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Optimization Model for Agricultural Processed Products Supply Chain Problem in Bandung During Covid-19 Period

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Abstract: Coronavirus disease, commonly called Covid-19, is a virus that causes a pandemic in almost every country globally. One of those countries is Indonesia, which has many big cities with dense populations. This study was conducted in Bandung, the capital of West Java, Indonesia. As a result of the Covid-19 pandemic, Bandung was seriously affected in various ways. One was the disruption in the distribution of the agricultural processed products supply chain, which changes producers and consumers' behaviour. Furthermore, as an effort by the government to break the spread of the virus, health protocols limit the distribution. The purpose of this study is to design an optimization model for the supply chain problem of agricultural processed products in Bandung during the Covid-19 period with the objective function is maximizing product suppliers so that all demands on consumers are fulfilled. The use of Local Food Hub (LFH) is a help in this research as a distribution centre point between the producer zone and the consumer zone. Finally, numerical experiments were carried out in two scenarios, namely Large-scale Social Distancing (LSD) and Partial Social Distancing (PSD). It was found that the optimal distribution solution was obtained if the PSD scenario was applied.

Keywords: Supply chain, agricultural processed product, Local Food Hub (LFH), Large-scale Social Distancing (LSD), Partial Social Distancing (PSD)

Introduction

According to Platto *et al.* [1], Novel coronavirus 2019 or 2019-nCov or Covid-19 is a Severe Acute Respiratory Syndrome (SARS), which has a very high rate of spread and the number of deaths in abundance. The International Taxonomy Committee decided that due to the Covid-19 pandemic, almost all countries were infected seriously with the virus [2]. One of those countries was Indonesia, which has many big cities with dense populations. This study is conducted in Bandung, the capital of West Java, Indonesia [3]. In addition, Bandung is one of the popular tourist destinations in Indonesia that attracts domestic and foreign tourists [4]. According to [5], besides being a big city, Bandung also benefits from its position as the provincial capital, the first and foremost distribution point for food, including agricultural processed products, where around 90% of food needs are supplied from outside the region. Rice, sugar, oil, and wheat flour are essential agricultural processed products supply that Bandung centralizes. Therefore, the availability of these processed products must always be maintained and adequately distributed to the consumer [6].

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However, with the declaration of Large-Scale Social Restrictions by the Indonesian government as an effort to break the virus ([7] and [8]), limiting the movement of consumers and producers [9], so the supply chain management of agricultural processed products and consumption standards or household purchasing power in Bandung are disrupted ([10] and [11]).

Based on these problems, immediate steps must be considered to deal with the supply chain system, mainly agricultural processed products [12]. One of the most effective and best strategies to ensure product distribution goes well is to develop a food hub [13]. Developing a food hub during the pandemic is very much needed for farmers in growing their business through offering a combination of production, distribution, and marketing services. Furthermore, according to [14], the food hub concentrates on connecting producers (farmers and ranchers) and consumers (hospitals, schools, restaurants, etc.) on a regional and local scale. In addition, according to [15], food hubs have the advantage of being an additional market provider on a broader scale, serving as a single pick-up point for distributors and customers. They can benefit consumers and the general public by creating new jobs.

Local Food Hubs (LFH) are food hubs operating on a local scale [16]. In the case of Bandung as a local scale, it must be ensured that LFH is constructed in every district, or at least in the best district, and functions optimally.

The purpose of this study is to design an optimization model for the supply chain problem of agricultural processed products in Bandung during the Covid-19 period with the objective function is maximizing product suppliers so that all demands on consumers are fulfilled. Sugar and cooking oil are agricultural processed products used in this research because they have the most significant influence besides the main staple food of Indonesian people, rice. The use of the LFH is a help as a distribution center point between the producer zone and the consumer zone on a local scale. Therefore, from the research, it will be known which district in Bandung is the optimal location for LFH development and how the supply chain is connected with product distribution between producers and LFH, then LFH and consumers. Finally, numerical experiments were carried out in two different scenarios, namely Large-scale Social Distancing (LSD) and Partial Social Distancing (PSD). This study provides the results of numerical experiments in the form of optimal solutions to supply chain problems for agricultural processed products in Bandung. This optimal result describes the distribution channel between producers, LFH, and consumers. In addition, this paper would provide scientific studies in dealing with supply chain problems for agricultural processed products in Bandung during the Covid-19 period, especially for the Bandung government in making policies. Determination of the best scenario is at the end of the study.

Several previous articles have discussed optimization models for supply chain problems. However, optimization models are more often expressed in linear mathematical programming, while performance models are more often described in simulation models [17]. One of them is research in [18] which discusses the Robust optimization model for food supply chain problems in vegetables, eggs, and rice in West Java Province during the Covid-19 period. This article is the primary reference for this research.

There are four differences between this paper and [18] related to the concepts. First, the commodities used are agricultural processed products, namely sugar and cooking oil, while the reference article uses rice, eggs, and vegetables. The choice of sugar and cooking oil commodities caused by they are the most influential agricultural processed products besides the main staple food of Indonesian people, rice. Second, using the Linear Programming method of solving because it has one objective function that maximizes the demand for the product, while the reference article uses the lexicographic method because it has two objective functions. According to [19], when the pandemic began, markets in Bandung had low demand due to the limited movement of producers in product distribution and consumers in purchasing products, so that price spikes became the next priority, and meeting consumer needs became a main priority. Third, the research was carried out on a smaller scale, namely the districts in Bandung.

In contrast, in the reference article, the study was carried out on a larger scale, namely cities in West Java Province, so that the naming of Regional Food Hubs (RFH) was changed to Local Food Hubs (LFH). Fourth, this study uses two scenarios, Large-scale Social Distancing (LSD) and Partial Social Distancing (PSD). At the same time, in the reference article, there is a third scenario, namely a New Era Scenario. The New Era Scenario is not used in Bandung because the government was still implementing Large Scale Social Restrictions as an effort to break the virus [20].

Therefore, there is one difference related to the methods; in [18], the location and distribution of all commodities will be determined in the same RFH. In the numerical simulation results, only one type of RFH is obtained for all commodities. However, in this paper, for each commodity, the location and distribution path is distinguished. In the numerical simulation output, there are two kinds of LFH: LFH for sugar and LFH for cooking oil. This development aims to specify the placement of commodities in LFH so that distribution from consumers, LFH, and producers are more focused on each commodity.

Methods

Notation List

Sets

I	:	Demand/consumer zone
J	:	Regional Food Hubs (RFH) zone
K	:	Production zone/producers zone
C	:	Commodity
R	:	Red zone (the most significant center of the spread of Covid-19)

Parameters

d_{ci}	:	Demand for products c in City i (tonnes)
v_{ci}	:	Selling prices of products c in City i (Rp/ton)
f_{ck}	:	Production capacity of products c in City Producers k (tonnes)
b_{ji}	:	Distribution costs between City j and City i to transport the product (Rp/tonnes)
b_{kj}	:	Distribution costs between City k and City j to transport the product (Rp/tonnes)
q	:	Product handling cost based on health protocol (Rp/tonnes)
h	:	RFH handling cost (Rp/hub)
n_c	:	The maximum amount of product c that can be distributed in one line (tonnes/ distribution)

Decision Variables

x_j = 1 if LFH is will be built in City j and
x_j = 0 if LFH will not be built in City j ($\forall j \in J$)
p_{cj} : LFH capacity for products c in City j (tonnes/day), $P_{cj} \in \mathbb{R}, \forall c \in C, j \in J$
y_{ckr} : The number of products c in City producers k that are sent to red zone LFH in City r, $y_{ckr} \in \mathbb{R}[0,1], \forall\, c \in C, k \in K, r \in R, R \subset J, K$.
w_{cjr} : The number of requests for products c in City j that are fulfilled by red zone LFH in City r, $w_{cjr} \in \mathbb{R}[0,1], \forall\, c \in C, j \in J, r \in R, R \subset I, J$.
m_{2r} : A variable that determines how many products' distribution of products c must be done from producers in the green zone to LFH in the red zone r.
m_{4r} : A variable that determines how many times the distribution of products c must be done from LFH in the green zone to consumers in the red zone r.
m_{1r} : A variable that determines the number of times the distribution of product c must be completed from producers in the red zone to LFH in the green zone r.
m_{3r} : A variable that determines the number of times the distribution of product c must be completed from LFH in the red zone to consumers in the green zone r

Problem Statement

An optimization model for supply chain problem developed by [18] with the objective function that is maximizing product suppliers for all demand as in (1) and minimizing logistics costs as in equation (2)-(6),

$$\max\{\textstyle\sum_{c\in C}\sum_{i\in I} v_{ci}\sum_{j\in J} w_{cji}\}, \quad (1)$$
$$\min(a + b + c + d\}, \quad (2)$$

where

$$a = h\textstyle\sum_{j\in J} x_{j,} \quad (3)$$

is an objective function that minimizes the cost of developing RFH,

$$b = \textstyle\sum_{c\in C}\sum_{j\in J}\sum_{i\in I} b_{ji} d_{ci} w_{cji}, \quad (4)$$

is an objective function that minimizes the cost of product distribution between RFH and consumers,

$$c = q\textstyle\sum_{c\in C}\sum_{j\in J} p_{cj}, \quad (5)$$

is an objective function that minimizes the cost of health protocols,

$$d = \textstyle\sum_{c\in C}\sum_{k\in K}\sum_{j\in J} b_{kj} f_{ck} y_{ckj,} \quad (6)$$

is an objective function that minimizes the cost of product distribution between producers and RFH.

In [18] have six general constraints and three additional scenarios that differentiate the type of distribution between producers and consumers, between Regional Food Hubs (RFH) and consumers, and their aims. The optimization model is related to the distribution of vegetables, rice, and eggs between producers, RFH, and consumers in cities affected by Covid-19 in West Java Province. The six general constraints are as follows:

$$\textstyle\sum_{k\in K} f_{ck} y_{ckj} = p_{cj}, \forall c \in C, j \in J, \quad (7)$$

is the RFH capacity constraint based on the number of products c produced in City k,

$$\textstyle\sum_{i\in I} d_{ci} w_{cji} = p_{cj}, \forall c \in C, j \in J, \quad (8)$$

is the RFH capacity constraint based on the number of requests for product c in City i,

$$\textstyle\sum_{j\in J} y_{ckj} \le 1, \forall\, c \in C, k \in K, \quad (9)$$

is the constraint that ensures that the production of a product c sent from the producer in City to the RFH in City will not exceed its capacity,

$$\textstyle\sum_{j\in J} w_{cji} \le 1, \forall c \in C, i \in I, \quad (10)$$

is the constraint that ensures that the fulfilment of the request by the RFH will not exceed the injunction requested by the City i,

$$y_{ckj} \le x_j, \forall\, c \in C, k \in K, j \in J, \quad (11)$$

is a constraint that guarantees that no product is delivered to the red zone if the RFH is not built in that zone,

$$w_{cji} \le x_j, \forall c \in C, j \in J, i \in I, \quad (12)$$

is a constraint that guarantees no demand is fulfilled if the RFH is not built in that zone.

Additional constraints for Large-scale Social Distancing (LSD) scenario:

$$y_{ckr} = 0, \forall k \in K - \{r\}, c \in C, r \in R, \quad (13)$$

is the constraint that guarantees that there will be no distribution of product c from producers in City k in the green zone to RFH in City in the red zone,

$$w_{cjr} = 0, j \in J - \{r\}, c \in C, r \in R, \quad (14)$$

is the guarantees constraint that there will be no distribution of a product c from RFH in the City j in the green zone to consumers in the City r in the red zone,

$$y_{cjr} = 0, \forall j \in J - \{r\}, c \in C, r \in R \quad (15)$$

is the guarantees constraint that there will be no distribution of a product c from producers in City r in the red zone to RFH in City j in the green zone,

$$w_{cri} = 0, \forall i \in I - \{r\}, c \in C, r \in R, \quad (16)$$

is the constraint that ensures no product distribution of a product c from RFH in City r in the red zone to consumers in City i in the green zone.

Additional constraints for Partial Social Distancing (PSD) scenario:

$$y_{cjr} = 0, \forall j \in J - \{r\}, c \in C, r \in R, \quad (17)$$

$$w_{cri} = 0, \forall i \in I - \{r\}, c \in C, r \in R, \quad (18)$$

$$\sum_{k \in K-\{r\}} y_{ckr} \leq m_{2r} n_c, \forall\, c \in C, r \in R, \quad (19)$$

is the constraint that ensures that the distribution of product c from producers in the green zone of City k to the RFH in City r in the red zone is permitted,

$$\sum_{j \in J-\{r\}} w_{cjr} \leq m_{4r} n_c, \forall\, c \in C, r \in R, \quad (20)$$

is the constraints that ensure that the distribution of products c from RFH in the green zone of City j to consumers in City r in the red zone is permitted.

Additional constraints for Era New Normal scenario:

$$\sum_{k \in K-\{r\}} y_{ckr} f_{ck} \leq m_{2r} n_c, \forall\, c \in C, r \in R, \quad (21)$$

is the constraint that ensures that the distribution of product c from producers in the green zone of City k to the RFH in City r in the red zone is permitted,

$$\sum_{j \in J-\{r\}} w_{cjr} d_{cr} \leq m_{4r} n_c, \forall\, c \in C, r \in R \quad (22)$$

is the constraint that ensures that the distribution of products c from RFH in the green zone of City j to consumers in City r in the red zone is permitted,

$$\sum_{j \in J-\{r\}} y_{crj} f_{cr} \leq m_{1r} n_c, \forall\, c \in C, r \in R \quad (23)$$

is the constraint that ensures that the distribution of product c from producers in the red zone of City r to the RFH in City j in the green zone is permitted,

$$\sum_{i \in I-\{r\}} y_{cri} d_{ci} \leq m_{3r} n_c, \forall\, c \in C, r \in R, \quad (24)$$

is the constraint that ensures that the distribution of products c from RFH in the red zone of City r to consumers in City i in the green zone is permitted, where:

$$x_j \in [0,1], \forall j \in J, \quad (25)$$

$$P_{cj} \in \mathbb{R}, \forall c \in C, j \in J, \quad (26)$$

$$y_{ckj}, y_{ckr}, y_{cjr} \in [0,1], \forall\, c \in C, k \in K, j \in J, \quad (27)$$

$$w_{cji}, w_{cjr}, w_{Cri} \in [0,1], \forall\, c \in C, j \in J, i \in I. \quad (28)$$

The description of the set, parameters, and objective variables used in the model can be seen in the Notation List section.

Methodology

The optimization model in this study refers to [18] with several changes. A numerical experiment in this research uses secondary data obtained from various sources. The data used is 2020 because 2020 is when the Covid-19 pandemic began in Indonesia [21], especially in Bandung. Thirty districts in Bandung act as a producer zone, a potential zone for LFH development, and a consumer zone. There are five districts as a red zone determined based on the high number of Covid-19 cases, namely Antapani, Arcamanik, Bandung Kulon, Batununggal, and Bojongloa Kaler [22].

Results and Discussions

Optimization Model of Agricultural Processed Product Supply Chain Problem

The primary reference of this research is the article written by [18]. There are four differences between this research and [18] as described in the previous chapter.

Therefore, the secondary data used in this research are different, namely data on agricultural processed products obtained from various sources. The optimization models for supply chain problems for agricultural processed products used are:

$$\max\{\sum_{c \in C} \sum_{i \in I} \sum_{j \in J} v_{ci} w_{cji}\}, \quad (29)$$

$$\sum_{k \in K} f_{ck} y_{ckj} = p_{cj}, \forall c \in C, j \in J, \quad (30)$$

$$\sum_{i \in I} d_{ci} w_{cji} = p_{cj}, \forall c \in C, j \in J, \quad (31)$$

$$\sum_{j \in J} y_{ckj} \leq 1, \forall\, c \in C, k \in K, \quad (32)$$

$$\sum_{j \in J} w_{cji} \leq 1, \forall c \in C, i \in I, \quad (33)$$

$$y_{ckj} \leq x_j, \forall\, c \in C, k \in K, j \in J, \quad (34)$$

$$w_{cji} \leq x_j, \forall c \in C, j \in J, i \in I. \quad (35)$$

Additional constraints for LSD scenario:

$$y_{ckr} = 0, \forall k \in K - \{r\}, c \in C, r \in (R \subset J), \quad (36)$$

$$w_{cjr} = 0, j \in J - \{r\}, c \in C, r \in (R \subset I), \quad (37)$$

$$y_{cjr} = 0, \forall j \in J - \{r\}, c \in C, r \in (R \subset K), \quad (38)$$

$$w_{cri} = 0, \forall i \in I - \{r\}, c \in C, r \in (R \subset J). \quad (39)$$

Additional constraints for PSD scenario:

$$y_{cjr} = 0, \forall j \in J - \{r\}, c \in C, r \in (R \subset K), \quad (40)$$

$$w_{cri} = 0, \forall i \in I - \{r\}, c \in C, r \in (R \subset J), \quad (41)$$

$$\sum_{k \in K-\{r\}} y_{ckr} \leq m_{2r} n_c, \forall\, c \in C, r \in (R \subset J), \quad (42)$$

$$\sum_{j \in J-\{r\}} w_{cjr} \leq m_{4r} n_c, \forall\, c \in C, r \in (R \subset I). \quad (43)$$

Compared with [18], this research uses a maximization objective function as in (29), six general constraints at (30)-(35), LSD scenario constraints in (36)-(39), and PSD scenario constraints in (40)-(43) with similar sets, parameters, and variables.

Case Study

All districts in Bandung act as potential producer zones, LFH development, and consumer zones that can be symbolized based on the required index. The index sequence is based on the order of a number of the districts in Table 1. Five districts in Bandung that have the highest active cases is Antapani, Arcamanik, Bandung Kulon, Batununggal, and Bojongloa Kaler [22].

Table 1. Demand and capacity of sugar and cooking oil

No	District	Demand		Capacity	
		Sugar (tonnes/year)	Cooking Oil (tonnes/year)	Sugar (tonnes/year)	Cooking Oil (tonnes/year)
1	Andir	1,350	905	1,971	1,284
2	Antapani	1,081	724	1,578	1,028
3	Arcamanik	1,057	708	1,544	1,006
4	Astana Anyar	4,451	2,982	6,499	4,234
5	Babakan Ciparay	1,920	1,286	2,804	1,827
6	Bandung Kidul	824	552	1,203	784
7	Bandung Kulon	1,838	1,231	2,683	1,748
8	Bandung Wetan	390	261	570	371
9	Batunuggal	1,642	1,100	2,397	1,562
10	Bojongloa Kaler	1,683	1,127	2,457	1,601
11	Bojongloa Kidul	1,181	791	1,725	1,124
12	Buah Batu	1,394	934	2,036	1,326
13	Cibeunying Kaler	956	640	1,395	909
14	Cibeunying Kidul	1,531	1,026	2,235	1,456
15	Cibiru	1,009	676	1,472	959
16	Cicendo	1,303	873	1,903	1,240
17	Cidadap	734	492	1,072	698
18	Cinambo	344	231	503	328
19	Coblong	54	36	78	51
20	Gedebage	556	372	812	529
21	Kiara Condong	1,773	1,188	2,589	1,687
22	Lengkong	967	648	1,411	920
23	Mandala Jati	4,452	2,982	6,499	4,234
24	Panyileukan	544	365	795	518
25	Ranca Sari	1,153	772	1,683	1,097
26	Regol	1,095	734	1,599	1,042
27	Sukajadi	1,392	932	2,032	1,324
28	Sukasari	1,052	705	1,537	1,001
29	Sumur Bandung	510	341	744	485
30	Ujungberung	1,196	801	1,747	1,138

There are two types of agricultural processed products used, sugar and cooking oil, so we have $c = \{1,2\}$, where index 1 is for sugar and index 2 is for cooking oil. Consumer demand for commodities can be calculated from the average per capita consumption multiplied by the number of residents in each district in Bandung, where all data used data in 2020.

The average sugar per capita consumption of people in Bandung is predicted 13.6 kg/capita/year, while cooking oil is 11.38 litres/capita/year or equivalent to 9.11 kg/capita/year [23]. The maximum amount of agricultural processed products distributed in one line is assumed to be 20 tons [24].

Numerical Experiments

This section discusses the results of numerical experiments applied to the optimization model of supply chain problems for agricultural processed products in LSD and PSD scenarios. Numerical calculations in this study use the help of software R, while the visualization depiction of the results on the Bandung map uses the help of Python language. Based on the model that has been determined in the previous sub-chapter, data on demand and production capacity are used. With the help of R software, the optimal solution for distributing agricultural processed products in the LSD scenario is as in Figures 1, 2, 3, and 4. Figures 1 and 2 visualize optimal results on the Bandung map for distributing sugar and cooking oil from the producer zone to the LFH zone. Based on the LSD scenario calculations, twenty-two districts are optimal for LFH construction, while the other eight districts are not optimal for LFH construction. In other words, 73% of districts in Bandung are ready to build LFH.

Furthermore, Figures 3 and 4 are optimal distribution visualizations of the second stage for sugar and cooking oil, from the LFH zone in the selected twenty-two districts to the consumer zone. The fulfilment ratio can be determined as shown in Table 2. The fulfilment ratio is the ratio that determines the percentage of the number of requests that are fulfilled in each consumer zone district. This ratio is determined by adding the number of distributions to each district's last location (consumers).

Based on Table 2, almost all requests have been fulfilled 100% for sugar and cooking oil. However,

Table 2. Sugar and cooking oil fulfillement ratio using LSD scenario

Consumer district	Demand (tonnes)		Fulfilled demand (tonnes)		Fulfillment ratio	
	Sugar	Cooking oil	Sugar	Cooking oil	Sugar	Cooking oil
Andir	1,350	905	1,350	905	100%	100%
Antapani	1,081	724	1,081	724	100%	100%
Arcamanik	1,057	708	0	0	0%	0%
Astana Anyar	4,451	2,982	4,451	2,982	100%	100%
Babakan Ciparay	1,920	1,286	0	0	0%	0%
Bandung Kidul	824	552	824	552	100%	100%
Bandung Kulon	1,838	1,231	0	0	0%	0%
Bandung Wetan	390	261	390	261	100%	100%
Batunuggal	1,642	1,100	0	0	0%	0%
Bojongloa Kaler	1,683	1,127	1,683	1,127	100%	100%
Bojongloa Kidul	1,181	791	1,181	791	100%	100%
Buah Batu	1,394	934	1,394	934	100%	100%
Cibeunying Kaler	956	640	956	640	100%	100%
Cibeunying Kidul	1,531	1,026	1,531	1,026	100%	100%
Cibiru	1,009	676	0	0	0%	0%
Cicendo	1,303	873	1,303	873	100%	100%
Cidadap	734	492	734	492	100%	100%
Cinambo	344	231	344	231	100%	100%
Coblong	54	36	54	36	100%	100%
Gedebage	556	372	556	372	100%	100%
Kiara Condong	1,773	1,188	0	0	0%	0%
Lengkong	967	648	0	0	0%	0%
Mandala Jati	4,452	2,982	4,452	2,982	100%	100%
Panyileukan	544	365	544	365	100%	100%
Ranca Sari	1,153	772	1,153	772	100%	100%
Regol	1,095	734	0	0	0%	0%
Sukajadi	1,,392	932	1,392	932	100%	100%
Sukasari	1,052	705	1,052	705	100%	100%
Sumur Bandung	510	341	510	341	100%	100%
Ujung Berung	1,196	801	1,196	801	100%	100%

there are still 8 districts that have not been fulfilled with a 0% ratio, namely Arcamanik, Babakan Ciparay, Bandung Kulon, Batununggal, Cibiru, Kiara Condong, Lengkong, and Regol districts. Due to the exhaustion of capacity to be distributed to other districts, there is no distribution to those districts.

Figures 5, 6, 7, and 8 present the numerical simulations result for the PSD scenario. Here, the same methods and steps were applied. The numerical simulation results using R software exhibit that twenty-five districts are optimal for LFH construction in the PSD scenario. In contrast, the other five districts are not optimal for LFH construction. In other words, 83% of districts in Bandung are ready to build LFH. Compared with the LSD scenario, the number of districts is three fewer, or the percentage of optimal districts is 10% higher. These outputs occur because the additional constraints for the PSD scenario cover more distribution on a larger scale. The PSD scenario allows the distribution of products from producers in the green zone to LFH in the red zone; otherwise, it is not permitted. It also enables the distribution of products from LFH in the green zone to consumers in the red zone; otherwise, it is not allowed. For the PSD scenario, the visualization of the optimal distribution on the Bandung map for agricultural processed products can be seen in Figures 5 and 6.

In contrast, the distribution of the next stage from LFH to the consumer zone is presented in Figures 7 and 8. For the fulfilment ratio of the PSD scenario, the districts whose demand has not been fulfilled are fewer than the LSD scenario. In PSD, there are only three districts with a ratio of 0%, namely Bojongloa Kidul, Buah Batu, and Cibeunying Kaler. The PSD scenario is the best scenario for achieving the maximum effort to fulfil sugar and cooking oil needs. Based on the results of numerical calculations for Scenarios 1 and 2, it can be seen that the distribution does not consider costs as described by [19]. Therefore, to meet and maximize demand in each district, the distribution is met by various districts. Table 3 summarizes the objective function results that maximize consumer demand for the models and both scenarios. Additionally, it shows the optimal solution that maximizes the food supplier to fulfil all demands in 30 districts in Bandung.

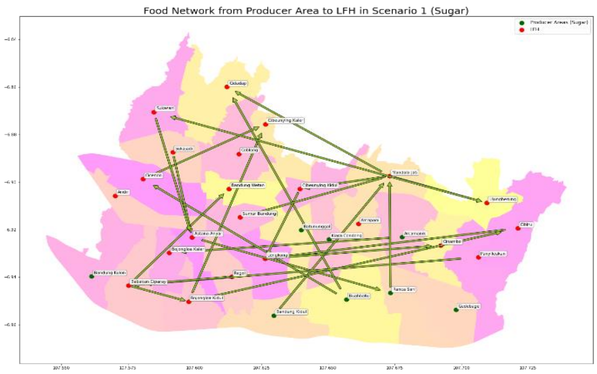

Figure 1. Sugar distribution network from producer to LFH in LSD scenario

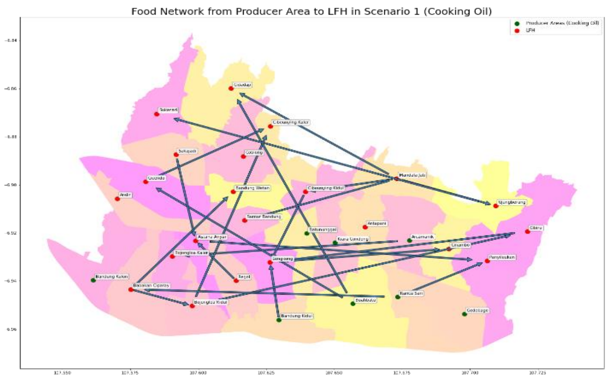

Figure 2. Cooking oil distribution network from producer to LFH in LSD scenario

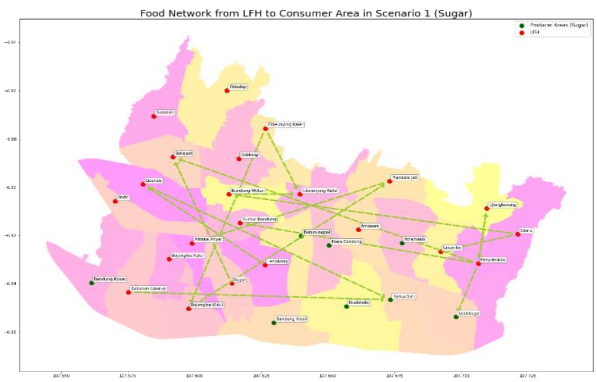

Figure 3. Sugar distribution network from LFH to consumer in LSD scenario

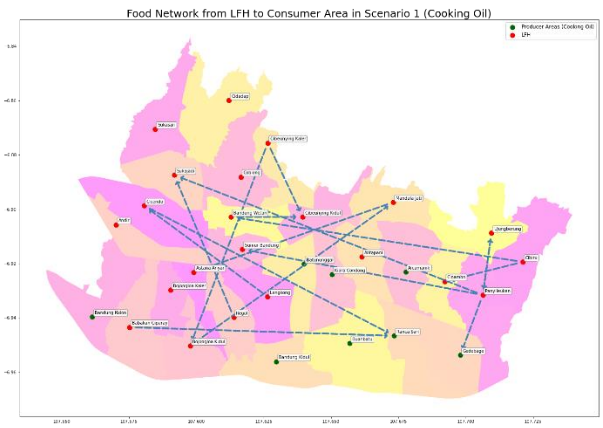

Figure 4. Cooking oil distribution network from LFH to consumer in LSD scenario

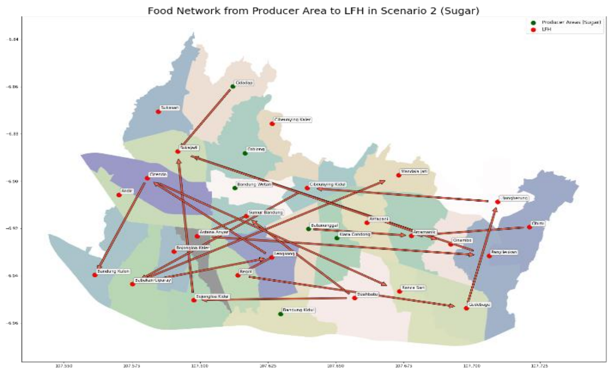

Figure 5. Sugar distribution network from producer to LFH in PSD scenario

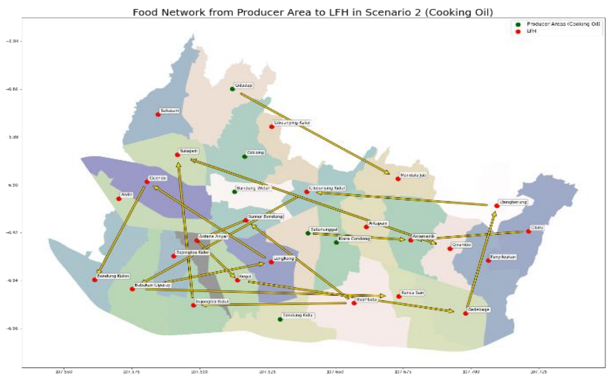

Figure 6. Cooking oil distribution network from producer to LFH in PSD scenario

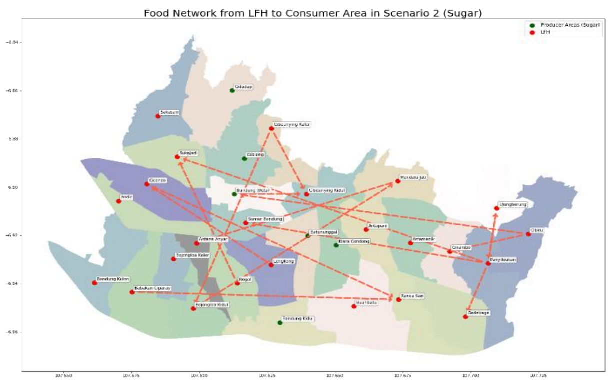

Figure 7. Sugar distribution network from LFH to consumer in PSD scenario

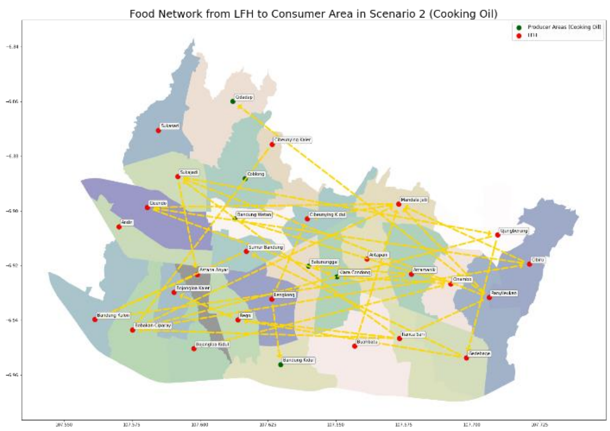

Figure 8. Cooking oil distribution network from LFH to consumer in PSD scenario

Table 3. Maximal consumer demand

Scenario	Supply chain agricultural processed products optimization model	
	Sugar (Rp)	Cooking Oil (Rp)
LSD	372,157,000	493,482,270
PSD	384,990,000	510,498,900

The optimal solution of the numerical experiment in the PSD scenario provides a more significant value than the LSD scenario. The optimal scenario is PSD because sugar and cooking oil distribution is more than in the LSD scenario. However, the PSD scenario requires higher costs than the LSD scenario. Furthermore, this study does not consider the cost of fulfilling demand, so to maximize consumer demand to be fulfilled, the PSD scenario is better to do. Furthermore, the best scenario is the PSD scenario, since producers allow to distribute from LFH and LFH to consumers from the green zone to the red zone during the procurement. Hence, the PSD scenario aims to reduce the spread of the virus, but the green zone can still support the distribution process to the red zone.

Conclusion

This study provides a numerical simulation of the optimization model of agricultural processed products supply chain problem in the form of sugar and cooking oil in Bandung during the Covid-19 pandemic. Large-scale Social Distancing (LSD) scenario and Partial Social Distancing (PSD) scenario are applied in the model and give the results that the optimal solution by optimization model PSD scenario provides a more considerable objective function value than LSD scenario. The optimal scenario is PSD because sugar and cooking oil distribution is more than in the LSD scenario. However, the PSD scenario requires higher costs than the LSD scenario. Furthermore, this study does not consider the cost of fulfilling demand, so with the aim of objective function maximizing consumer demand to be fulfilled, the PSD scenario is better to do.

Future research can use an optimization model that considers the cost of developing LFH, health protocols, and the distribution cost between districts by adding new objective functions. After that, the addition of more than one objective function is solved using the Lexicographic method. Referring to [25], the Lexicographic method sorts objective functions based on their importance and priority, and then they are solved one by one [25]. This consideration aims to minimize the logistics costs of supply chain problems so that the solutions obtained can be more helpful to the government if they are constrained by costs.

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