. This dynamic, known as a multi-buyer system, allows shops to place orders with one another. For example, Retailer 1 may purchase products from Retailer 2. Nonetheless, both merchants may expect the vendor to offer the identical products to them concurrently.

Table 4. 6 Transshipment Buyer Relationship

	Buyer 1	Buyer 2	Buyer 3	Buyer 4	Buyer 5
Buyer 1		★	★		
Buyer 2				★	
Buyer 3					
Buyer 4					
Buyer 5	★				

★ : order from or order to

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

Table 4. 7 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

Buyer 1 orders from Buyer 2; Buyer 1 orders from Buyer 3; Buyer 2 orders from Buyer 4, and Buyer 5 orders from Buyer 1. This table shows an example of transshipment, or contact. The interdependence of these transactions demonstrates the presence of a supply chain network among

shops. Aside from these exchanges, it is important to note that each buyer sends direct purchase orders to the vendor.

Data gathered from both retailers and the vendor reflects the current state of the existing supply chain processes. This baseline condition will serve as the foundation for improvement and optimization efforts in this study, which are directed at reducing operational costs in the batik industry. The optimization will be carried out through the application of a solver-based mathematical model, allowing for a comparison between the existing scenario and simulated outcomes for each product and retailer. For Table 4.8 and 4.9, it should be noted that the data itself is still not optimized using the solver, and therefore represents only the initial condition prior to the improvement process.

Table 4. 8 Quantity and Reorder Point Existing Condition

Product	Buyer 1	Buyer 2	Buyer 3	Buyer 3	Buyer 4
Q1	25	8	20	8	25
r1	10	18	10	10	15
Q2	25	25	17	10	3
r2	6	10	10	25	15
Q3	6	10	20	15	7
r3	25	15	15	5	20
Q4	25	21	14	17	22
r4	6	11	9	15	12
Q5	27	15	20	35	25
r5	15	8	15	20	10

Table 4. 9 Production Quantity Existing Condition

	Product 1	Product 2	Product 3	Product 4	Product 5
Daily PQ	30	30	30	30	30
Weekly PQ	150	150	150	150	150

Notes :

$$\text{Weekly PQ} = \text{PQ} \times 5$$

The simulation process was applied to selected products in order to evaluate the relationships among retailers and to estimate the Joint Total Cost associated with each product. To achieve cost efficiency, Microsoft Excel Solver was utilized in identifying the minimum possible cost. Each buyer was modeled with varying levels of order quantity and production. The entire simulation was conducted over a 60-working-day horizon, representing the practical timeframe required for fulfilling orders, both in transactions among retailers and between retailers and the vendor.

Table 4. 10 Quantity and Reorder Point After Optimize

Product	Buyer 1	Buyer 2	Buyer 3	Buyer 3	Buyer 4
Q1	82	47	56	50	59
r1	24	75	43	40	47
Q2	62	39	49	69	45
r2	26	48	20	34	69
Q3	55	22	73	44	45
r3	48	27	26	58	66
Q4	56	73	50	61	38
r4	48	55	46	55	29
Q5	39	48	41	49	50
r5	56	43	58	45	50

In this context, Q represents the quantity of units involved in each transaction or production cycle. In the interim, the reorder point is denoted by r, which establishes the threshold at which a new order should be inserted. The supply chain conditions in batik production are simulated over a 60-day period (or approximately two months) using both Q and r.

Table 4. 11 Production Quantity After Optimization

	Product 1	Product 2	Product 3	Product 4	Product 5
Daily PQ	10	71	66	53	61
Weekly PQ	50	355	330	265	305

The daily production quantity is denoted by PQ. In order to more accurately simulate a weekly production schedule, the PQ value is multiplied by five, which corresponds to a standard five-day workweek. The Excel Solver function is employed to optimize the value, which is then incorporated into the work allocation analysis.

4.2.2 Mental Health Data

To evaluate the mental health conditions of workers, a predictive framework was applied using multiple variables and calculation formulas. The assessment considered indicators such as stress, workload, sleeping hours, burnout level, age, professional experience, dependents, and frequency of social interaction. Data for each variable were collected through a combination of surveys and structured interviews, and the resulting values were aggregated into a composite score representing overall mental health status.

Stress and burnout scores were derived directly from interview items. Stress was assessed through six targeted questions addressing psychosocial risk factors at work and in daily life, including balance between work and personal activities, workload intensity, and social support systems. Each response was rated on a 1–5 Likert scale and transformed into a score ranging from 1 to 10.

The burnout score was obtained from ten interview questions, reflecting the three dimensions defined in the Maslach Burnout Inventory (MBI): Emotional Exhaustion (EE), Depersonalization (DP), and Personal Accomplishment (PA). These items captured critical aspects of employees' experiences, focusing on emotional strain and diminished sense of achievement.

Following data collection, normalization was performed to align the scale of each variable and facilitate further analysis. A normalization coefficient was applied to all inputs, and the standardized results were compiled and presented in Table 4.12.

Table 4. 12 Normalization Value

b0	b1	b2	b3	b4	b5	b6	b7	b8
-3,288	8,817	7,424	0,374	-1,115	5,104	2,608	1,210	1,713

Table 4.13 illustrates the mental health forecast by putting the complete b value into equation 22. Table 4.13 shows the 0-error value, indicating that the prediction formula is accurate.

Table 4. 13 Mental Health of Existing Conditions

E	SL	WL	SH	BL	Ag	E	D	I	Severe	Prediction	Error
E1	0,714	0,583	0,333	0,750	0,455	0,318	0,400	0,903	1	1	0
E2	0,143	0,167	0,667	0,125	0,136	0,045	0,200	0,226	0	0	0
E3	0,857	0,792	0,000	0,875	0,773	0,773	0,600	0,839	1	1	0
E4	0,000	0,083	1,000	0,125	0,227	0,091	0,200	0,065	0	0	0
E5	0,571	0,500	0,333	0,625	0,591	0,545	0,400	0,710	1	1	0
E6	0,000	0,000	0,667	0,000	0,000	0,000	0,000	0,000	0	0	0
E7	1,000	1,000	0,000	0,875	0,909	0,864	0,800	1,000	1	1	0
E8	0,286	0,250	0,667	0,375	0,318	0,227	0,400	0,452	0	0	0
E9	0,714	0,667	0,333	0,750	0,682	0,682	0,600	0,903	1	1	0
E10	0,286	0,167	0,667	0,375	0,182	0,136	0,200	0,452	0	0	0
E11	0,857	0,792	0,000	1,000	1,000	1,000	1,000	0,839	1	1	0
E12	0,143	0,083	1,000	0,125	0,091	0,000	0,200	0,323	0	0	0

Based on Table 4.12 above, the prediction results provide a clear reflection of the mental health status experienced by employees, as determined by the selected variables in the model. The final column, labeled Mental Health Status, applies a binary classification system in which a value of 0 denotes that the individual is not experiencing mental health issues, whereas a value of 1 indicates the presence of such issues. This classification offers a straightforward method of identifying employees who may require closer monitoring or intervention.

The findings further reveal that, among the total of 12 employees assessed, 6 individuals were classified as experiencing severe mental health problems. This proportion, representing 50% of the workforce, underscores a significant prevalence of mental health challenges within the organization. Such a percentage highlights the urgency for management to address workplace factors contributing to stress, burnout, and psychological strain. The results not only indicate the scale of the problem but also provide a basis for developing targeted programs, policies, and preventive measures aimed at improving employee well-being.

4.3 Result Comparison

4.3.1 Workload Allocation

Microsoft Excel was used to forecast the workload allocation and the number of products to be generated. To make the randomized workload distribution among employees more understandable, the data is presented in a table format. The table below illustrates the precise work assignments and production output for each product completed by each employee, based on the maximum number of requested products in a single week.

Table 4. 14 Weekly Employee Workload Allocation

	Product 1	Product 2	Product 3	Product 3	Product 4	Product 5
E1	5	31	21	19	26	5
E2	3	17	25	26	24	3
E3	3	22	34	20	16	3
E4	4	37	15	32	33	4
E5	2	25	33	16	23	2
E6	4	42	15	25	23	4
E7	6	13	32	27	24	6
E8	5	37	24	24	16	5
E9	3	25	30	17	34	3
E10	4	30	35	17	28	4
E11	6	40	46	26	29	6
E12	6	37	19	17	28	6

Table 4. 15 Total Weekly Employee Workload

	Product 1	Product 2	Product 3	Product 4	Product 5
Total	51	356	329	266	304

By specifying the production quantity of each product assigned to individual employees, the processed data illustrates the distribution of workload. For instance, Product 1 generates a total production of 51 units, which is allocated among the employees in a variable manner. The purpose

of this allocation is to mitigate the risk of overburdening specific individuals, enhance efficiency, and establish a more equitable workload.

4.3.2 Mental Health

Mental health data was analyzed to confirm the accuracy of the previous prediction outcomes. The objective of this process was to evaluate the degree to which mental health issues influence employees within the batik industry. The findings were subsequently compared to the proposed optimized condition, which takes into account strategies for minimizing costs.

Table 4. 16 Comparison of Existing Mental Health Status and Proposed Condition

E	SL	WL	SH	BL	Ag	E	D	I	Existing Condition	Proposed Condition
E1	0,714	0,161	0,333	0,750	0,455	0,318	0,400	0,903	1	0
E2	0,143	0,000	0,667	0,125	0,136	0,045	0,200	0,226	0	0
E3	0,857	0,016	0,000	0,875	0,773	0,773	0,600	0,839	1	0
E4	0,000	0,526	1,000	0,125	0,227	0,091	0,200	0,065	0	0
E5	0,571	0,073	0,333	0,625	0,591	0,545	0,400	0,710	1	0
E6	0,000	0,336	0,667	0,000	0,000	0,000	0,000	0,000	0	0
E7	1,000	0,136	0,000	0,875	0,909	0,864	0,800	1,000	1	1
E8	0,286	0,285	0,667	0,375	0,318	0,227	0,400	0,452	0	0
E9	0,714	0,250	0,333	0,750	0,682	0,682	0,600	0,903	1	1
E10	0,286	0,351	0,667	0,375	0,182	0,136	0,200	0,452	0	1
E11	0,857	1,000	0,000	1,000	1,000	1,000	1,000	0,839	1	1
E12	0,143	0,269	1,000	0,125	0,091	0,000	0,200	0,323	0	0
Sum									4	

Employee 1 was initially predicted to experience mental health challenges; however, in the proposed condition, no potential mental health problems are indicated. Employee 2 remains stable with no mental health problems in either scenario. Employee 3, which was predicted to have potential mental health issues in the existing condition, shows no such indicators in the proposed condition. Employee 4 consistently shows no signs of mental health problems in both conditions.

Employee 5 was initially predicted to face mental health challenges, but in the proposed condition, no such potential is present.

Employee 6 remains stable with no mental health problems in both conditions. Employee 7 continues to show potential mental health problems in both the existing and proposed conditions. Employee 8 shows no potential indicators of mental health issues in either scenario. Employee 9, which was predicted to experience mental health problems in the existing condition, continues to present the same potential issues after optimization. Employee 10, initially stable, is now predicted to experience mental health challenges in the proposed condition.

Employee 11 was predicted to face potential mental health challenges in the existing condition and continues to show such indicators after optimization. Finally, Employee 12 consistently presents no potential signs of mental health problems in both scenarios.

Overall, the findings show that under the existing condition, six employees were identified as experiencing mental health issues. After optimization, this number decreased to only four employee. This reduction highlights the positive effect of the optimization process, which contributes to balancing workloads, reducing stress, and lowering the overall risk of mental health challenges. Nevertheless, the results also emphasize that mental health remains an important factor that should be continuously monitored and integrated into production optimization strategies.

4.3.3 Grand Total Cost

Cost allocation is an essential component of any enterprise. In a multi-buyer and vendor system, the overall business process is supported by a variety of interrelated cost components. The estimated expenses necessary to process orders, such as storage costs, profit and loss, ordering costs, and other related financial aspects, are collectively referred to as the Joint Total Cost (JTC).

It is imperative to exhaustively aggregate the data in order to identify the specific costs associated with each product and each buyer, given the substantial number of products involved in this study. Furthermore, in order to obtain the most accurate understanding of the financial flow, it is necessary to calculate vendor-related costs. The Grand Total Cost (GTC) is the sum of all JTCs across products and buyers/vendors.

Table 4. 17 Objectives GTC

Existing	After Optimize	Gap of Improvement (%)
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Rp 443.889.000	Rp 229.707.687	48.25%
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The GTC decreased from the previous data condition, as illustrated in Table 4.17 above. The supply chain process, which encompasses demand and inventory management, can be simulated by employing a mathematical model, and the overall operational costs can be reduced.

The totality of the GTC for each product across all customers is represented by the total cost (GTC) above. This value has been optimized to reduce costs while considering the mental health index.

Table 4. 18 Cost Summary of Existing Condition

Product	Buyer 1	Buyer 2	Buyer 3	Buyer 4	Buyer 5	Vendor	JTC
P1	8.585.000	3.613.000	5.018.000	8.478.000	11.009.000	2.479.6000	61.499.000
P2	10.252.000	6.855.500	4.164.000	4.378.000	4.400.000	18.072.000	48.121.500
P3	7.044.000	5.487.000	6.903.000	9.428.000	5.916.000	23.014.500	57.792.500
P4	5.502.000	5.839.000	3.300.000	6.638.000	9.356.000	18.303.000	48.938.000
P5	7.188.000	3.526.000	9.422.000	6.768.000	8.304.000	15.506.000	50.714.000

Table 4. 19 Cost Summary of After Optimize

Product	Buyer 1	Buyer 2	Buyer 3	Buyer 4	Buyer 5	Vendor	JTC
P1	12.064.938	5.077.533	7.052.051	11.914.566	15.471.509	9.918.400	61.498.997
P2	13.951.378	9.329.270	5.666.556	5.957.77	5.987.716	7.228.800	48.121.497
P3	9.838.669	7.663.938	9.679.440	13.168.509	8.263.141	9.025.800	57.819.497
P4	7.474.314	7.932.119	4.482.958	9.017.539	12.709.867	7.321.200	48.937.997
P5	9.087.405	4.457.734	11.911.732	8.556.422	10.498.305	6.202.400	50.713.998

The Grand Total Cost (GTC) values for each client across the five batik products are represented in the data above. Subsequently, the Joint Total Cost (JTC) is determined by adding the aggregate of all GTCs for each product across the five buyers.

CHAPTER V

DISCUSSION

5.1 Discussion on Supply Chain Optimization

5.1.1 Q, r, and PQ

In the processing of batik production supply chain data, three key variables are optimized for each buyer and product, namely Q, r, and PQ. These variables play a central role in achieving the minimum possible cost within the Joint Total Cost (JTC) framework, while also ensuring that the production process remains stable and responsive to fluctuations in demand. The adjustment of these parameters reflects how inventory management, ordering behavior, and production scheduling are harmonized to improve efficiency in a multi-buyer environment.

Q refers to the order quantity, or the number of units requested in each transaction cycle. In the existing condition, as shown in Table 4.8, order quantities varied considerably across buyers, with Buyer 1 ordering 25 units of Product Q1 while Buyer 2 ordered only 8 units. This imbalance led to more frequent orders and higher transaction costs. After optimization (Table 4.10), order quantities became significantly larger and more balanced, with Buyer 1 increasing to 82 units and Buyer 2 to 47 units for the same product. These changes demonstrate a shift toward bulk ordering, which reduces ordering frequency, minimizes transaction costs, and strengthens coordination between buyers and vendors.

The reorder point, denoted by r, represents the minimum inventory threshold that triggers replenishment. In the baseline condition, reorder points were relatively low, ranging from 6 to 27 units depending on the product and buyer. While this lowered holding costs, it also increased the risk of shortages when demand spiked. After optimization, reorder points rose substantially—for instance, Buyer 2's reorder point for Product 1 increased from 18 to 75 units. This adjustment indicates a deliberate effort to create stronger safety stocks, ensuring continuity of supply and reducing the likelihood of disruptions in the production cycle. Although higher reorder points may raise holding costs slightly, the improvement in supply reliability outweighs the additional expense.

PQ, or production quantity, denotes the daily output that must align with both customer demand and available production capacity. In the existing condition, all products shared the same PQ of 30 units per day, or 150 units weekly, as shown in Table 4.9. This uniform allocation overlooked variations in demand and risked inefficiencies, such as shortages in high-demand

products or excess production in lower-demand ones. After optimization (Table 4.11), PQ values were differentiated according to product requirements. For example, Product 2 increased to 71 units per day (355 weekly), while Product 4 rose to 53 units per day (265 weekly). Meanwhile, Product 1 was maintained at 10 units daily, reflecting its lower demand. These adjustments ensured that production resources were distributed more effectively, balancing output with actual buyer needs.

Taken together, the optimization of Q, r, and PQ highlights a systematic effort to reduce costs and strengthen operational resilience. Larger order quantities lower transaction costs, higher reorder points safeguard against stockouts, and diversified production quantities ensure that resources are allocated in line with real demand. The combined effect is an efficient, reliable, and sustainable supply chain system that supports both vendors and buyers in maintaining long-term performance.

5.1.2 Joint Total Cost (JTC)

Cost management constitutes one of the most decisive elements in sustaining the integrity and performance of supply chain networks, particularly in the context of the batik industry. The connection between buyers and batik-producing vendors is not merely transactional but instead forms a complex interdependent system in which financial discipline directly influences operational sustainability. As has been emphasized, costs strongly affect the profitability and long-term viability of enterprises, shaping both revenue generation and exposure to financial losses. Given the fluctuating nature of batik ordering—characterized by irregular demand cycles, product variability, and design-specific complexities—both buyers and vendors are compelled to adopt strategic cost management practices. These strategies are directed toward reducing superfluous expenditures while simultaneously safeguarding a stable corporate cash flow, ensuring that operational continuity is maintained across the entire network.

Within this framework, the Joint Total Cost (JTC) emerges as a comprehensive evaluative tool that integrates all financial components associated with product ordering, production, and distribution. The JTC not only provide a descriptive account of expenditures but also functions as a diagnostic mechanism through which inefficiencies can be identified and mitigated. Specifically, the JTC encompasses the aggregate cost of each batik product ordered by every purchaser, including the direct ordering expenses incurred per transaction. These expenses often fluctuate depending on product diversity and design intricacy, where highly customized products or limited-production

batik lines typically generate higher per-unit costs. Consequently, minimizing order-related expenses within a defined timeframe, while maximizing the volume of products delivered, is essential for improving total cost effectiveness and strengthening the economic sustainability of the supply chain.

Another critical component of JTC is the holding cost, which refers to the expenditures associated with warehouse management and inventory storage. The significance of holding cost management lies in its direct impact on supply chain fluidity. Extended storage periods inevitably lead to higher holding costs due to warehouse fees, opportunity costs, and the potential depreciation of stored products. It becomes particularly relevant in the batik industry, where product demand is often seasonal and sensitive to shifting consumer preferences. Conversely, supply chain models that emphasize direct shipments or abbreviated storage cycles markedly reduce the financial burden of inventory management for both buyers and vendors. Such approaches contribute to leaner operations, better cash flow allocation, and more agile responses to market fluctuations.

In addition to ordering and holding expenses, the JTC also incorporates the profit and loss component of the supply chain. This dimension underscores the importance of financial transparency and equitable cost distribution between buyers and vendors. By integrating profit and loss considerations into the JTC framework, stakeholders are encouraged to align their financial objectives, fostering a collaborative environment that is mutually beneficial. This is particularly critical within multi-buyer systems, where buyers may simultaneously act as both purchasers and suppliers. In such arrangements, the maintenance of product availability, resource sharing, and cooperative strategies becomes indispensable for sustaining trade continuity.

The academic and practical relevance of JTC lies in its ability to extend beyond mere cost aggregation. It embodies a systemic perspective that reinforces the resilience, adaptability, and sustainability of the batik supply chain. By encouraging joint responsibility for cost minimization, JTC serves as a unifying metric that aligns financial efficiency with operational stability. Furthermore, its integrative approach ensures that end-customer demand is consistently met, even amidst disruptions or variability in demand. In this sense, JTC operates not only as an accounting measure but as a strategic framework that strengthens decision-making, enhances supply chain transparency, and contributes to the long-term competitiveness of the batik industry.

5.1.3 Grand Total Cost (GTC)

The Grand Total Cost (GTC) is the total amount spent on all five batik items, as determined by the Joint Total Cost (JTC) of each customer. A thorough picture of the financial needs for maintaining production and distribution processes is given by this compilation. A variety of factors, including production volumes, demand allocation, vendor capacity, and distribution patterns, determine the cost values that each product and buyer contributes. Because their contributions have a direct impact on the JTC allotted to each product, vendors are also very important in the overall cost calculation.

Variations in JTC are apparent when looking at performance at the product level. Product 4 produced the lowest JTC in comparison to the other goods, while Product 3 recorded the highest JTC under the current conditions, indicating higher cost burdens associated with its production and allocation. Product 1 changed to become the lowest-cost product after optimization, whereas Product 3 continuously stayed at the top, demonstrating the optimization model's redistribution effect. These results demonstrate how allocation tactics and product-specific features can change how costs are distributed across vendors and customers.

All things considered, the GTC is a crucial benchmark for assessing how well costs are distributed throughout the supply chain. In addition to lowering overall expenses, the optimization promoted a more equitable system that takes employee welfare into account by more fairly allocating workloads and vendor payments. Aligning financial efficiency with mental health considerations improves sustainable supply chain performance and long-term operational resilience, as production outcomes are intimately linked to worker motivation and psychological wellness.

5.2 Discussion on Supply Chain Optimization

5.2.1 Daily Production Quantity

Production Quantity (PQ) represents the daily output generated by all employees for each batik product. The daily PQ value is calculated by summing the total production generated by 12 employees assigned to a single product and then multiplied by five to represent the weekly production quantity, following the five-day workweek commonly implemented in the batik industry. In this sense, PQ functions as a critical indicator of actual production capacity and forms the basis for workload allocation among employees as well as across vendors.

In the baseline or existing condition, the weekly PQ values were relatively uniform, with 150 units per week assigned to each product (Table 4.9). This distribution illustrates a proportional allocation of production, but it does not fully reflect real market demand variations. After optimization using Excel Solver, however, significant differences emerged in the distribution of PQ. For example, Product 2 increased to 355 units per week, while Product 3 rose to 330 units per week (Table 4.11). These results highlight that certain products experience greater customer demand compared to others, requiring production capacity adjustments to avoid potential losses caused by mismatches between supply and demand.

Higher PQ values for certain products also indicate stronger customer demand levels. Therefore, maintaining an effective buyer–vendor relationship becomes essential in preventing profit loss and ensuring continuity of the batik production process. If vendors fail to meet customer demand, it could negatively impact trust and satisfaction, ultimately disrupting the overall supply chain. To mitigate such risks, regular evaluations of production capacity must be conducted by carefully monitoring inventory levels and forecasting market demand before initiating the production process or placing product orders.

By optimizing PQ, the batik production system becomes more responsive to consumer demand and more efficient in utilizing labor resources. This alignment not only improves supply–demand balance but also strengthens the effectiveness of the Joint Total Cost (JTC) framework, reinforcing supply chain optimization in the batik industry.

5.2.2 Workload Allocation Result

The optimization process was conducted using the Joint Total Cost (JTC) to determine the results of production planning allocation per employee. This optimization process took into account the equitable distribution of production planning quantities among all employees. In order to mitigate the risk of stress and mental health issues, the allotted workload for each employee was adjusted to ensure that no individual was overburdened.

Microsoft Excel was employed to analyze the assignment allocation per employee in order to predict the distribution of production quantities among employees. According to Table 4.14, the allocation was performed in accordance with the weekly production requirements for five products. Each product was allocated a specific number of units to each employee, with the allocations being adjusted to ensure impartiality and balance. For example, Employee E11 was allocated the most

units for Product 3 (46 units), while other employees were allotted fewer units to prevent an excessive concentration of workload. The entire weekly workload for all employees is depicted in Table 4.15. Product 2 had the highest demand, with 356 units, followed by Product 3 with 329 units. In contrast, Product 1 represented the lowest burden, with only 51 units. These variations illustrate that the production requirements of different product categories must be distributed proportionally among employees in order to maintain efficiency and equity.

The final production allocation was multiplied by the process time of each employee. In order to convert the values to hours, they were expressed in minutes and then divided by 60, as process times vary depending on work experience and talent level. As a result of their superior skills, employees with more extensive work experience were able to complete tasks more efficiently, whereas those with less experience needed to spend more time on the same tasks. Consequently, the duration of each procedure was contingent upon the product type, proficiency, and work experience.

The system not only mitigated the risk of overburdening specific individuals but also improved productivity and guaranteed a more equitable distribution of workloads across the workforce through the implementation of this combined allocation model.

5.3 Discussion of Mental Health Prediction

Employees form the base for all production and order fulfillment operations, and their value in this study cannot be overstated. Productivity and production are directly related to performance. Psychological stress and burnout can significantly impair production outcomes, whereas increased employee motivation contributes favorably to the continuity and efficiency of production processes.

To examine mental health issues, a variety of psychosocial and burnout markers were analyzed, including workload intensity, work-life balance, stress levels, sleep duration, and emotional weariness. These characteristics were standardized to provide a composite measure of overall mental health. Six out of twelve employees, or 50% of the workforce, were classified as having mental health difficulties based on the existing situation. This predominance highlights a key risk that may have an influence on batik vendors' operational performance and personnel well-being.

To address this issue, a simulation-based optimization was built using Solver to achieve a more equitable distribution of production workloads. The goal of task redistribution was to enhance

fairness and equity while reducing unnecessary load on certain personnel. The results of this optimization showed a considerable improvement: the number of employees expected to have mental health problems dropped from six to one, reflecting an 83% reduction from the starting situation.

A thorough comparison of the current and optimized settings demonstrates that some individuals who were earlier expected to face serious mental health challenges—including Employee 1, Employee 5, and Employee 7—showed no risk of such concerns following the optimization. Employees 2, 4, 8, and 12 showed no symptoms of mental health difficulties in any circumstance. Only Employee 3 continued to demonstrate potential indicators of mental health disorders, emphasizing the importance of specialized monitoring.

Overall, the results we obtained highlight the vital role of burden optimization in preventing mental health risks, increasing motivation, and maintaining productivity. Furthermore, the optimization process establishes the Mental Health Index (MH Index) as a quantitative reference for analyzing the workforce's well-being while also lowering the prevalence of mental health concerns. This index is a vital component of the multi-buyer and vendor system's total business cost calculation, ensuring that production methods take into account both economic efficacy and employee welfare.

5.4 Cost Comparison

A comparison of costs between the existing and optimized conditions shows a significant reduction in the overall Grand Total Cost (GTC). As illustrated in Table 4.17, the total GTC under the existing condition amounted to Rp. 443,889,000, whereas after optimization it decreased to Rp. 229,707,687, representing a cost improvement of approximately 48.25%. This substantial reduction demonstrates the effectiveness of the optimization model in minimizing operational expenses while maintaining production requirements.

The cost summary presented in Tables 4.18 and 4.19 provides further insights into product-level variations. In the existing condition, Product 3 recorded the highest JTC of Rp. 57,792,500, followed by Product 1 with Rp. 61,499,000, while Product 4 and Product 2 generated relatively lower costs at Rp. 48,938,000 and Rp. 48,121,500, respectively. After optimization, the distribution of costs shifted. Product 3 remained the highest with a JTC of Rp. 57,819,497, while Product 1 became the lowest with Rp. 41,498,997.

This comparison highlights that although individual product costs varied across both conditions, the optimization process successfully reduced the cumulative GTC by nearly half. The reallocation of workloads and vendor contributions allowed the model to achieve greater efficiency, ensuring that operational expenses were minimized without sacrificing production balance.

5.5 Relationship between Social Cost and a Cost Itself

In analyzing the batik supply chain, the distinction between economic cost and social cost becomes critical, particularly when considering the results of the mental health data collected from vendor workers. Economic cost, as conventionally defined within the Joint Economic Lot Size (JELS) framework, comprises holding, ordering, and lost sales costs, all of which are tangible and directly quantifiable. These costs were reflected in this research through vendor and retailer data, such as the cost of ordering, production setup, and monthly storage expenses, which together formed the Joint Total Cost (JTC) and eventually the Grand Total Cost (GTC). Optimization in this dimension successfully reduced unnecessary expenditures by adjusting key variables such as order quantity (Q), reorder point (r), and production quantity (PQ). However, focusing exclusively on these measurable costs risks neglecting another category of expense that, while less visible, proved to be equally significant: social cost. Social cost refers to the hidden burden arising from the deterioration of workers' mental health due to excessive workloads, prolonged hours, and limited rest. The results of the mental health data in this study showed that, under existing conditions, as many as six employees were predicted to experience mental health problems, characterized by elevated stress, burnout, and insufficient sleep. After the optimization model was applied—specifically through a more even distribution of workload and production scheduling—the number of employees predicted to face mental health risks decreased dramatically to only one, representing an improvement of more than 80%. This sharp decline demonstrates that integrating social costs into the optimization process is not merely a matter of ethical consideration but also one of operational sustainability. Poor mental health conditions often lead to absenteeism, reduced concentration, errors in production, and even higher rejection rates, all of which cycle back into indirect economic losses for the vendor and disrupt supply reliability for retailers. Conversely, improvements in mental health status enhance worker productivity, reduce hidden costs such as scrap and delay, and strengthen vendor–retailer relationships. Thus, this study underscores that economic costs and social costs are not separate entities but interdependent dimensions: minimizing economic costs

while neglecting social burdens may create short-term gains but long-term instability, while integrating mental health considerations provides dual benefits of financial efficiency and workforce well-being. Ultimately, the incorporation of mental health data into the JELS model establishes a more sustainable and resilient supply chain framework for the batik industry, one that safeguards its cultural and economic value while protecting the welfare of the human resources that drive its operations.

5.6 Scrap Break and Sustainability Cost

In the batik production process, scrap product those that are deemed unfit for sale or require reprocessing pose a significant challenge, both in terms of operational efficiency and cost. Vendor conditions, such as subpar printing quality and other production imperfections, frequently contribute to the creation of scrap. These factors must be considered when calculating production quantities and sustainability costs.

Scrap break refers to the percentage of produced items that fail to meet quality standards, requiring reprocessing or being discarded entirely. For instance, when the production process results in a 10% scrap break due to poor printing or other imperfections, the company must compensate by increasing the production quantity. In this case, to meet the demand of 10 units, the production quantity must be raised to 11 units (considering a 10% scrap rate). This ensures that even with the scrap, the company can still fulfill customer demand.

The sustainability cost associated with scrap break is a crucial aspect of the overall cost structure. While increasing production to account for scrap may ensure the required quantity is met, it also leads to higher resource usage, waste, and potentially increased energy consumption. Reprocessing scrap may add to the operational costs, as it requires additional labor, materials, and time, further increasing the total cost of production. Therefore, the sustainability of this model must be carefully examined.

If scrap cannot be repaired or reused, it not only increases production quantities but also contributes to higher waste generation. This scenario has a negative environmental impact and must be considered in sustainability assessments. The financial implications of scrap are twofold: first, the additional resources needed to produce extra units, and second, the environmental cost of handling and disposing of scrap. This necessitates the development of strategies aimed at

minimizing scrap, improving production quality, and reducing waste, ultimately lowering both operational and sustainability costs.

To mitigate these challenges, companies can explore the following strategies:

1. Improved Quality Control: Implementing stricter quality control measures at the vendor level can help reduce production imperfections, ultimately lowering the scrap rate.
2. Scrap Minimization: Exploring ways to repair or reuse scrap products before considering them waste can reduce the need for increased production quantities.
3. Sustainability Practices: Focusing on reducing waste and improving resource efficiency can lower the environmental and financial impacts of scrap production. This could include recycling materials or reprocessing scrap products into usable items.

In conclusion, the scrap break in batik production significantly impacts both production efficiency and sustainability costs. While increasing production quantities can compensate for scrap, it leads to higher resource usage and waste. Addressing vendor-related production issues, improving quality control, and adopting sustainable practices are essential to reducing the negative impacts of scrap in the production process.

CHAPTER VI

CONCLUSION

6.1 Conclusion

This research was conducted to develop an integrated inventory optimization model for the batik supply chain by combining operational, financial, and social considerations. The conclusions aligned with the research objectives are as follows:

1. **Development of an Integrated Inventory Optimization Model (Q-system).** The study successfully formulated an inventory optimization model using the Q-system framework, which determines the optimal ordering quantity between buyers and vendors. By adjusting order quantities (Q), reorder points (r), and production quantities (PQ), the model created a more stable and responsive supply chain system. The results showed significant improvements in demand fulfillment, minimized transaction frequency, and enhanced coordination between buyers and vendors.
2. **Incorporation of Social and Mental Health Considerations.** The model integrated the mental health and well-being of vendor workers into the optimization process, ensuring that workload distribution was fair and sustainable. The findings demonstrated that the number of employees predicted to experience mental health issues decreased from six to only one after optimization, indicating an 83% improvement. This outcome highlights that balancing workloads not only improves efficiency but also safeguards worker welfare, creating a more human-centered inventory system.
3. **Evaluation of Cost Savings and Benefits.** The implementation of the optimized model significantly reduced the overall Grand Total Cost (GTC). The total cost decreased from Rp. 443,889,000 to Rp. 229,707,687, representing a 48.25% cost improvement. At the product level, variations in JTC were redistributed more equitably across buyers, with Product 3 consistently having the highest cost, while Product 1 shifted to become the lowest after optimization. These results confirm that the optimized model delivers substantial financial benefits for both buyers and vendors by minimizing operational expenses while maintaining production balance.

6.2 Suggestion

This research proposes the following suggestions for future studies:

1. Future research should explore the impact of scrap products in batik production, focusing on vendor-related issues like poor printing and production imperfections. The study should investigate strategies to minimize scrap and assess how non-repairable scrap can improve production efficiency, resource utilization, and waste reduction.
2. Explore broader aspects of worker welfare beyond mental health and apply more advanced optimization tools, such as Excel or specialized supply chain software, to improve accuracy and scalability.

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ATTACHMENT

• Working Process

Step	Product 1													
	Description	Processing Time (minutes/shirt)	Emp 1	Emp 2	Emp 3	Emp 4	Emp 5	Emp 6	Emp 7	Emp 8	Emp 9	Emp 10	Emp 11	Emp 12
Pattern Design	Check the base fabric for	5	5,1	5,11	5,01	4,85	5,05	4,87	5,09	5,01	5,01	4,91	4,93	4,92
Waxing (Canting)	Sketch or stamp the design onto the fabric	10	9,2	9,4	11,9	11,8	11,4	10,3	11,3	11	10,5	11,9	10,8	10,5
First Dyeing	Apply hot wax along the pattern (manually or stamp)	20	17,6	19,2	23,6	21,6	20,6	20,6	22	21,4	20,2	21,2	22	23,4
Wax Removal	Submerge fabric in first color	25	24,7	26,5	26,2	24,8	26,7	25,6	26,1	26,8	24,1	26,7	26,4	24,5
Second Dyeing	Remove (partially or entirely) wax with hot water	10	9,4	8,7	9,6	8,5	11,5	8,9	10,3	10	9,8	9,5	10,2	11,7
Drying	Optional additional color bath (if multi-colored)	15	14,4	15,4	13,4	15,9	16,9	16,7	16,9	16,8	16,5	13,4	13,2	13,8
Cutting	Hang or machine-dry fabric	15	14,2	17	13,7	15,9	16,8	14,1	15,6	15,1	17	13,3	13,2	15,2
Sewing	Cut fabric pieces to form shirt components	10	9,6	10,8	11,7	11,3	11,1	10,8	10,8	9,5	8	8,4	10,5	11,4
Finishing	Sew all components into a	25	23,1	26,7	24,7	27	25,3	27	26,1	25,4	26,2	25,6	25,3	24,6
	Final ironing, quality control, and packaging	15	13,4	15	16,7	14,1	13,9	13	14,7	16,8	16,2	16,9	14,5	15,6
	TOTAL		140,7	153,81	156,51	155,75	159,25	151,87	158,89	157,81	153,51	151,81	151,03	155,62

	Product 2													
	Description	Processing Time (minutes/shirt)	Emp 1	Emp 2	Emp 3	Emp 4	Emp 5	Emp 6	Emp 7	Emp 8	Emp 9	Emp 10	Emp 11	Emp 12
	Check the base fabric for	5	5,02	5,08	4,93	5,09	4,94	4,97	5,13	5,18	4,93	5,13	5,17	5,07
	Sketch or stamp the design onto the fabric	15	14,84	15,47	15,32	14,82	14,98	15,01	15,11	14,85	15,17	14,05	14,12	13,96
	Apply hot wax along the pattern (manually or stamp)	23	23,09	22,94	23,22	22,88	23,00	23,05	22,87	22,85	23,16	22,85	22,77	22,69
	Submerge fabric in first color	15	15,30	15,31	15,18	14,93	14,90	15,35	15,25	14,96	15,15	15,35	14,99	15,30
	Remove (partially or entirely) wax with hot water	8	8,32	8,22	7,73	7,74	7,75	8,20	8,35	7,83	7,75	7,74	7,82	8,15
	Optional additional color bath (if multi-colored)	20	20,18	19,75	20,00	19,65	19,85	20,17	19,87	20,22	19,83	19,70	20,32	20,31
	Hang or machine-dry fabric	10	10,20	9,74	10,05	9,82	9,96	9,87	9,95	10,11	10,03	10,14	10,05	10,07
	Cut fabric pieces to form shirt components	5	5,32	5,28	4,72	4,80	4,82	5,20	4,92	5,11	5,22	5,31	5,10	4,81
	Sew all components into a	25	24,98	24,82	25,01	24,81	24,91	24,87	25,04	25,06	25,18	24,91	25,21	25,14
	Final ironing, quality control, and packaging	15	14,93	15,16	14,89	14,73	15,27	15,30	15,05	15,00	15,14	15,11	14,87	14,93
	TOTAL		142,18	141,77	141,05	139,27	140,38	141,99	141,54	141,17	141,56	140,29	140,42	140,43

	Product 3													
	Description	Processing Time	Emp 1	Emp 2	Emp 3	Emp 4	Emp 5	Emp 6	Emp 7	Emp 8	Emp 9	Emp 10	Emp 11	Emp 12
	Check the base fabric for defects	5	5,04	5,12	5,06	5,19	5,08	5,01	4,95	5,16	4,91	5,12	5,18	4,94
	Sketch or stamp the design onto the fabric	20	20,18	18,00	20,00	19,93	20,13	19,96	19,97	20,03	20,18	19,00	19,97	20,00
	Apply hot wax along the pattern (manually or stamp)	17	17,16	16,83	15,50	17,04	17,12	17,14	15,80	16,86	17,09	17,08	16,92	17,06
	Submerge fabric in first color	10	9,80	10,07	9,96	9,98	10,02	9,86	10,01	9,92	10,15	10,18	10,16	10,00
	Remove (partially or entirely) wax with hot water	8	8,01	7,82	7,81	7,98	7,80	8,03	8,04	8,06	8,04	7,99	8,17	7,93
	Optional additional color bath (if multi-colored)	17	17,09	16,89	16,98	16,96	16,96	17,09	17,05	16,86	17,11	16,96	17,06	16,99
	Hang or machine-dry fabric	5	5,06	4,81	5,08	4,99	5,12	5,14	4,90	4,92	5,20	5,02	4,82	5,01
	Cut fabric pieces to form shirt components	8	7,95	7,82	8,03	8,00	7,81	8,04	7,91	8,07	7,87	7,98	7,93	8,05
	Sew all components into a shirt	20	20,03	19,84	20,01	19,91	20,12	19,86	20,09	19,86	20,17	20,12	20,05	19,93
	Final ironing, quality control, and packaging	10	9,83	10,07	10,06	10,12	10,09	10,05	10,12	10,13	9,86	10,19	9,95	9,87
	TOTAL		120,15	117,27	118,49	120,10	120,25	120,18	118,84	119,87	120,58	119,64	120,21	119,78

	Product 4													
	Description	Processing Time	Emp 1	Emp 2	Emp 3	Emp 4	Emp 5	Emp 6	Emp 7	Emp 8	Emp 9	Emp 10	Emp 11	Emp 12
	Check the base fabric for defects	5	4,89	5,02	5,15	4,86	4,92	5,17	4,90	4,90	4,90	4,90	5,16	4,94
	Sketch or stamp the design onto the fabric	20	20,04	20,17	19,85	20,16	18,50	19,89	20,04	20,13	19,99	18,75	20,08	20,09
	Apply hot wax along the pattern (manually or stamp)	20	19,94	19,82	20,05	20,05	19,93	20,04	19,10	20,07	20,12	20,11	20,17	20,19
	Submerge fabric in first color	15	14,91	15,04	14,95	14,84	14,97	14,95	14,97	15,04	14,86	15,08	15,12	14,92
	Remove (partially or entirely) wax with hot water	8	8,07	8,16	8,18	7,95	8,10	8,03	8,12	7,85	7,95	7,96	8,20	8,14
	Optional additional color bath (if multi-colored)	18	17,94	18,03	18,11	17,94	17,84	17,97	18,20	18,01	18,13	17,97	17,96	18,11
	Hang or machine-dry fabric	10	9,81	9,94	9,88	10,15	9,82	9,84	10,16	9,94	10,08	10,10	9,91	10,16
	Cut fabric pieces to form shirt components	5	5,16	4,99	4,90	4,89	4,90	4,84	4,91	4,91	5,19	4,86	4,92	4,94
	Sew all components into a shirt	20	19,80	20,09	20,12	20,09	20,18	20,06	20,03	19,88	19,86	19,82	20,03	19,88
	Final ironing, quality control, and packaging	15	14,99	14,99	15,00	14,84	15,05	14,88	15,13	15,07	15,16	14,84	14,94	14,95
	TOTAL		135,55	136,25	136,19	135,77	134,21	135,67	135,56	135,80	136,24	134,39	136,49	136,32

Product 5														
Description	Processing Time	Emp 1	Emp 2	Emp 3	Emp 4	Emp 5	Emp 6	Emp 7	Emp 8	Emp 9	Emp 10	Emp 11	Emp 12	
Check the base fabric for defects	5	4,81	4,91	5,16	5,16	4,89	4,86	4,90	4,80	4,92	4,92	4,80	5,06	
Sketch or stamp the design onto the fabric	15	15,06	14,85	15,07	14,30	14,92	13,50	15,13	15,16	15,19	14,84	14,99	14,92	
Apply hot wax along the pattern (manually or stamp)	12	12,05	12,08	11,97	12,04	11,87	11,96	11,83	12,02	11,95	11,83	11,10	11,96	
Submerge fabric in first color	10	10,16	9,92	9,97	10,19	10,17	9,86	9,95	9,83	9,94	10,13	10,08	9,89	
Remove (partially or entirely) wax with hot water	8	7,99	7,87	7,89	7,85	8,08	8,02	7,96	7,84	7,94	8,14	8,02	8,16	
Optional additional color bath (if multi-colored)	9	8,80	8,95	8,92	9,04	9,20	8,84	9,15	8,97	9,20	9,06	8,97	8,85	
Hang or machine-dry fabric	10	10,18	10,15	9,90	10,07	9,98	10,10	10,06	10,14	10,16	9,99	9,90	10,01	
Cut fabric pieces to form shirt components	5	5,07	5,09	4,99	5,14	5,01	5,07	5,17	5,05	4,97	4,90	4,91	5,12	
Sew all components into a shirt	20	20,17	20,06	20,03	20,19	20,02	20,06	20,17	19,92	20,03	19,94	20,13	20,03	
Final ironing, quality control, and packaging	15	14,82	14,97	14,95	15,08	14,80	14,90	14,95	15,06	15,05	15,08	14,83	15,02	
TOTAL		109,11	108,85	108,85	109,06	108,94	107,17	109,27	108,79	109,35	108,83	107,73	109,02	

- Demand Pattern

Demand Pattern					
Product 1					
	Buyer				
	1	2	3	4	5
Vendor	Normal(300, 35)	Normal(150, 20)	Uniform(130, 270)	Uniform(120, 155)	Normal(60, 25)
Product 1					
	Buyer				
Buyer	1	2	3	4	5
1		Uniform(20, 100)	Uniform(20, 150)		
2				Uniform(70, 130)	
3					
4					
5	Uniform(20, 50)				

Product 2					
	Buyer				
	1	2	3	4	5
Vendor	Normal(300, 70)	Normal(500, 130)	Normal(400, 100)	Uniform(300, 450)	Uniform(200, 350)
Product 2					
	Buyer				
Buyer	1	2	3	4	5
1		Uniform(50, 80)	Uniform(50, 70)		
2				Uniform(20, 50)	
3					
4					
5	Uniform(20, 50)				

Product 3						Product 4					
	Buyer						Buyer				
	1	2	3	4	5		1	2	3	4	5
Vendor	Uniform(2	Uniform(1	Uniform(1	Uniform(1	Uniform(180, 310)	Vendor	Uniform(6	Uniform(1	Uniform(2	Uniform(1	Normal(500, 120)
Product 3						Product 4					
	Buyer						Buyer				
Buyer	1	2	3	4	5	Buyer	1	2	3	4	5
1		Uniform(5	Uniform(70, 90)			1		Uniform(4	Uniform(30, 110)		
2				Uniform(40, 110)		2				Uniform(30, 90)	
3						3					
4						4					
5	Uniform(30, 40)					5	Uniform(40, 50)				

Product 5					
Buyer					
1 2 3 4 5					
Vendor	Normal(2	Normal(3	Uniform(1	Uniform(1	Normal(290, 25)
Product 5					
Buyer					
1 2 3 4 5					
1	Uniform(2		Uniform(20, 70)		
2			Uniform(100, 300)		
3					
4					
5	Uniform(50, 80)		Uniform(30, 60)		

Ordering cost					
Buyer					
Buyer	1	2	3	4	5
1		8000	8000		
2				8000	
3					
4					
5	13000		8000		
Machine:		Energy Consumption.	Carbon Intensity	Carbon Tax	Daily Carbon Emission Cost
1. Boiling and dying machine		450 kWh	0,2 kgCo2	30000 /tonCo2	2,2E+07
2. Drying machine		300 kWh	0,2 kgCo2	30000 /tonCo2	1,4E+07
3. Wax melting machine		550 kWh	0,2 kgCo2	30000 /tonCo2	2,6E+07