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A Decision Model to Plan Optimally Production-Distribution of Seafood Product with Multiple Locations

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Abstract: This study examines a multi-product fish production and distribution system in which multi-fish products are produced simultaneously from a wide range of raw resource classes. The objective of environmentally sustainable production planning is to meet market demand in accordance with environmental constraints. This paper sets out a management model that converts fisheries into multiple marine objects and moves them to various dispensing centers. It also incorporates a model to improve production and distribution planning at the same time. The problem is formulated as a mixed integer programming model. Then, we addressed a strategy of releasing non-basic variables from their bounds to force basic non-integer variables to take integer value. As an implementation, we solved a fish production planning problem faced by an industry located in Kisaran city, North Sumatra province, Indonesia.

Keywords: decision sciences; optimization; direct search method; supply chain; fisheries

MSC: 90B30; 90B50

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1. Introduction

The nation of Indonesia is composed of more than 17,000 islands and is the world's biggest archipelago. It should come as no surprise that Indonesia, which is home to the largest archipelago on the planet, is also one of the most important producers and suppliers of fishery products on the global market [1]. The fisheries of Indonesia are extremely significant on a worldwide scale. Over 3000 different kinds of fish may be found in the waterways of the nation. This industry also provides jobs for coastal residents in order to strengthen the monetary benefits of local government and maintain sustainability. Approximately 12 million Indonesians find work in the fisheries sector. Most fisheries corporations are organized into processing and distribution networks that import processed raw fish resources into marine products and hand out end-products to their consumers. The aim is to make the right item at the best market value at the appropriate time. These production and distribution networks are known as supply chains. Managers will manage all procurement, manufacturing and delivery resources in the preparation of the supply chain. Specifically, the strategy demonstrates the need for managers to assess the cost of raw materials, inventory and shipping, taking into account manufacturing, output, storage and transshipment efficiency.

There are various links in the supply chain that are unable to support commercial fishing operations on their own. Establishing the value chain that will pay for the supply of goods and services still requires a significant amount of effort to be put in. Large-scale fishing operations are unable to be supported by the small-scale fisheries that provided the product in the first place. Distribution and sales are not as well developed as they should be in order to be capable of putting considerable quantities of things on the market. This is because the capacity of the cold chain is quite limited. More than eighty percent of Indonesia's fisheries were still run the same way they had been for generations, with fishermen operating out of their houses and using just the most basic gear available to them [2].

The production planning shall include the number of times each method has to be carried out, and the method shall use the amount of each class of raw materials throughout each planning cycle. The aim is to minimize the cost of manufacturing methods, inventories/back-order use of raw materials and employees in line with the requirements of goods, equipment efficiency and raw materials inventories. Another essential aspect of production planning is the evaluation of lot sizes: the assessment of the amount to be released for each product at a specified time. The revised output and survey on lot size can be reported in production planning in [3]. Battini et al. [4] shows an efficient lot sizing optimization.

Instead, finished fish items would be distributed to consumers. Logistic complexity is described below as a routing issue in supply chain management. The system allocates manufactured goods to a number of geographically dispersed consumers by means of a stream of qualified vehicles from a central distribution facility named a warehouse. The aim of the routing problem is to identify how many goods customers need to receive, how vehicles are assigned and the route to be traveled [5].

Throughout this article, we discuss the challenges of production and distribution planning across Indonesia's marine fisheries business. Marine fisheries are an important aspect of Indonesia's economic growth. This industry also provides jobs for coastal residents in order to strengthen the monetary benefits of local government and maintain sustainability. There are three industrial fisheries, open-sea fishing, fish farming and processed fish. The focus of this paper is on the last processed fish sector.

The maritime industry will usually be located throughout the coastal region. Several types of processed seafood, such as fried salmon, salted seafood, crunchy fishbowl, terrain (preserved fish), etc., are included throughout the production phase. The local small conventional corporation is dominated by this sector and uses a traditional management strategy. However, they do not have sufficient expertise and expertise to support the government and its citizens in managing the supply chain network [6].

The integration of production and distribution system (IPDS) have been considered in the articles regarding to supply chain since the mid-1980s. The IPDS can be found as an informative and detailed overview in [5,7–9]. In [10,11], they addressed IPDS in an optimization procedure that also optimizes decision variables for separate output and distribution functions. The authors of [12] intended to address the issue of interrelating lot sizing and system inventory routing based on a linear mixed-integer method in order to optimize the network. They introduced a two-step technique that first approximated the number of daily deliveries and subsequently resolved the problem of vehicle routing on each scheduling day. Reference [13] is based on the model applied for the development and preparation of unpreserved food products. They thought of the issue as a full-scale programming model. Reference [14] has recently been established as a model for optimizing integrated inventory and delivery of routing problems in the agricultural supply chain.

Inputs are used for the processing of seafood products for the production of a manufactured product or service. In certain types, which may be referred to as contaminants or waste, these products are ultimately not used and dispersed throughout the system. Where pollution exceeds the capacity of the system to maintain and manage pollution, environmental threats arise. As regards the importance of preparing for processed seafood for sustainable development, the mathematical programming model provides a stimulus for research. Reference [15] proposed a multi-objective model to address environmentally sound sustainable development planning. It is a traditional model of output. Reference [16], in turn, used the optimization process approach to minimize the use of freshwater in order to address the production planning of crude palm oil. In particular, the cultivation of fish is a challenging issue, given the impact of the production variables and the environmental impacts. An interesting study on sustainable growth of integrated production and logistics can be found in [17–19]. Multi-period strategies for development and distribution are addressed in [20]. Researchers in [21–23] used a fuzzy multi-criteria model to determine production and distribution management.

Alkahtani [24] developed model for the process outsourcing to determine the optimal production quantity and to manage optimal outsourcing quantity among vendors. He et al. [25] also developed an inventory model for fresh product and deep processed product to obtain the pricing and product strategy for the industrial company. Reyes-Barquet et al. [26] presented mathematical optimization model for hydrogen supply chain to define the annual profit.

Coronado Mondragon et al. [27] provided a conceptual approach for the fishing industry. In order to digitalize the supply chain, they combined a number of different technologies, including sensor management based on the idea of wireless sensor networks and the analysis of large amounts of data produced by sensors using a Python-based time series scatter diagram procedure.

Bakhrankova et al. [28] came up with the integrated planning that was used for the fishing sector in Norway. The authors developed a comprehensive stochastic model that takes into consideration uncertainty in both the upstream and downstream processes, as well as degradation and shelf-life limits. Mawengkang [29] using stochastic programming models to discuss the preparation of processed fish products.

This paper concerns the modeling of the organized processing and delivery of seafood items. In this model, we stress the importance of achieving the objectives of fiscal, social and environmental sustainability. With a focus on formulating the issue, we propose a mixed integer programming (MIP) approach, as the need for seafood is considered deterministic. A direct search method is designed to solve the model.

Our research contribution is mainly a method for solving mixed integer programming. The ultimate concept of the method addressed in this paper is to release a non-basic variable from its bound in such a way will force to move a corresponding non-integer basic variable point to its neighborhood integer point. The main idea to choose the non-basic variables in the process is mainly based on minimizing the deterioration of the optimal continuous solution. Then, a ratio test is developed for keeping the integer results in the feasible region.

2. Mathematical Framework of the Problem

The integration planning problem of production and distribution addressed in this paper tends to be modeled as a MIP problem. The general expression of the model can be written as in Equation (1):

$$\underset{x\in R^n}{minimize} f^0\left(x^N\right)+c^T x^L \tag{1}$$

Subject to

$$f\left(x^N\right)+A_1x^L=b_1,\ \ (m_1 \text{ rows})$$

$$A_2x^N+A_3x^L=b_2,\ \ (m_2 \text{ rows})$$

$$l\le x\le u,\ \ (m=m_1+m_2)$$

$$x_j \ \text{ integer}, j\in J_1$$

in which the model contains n variables with m constraints, $m<n$.

From Equation (1), it can be seen that some proportion of variables x are in nonlinear form, can be found in the objective and constraints function. Furthermore, some variables may also be valued as an integer. We specify a nonlinear element if either its objective function or its limitation appears to be nonlinear in the formulation of the problem.

The linear constraints can then be written as follows.

$$Ax=[A]\begin{bmatrix}x_B\\x_S\\x_N\end{bmatrix}=b \tag{2}$$

Matrix A is partitioned into matrix basic B, matrix super basic S and matrix non-basic NB

$$A = [B\,S\,N]$$

B is a non-singular $m \times m$ matrix, x_N are "non-basic" variables in which their values are at one of their bounds. x_B and x_S are considered as basic and super basic variables, respectively, then to uphold feasibility to proceed in the next movement they must fulfill the expression

$$B\Delta x_B + S\Delta x_S = 0 \tag{3}$$

then, as the basis is a non-singular matrix, the following equation is satisfied.

$$\Delta x_B = -B^{-1} S \Delta x_S \tag{4}$$

Owing to Equation (4), the super basics can be said as motivating powers, because of phase Δx_S determines process Δx as a whole. The key function of the algorithm is to think that the x_S component remains minimal. This can be done not only if the number of nonlinear variables is much less than the linear variables, but also in fact in many cases where all variables are nonlinear. Related thoughts on the framework of nonlinear integer systems would be developed. The proportion of integer variables in the problem is assumed to be minimal.

3. Problem Description

The fish industry to be considered is located at Kisaran city, Indonesia. The industry managed by the local people is planned to produce N processed fish in such a way to satisfy market for each period t. For instance, each period within three months. A bounded number of raw fish material can be stored for a short duration in the manufacturing site incurred cost of ρ_{jt}.

The seafood product will be transferred to a set of n distribution points constructed by the industry management situated near by to the production site. Each distribution point i (i = 1,2,...,n) has a non-negative and known demand D^i_{jt} of j kind fish product within a period t of the planning period. A restricted quantity of inventory can be stored in distribution points i with holding cost of ρ^i_{jt}.

Now let us consider the logistic routing problem. We use the concept of Vehicle Routing Problem (VRP). A variety of vehicles with the same capacity are available for transporting goods from the factory to the points of distribution. The fleet used is hired by the fish manufacture. The hiring costs are calculated on the basis of the number of journeys that can be made by each fleet. For example, each vehicle should make at least one transition for each cycle and each point must be inspected at least once for each period of time, other tasks are needed in the model. The decision model is to determine the least of the total of operational costs.

Firstly, the parameters and decision variables are described using the following notations.

Indices and sets

- T : time periods
- N : products
- M : raw fish (original resources)
- L : the center point for distribution
- V : fleet of vehicles

Decision Variables

- X_{jt} : Amount of sea food production $j \in N$ in time $t \in T$ (ton)
- z^l_{jvt} : Amount of sea food production $j \in N$ to be sent to the point of distribution $l \in L$ in time $t \in T$ by fleet $v \in V$ (ton)
- u_{it} : Extra raw fish $i \in M$ to be bought for $t \in T$ (unit)
- k_t : Total workers to be used in time $t \in T$ (man-period)

- k_t^- : Number of unnecessary workers in time $t \in T$ (man-period)
- k_t^+ : Number of extra workers in time $t \in T$ (man-period)
- I_{jt}^0 : Amount of sea food production $j \in N$ to be kept at the production site in time $t \in T$
- I_{jt}^l : Amount of fish production $j \in N$ to be kept at time $t \in T$ in the center of distribution $l \in L$ (units)
- B_{jtl} : The unmet demand of sea food production $j \in N$ in time $t \in T$ in the center of distribution $l \in L$ (units)
- C_{jvt} : $\begin{cases} 1 \text{ if delivery of sea food } j \in V \text{ is done by fleet } v \in V \text{ in time } t \in T \\ 0 \text{ otherwise} \end{cases}$
- H_{vt} : $\begin{cases} 1 \text{ if vehicle } v \in V \text{ is used for distribution center in time } t \in T \\ 0 \text{ otherwise} \end{cases}$

Parameters

We define all costs with the following character $\alpha, \beta, \gamma, \delta, \mu, \rho, \lambda, \eta, \tau$

- D_{jt} : Customers' need for fish $j \in N$ in time $t \in T$ (units)
- U_{jt} : The largest amount of u_{jt}, for product $j \in N$ in $t \in T$
- r_{ij} : Number of raw fish $i \in M$ required to get a unit of fish product $j \in N$
- f_{it} : Number of raw fish $i \in M$ can be processed at time $t \in T$ (units)
- a_j : Total workers are necessary to obtain a unit of fish product $j \in N$
- w_{jt}^p : Superfluous of fish product $j \in N$ in time $t \in T$ (units)
- UI_{jt}^0 : Maximum capacity of inventory of product $j \in N$ at the production site in time $t \in T$ (units)
- UI_{jt}^l : Maximum capacity of inventory of product $j \in N$ at the center $l \in L$ in time $t \in T$ (units)
- g : The maximum weight a vehicle can carry
- b : Workers working hour per period

4. The Model

Minimizing

$$\begin{gathered}\sum_{j\in N}\sum_{t\in T}\alpha_{jt}x_{jt} + \sum_{i\in M}\sum_{t\in T}\beta_{it}u_{it} + \sum_{t\in T}\mu_t k_t + \sum_{t\in T}\gamma_t k_t^- + \sum_{t\in T}\delta_t k_t^+ + \sum_{j\in N}\sum_{t\in T}\eta_{jt}w_{jt}^p + \\ \sum_{j\in N}\sum_{t\in T}\rho_{jt}^0 I_{jt}^0 + \sum_{j\in N}\sum_{t\in T}\lambda_{jt}B_{jt} + \sum_{v\in V}\sum_{t\in T}\tau_{vt}H_{vt} + \sum_{j\in N}\sum_{t\in T}\sum_{l\in L} I_{jt}^l\end{gathered} \tag{5}$$

Subject to

$$\sum_{i\in N} r_{ji}x_{jt} \le f_{it} + u_{it}, \;\; \forall i \in M, \forall t \in T \tag{6}$$

$$u_{it} \le U_{it}, \;\; \forall i \in M, \forall t \in T \tag{7}$$

$$\sum_{j\in N} a_j x_{jt} \le bk_t, \;\; \forall t \in T \tag{8}$$

$$0.10x_{jt} \le w_{jt}^p \le 0.20x_{jt}, \;\; \forall t \in T \tag{9}$$

$$\sum_{j\in N}\sum_{t\in T} w_{jt}^p \le C^p \tag{10}$$

$$I_{jt}^l = I_{jt-1}^l + \sum_{v\in V} Z_{jvt}^l - D_{jt}, \;\; \forall j \in N, t \in T \tag{11}$$

$$I_{jt}^0 \le UI_{jt}^0, \;\; \forall j \in N, t \in T \tag{12}$$

$$I_{jt}^l \le UI_{jt}^l, \;\; \forall j \in N, l \in L, t \in T \tag{13}$$

$$k_t = k_{t-1} + k_t^+ - k_t^-, \;\; t = 2, \dots T \tag{14}$$

$$x_{jt} + B_{jt-1} + I^0_{jt} - B_{jt} = D_{jt}, \ \ \forall j \in N, \forall t \in T \tag{15}$$

$$Z^l_{jvt} \le g.C_{jvt}, \ \ \forall j \in N, v \in V, l \in L, t \in T \tag{16}$$

$$\sum_{j \in N} Z^l_{jvt} \le g, \ \ \forall v \in V, l \in L, t \in T \tag{17}$$

$$\sum_{j \in N} C_{jvt} \le 1, \ \ \forall v \in V, t \in T \tag{18}$$

$$\sum_{v \in V} C_{jvt} \le 1, \ \ \forall v \in V, t \in T \tag{19}$$

$$\sum_{j \in N} C_{jvt} \le f.H_{vt}, \ \ \forall v \in V, t \in T \tag{20}$$

$$x_{jt}, u_{it}, k_t, k^-_t, k^+_t, Z^l_{jvt}, I^0_{jt}, I^l_{jt}, B_{jt} \ge 0, \ \ \ \forall j \in N, \forall i \in M, \forall t \in T, \forall l \in L, \forall v \in V \tag{21}$$

$$C_{jvt}, H_{vt} \in \{0,1\}, \ \ \forall j \in N, v \in V, t \in T \tag{22}$$

Equation (5) is the objective of the planning problem, expressed as minimizing the overall costs. Equation (6) states the quantity of raw fish $i \in M$ which will be processed to produce the amount of $j \in N$ so as to have not more than the quantity of raw fish available at $t \in T$ along with the extra raw fish required. Nevertheless, the additional resource must be restricted for an upper bound (Equation (7)). In (8), shown the total of workforce which is ready to work to produce fish $j \in N$. The total fish defective can be found in Equation (9). Then, Equation (10) shows that the fish defective must be processed within the capacity C^p. Equations (11)–(13) illustrate about the inventories which are available at the manufacturing site and distribution center. Equation (14) is to guarantee that the amount of labor in period t is equivalent to the total workforce from the period $t-1$ plus a change in the amount of workforce during period t. Equation (15) shows whether the quantity of product to be put in the store or buying from others in order to add the shortage in relating to fulfill market demand. Equations (16) and (17) state the maximum amount of product to be delivered to all distribution centers. Equation (18) is formulated so as to satisfy the necessity of a distribution point in the time period. In order to ensure that each fleet is used at most once we need Equation (19). Equation (20) is to guarantee that the same vehicle is used to deliver product from the center of delivering. Equations (21) and (22) represent the definition of variables used.

5. Proposed Method for Tackling the Problem

The algorithm starts by solving the relaxed problem. If the result of the relaxed problem is already fully feasible, then Stop, otherwise Go To Level 1.

Level 1. Consists of 7 Steps.

1. Find a row which has the smallest integer infeasibility

   (This is due to it being preferable to get a minimal deviation in the objective function value)

2. Calculate

$$v^T_{i*} = e^T_{i*} B^{-1}$$

3. Determine

$$\sigma_{ij} = v^T_{i*} \alpha_j$$

   With relates to

$$\min_j \left\{ \left| \frac{d_j}{\alpha_{ij}} \right| \right\}$$

Assess the maximum moving step of non-basic j at their lower and upper limit, or else go to the other non-integer non-basic or super basic j (if any). Eventually, the column j^* is to be escalated from LB or reduced from upper bound. If empty go to next row.

4. Compute

$$B\alpha_{j^*} = \alpha_{j^*}\text{for } \alpha_{j^*}$$

5. Perform a test for the basic variables to maintain feasibility
6. Replace basic variable
7. If there are no more rows to process, go to Level 2, otherwise

Go to Step 1.
Level 2.

Step 1. Alter integer infeasible super basics by an appropriate step to achieve complete integer feasibility.

Step 2. Alter integer feasible super basics. The aim of this move is to undertake a highly positioned neighborhood search in order to validate the optimum local condition.

6. Computational Illustration

As an illustration, we tackle a problem for managing a plan of production faced by a fish processing industry located in Kisaran, Indonesia. The data for the model described in the previous section are shown in Tables 1–16.

- The amount of product $N = 8$
- The number of set resources $M = 3$
- Time period $TP = 4$
- Distribution center $L = 3$
- The number of vehicles used $V = 5$

Table 1. Production Cost (IDR Million/ton).

Product	TP			
	1	2	3	4
1	2300	2300	2350	2400
2	780	800	800	850
3	6700	6700	6750	6800
4	8500	8550	8600	8600
5	15,100	15,100	15,200	15,200
6	3500	3550	3600	3600
7	1600	1600	1750	1800
8	8000	8200	8250	8300

Table 2. Added Resources Cost (IDR/ton).

Resources	TP			
	1	2	3	4
Machine 1	45,600	45,800	45,800	45,900
Machine 2	34,300	34,600	34,600	34,700
Machine 3	32,200	32,300	32,300	32,500

Table 3. Costs for workers (IDR Million/man-period).

Cost Notation	TP			
	1	2	3	4
μ	22,000	22,500	22,500	23,000
γ	24,000	24,000	25,500	26,000
δ	25,000	25,000	25,600	27,000

Table 4. Raw fish for each Product (ton).

Resources	Product, *j*							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Machine 1	6	5	6	8	7	6	5	9
Machine 2	4	4	5	6	6	5	5	8
Machine 3	5	3	5	6	6	5	5	7

Table 5. Capacity of Resource available.

Period	Machine 1	Machine 2	Machine 3
1	20,000	18,000	21,000
2	20,000	18,000	20,000
3	20,000	19,000	21,000
4	19,000	17,000	20,000

Table 6. Upper Bound for Additional Resources.

Period	Machine 1	Machine 2	Machine 3
1	300	300	200
2	300	300	200
3	250	300	200
4	200	250	250

Table 7. Workforce Needed to Produce Each Product.

Product	Workforce (man/ton)
1	6
2	12
3	24
4	24
5	24
6	20
7	15
8	8

Table 8. Inventory Holding Cost (IDR Million/ton).

Product	Period			
	1	**2**	**3**	**4**
1	2700	2700	2700	5000
2	2500	2500	2500	4000
3	2400	2400	2400	2600
4	3000	3000	3000	5000
5	2400	2400	2400	2700
6	2000	2000	2000	2300
7	3000	3000	3000	4000
8	2500	2500	2500	2500

Table 9. Costs to Purchase from Outside (IDR Million/ton).

Product	Cost
1	6700
2	4800
3	10,000
4	16,200
5	27,800
6	11,000
7	15,500
8	2500

Table 10. Data for Market Demand (ton).

Product, *j*	Situation, *s*	Period, *t*			
		1	2	3	4
1	Good	20,000	20,000	20,500	20,500
	Fair	18,000	18,000	18,000	19,000
	Poor	15,000	15,000	15,000	16,000
2	Good	115,000	115,000	115,000	116,000
	Fair	112,000	112,000	112,500	113,000
	Poor	90,000	90,000	90,000	90,000
3	Good	4000	4000	4500	4500
	Fair	3600	3600	3600	4000
	Poor	3000	3000	3100	3100
4	Good	5000	5000	5000	5500
	Fair	4500	4500	4500	4600
	Poor	4000	4000	4000	4100
5	Good	3500	3500	4000	4000
	Fair	3000	3000	3500	3500
	Poor	2000	2000	2200	2200
6	Good	4000	4000	4000	4200
	Fair	3600	3600	3600	3700
	Poor	3000	3000	3000	3100
7	Good	5100	5100	5200	5300
	Fair	4500	4500	4500	4600
	Poor	4000	4000	4100	4100
8	Good	5000	5000	5100	5100
	Fair	4500	4500	4600	4600
	Poor	4200	4200	4200	4200

The data of the problem can be found in Tables 1–10.

Table 1 shows the production cost for each processed fish product in each period. Tables 2 and 3, respectively, present the cost incurred for additional resource and hiring workforce. Tables 4 and 5 show the capacity of resource needed and available for each machine. The upper bound for additional resources are given in Table 6. The data for workforce needed to produce each fish product is shown in Table 7. The cost for holding products in inventory can be found in Table 8. Table 9 shows the cost if the management has to purchase from outside the product in order to meet the demand.

Uncertainty occurs in the demand of each processed fish product in each period. The realization for the demand in every situation and in each period is shown in Table 10.

7. Computational Results

After solving the processed fish product problem by applying the proposed method discussed in Section 6, we obtain the results as shown in Tables 11–16.

Table 11. Amount of each product in each period (X_{jt}) (in ton).

Product	Period			
	1	2	3	4
1	250.00000	250.00000	250.00000	30,453.33200
2	900.00000	900.00000	900.00000	950.00000
3	200.00000	310.00000	400.00000	450.00000
4	200.00000	450.00000	450.00000	460.00000
5	200.00000	200.00000	200.00000	300.00000
6	200.00000	360.00000	360.00000	370.00000
7	200.00000	450.00000	450.00000	300.00000
8	33,183.33193	30,913.33199	32,323.33193	300.00000

Table 12. Extra raw each resource to be bought for each period (u_{it}).

Resource	Period			
	1	**2**	**3**	**4**
1	300.00000	300.00000	250.00000	200.00000
2	300.00000	300.00000	300.00000	250.00000
3	200.00000	200.00000	200.00000	150.00000

Table 13. Number of workers.

Period	Regular Worker	Lay-Off Worker	Additional Worker
1	29,738	20,816	0
2	17,492	12,245	0
3	17,492	0	17,492
4	10,289	7202	0

Table 14. Amount of each fish production to be kept at each time period (TP) in each of the center of distribution $\left(I_{jt}^{l}\right)$.

		DC 1	DC 2	DC3
Product 1	TP 1	0.00000	0.00000	0.00000
	TP 2	0.00000	0.00000	0.00000
	TP 3	0.00000	0.00000	0.00000
	TP 4	0.00000	0.00000	0.00000
Product 2	TP 1	0.00000	0.00000	0.00000
	TP 2	0.00000	0.00000	0.00000
	TP 3	0.00000	0.00000	0.00000
	TP 4	0.00000	0.00000	0.00000
Product 3	TP 1	0.00000	0.00000	0.00000
	TP 2	90.00000	0.00000	0.00000
	TP 3	50.00000	0.00000	0.00000
	TP 4	0.00000	0.00000	0.00000
Product 4	TP 1	600.00000	0.00000	0.00000
	TP 2	50.00000	0.00000	0.00000
	TP 3	140.00000	0.00000	0.00000
	TP 4	0.00000	0.00000	0.00000
Product 5	TP 1	0.00000	0.00000	0.00000
	TP 2	50.00000	0.00000	0.00000
	TP 3	200.00000	150.00000	0.00000
	TP 4	100.00000	50.00000	0.00000
Product 6	TP 1	0.00000	0.00000	0.00000
	TP 2	40.00000	0.00000	0.00000
	TP 3	40.00000	0.00000	0.00000
	TP 4	50.00000	0.00000	0.00000
Product 7	TP 1	0.00000	0.00000	0.00000
	TP 2	60.00000	0.00000	0.00000
	TP 3	70.00000	0.00000	0.00000
	TP 4	230.00000	160.00000	0.00000
Product 8	TP 1	0.00000	0.00000	0.00000
	TP 2	0.00000	0.00000	0.00000
	TP 3	0.00000	0.00000	0.00000
	TP 4	0.00000	0.00000	0.00000

Table 15. The unmet demand of each product in each period in each of DC $\left(B_{jtl}\right)$.

		DC 1	DC 2	DC3
Product 1	Period 1	50.00000	70.00000	100.00000
	Period 2	100.00000	140.00000	200.00000
	Period 3	145.00000	210.00000	300.00000
	Period 4	30,393.33200	30,473.33200	30,593.33200
Product 2	Period 1	100.00000	200.00000	300.00000
	Period 2	100.00000	988.00000	300.00000
	Period 3	100.00000	1776.00000	300.00000
	Period 4	150.00000	2613.00000	350.00000
Product 3	Period 1	0.00000	50.00000	100.00000
	Period 2	0.00000	0.00000	110.00000
	Period 3	0.00000	0.00000	200.00000
	Period 4	0.00000	50.00000	340.00000
Product 4	Period 1	0.00000	0.00000	100.00000
	Period 2	0.00000	0.00000	150.00000
	Period 3	90.00000	0.00000	200.00000
	Period 4	0.00000	0.00000	250.00000
Product 5	Period 1	100.00000	100.00000	100.00000
	Period 2	0.00000	0.00000	100.00000
	Period 3	0.00000	0.00000	80.00000
	Period 4	0.00000	0.00000	160.00000
Product 6	Period 1	0.00000	0.00000	100.00000
	Period 2	0.00000	0.00000	160.00000
	Period 3	0.00000	0.00000	220.00000
	Period 4	0.00000	0.00000	280.00000
Product 7	Period 1	0.00000	0.00000	100.00000
	Period 2	0.00000	0.00000	150.00000
	Period 3	0.00000	0.00000	190.00000
	Period 4	0.00000	0.00000	80.00000
Product 8	Period 1	32,983.33193	32,983.33193	33,083.33193
	Period 2	63,396.66392	63,446.66392	63,576.66392
	Period 3	95,209.99585	95,309.99585	95,479.99585
	Period 4	94,999.99585	95,149.99585	95,359.99585

Table 16. The result of delivery route $\left(C_{jvt}\right)$.

		Periode 1	Periode 2
Product 1	Vehicle 1	0	0
	Vehicle 2	0	0
	Vehicle 3	0	1
	Vehicle 4	0	0
Product 2	Vehicle 1	1	0
	Vehicle 2	0	1
	Vehicle 3	0	0
	Vehicle 4	0	0
Product 3	Vehicle 1	0	0
	Vehicle 2	0	0
	Vehicle 3	1	0
	Vehicle 4	0	0
Product 4	Vehicle 1	0	0
	Vehicle 2	1	0
	Vehicle 3	0	0
	Vehicle 4	0	0
Product 5	Vehicle 1	0	0
	Vehicle 2	0	0
	Vehicle 3	0	0
	Vehicle 4	0	0

One implication of the result of the model is that one must be careful in deciding the amount of demands to meet. More products to be produced means that the management needs more workers and more raw materials. Accepting more orders than the mill can produce can be very costly. We also implicate here that the inventory holding cost will increase.

8. Conclusions

This research is not free from limitations but can enlighten the direction of related future research. The number of integerizing steps would be finite if the number of integer variables contained in the problem were finite. However, it should be noted that the computational time for the integerizing process does not necessarily depend on the number of integer variables, since many of the integer variables may have an integer value at the continuous optimal solution.

However, it should be noted that difficulties may arise if the problems involve a large number of equality constraints rather than the inequality constraints and/or the number of integer variables that are much greater than the number of constraints in such a way that the number of non-integer non-basic variables are small. This problem is for future research.

A mixed integer optimization model was created in this paper for tackling the problem of multiple processed fish production planning considering sustainability. The particular problem under study was taken from a processed fish industry located at the shoreline area in North Sumatra Province, Indonesia. The demand of the fish product is assumed known (deterministic). In the model, we include how to determine the optimal number of workers to be used, in such a way that the industry would be able to recruit several local people. The binary variables include deciding which vehicle to be used to deliver the processed products. The model also considers the sustainable production system. We address an improved direct search algorithm for handling the problem. The strategy that we adopt for the algorithm is to release non-basic variables in such a way that it will force non-integer basic variables to obtain integer values.

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