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Location Models with Multy Criterious Networks (Case Study: The Industrial of Rice Processing in The Batubara District)

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ABSTRACT

Determining location is a problem encountered in many areas of everyday life. Determining this location becomes complex when many factors are taken into consideration, where one factor and another can conflict. One of the issues that will be discussed in this research is determining the location of the rice processing industry. This problem needs to be studied considering that the opportunity to establish a rice industry in several regions in Indonesia is very high considering that the potential for the main raw material (rice) is very large, as is the rice market where the largest population of the Indonesian nation makes rice the main food ingredient. The case study that will be discussed in this research is the rice processing industry in Batu Bara Regency. Batu Bara Regency is one of the districts/cities in North Sumatra Province which has enormous rice potential. In order to improve the welfare of farmers and provide good quality rice for the community, a Rice Processing Industry is needed. The problem in the rice processing industry is very complex, apart from the seasonal availability of rice raw materials, is the location where the rice processing factory is located. Various criteria need to be considered in this determination relating to the distance of the rice processing industry factory to each source of the main raw material (rice). Determining this location is very complex because it involves multiple criteria. This research will provide a location determination model using a Multi Criteria Network. The criteria used to determine the location of the rice processing industry in Batu Bara Regency are the transportation distance from the raw material center, travel time, and the condition of the road connecting the raw material center to the factory location. Based on the criteria for distance between rice centers and rice processing industrial factories, a route with a total minimum distance score of 0.71 is obtained. Meanwhile, based on travel time, the best route was obtained with a minimum total time score of 1.61. Based on the quality of the road taken, the best route was obtained with a maximum total score of 0.25. By considering the three criteria, the best route was obtained with a total optimum score of 2.96.

Keyword: Multi Criteria Network, Location Determination, Rice Industry, Multi Criteria Decision

1. Introduction

Location problems arise in various sectors. One of them is in the field of city layout where problems arise in determining government offices, business areas, social areas and residential areas. In the regional development sector, location problems also arise, including the determination of agricultural areas, industrial areas, tourist areas, residential areas, protected forest areas and so on. This illustrates the importance of the problem of determining location which is very important to study[1]. In a narrower context, an example is the establishment of a rice processing industry. Based on the statistical data obtained, Batubara Regency is one of the rices producing areas in North Sumatra. In 2020 lowland rice production in Batu Bara Regency reached 166,054,13.93 tons with an average production of 5,761 tons/ha. The districts with the largest rice production are Air Putih District and Medang Deras District. The total rice harvest area in Batu Bara Regency in 2020 was 16,347.88 Ha. The sub-districts that have large rice harvest areas are Air Putih Sub-district, Medang Deras Sub-district, and Sei Balai Sub-district. This makes Batubara Regency one of the rices producing districts in North Sumatra[2],[3]. Considering the importance of rice for Indonesian people, it is necessary to develop rice agribusiness in Indonesia. Meeting consumer needs for rice with various levels of quality needs to be followed by improvements in the use of more advanced and comprehensively integrated technology. In connection with this, the Batu Bara Regency Government will establish a Rice Processing Industry. This is feasible to establish because of the availability of the main raw materials and potential consumers who will be the market for the rice produced. Problems that arise include where the location of the rice processing industrial factory is to be established so that the location is strategic considering the following factors: distance to the main source of raw materials, distance to marketing locations, distance from community settlements so as to avoid pollution, availability of road facilities. for transportation, availability of main supporting elements such as electricity and water, and security in the environment around the factory[4]-[8].

By developing a location optimization model with multi attributes, it will be possible to determine the best location from several alternative locations to be selected. In essence, the model developed can be used to determine the location of other fields, not only for the location of the rice processing industry. Various methods can be applied in solving multi-attribute decision making problems. In this research, the Order Preference by Similarity to Ideal Object (TOPSIS) method is used based on a measure of centrality in social networks consisting of Degree Centrality, Closeness Centrality, Betweeness Centrality and Bonacich Power Centrality so that the location of the rice processing industry determined is a location that can be reached by all sub-district that produces rice[9]-[12].

2. Methodology

2.1. Multi Attribute Network

Social network experts claim that the structure of relations between individuals (points) has important consequences for the individuals and the system as a whole (Knoke 1990). Social network analysis (Social Network Analysis) is a science that views social relationships as nodes and ties. Nodes are individuals in the network, while ties are the relationships between those nodes. Vertices in graph theory can be represented as individuals, groups, communities, and so on[13],[14]. Meanwhile, the side is a "relationship" between individuals. In 1948 someone named Alex Bavelas conducted research on communication networks using the concept of centrality which was applied to communication networks and was the beginning of modern social network analysis (Freeman, 2005: 378). Around 1970, Freeman grouped the basics of centrality into four parts, namely degree, closeness, betweenness and bonacich power centrality. Network analysis is increasingly developing as evidenced by the birth of software that can be used to make it easier to analyze a social network. Social network analysis can be visualized in two ways, namely by using matrices and using graphs[15]-[19].

2.2. Degree Centrality

Degree Centrality has the simplest concept, namely a measurement made by looking at the number of links a node has (Freeman, 1978). By analogy, Degree Centrality is a measure of direct influence or the ability of an individual to influence other individuals directly or within a period of time (Borgatti, S.P, 2005). The measure of Degree Centrality has generally been expanded by the number of weights in the network (Barrat et al., 2004). This is also called the strength of a node because there is weight in it. The equation is as follows:

$$DC_i = \sum_{i-1}^{n} w_{ix} \tag{1}$$

Where w_{ix} is the sum of the values of the adjacency matrix in rows 1 to n (the number of rows in the adjacency matrix A) and the x column. In social networks represented in directed graphs, there are two types of degree centrality, namely, in-degree centrality which is symbolized by $DC_{in}(i)$ and out-degree centrality which is symbolized by $DC_{out}(i)$. Incoming degree centrality and outgoing degree centrality can be formulated as follows [20],[21].

$$DC_{in}(i) = \sum_{i-1}^{n} w_{ix} \tag{2}$$

$$DC_{out}(i) = \sum_{i-1}^{n} w_{xi} \quad (3)$$

To make it easier to read the degree centrality value, the degree centrality value will be searched on a scale or can be denoted as ($D'Ci$) which is the degree centrality value which is entered into the range 0 to 1, by dividing the degree centrality value by the maximum degree centrality value (DC_{max}).

Formula for Maximum Closeness Centrality Value

$$DC_{max} = |N| - 1.w * \quad (4)$$

Thus, nodes that have greater influence are nodes that have more neighbors with large weights (Opsahl et al., 2010) [22].

2.3. Betweeness Centrality

In social network analysis, betweenness centrality measures the number of connections an individual has in a social network. This is synonymous with the "strength" or "influence" of the individual. the easier it is to control [23]. According to Freeman (1978) Betweenness Centrality is useful as a control in networks. As a result, the more often a node is located on the shortest path between two other nodes, the greater its involvement in influencing the network and the more interactions that node has when compared to two nodes that are not adjacent (Wassermant & Fraust, 1994). Betweenness centrality in a social network can be interpreted as "the ability of node i to require node a to reach node j via the shortest path" (Borgatti, 2005).

$$w: E \rightarrow [0, \infty] \quad (5)$$

The algorithm used to determine the shortest path is the Dijkstra Algorithm. The Dijkstra algorithm, named after its inventor Edsger W. Dijkstra, is a greedy algorithm used to solve the shortest path problem for a directed graph with infinite edge weights. -negative, but this also applies to undirected graphs. The greedy principle in the Dijsktra algorithm states that at each step the side with the minimum weight is selected and included in the solution set. The input of this algorithm is a weighted directed graph G and a source point s in G, where V is the set of all points in the graph G. Each edge of this graph is a pair of points (u, v) which represents the relationship of point u to point v. The set of all edges is called E [24]. The weight of all sides is calculated by:

The algorithm steps are as follows:

1. Prepare the adjacency matrix M = [mij], table S = [si], table D = [di] and determine which point will be the starting point (for example point a),
2. Enter a value of 0 for each point i in table S, which means that not a single point in the initial stage has been entered as the shortest path, and an infinite value in table D, which means that no shortest path has been found from the initial point a to another point,
3. Then weight the distance from the starting point (point a) to each point i which is directly connected to point a, the value is input into table D, meaning, if the path from the starting point a to a point i is smaller than the value previously stored in the table D, then that value will be the next value stored (in this case, for the initial step, the previously stored value is definitely greater because in point 2, the value is infinite).
4. Give a value of 1 in table S for sa, which means point a has entered the shortest path,
5. Select the next point which will replace the role previously used by the initial point a. What is of concern in selecting this point is that it has the smallest value in the D table, but has a value of 0 in the S table.
6. Simply repeat point 3 and so on.

2.4 Bonacich Power Centrality

Bonacich Power centrality is used to measure how important a node is in a network. Bonacich power centrality can be used on directed and weighted graphs. According to Bonacich and Lloyd (2001), the importance of a node is based on the magnitude of the contribution made and the communication that the individual has attached to the social network in question when compared with other individuals. Bonacich power centrality is generated by two parameters, namely α and β. Parameter α is a scale factor used to normalize scores or results, while parameter β reflects the extent to which an individual's status is a function of the status to whom he is connected. If β is positive, bonacich power centrality is a conventional measure of centrality in which the status of each individual is a positive function of their status with those in the relationship. The result of the bonacich power centrality with positive β is equivalent to the centrality of the eigenvector. If $\beta = 0$ it is the same measure as degree centrality. For a negative β would be appropriate in a bargaining situation where power comes from those connected to the powerless. To find positive β it starts by giving each actor a centrality estimated to be equal to their own degree, then adding a weighted function of the degree of the actor to whom they are connected and repeating until finally approaching an answer (Hanneman and Riddle: 2005). In the matrix, the centrality of bonacich power is formulated as follows.

$$D(\alpha, \beta) = \alpha(I - \beta R) - 1R1 \tag{6}$$

3. Result and Discussion

From the survey results, potential alternative sub-districts for rice processing industry locations were obtained, namely: Air Putih Sub-district. Travel distance data between sub-districts is shown in Table 1.

Table 1. Distance Between Districts (Km)

Districts	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1										
K2	18,7									
K3	26,2	6								
K4	X	X	18							
K5	27,8	X	X	X						
K6	42	X	23,5	9,7	X					
K7	X	X	X	X	14	13,5				
K8	X	X	X	15	X	17	14			
K9	X	X	X	X	X	X	11	X		
K10	X	X	X	X	X	X	X	13,2	15,1	

Table 2. Travel Time Between Districts (Minutes)

Districts	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1										
K2	61									
K3	67	11								
K4	X	X	30							
K5	60	X	X	X						
K6	96	X	51	14	X					
K7	X	X	X	X	27	20				
K8	X	X	X	22	X	28	22			
K9	X	X	X	X	X	X	23	X		
K10	X	X	X	X	X	X	X	21	25	

Table 3. Inter-District Road Conditions (In Score)

Districts	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1										
K2	5									
K3	4	10								
K4	X	X	10							
K5	6	X	X	X						
K6	3	X	5	10	X					
K7	X	X	X	X	9	10				
K8	X	X	X	9	X	9	9			
K9	X	X	X	X	X	X	8	X		
K10	X	X	X	X	X	X	X	9	7	

Where:
K1: Medang Deras District
K2: Sei Suka District
K3: Air Putih District
K4: Fifty District
K5: Fifty Coastal District
K6: Datuk Fifty District
K7: Talawi District
K8: Datuk Tanah Datar District
K9: Nibung Hangus District
K10: Sei Balai District

An image of routes between sub-districts which are rice centers based on distance, travel time, road conditions and rice production volume between sub-districts is shown in Figure 1.

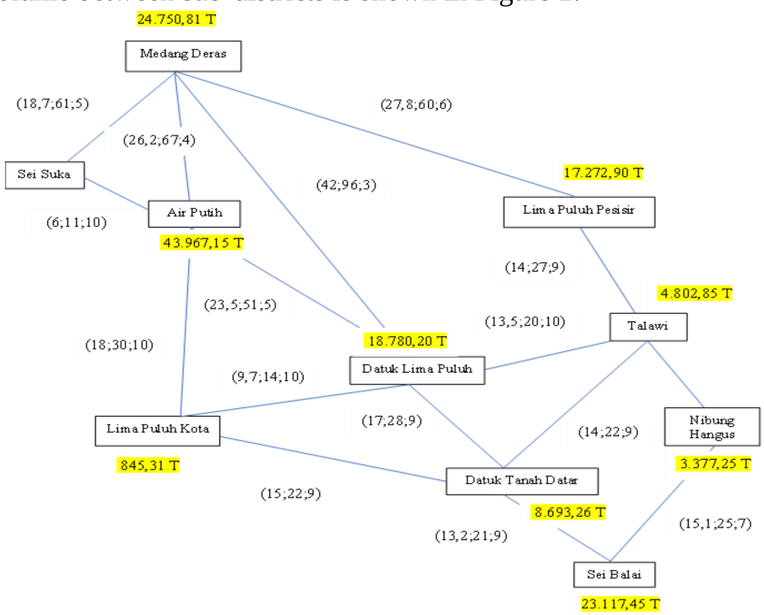

Figure 1. Distance, Travel, Travel Time, and Road Conditions Between Districts

The best solution for the position of industrial factories in Air Putih District with all rice center districts, based on each criterion, and the combined criteria is obtained as follows:

1. Based on the criteria for distance between sub-districts and factory locations, a weight score is obtained for accommodating the amount of production in each rice center (sub-district) and the distance between sub-districts and factory locations is as in the following figure.

By using the Network application on QM Mehtod, the best route is obtained which minimizes the total distance score, namely the path with the thick line. With this route, 0.71 is obtained. The best route is as follows:

(Medang Deras --Sei Suka) – (Sei Suka -- Air Putih) - (Air Putih – Fifty) – (Fifti – Datuk Fifty), (Fifti – Datuk Tanah Datar) – (Datuk Tanah Datar – Talawi) – (Talawi – Fifty Coasts), (Talawi – Scorched Nibung) – (Scorched Nibung – Sei Bilah).

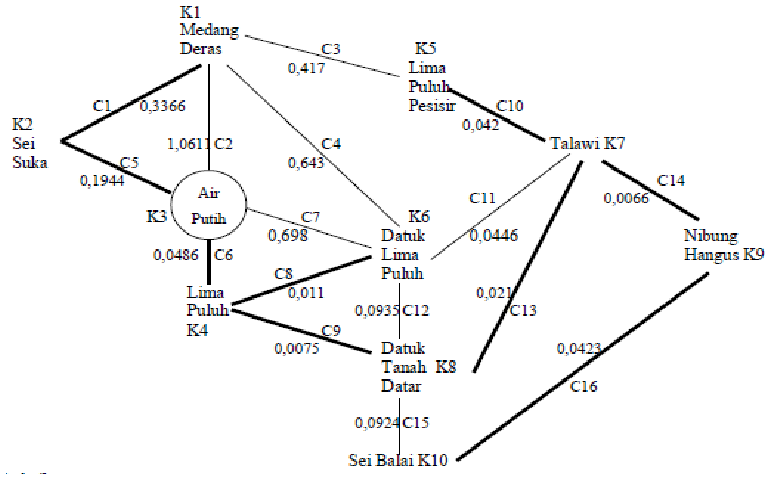

Figure 2. Alternative route 1

2. Based on the criteria for travel time between sub-districts and factory locations, a weight score is obtained for accommodating the amount of production in each rice center (sub-district) and the travel time between sub-districts and factory locations is as in the following figure.

By using the Network application on QM Mehtod, the best route is obtained which minimizes the total distance score, namely the path with the thick line. With this route we get 1.61. The best route is as follows:
Medang Deras – Fifty Coasts) – (Fifti Coasts -- Talawi) - (Talawi – Datuk Fifty), (Talawi – Datuk Tanah Datar), (Talawi – Nibung Hangus) – (Nibung Hangus – Sei Balai)

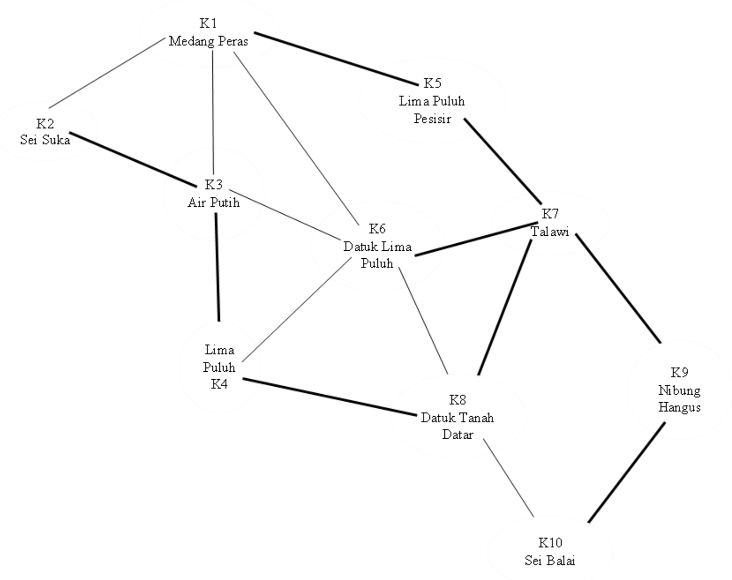

Figure 3. Alternative route 2

3. Based on the criteria for the quality of roads between sub-districts and factory locations, a weight score is obtained for accommodating the amount of production in each rice center (sub-district) and the quality of roads between sub-districts and factory locations is as in the following figure.

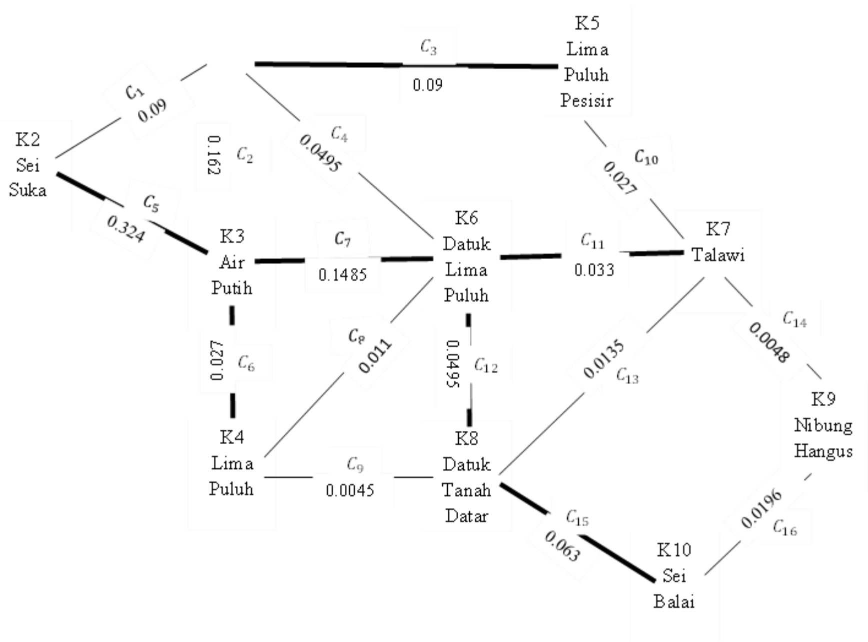

Figure 4. Alternative route 3

By using the Network application on QM Mehtod, the best route is obtained which maximizes the total road quality score with a thick line. With this route, 0.25 is obtained. The best route is as follows:
(Medang Deras – Fifty Coasts), (Sei Suka -- Air Putih) - (Air Putih – Fifty), (Air Putih – Datuk Fifty) -- (Datuk Fifty – Datuk Tanah Datar), (Datuk Fifty – Talawi) – (Talawi – Nibung Scorched) -- (Nibung Scorched – Sei Balai)

4. Based on multiple criteria: travel distance, travel time, and quality of roads between sub-districts and factory locations, a weight score is obtained for accommodating the amount of production in each rice center (sub-district) and the three districts and factory locations as in the following figure.

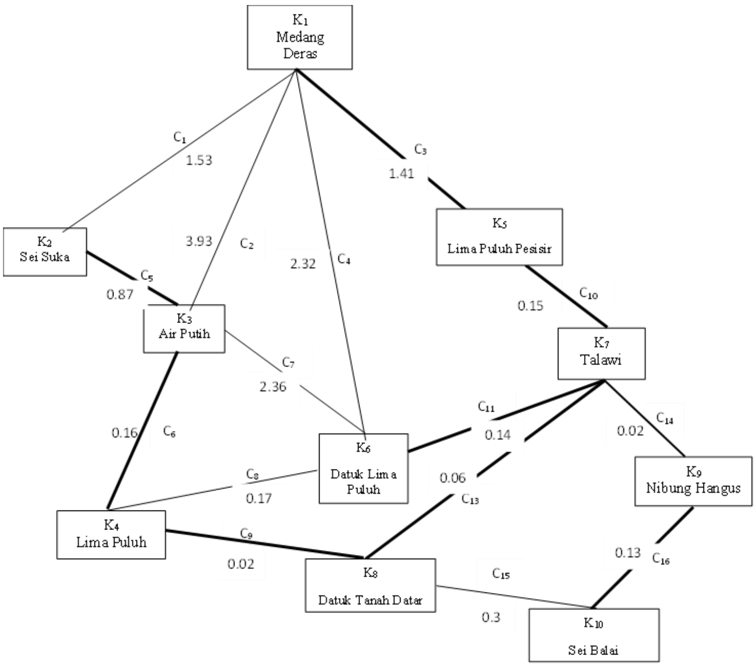

Figure 5. Alternative route 4

By using the Network application on QM Mehtod, the best route is obtained which maximizes the three criteria with thick lines. With this route, you get 2.96. The best route is as follows:
(Medang Deras – Fifty Coasts), (Sei Suka -- Air Putih) - (Air Putih – Fifty)-- (Fifti – Datuk Tanah Datar) -- (Datuk Tanah Datar – Talawi)—(Talawi – Fifty Pesisir), (Talawi -- Datuk Tanah Datar), (Talawi – Nibung

Hangus) -- (Nibung Hangus – Sei Balai).

4. Conclusion and Future Research

The research that has been carried out includes collecting the necessary data including: (1) alternative locations for the rice processing industry, (2) rice production per year from each sub-district that produces rice, (3) distance between sub-districts that produce rice, (4) travel time between sub-districts that produce rice, and (5) Condition of roads between sub-districts that produce rice. Each criterion provides a different best route. In order to accommodate the three criteria simultaneously, a fuzzy multicrete network is used. The best route for transporting rice from rice centers in Batu Bara Regency (in 10 sub-districts) is as follows: (Medang Deras – Limapuluh Pesisir), (Sei Suka -- Air Putih) - (Air Putih – Limapuluh)-- (Fifty – Datuk Tanah Datar) -- (Datuk Tanah Datar – Talawi)—(Talawi – Fifty Coastal), (Talawi -- Datuk Tanah Datar), (Talawi – Nibung Hangus) -- (Nibung Hangus – Sei Balai).

References

[1] Asmiati. (2018). Graf dan Aplikasinya Pada Jarak Terpendek. Matematika. Yogyakarta.
[2] Badan Pusat Statistik Kabupaten Batu Bara. (2019). Produksi Padi 2019. Kabupaten Batu Bara : Badan Pusat Statistik.
[3] Bantacut, T. (2017). Teknologi Pengolahan Padi Terintegrasi Berwawasan Lingkungan. Jurnal Edisi No.47/XV/Juli/2006 Institut Pertanian Bogor.
[4] Barrat, A., Barthelemy, M., Pastor-Satorras, R., & Vespignani, A. (2004). The architecture of complex weighted networks. Proceedings of the national academy of sciences, 101(11), 3747-3752.
[5] Beauchamp, M. A. (1965). An improved index of centrality. Behavioral science, 10(2), 161-163.
[6] Bonacich, P., & Lloyd, P. (2001). Eigenvector-like measures of centrality for asymmetric relations. Social networks, 23(3), 191-201.
[7] Bondy, J.,A., & Murty U. S. R. (1982). Graph Theory with Applications. New York: Elsevier Science Publishing.
[8] Borgatti, S. P. (2005). Centrality and network flow. Social networks, 27(1), 55-71.
[9] Freeman, L. C. (1978). Centrality in social networks conceptual clarification. Social networks, 1(3), 215-239.
[10] Hanneman, R. A., & Riddle, M. (2005). Introduction to social network methods. Harju, Tero. (2012). Graph Theory. Finland: Department of Mathematics, University of Turku.
[11] Hasbullah, R., Fadhallah, E.G., Almada, D.P., Koswara, S., Surahman, M. (2016). *Teknologi Pengolahan dan Pengembangan Usaha Beras Pratanak.* Prosiding Seminar Nasional Hasil – Hasil PPM IPB 2016. ISBN: 978-602-8853-29-3.
[12] Heizer, J.and Render, B. (2009), Operations Management, United States of America: Pearson Prentice Hall.
[13] Heizer, J., Render, B. & Munson, C. (2017). Principles of Operations Management Sustainability and Supply Chain Management. London: Pearson.
[14] Huisman, M. (2005). Software for Social Network Analysis. Journal of Models and Methods in Social Network Analysis. Hlm.310-316.
[15] Knoke, David. (1990). Political Network: The Structural Perspective. Cambridge: Cambridge University Press.
[16] Kusumadewi, S., Hartati, S., Harjoko, A., Wardoyo, R. (2006). Fuzzy multi- attribute decision making (Edisi ke-1). Yogyakarta: Graha Ilmu
[17] Liu, Z., Jiang, C., Wang, J., Yu, H. (2015). The node importance in actual complex networks based on a multi-attribute ranking method. Knowledge- Based Systems, 84, 56-66.
[18] Lokasi Strategis dan Pengertian Lokasi. (2015, 25 April). Diakses 20 Februari 2020, dari http://www.definisi-pengertian.com/2015/04/lokasi-strategis-dan-pengertian-lokasi.html
[19] Newman, M.E. (2008). The mathematics of networks. The New Palgrave Encyclopedia of Economics.

[20] Okamoto, K., Chen, W., & Li, X. Y. (2008). Ranking of closeness centrality for large-scale social networks. In international workshop on frontiers in algorithmics (pp. 186-195). Springer Berlin Heidelberg.
[21] Opsahl, T., Agneessens, F., &Skovoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. Social networks, 32(3), 245-251.
[22] Wasserman, S., & Faust, K. (1994). Social Network Analysis: Methods and Applications. New York: Cambridge University Press.
[23] Wei, W., Pfeffer, J., Reminga, J., & Carley, K. M. (2011). Handling weighted, asymmetric, self-looped, and disconnected networks in ORA. Asymmetric, Self-Looped, and Disconnected Networks in ORA (August 2011).
[24] Wijayati, T. (2014, 07 Oktober). Teori Lokasi. Diakses 20 Februari 2020, dari http://blog-ekono.blogspot.com/2014/10/