The logistics system planning for red onion: case study of Sulawesi and Maluku Islands

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Abstract. Red onion is a horticultural product produced in several regions of Java Island. This commodity only grows in certain seasons where the production time of one region to other regions is different. The lack of logistics design makes traders from producing regions unable to deliver it to demanded areas due to inappropriate selection of transportation combination and its schedule. This increases its distribution cost in Sulawesi Island and Maluku regions. This research aims to plan a red onion logistics system distribution for West Sulawesi, Southeast Sulawesi, Central Sulawesi, Gorontalo, North Sulawesi, Maluku and North Maluku, by taking into account the production location based on the onion harvest time, combination of shipping method, ship type, scheduling and quality so it will arrive on time with maintained quality. The logistic system is designed by using an optimization method to obtain optimal transportation modes and minimum unit costs. The optimization results show that the most suitable shipment is to use container ship owned by private shipping company, either in full container load (FCL) or in less container load (LCL). The average logistics costs to Sulawesi Island and Maluku Region are IDR 3,037/kg (USD 0.21/kg) and IDR 2,296/kg (USD 0.16/kg), respectively. These are 31\% and 27\% lower than the previous values, while the average damage rates are 4\% and 5\%, 6\% and 5\% lower than before.

1. Introduction

Red onion (\textit{Allium ascolonicum} \textit{L.}) is one of the many horticultural products cultivated in the lowlands of Indonesia. Red onion have an important role for the people in Indonesia because this product is widely used as a spice in cooking [1]. Unfortunately, red onion production in Indonesia is concentrated in Java. East Java Province produce substantial amount of onion throughout the year with a surplus of production of more than 10,000 tons annually. On the other hand, most areas in Sulawesi and Maluku regions cannot meet their onion needs which then cause a shortage. When shortage occurs, the price of this commodity will be much higher than that in Java [2]. It was reported that, in June 2018, the price of red onion in North Maluku, i.e., IDR 55,000, was more than doubles East Java’s Figure, IDR 22,350 [3], currently at an exchange rate of USD 1.0 equivalent to IDR 14,225. With regard to red onion distribution, it is described two important characteristics of this commodity that have to be paid into account, namely, production seasonality and short shelf life/perishable product [4]. Uneven and seasonal onion production makes the price unstable, while short shelf life requires timely handling. Lack of logistical planning systems also contributes to high level of damage [5,6]. Field survey conducted on January 2019 found that the damage rates when shipping onion to Sulawesi and Maluku are 9\% to 10\%.
The role of sea transportation is important because it is the only mode that can be used to distribute red onion inter-island at the lowest cost compared to the other modes [7-9]. Damage rate will also be considered because it represents length of the distribution.

2. Research Methodology

Red onion distribution from East Java to Sulawesi and Maluku regions starts from inter-island wholesaler located in five regency (kabupaten), i.e., Nganjuk, Bojonegoro, Probolinggo, Pamekasan, and Sampang. Each capital city of a regency, which bears the same name with the regency’s, will become city of origin. After proper preparatory treatment, i.e., cleaning and drying, onion are packed and then transported to Port of Tanjung Perak, by using truck or pickup car. Tanjung Perak is the port of origin for vessels used for shipping the commodity to a particular destination port located in or close to 7 (seven) provinces in the regions, that is, Southeast Sulawesi, West Sulawesi, Central Sulawesi, Gorontalo, North Sulawesi, Maluku, and North Maluku. After that, the onion is carried to the central market by using truck or pickup. (see Figure 1). The use of two types of transportation modes is called intermodalism (or sometimes interchangeably known as multimodalism) [10].

\[
\begin{align*}
z &= \text{Min} \left( \sum_{i=1}^{10} BF_{ij} \cdot X_{ij} + \sum_{j=1}^{10} BL_{ij} \cdot X_{ij} + \sum_{j=1}^{10} BG_{ij} \cdot X_{ij} \right) + \sum_{k=1}^{5} BT_{ki} \cdot JT_{ki} + \sum_{k=1}^{5} BP_{ki} \cdot JP_{ki} + \sum_{t=1}^{7} BT_{jt} \cdot JT_{jt} + \sum_{t=1}^{7} BP_{jt} \cdot JP_{jt} \\
&+ B_o
\end{align*}
\]

\[
i = 1; j = 1,2, ..., 10, k = 1,2, ..., 5, t = 1,2, ..., 7
\]

which is subject to
\[
\sum_{q=1}^{r} \left( X_{Fi_jq} + XL_{ijq} + XG_{ijq} \right) \geq D_j, \forall j = 1, 2, 3, \ldots, 10
\] (2)

\[
\sum_{j=1}^{10} \left( X_{Fi_jq} + XL_{ijq} \right) \leq KM_q, \quad q = 1, 2, 3, \ldots r
\] (3)

\[
\sum_{j=1}^{10} X_{Gi_jq} \leq KM_q, q = 1, 2, 3, \ldots r
\] (4)

\[
\sum_{t=1}^{7} JT_{jt} = \sum_{q=1}^{3} \frac{X_{Fi_jq} + XL_{ijq}}{KM_q} ; j = 1, 2, 3, \ldots, 10
\] (5)

\[
\sum_{t=1}^{7} JP_{jt} = \sum_{q=1}^{3} \frac{XG_{ijq}}{KM_q} ; j = 1, 2, 3, \ldots, 10
\] (6)

\[
XF_{ijq}, XL_{ijq}, XG_{ijq}, D_j, KM_q, JT_{jt}, JP_{jt} \geq 0
\] (7)

where,

\(i\) = Port of origin, 1

\(j\) = Port of destination 1, 2, 3, 4, \ldots, 10

\(k\) = City of origin 1, 2, 3, 4, \ldots, 5

\(t\) = City of destination 1, 2, 3, 4, \ldots, 7

\(q\) = Ship 1, 2, 3, \ldots, 10

\(r\) = Maximum number of ship available

\(BF_{ij}\) = Shipping cost FCL from \(i\) to \(j\)

\(BG_{ij}\) = Shipping cost general cargo from \(i\) to \(j\)

\(BL_{ij}\) = Shipping cost LCL from \(i\) to \(j\)

\(D_j\) = Demand unloaded at port \(j\)

\(XF_{ijq}\) = Number of FCL cargo from \(i\) to \(j\) carried by vessel \(q\) (TEUs)

\(XL_{ijq}\) = Number of LCL cargo from \(i\) to \(j\) carried by vessel \(q\) (TEUs)

\(XG_{ijq}\) = Amount of general cargo from \(i\) to \(j\) carried by vessel \(q\) (ton)

\(BT_{ki}\) = Truck cost from \(k\) to \(i\)

\(BP_{ki}\) = Pickup car cost from \(k\) to \(i\)

\(JT_{ki}\) = Number of truck from \(k\) to \(i\)

\(JP_{ki}\) = Number of pickup car from \(k\) to \(i\)

\(KM_q\) = Loading capacity of ship \(q\)

\(BT_{jt}\) = Truck cost from \(j\) to \(t\)

\(BP_{jt}\) = Pickup Car Cost from \(j\) to \(t\)

\(JT_{jt}\) = Number of truck from \(j\) to \(t\)

\(JP_{jt}\) = Number of pickup car from \(j\) to \(t\)

\(B_0\) = Cargo damage cost

Total amount of red onions carried by a selected vessel using a shipment method (FCL, LCL or general cargo) and then unloaded at a particular port, has to be greater than the amount of the commodity demanded by the corresponding province (see equation (2)). The number of container shipped to a port of unloading using FCL and LCL methods has to be less the loading capacity of the selected vessel. This also applies to onions transported in general cargo (see equations (3) and (4)). The number of trucks
required for transporting containers from a particular port of unloading and the number of pickup cars
needed for carrying onion in general cargo can be obtained using equations (5) and (6).

3. Outlook of Regions Under Study
Red onion from East Java is transported and distributed to 7 (seven) provinces by considering shortage
level of each province. For example, the weekly shortage level in 2019 is shown in Table 1. Southeast
Sulawesi experiences the lowest level, while Central Sulawesi reaches the highest point at 106 ton
weekly.

Table 1. Weekly shortage of red onion

| Province         | Shortage (ton) |
|------------------|----------------|
| Central Sulawesi | 106            |
| Maluku           | 98             |
| Gorontalo        | 59             |
| North Sulawesi   | 34             |
| West Sulawesi    | 27             |
| North Maluku     | 25             |
| Southeast Sulawesi | 17         |

Figure 2. Share of red onion production in East Java

Table 2. Harvesting period

| Regency          | Month  | Nganjuk | Bojonegoro | Probolinggo | Pamekasan | Sampang |
|------------------|--------|---------|------------|-------------|-----------|---------|
| Nganjuk          | January|         |            |             |           |         |
| Probolinggo      | February|         |            |             |           |         |
| Pamekasan        | March  |         |            |             |           |         |
| Sampang          | April  |         |            |             |           |         |
| Others           | May    |         |            |             |           |         |
| Others           | June   |         |            |             |           |         |
| Others           | July   |         |            |             |           |         |
| Others           | August |         |            |             |           |         |
| Others           | September|        |            |             |           |         |
| Others           | October|         |            |             |           |         |
| Others           | November|        |            |             |           |         |
| Others           | December|        |            |             |           |         |

Figure 2 shows share of onion production, the majority of which is composed by 5 (five) regencies
(kabupaten): Nganjuk, Probolinggo, Sampang, Bojonegoro, and Pamekasan. Production from these
regencies is more than 85% of total province production. Each regency capital has a role as red onion
collecting centre before delivering it to Surabaya, which becomes the main port of distributing this commodity to Sulawesi and Maluku regions. Thus, each city, which has the same name with the corresponding regency, is an origin area of onion delivery (see Figure 2).

These regencies have different harvesting periods in one year. Nganjuk experiences the longest, e.g., eight months, while Pamekasan and Sampang have the shortest period of harvest: two months. Bojonegoro and Probolinggo periods are almost the same, four and five months, respectively. In general, harvesting time in East Java occurs throughout the year, where most of the time takes place in the beginning of the year (see Table 2).

![Figure 3. Projection of red onion production and consumption [12]](image)

After being able to identify the harvesting period of a particular regency, it is necessary to find out whether the total amount of red onion can fulfill the domestic demand of East Java. The amount of onion that will be exported to the shortage provinces is obtained by subtracting the total amount of the production with the consumption. This is called the excess/surplus of the production. Figure 3 shows projection of annual production, consumption and surplus of red onion in this province. The projection is made based on 2013-2017 onion production and the population of this province in the same period.

Based on the projection of surplus in 2019, the production quantity of each regency can be obtained by using the share of production as shown in Table 3. In this study, it is assumed that onion produced in these regencies will be used to fulfill shortage in Sulawesi and Maluku regions, particularly for 2019 shipment.

| Regency   | Share of production (%) | Quantity (ton) | Harvesting Time (month) | Average Quantity per Harvest Time (ton) |
|-----------|-------------------------|----------------|-------------------------|----------------------------------------|
| Nganjuk   | 51.54                   | 112,528        | 8                       | 14,066                                 |
| Probolinggo | 17.64                  | 38,514         | 5                       | 7,703                                  |
| Sampang   | 6.13                    | 13,384         | 2                       | 6,692                                  |
| Bojonegoro | 5.16                    | 11,266         | 4                       | 2,816                                  |
| Pamekasan | 4.93                    | 10,764         | 2                       | 5,382                                  |

4. Distribution Analysis

4.1 Analysis of Shipping
Sea transportation mode will be used to transport and distribute red onion from East Java to Sulawesi and Maluku regions, by considering schedules of available vessels. The number of available vessel is 42. It is planned to ship red onion from Port of Tanjung Perak, Surabaya weekly to several port located in the destination regions. The unloading ports are Ambon, Bitung, Gorontalo, Kendari, Makassar, Manado, Pantoloan, Pare-pare, Ternate, and Toli-toli. For being able to select the vessel, it is important to pay attention on onion most essential characteristic, i.e., perishable goods. This characteristic will affect the onion quality because of the length of shipment during the distribution. The total distribution time, i.e., lead time, directly corresponds with the most critical leg of the distribution, that is, sea transportation. The maximum lead time is determined based on the highest tolerable shrinkage rate according to National Standardization Bureau [13]. The maximum rate is 10%.

The shrinkage rate is calculated by measuring weight loss of red onion premium sample taken from Nganjuk Regency. The process was started after taking 300 grams of onion which was subsequently dried for three days and cleaned. After that, it was stored in a place such that is resemblance with the temperature of a shipping container, i.e., 38°C. For 20 consecutives days, the weight of the onion was measured by adopting method developed by [14]. It was found that the average rate of weight loss is 0.762% per day. This rate is then used for obtaining when the maximum permissible weight loss (10%) occurred: it was on the 13th day of the measurement. This means that the longest allowable lead time is 13 days.

Table 4. Week 1 vessel schedule

| Vessel       | Port of Unloading | Destination      | ETD  | ETA  | Load Carried (ton) |
|--------------|-------------------|------------------|------|------|--------------------|
| Javelin      | Pare-Pare         | Sulawesi Barat   | 16/05| 18/05| 27                 |
| Meratus Gorontalo | Toli-Toli          | Sulawesi Tengah  | 16/05| 18/05| 106                |
| Sinabung     | Ternate           | Maluku Utara     | 16/05| 20/05| 25                 |
| Luzon        | Bitung            | Sulawesi Utara   | 16/05| 21/05| 34                 |
| Meratus Kampar | Ambon             | Maluku           | 16/05| 22/05| 98                 |
| Tanto Permai | Gorontalo         | Gorontalo        | 17/05| 20/05| 59                 |
| Tanto Handal | Kendari           | Sulawesi Tenggara| 19/05| 22/05| 17                 |

Lead time of red onion is composed by land and sea transportation. The land portion is assumed to be one day before departing the port of origin and one day after arriving at a particular port of destination. Therefore, the voyage of the selected vessel has to be no later than 11 days.

Table 4 shows week 1 schedule of seven vessels operated by some shipping companies. The first vessel leaves Tanjung Perak for Pare-pare in Sulawesi Barat in the middle of May, 2019, by carrying 27 tons of red onion. Each vessel has to sail at least two days before unloading the commodity at a particular destination port. The last ship arrives in Kendari after three days voyage. The longest trip requires six days for the vessel to arrive in Ambon. Cargo carried varies depending on the weekly demand of a particular province, which is the same with the shortage shown in Table 1.

Vessel selected for shipping the onion is directly called at a particular port of unloading in each province, except for West Sulawesi. Ports of unloading for West Sulawesi are either Makassar or Pare-pare because no vessel will be called at any port in this province. Freight is the amount of cargo carried by ships. The amount of cargo carried must be able to meet the demands of each province. 3 (three) shipping methods, 20 foot full container load (FCL), 20 foot less than a container load (LCL) and general cargo (GC) shipments are available. The first two ones are provided by all shipping lines, while the last one is only by Pelni. The most important factor when selecting a particular vessel is that the vessel will call at a port of unloading that has the closest distance to the central market in each province. This is carried out because such selection will reduce truck/pickup costs.

In the first week, all red onions are delivered using FCL and LCL methods, in which FCL is the most. Each container is loaded by 12 to 17 tons of onion. The remaining onion, for LCL, also varies from 3 to 8 ton per box (see Table 5).
Table 5. Shipping method

| Selected Ship | Shipping Line | Cargo Carried (ton) | FCL (TEU's) | LCL (ton) |
|---------------|---------------|--------------------|-------------|----------|
| Javelin       | Mentari       | 27                 | 2           | 0        |
| Meratus Gorontalo | Meratus    | 106                | 7           | 8        |
| Tanto Handal  | Tanto Lines   | 17                 | 1           | 3        |
| Tanto Permai  | Tanto Lines   | 59                 | 4           | 3        |
| Luzon         | SPIL          | 34                 | 2           | 6        |
| Meratus Kampar| Meratus       | 98                 | 7           | 0        |
| Sinabung      | Pelni         | 25                 | 2           | 0        |

4.2 Red Onion Production Location

The location of red onion production is determined by considering 3 (three) factors, i.e., the availability of red onion at the time the logistical planning is carried out (i.e., May 2019), the harvesting period as well as the distance between the production location and port of origin. As mentioned in Table 2, Probolinggo is the only production site in May, making this regency as the only origin for the week 1 shipment. A day before vessel departure time from Port of Tanjung Perak, the onions will be transported using truck or pickup to this port. Table 6 shows three days of shipment from City of Probolinggo.

Table 6. Production site and volume of shipment

| Location     | Volume of shipment (ton) |
|--------------|--------------------------|
|              | 16/05/2019 | 17/05/2019 | 19/05/2019 |
| Nganjuk      | 0          | 0          | 0          |
| Bojonegoro   | 0          | 0          | 0          |
| Probolinggo  | 290        | 59         | 17         |
| Pamekasan    | 0          | 0          | 0          |
| Sampang      | 0          | 0          | 0          |
| Total        | 290        | 59         | 17         |

4.3 Damage Level

It is important to conduct damage analyses for each shipment because of the characteristics of red onion as perishable goods. Table 7 shows damage estimation of week 1 shipment. Damage rate is made based on the results of the aforementioned average daily weight reduction, that is, 0.762% per day. After calculating the total distribution time of week 1 shipment, damage rates can be obtained. All rates are less than the maximum allowable level, i.e., 10%.

Table 7. Total distribution time of week 1 shipment

| Vessel        | Onion Departure | Vessel Departure | Vessel Arrival | Onion Arrival | Total Shipment Time (Days) | Damage Estimation |
|---------------|-----------------|------------------|----------------|---------------|-----------------------------|-------------------|
| Javelin       | 15/05           | 16/05            | 18/05          | 19/05         | 4                           | 3.0%              |
| Meratus Gorontalo | 15/05       | 16/05            | 18/05          | 19/05         | 4                           | 3.0%              |
| Sinabung      | 15/05           | 16/05            | 20/05          | 21/05         | 6                           | 4.6%              |
| Luzon         | 15/05           | 16/05            | 21/05          | 22/05         | 7                           | 5.3%              |
| Meratus Kampar| 15/05           | 16/05            | 22/05          | 23/05         | 8                           | 6.1%              |
| Tanto Permai  | 16/05           | 17/05            | 20/05          | 21/05         | 5                           | 3.8%              |
| Tanto Handal  | 18/05           | 19/05            | 22/05          | 23/05         | 5                           | 3.8%              |

5. Discussions

In this study, the logistics cost of red onion is the total costs required to send one kg of onion to each province. The costs consists of 6 (six) components, i.e., onion post harvest handling costs, packaging
cost, stuffing and striping cost, land transportation costs, sea transportation costs, cargo damaged cost. The first three items are considered fixed, while the others are obtained from the optimization.

Four shipments to fulfill weekly demand of red onion to all provinces under study were observed. In general, the total logistics cost is influenced by the choice of ship and the combination of shipment method (FLC, LCL or general cargo). The selected ship will determine where it will call and unload its cargo before carrying it to the final destination, i.e., central market in a capital city of a particular province. The distance between the unloading port and the market will affect the cost of trucking. The amount of logistics cost is also influenced by the amount of cargo carried: the more the cargo is carried, the lower the transportation rate will be.

Weekly delivery gives different logistics cost/kg as shown in Figure 4, as a result of the availability of vessel in a particular week. West Sulawesi and Maluku experience the most stable logistics cost because vessel sailing to these provinces are almost the same. The most interesting fact is the week 1 logistics cost to North Sulawesi. This is the highest one because the selected vessels have freight rate more than doubled the freight of private companies. However, in general, the logistics cost is stable around IDR 3,000/kg.

![Figure 4. Weekly logistics cost](image)

In contrast to the above findings, total logistics cost of each province is very fluctuated. The largest total logistics cost is as a result of distributing red onion to Central Sulawesi, while the lowest is to Southeast Sulawesi. This follows the fact that the largest and the lowest amount of onions are distributed to these provinces, respectively (see Figure 5).

The common practice of distributing red onion is done without paying attention on truck/pickup car costs and the location of unloading port. This means that there is no integration between these two mode of transportation, leading to the high cost of the distribution. Figure 6 shows these circumstances. Here, the logistics cost for distributing red onion to North Sulawesi could reach as high as IDR 5,900/kg which is the highest cost among the other provinces. The lowest cost is contributed by Maluku, i.e., IDR 3,500/kg. This is in contrast with that depicted in Figure 4.

Figure 6 also shows rate of reduction after planning the distribution of red onion. The rate is proportional to the initial unintegrated logistics cost: the higher the cost, the higher the reduction rate. North Sulawesi experiences the highest rate, followed by Southeast Sulawesi and North Sulawesi, respectively. On the other hand, West Sulawesi has the lowest reduction rate. Again, the planned logistics cost can be reduced substantially due to a combination between sea transportation mode
selection, i.e., vessel selection, and type of shipment, that is, (FLC, LCL, and general cargo). Previous shipment method only used ships owned by Pelni and Ro-Ro vessels.

Care must be taken during the distribution of the onion in order for ensuring the integrity of the distribution, from the point of origin to the onion final destination. Now, this can be carried out by applying information technology which is considerably enhanced by the existence of Internet. When dealing with geographical separation, i.e., distributing red onion to different islands, stakeholders involved in the distribution have to able to trace the existence of the onion timely. By exchanging the information, necessary measure can be taken, when required, in order to keep the process moving integrally [15]. This is inline with the ability to identify the product, in this case red onion, at any stage of the process as stated by ISO [16]. However, the level of traceability applied will depend on the complexity of the distribution [17].

6. Conclusions
After analyzing and discussing the distribution of red onion for 4 (four) times of shipment in May and June 2019, the optimum logistics costs/kg to West Sulawesi, Central Sulawesi, Southeast Sulawesi, Gorontalo, North Sulawesi, Maluku, and North Maluku can be obtained, that is, IDR 3,210, IDR 3,456, IDR 2,866, IDR 2,860, IDR 2,848, IDR 2,696, and IDR 3,321, respectively, at an exchange rate of USD 1.0 equal to IDR 14,225. This means, the average logistics costs to Sulawesi Island and Maluku Region are IDR 3,037/kg (USD 0.21/kg) and IDR 2,296/kg (USD 0.16/kg), consecutively. The total delivery time varies widely. West Sulawesi and Central Sulawesi have the shortest time, i.e., four days, while Southeast Sulawesi and Gorontalo are a day longer, i.e., five days. North Sulawesi is seven days, while Maluku and North Maluku share the longest time: eight days.

These optimum logistics costs are lower than the previous distribution costs. The rate of reduction enjoyed by West Sulawesi, Southeast Sulawesi, Gorontalo, North Sulawesi, Maluku, and North Maluku are 13%, 22.4% 36.6%, 30.2%, 52.4%, 23.1% and 34.6%, respectively. These rates also reduce the damage by 7% for shipment to West Sulawesi and Central Sulawesi, 6% for shipment to Southeast Sulawesi, and 5% for shipment to Gorontalo, North Sulawesi, Maluku, and North Maluku. These are 31% and 27% lower than the previous values, while the average damage rates are 4% and 5%, 6% and 5% lower than before.

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