Development of Supply Chain Network Design Model for Commercialization of Batik Waste Processing Equipment with Credit System

Adindha Karunia Ciptaning Pragowoaji
Undergraduate Student of Industrial Engineering Department
Faculty of Engineering
Universitas Sebelas Maret
Jl. Ir. Sutami, 36A, Surakarta, Indonesia
adindha.karunia.c.p@student.uns.ac.id

Nasyita Vivi Amalia
Industrial Engineering Department, Faculty of Engineering
Universitas Primagraha
Serang, Banten, Indonesia
nasyitavivi@primagraha.ac.id

Wahyudi Sutopo, Yuniaristanto
[3)] University Centre of Excellence for Electrical Energy Storage Technology
[4)] Research Group Industrial Engineering and Techno-Economic, Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret
Jl. Ir. Sutami, 36 A, Surakarta, Indonesia
wahyudisutopo@staff.uns.ac.id, yuniaristanto@ft.uns.ac.id

Abstract

Batik is a cultural heritage that has been widely used as formal clothing in Indonesia. Batik SME strives to develop its production process to meet the high demand. However, batik production waste management is a crucial thing that has not been fully implemented. Numerous educational institutions have begun to use technical improvements linked to batik waste processing technology, but commercialization issues continue to hinder the implementation process. This study will develop a mixed-integer linear programming (MILP) model to address the supply chain network for commercializing batik waste processing equipment KOMBAT. The model will be developed by considering the credit payment factor using ILOG CPLEX to maximize profit. From the model output, the number and location of the supplier, the number of goods assigned from suppliers to each demand point, and the overall cost of the supply chain were known.

Keywords
Supply Chain Network Design, Batik Waste Processing Equipment, Mixed Integer Linear Programming, ILOG CPLEX, Credit Payment

1. Introduction

Batik is an Indonesian cultural work of historical and artistic significance. The different patterns and colors are a representation of a region's distinctiveness. As a cultural treasure, the craft of batik has progressed from being utilized solely by the royal family to becoming popular attire worn by both men and women (Trixie 2020). Batik is now employed as formal clothing for public workers and school children, and it has even made its way into daily clothing.

Batik is in demand by the national market and the global market and has made a significant contribution to the national economy. The Ministry of Industry noted that batik exports in 2020 reached USD 532.7 million. During the first quarter of 2021, it penetrated USD 157.8 million (Ministry of Industry 2021). To meet the demand for batik both from within and outside the country, a total of 49,000 batik SME business units are still actively producing with a total of 200,000 Indonesian batik craftsmen (Amalia et al. 2020). However, Indonesia's dense concentration of batik companies is not matched by adequate waste management. So far, liquid waste from the batik industry has simply been stored in reservoirs and allowed to leak into the earth without additional treatment (Jannah and Muhimmatin 2019). Liquid waste is produced during the fabric production, dyeing, and 'pelorodan' steps (Jannah and Muhimmatin 2019). Batik liquid waste contains toxic substances such as chromium (Cr), lead (Pb), nickel (Ni), copper (Cu), and manganese (Mn). It can elevate COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) levels in the water, causing ecological disruption (Sugiyana 2003).

To address the concern over this issue, numerous educational institutions have begun to use technical improvements linked to batik waste processing technology. One of them is the UNDIP research team that developed KOMBAT (Electrolyte Coagulation and Batik Waste Ozonation) with an economic life of 5 years of use. However, commercialization issues continue to hinder the implementation process. As a result, Amalia (2020) conducted prior research to assess the feasibility of commercialization and the formulation of mathematical models in the supply chain network system for batik waste processing equipment. The study considers three methods of payment: cash, credit, and renting the equipment. Cash payments are direct payments in cash and whole, without any remaining payment costs, made between the vendor and the buyer at the time of delivery of goods. The supplier will apply a rental rate for batik waste processing equipment per hour of use in rental payment. Meanwhile, the firm implements the credit sales system by supplying items following the buyer's request, and the company has a bill to the customer for a set length of time. Sales on credit cannot immediately generate cash receipts but will result in accounts receivable, which, if appropriately managed, can increase the company's profitability (Tiong 2017). Credit sales and accounts receivable turnover will benefit the company since they will make it more desireable to prospective buyers, resulting in an increase in sales volume, which equals an increase in revenues or profits. Fahlevi and Yani (2021) performed study to examine the influence of credit sales and account receivable control on an Indonesian public broadcaster’s operational profit. According to the study, the sale of loans has positive influence on profit, and the more credit sales there are, the higher the profit.

1.1 Objectives

The previous research used the rental payment method in mixed-integer linear programming (MILP) models. This alternative was chosen because the rent fee is regarded as reasonably priced for the SMEs that serve as ultimate consumers in this sector. Because the other two payment choices have yet to be modeled, this gap will be addressed in this study to supplement the findings of earlier studies. In this study, the mixed-integer linear programming model submitted by Amalia (2020) will be developed by taking into account the credit payment factor using ILOG CPLEX 20.1.0.

2. Literature Review

2.1 Supply Chain Network Design

Amid the rapid development of the business environment, firms no longer compete with one another instead, a supply chain competes with other supply chains to be superior. As a result, supply chain management is an essential factor that must be considered and applied to enhance the company’s and the overall supply chain’s long-term performance. Supply chain management is the management of products or services beginning with the design stage and progressing to the various stages of production from raw materials to finished products, concluding with the delivery of products/services to end users, and finally entering the reuse, recycling, or disposal phases depending on the product/service, industry and company business models (Fritz 2019). In short, supply chain management is the process of planning, managing, and scheduling products flows from procurement to distribution to consumers.

The goal of supply chain (SC) design is to reduce costs so that items may reach customers at the lowest possible price and with the most flexibility. Decisions on supply chain network design (SCND) include facility function assignment, facility location, storage, transportation, and capacity and market allocation for each facility (Chopra and Meindl 2013). There are two layers of supply chain planning: strategic and tactical (Singh et al. 2013). Network configuration is decided at the strategic level of planning (number, allocation, capacity, and technology of facilities). At the tactical level, choices on aggregate quantities and material flow for purchase, processing, and distribution are made. The SC's strategic configuration is seen as a critical aspect impacting effective tactical operations and, as a result, having a long-term influence on the organization (Singh et al. 2013). Because purchasing expenses account for the bulk of sales income in the context of small and medium-sized business (SMEs), cost-effective SCM is critical for survival and growth (Quayle 2003). One of the aspects that is critical to look into is the facility location since it may cut distribution costs and maximize the fulfillment of customer needs (Wati et al. 2017). In general, allocation costs/distribution costs are most affected by the chosen location. It can be said that the location factor will significantly affect the company's overall profit (Wati and Nuha 2018).

There have been various earlier studies on using Mixed Integer Linear Programming (MILP) to minimize total supply chain costs. Sutopo and Aisyati (2010) successfully established a raw material terminal location-allocation model for the rattan finished product industry. The number and location of terminals that may be opened, the allocation of rattan delivered from the source to the terminal, and the overall cost of the supply chain have all been reduced by considering 5 terminal sites. Wati et al. (2017) attempted to create a model for determining the distribution center's location. This study's model produced various decision factors, including the location and number of distribution centers established, the number of units transported, and the frequency of delivery. In the following study, Wati and Nuha (2018) developed a Capacitated Maximal Covering Location Problem (CMCLP) to estimate the location of warehouse establishment. The model determines the optimal site for the facility and specifies the quantity of commodities assigned from the distribution center to each demand point and the maximum number of requests that may be satisfied.

2.2 Supply Chain Network Design of KOMBAT Commercialization

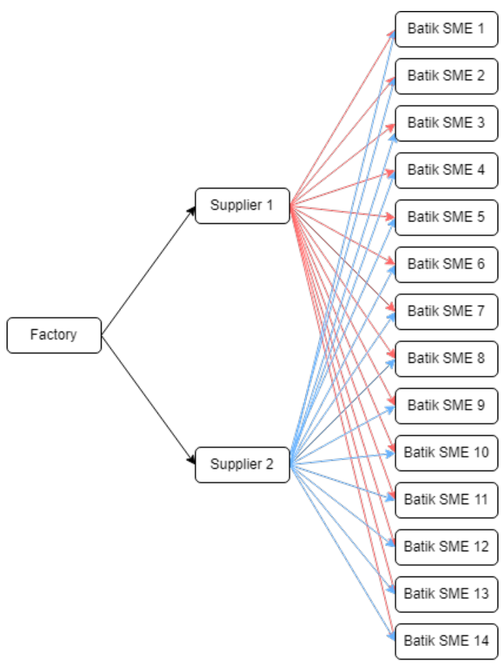

Figure 1. Supply Chain Network Design

There are three entities involved: factories, suppliers, and Batik SMEs. UNDIP Semarang will be the manufacturer which provides the batik waste processing equipment. The factory will supply the second entity, namely suppliers, with the necessary batik waste processing tool and consumable goods. The supplier is the party that sends KOMBAT to batik SMEs to satisfy the requirement for batik waste processing tools. There are two suppliers in this network design, namely Petarukan and Kramat. The third entity is the batik industry (Batik SMEs) which in this study came from Pekalongan Regency (Figure 1), Pemalang Regency, and Tegal Regency.

3. Methods

The goal of this study is to create a mixed-integer linear programming (MILP) model that will discover the best answer for supplier opening choices. Because of its flexibility for complex large-scale problems and capacity to give a worldwide certificate of optimality for the discovered solution, Mixed Integer Linear Programming (MILP) is the most often utilized optimization technique (Moretti et al. 2021).The model will be developed with the factory's and the two suppliers' capacities in mind. Since this research will focus on credit payment options, the influence diagram from the previous study by Amalia (2020) will be adjusted to the payment method.

The feasibility of opening suppliers economically will also be reviewed from an economic engineering point of view. The investment feasibility will be analyzed by calculating Break Even Point (BEP), Return of Investment (ROI), Net Present Value (NPV), Payback Period (PBP), Internal Rate of Ratio (IRR), and Benefit Cost Ratio (B/C Ratio). The break-even point is the point at which the revenue equals the capital issued, with no loss or profit, and is calculated by dividing the fixed costs per year by the price per unit after deducting the variable expenses per unit. Meanwhile, Return on Investment (ROI) is the ability of capital invested in total assets to create net profit, which is calculated by dividing net profit by total investment. Net Present Value (NPV) is a way of computing the net value (net) at the time of calculation. The Internal Rate of Return (IRR) is the discount rate that results in a project's NPV being zero. The B/C ratio then calculates the present value of each invested capital by dividing the current value of cash inflow by the present value of original investment. From the economic engineering analysis, the feasibility of this project will be measured.

4. Data Collection

The data used is secondary data taken from previous research by Amalia (2020). Those data are tools and consumables demand from each Batik SMEs, fixed cost and variable cost calculation that have been adjusted with the payment method, and data on investment cost and capital for establishing each supplier. Table 1 states the demand data from each Batik SME. Table 2 lists the needs for consumables in the form of filtration components needed by batik waste processing equipment in gauze, bioform, activated carbon, and zeolite. Both suppliers require the same consumables so that the variable costs of both suppliers are the same. The investment costs of the two suppliers are different because the Petarukan supplier needs to provide funds for land and buildings while the Kramat supplier only requires building costs (Tables 3 and table 6). Table 4 and table 7 represent the capital needed for each supplier to purchase batik waste processing equipment from the factory. Tables 5 and 8 show the list of fixed costs that each supplier must incur.

Table 1. Demand Data

Regency	District	Batik SMEs	Demand (unit/year)	Demand (package/year)	Demand (package /5 year)
Pekalongan	Wiradesa	Batik Wirokuto	12	3,168	15,840
		Batik Pesisir	8	2,112	10,560
		Batik Ratna Sari	5	1,320	6,600
	Tirto	Afif Batik	4	1,056	5,280
		Batik Putra Bima	8	2,112	10,560
		Batik Liariz	2	528	2,640
	Buaran	CV. ASATEX	14	3,696	18,480
		Batik Tiga Benua	9	2,376	11,880
		Mulia Batik Sejati	5	1,320	6,600
Pemalang	Taman	Batik Sekar Manggar	4	1,056	5,280
		Batik Arum Cempaka	2	528	2,640
Tegal	Talang	Mitra Amalia Batik	14	3,696	18,480
		Putra Amalia Batik	14	3,696	18,480
		Batik Nur Elza	9	2,376	11,880
Total			110	29,040	145,200

Table 2. Variable Cost for Both Suppliers

Item	**Unit**	**Total**	**Price**	**Variable Cost (per-unit)**	**Variable Cost (per- 5 years)**
Karbon aktif	Sak	0,1	IDR 50,000	IDR 5,000	IDR 726 million
Zeolit	Kg	1	IDR 4,000	IDR 4,000	IDR 580 million
Kasa	Box	1	IDR 5,000	IDR 5,000	IDR 726 million
Biofarm	Kg	0,5	IDR 11,000	IDR 5,500	IDR 798 million
Total				IDR 19,500	IDR 2,831.4 million

Table 3. Investment Cost for Petarukan Supplier

No.	Item	Total	Unit	Price (IDR)	Investment (IDR)	Economic Age	Depreciation (IDR)	Capital Interest (IDR)
1	Land and Building (6 x 10) M	1	Unit	80 million	80 million	20	4 million	4.2 million
Total					**80 million**		**4 million**	**4.2 million**

Table 4. Capital for Petarukan Supplier

No.	Item	Total	Unit	Price	Capital
1	Batik waste processing tool	60	Unit	IDR 11 million	IDR 660 million
Total					**IDR 660 million**

Table 5. Fixed Cost for Petarukan Supplier

Item	Total	Unit	Fixed cost (per-5 years)	Fixed Cost (per unit)
Depreciation	1	Unit	IDR 4 million	IDR 28
Capital Interest	1	Unit	IDR 4.2 million	IDR 29
Maintenance	1	Unit	IDR 1 million	IDR 7
Employee Salary	3	People	IDR 69.12 million	IDR 476
Total			IDR 78.32 million	IDR 539

Table 6. Investment Cost for Kramat Supplier

No.	Item	Total	Unit	Price (IDR)	Investment (IDR)	Economic Age	Depreciation (IDR)	Capital Interest (IDR)
1	Building (6 x 10) M	1	Unit	50 million	50 million	20	2.5 million	2.625 million
Total					**50 million**		**2.5 million**	**2.625 million**

Table 7. Capital for Kramat Supplier

No.	Item	Total	Unit	Price	Capital
1	Batik waste processing tool	50	Unit	IDR 11 million	IDR 550 million
Total					**IDR 550 million**

Table 8. Fixed Cost for Kramat Supplier

Item	Total	Unit	Fixed cost (per-5 years)	Fixed Cost (per unit)
Depreciation	1	Unit	IDR 2.5 million	IDR 17
Capital Interest	1	Unit	IDR 2.625 million	IDR 18
Maintenance	1	Unit	IDR 1 million	IDR 7
Employee Salary	3	People	IDR 69.12 million	IDR 476
Total			IDR 75.245 million	IDR 518

Calculations of payment schemes on credit are conducted to see the feasibility of the investment. The purchase price of the tool from the factory is IDR 11 million and will be marked up to 40%, so that the selling price will be IDR 15.4 million. The loan repayment period is twice a year for five years so that there are a total of ten installments of payments. Loans are paid semi-annually or twice a year for five years with an effective interest rate of 6% per annum according to the BRI KUR rate. Table 9 shows the computation of the number of installments for each period, while the revenue per-period calculation is in Table 10. In this study, manual profit calculations (Table 11 and table 12) were also carried out, and later the results will be compared with the result from the MILP model.

Table 9. Installments for each period

Period	Principal Balance (million)	Principal (million)	Interest Installment (million)	Total Installment (million)
0	IDR 15.40	-	-	-
1	IDR 13.86	IDR 1.54	IDR 0.4620	IDR 2.0020
2	IDR 12.32	IDR 1.54	IDR 0.4158	IDR 1.9558
3	IDR 10.78	IDR 1.54	IDR 0.3696	IDR 1.9096
4	IDR 9.24	IDR 1.54	IDR 0.3234	IDR 1.8634
5	IDR 7.70	IDR 1.54	IDR 0.2772	IDR 1.8172
6	IDR 6.16	IDR 1.54	IDR 0.2310	IDR 1.7710
7	IDR 4.62	IDR 1.54	IDR 0.1848	IDR 1.7248
8	IDR 3.08	IDR 1.54	IDR 0.1386	IDR 1.6786
9	IDR 1.54	IDR 1.54	IDR 0.0924	IDR 1.6324
10	-	IDR 1.54	IDR 0.0462	IDR 1.5862
Total		**IDR 15.4**	**IDR 2.5410**	**IDR 17.9410**

Table 10. Revenue per-Period Calculation

Period	Total Credit Installments per-semester (million)	Revenue from selling consumables per-semester (million)	Total Revenue per-year (million)
0	-	-	-
1	IDR 220.220	IDR 424.71	IDR 1,284.778
2	IDR 215.138	IDR 424.71	
3	IDR 210.056	IDR 424.71	IDR 1,264.450
4	IDR 204.974	IDR 424.71	
5	IDR 199.892	IDR 424.71	IDR 1,244.122
6	IDR 194.810	IDR 424.71	
7	IDR 189.728	IDR 424.71	IDR 1,223.794
8	IDR 184.646	IDR 424.71	
9	IDR 179.564	IDR 424.71	IDR 1,203.466
10	IDR 174.482	IDR 424.71	
Total	**IDR 1,973.51**	**IDR 4,247.1**	**IDR 6,220.610**

Table 11. Profit Manual Calculation

No	Item	Unit	Total	
1	Consumables demand	Unit/ 5 years	145,200	
2	Consumables selling price	IDR/Package	IDR 29,250	
	Revenue from selling consumables	**IDR/ 5 years**		**IDR 4,247.1 million**
3	Tool demand	Unit/ 5 years	110	
4	Principal balance	IDR/Unit	IDR 15.4 million	
5	Interest installment	IDR/Unit	IDR 2.541 million	
	Revenue from selling tools	**IDR/ 5 years**		**IDR 1,973.51 million**
	Total Income			**IDR 6,220.61 million**
5	Variable Cost	IDR/ 5 years	IDR 2,831.4 million	
6	Fixed Cost	IDR/ 5 years	IDR 153.565 million	
	Total Cost			**IDR 2,984.965 million**
7	Investation	IDR	IDR 130 million	
8	Capital to buy tools	IDR	IDR 1,210 million	
	Total Investation			**IDR 1,340 million**
	Total Profit	**IDR/ 5 years**		**IDR 1,895.645 million**
		IDR/ year		**IDR 379.129 million**

Table 12. Data Recapitulation

Data		Value
Number of Factory		1
Number of Supplier		2
Number of Batik SMEs		14
Period		10
MARR		0,1
Supplier Capacity (unit)	Petarukan	113,200
	Kramat	32,000
	Total	145,200
Investment Cost	Petarukan	IDR 80 million
	Kramat	IDR 50 million
	Total	IDR 130 million
Capital to buy tools	Petarukan	IDR 660 million
	Kramat	IDR 550 million
	Total	IDR 1.21 billion
Fixed cost (per- 5 years)		IDR 153.565 million
Variable cost (per-5 years)		IDR 2.8314 billion
Selling price of consumables		IDR 29,250

5. Results and Discussion

5.1 Numerical Results

Before proceeding into model notation, investment feasibility analysis has been carried out by calculating the Break Even Point (BEP), Return of Investment (ROI), Net Present Value (NPV), Payback Period (PBP), Internal Rate of Ratio (IRR), and Benefit Cost Ratio (B/C Ratio). Based on the calculation result, the minimum number of consumables sold to be economically profitable (BEP) is 15,570 packages with a return of investment of 141%, and the PBP will be 0.41 years or five months. The NPV for five years is IDR 3,390,832,742. The calculation of IRR and B/C Ratio also shows that the investment is feasible where IRR 41.31% > MARR 15%; IRR 44.31% > 20%

MARR, and B/C ratio 2.0840 ≥ 1. Following confirmation from economic engineering that supplier establishment is feasible, the next stage is model formulation.

5.2 Graphical Results

An influence diagram is a tool used to illustrate a decision model in graphic form to aid in model building, development, and understanding of a system. The model components employed in this research are depicted in Figure 2.

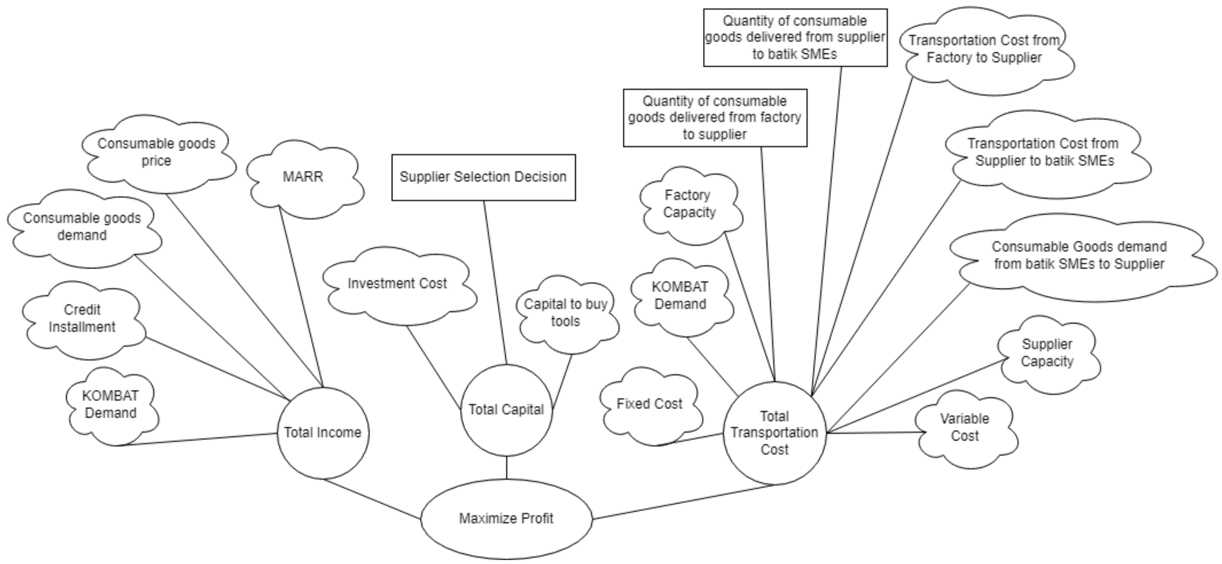

Figure 2. Influence Diagram

5.3 Proposed Improvements

Mathematical models are modified from Amalia (2020).

Index:

- i = Index for factory
- j = Index for supplier
- k = Index for batik SMEs
- t = Index for period

Parameter:

- M = MARR
- P = Consumable goods selling price
- CI_t = Credit installment
- CT_{ij} = Transportation cost from *factory i* to *supplier j*
- CT_{jk} = Transportation cost from *supplier j* to batik SMEs *k*
- DS_k = Consumable goods demand from batik SMEs
- DT_k = Tool demand from batik SMEs
- CAP_i = Capacity of *factory i*
- CAP_j = Capacity of *supplier j*
- IC_j = Investment costs for opening *supplier* j
- CC_j = Capital for purchasing tools by *supplier* j
- FC_t = Fixed cost on period *t*
- VC_j = Variable cost by *supplier j*

Decision Variables:

X_j = Valued 1 if supplier j is opened
Valued 0 otherwise

Y_{ij} = Quantity of consumables shipped from *factory i* to *supplier j*

Z_{jk} = Quantity of consumables shipped from *supplier j* to IKM batik *k*

Objective Function:
Maximization of Profit
= (Consumable goods selling price * number of consumables sent from suppliers to batik SMEs) + (amount of loan installment in a certain period * tool demand from batik SMEs) - (total transportation costs from factory to supplier * number of consumables sent from factory to suppliers) – (total transportation costs from suppliers to batik IKMs * number of consumables sent from suppliers to batik SMEs) – (total fixed cost in a certain period) – (total variable cost * number of consumables sent from suppliers to batik SMEs) – ((total investment costs + capital for purchasing tools) * binary supplier selection decisions)

Maximize Z

$$= (\sum P + Zjk) + (\sum_t^T CIt \, . DTk) - (\sum_i^I CTij \, . Yij) - (\sum_k^K CTjk \, . Zjk) - (\sum_t^T FCt) - (\sum_j^J VCj \, . Zjk) - \left(\sum_j^J (ICj + CCj) \, . Xj\right) \quad (1)$$

Constraints:

$$\sum Y_{ij} \leq CAP_i \quad (2)$$

$$Y_{ij} \leq CAP_j . X_j \quad (3)$$

$$\sum Z_{jk} = DS_k \quad (4)$$

$$\sum Z_{jk} \leq CAP_j . X_j \quad (5)$$

$$\sum Y_{ij} = \sum Z_{jk} \quad (6)$$

The objective function is to maximize profit (1). Constraint set (2) ensures that the total quantity of consumables sent from the factory to the supplier does not exceed the factory's capacity. Constraint set (3) ensures that the amount of consumables from the factory to the supplier does not exceed the ability of the opened supplier. Constraint set (4) ensures that the total quantity of consumables from suppliers to batik SMEs is the same as the amount of demand. Then the constraint set (5) ensures that the number does not exceed the opened supplier's capacity. Constraint set (6) is the last one and aims to ensure that the total quantity of consumables from the factory to the supplier is the same as the total quantity of consumables sent from the supplier to batik SMEs.

5.4 Validation

The data is processed using ILOG CPLEX software based on the model that has been formulated. The model is written into the software by first defining the index, parameters, and decision variables used. After that, the objective function and model constraints are described in a programming language through OPL (Optimization Programming Language). The data entered into the program are: number of factories, number of suppliers, number of customers, period, transportation costs from factory to supplier and from supplier to customer, demand for tools and consumables, factory and supplier capacity, investment costs and capital to purchase tools, selling price of consumables, as well as total loan installments per period.

Based on the model output, it is known that both suppliers will be opened with the quantity of consumables sent from the factory to Petarukan, namely 113,200 packages and 32,000 packages to Kramat. The quantity of consumables sent from suppliers to Batik SMEs can be seen in Table 13.

Table 13. Quantity of Consumables Sent from Suppliers to Batik SMEs (package)

	Petarukan	Kramat
Batik Wirokuto	15,840	0
Batik Pesisir	10,560	0
Batik Ratna Sari	6,600	0
Afif Batik	5,280	0
Batik Putra Bima	10,560	0
Batik Liariz	2,640	0
CV Asatex	18,480	0
Batik Tiga Benua	11,880	0
Mulia Batik Sejati	6,600	0
Batik Sekar Manggar	5,280	0
Batik Arum Cempaka	2,640	0
Mitra Amalia Batik	0	18,480
Putra Amalia Batik	16,840	1,640
Batik Nur Elza	0	11,880

Table 14. Comparison of Manual Calculation and Model Output

	Manual Calculation (million)	Model Output (million)
Total Revenue from Consumables	IDR 4,247.1	IDR 4,247.1
Total Credit	IDR 1,973.51	IDR 1,973.4
Transport from Factory to Supplier	IDR 1,190.5	IDR 1,190.5
Transport from Supplier to Batik SMEs	IDR 56.432	IDR 56.432
Total Capital	IDR 1,340	IDR 1,340
Total Fixed Cost	IDR 153.565	IDR 153.570
Total Variable Cost	IDR 2,831.4	IDR 2,831.4
Total Profit	**IDR 648.713**	**IDR 648.598**

As seen in table 14 that present the output objective function of the model development using ILOG CPLEX, the total profit is IDR 648.598 million. There is a difference of IDR 115,000 compared to the result of manual calculations, which has bigger value.

6. Conclusion

The development of the supply chain network design model for commercialization of batik waste processing tool with a credit payment system has been successfully carried out in this research. The results show that the establishment of two suppliers in Petarukan and Kramat is feasible with the accumulated profit to be obtained for 5 years is IDR 648.598 million.

It is hoped that the results of this study can be used by investors who are considering to open a business for commercializing batik waste processing tool with a credit payment method. This study has not considered the credit management system, so further research is needed to fill the gap.

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Biographies

Adindha Karunia Ciptaning Pragowoaji is an undergraduate student of Industrial Engineering Department at Universitas Sebelas Maret, Surakarta Indonesia. She has an interest in management processes involving supply chain and human resources.

Nasyita Vivi Amalia is a lecturer at the Department of Industrial Engineering, Faculty of Engineering, Universitas Primagraha. She received her Bachelor in Industrial Engineering from Universitas Pancasakti Tegal and Master in Industrial Engineering from Universitas Sebelas Maret Surakarta. Her research interests are related to techno-economics, logistics, commercialization technology, and batik wastewater treatment equipment. She has published two articles Scopus indexed.

Wahyudi Sutopo is an industrial engineering professor and coordinator of the research group of Industrial Engineering and Techno-economy (RG-RITE) from the Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia. In 2011, he earned his Ph.D. in Industrial Engineering and Management from Institut Teknologi Bandung. He is also an active researcher for the University Center of Excellence for Electrical Energy Storage Technology (UCE-EEST). He has participated in several projects with The Indonesia Endowment Funds for Education (LPDP), Sustainable Higher Education Research Alliances (SHERA), MIT-Indonesia Research Alliance (MIRA), PT Pertamina (Persero), PT Toyota Motor Manufacturing Indonesia, and various other companies. His research interests include logistics and supply chain management, engineering economy, cost analysis and estimation, and technology commercialization. He is a member of the Board of Industrial Engineering Chapter - The Institute of Indonesian Engineers (BKTI-PII), Indonesian Supply Chain and Logistics Institute (ISLI), Society of Industrial Engineering and Operations Management (IEOM), and Institute of Industrial and Systems Engineers (IISE).

Yuniaristanto is a lecturer of the Industrial Engineering Department, Faculty of Engineering, Universitas Sebelas Maret. He obtained his Master of Engineering from Institut Teknologi Bandung and Bachelor of Engineering in Industrial Engineering from Institut Teknologi Sepuluh November. He is part of the Industrial Engineering and Techno -Economy (RITE) Research Group. His research interests are Logistics, Supply Chain Management, and Production/Operations Management.