Supply Chain Analysis of Local Tomato Commodity in Jember

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ABSTRACT

Tomatoes are a leading commodity with good market prospects. The Jember Regency Statistical Data Center shows that production development has experienced fluctuations, from BPS data in 2021 the tomato harvest area in Jember Regency was 130ha, resulting in total tomato production of 13,720kw, while in 2022 the tomato harvest area was 139ha, total production was 10,051kw. The areas experiencing fluctuations in the decline in tomato production in Jember Regency are Sumberjambe, Sukowono and Kalisat villages. Identifying the causes of losses is very important to find out the causes of losses (loss of yield) in tomato commodities along the tomato supply chain. Therefore, steps are needed to overcome and minimize obstacles in the tomato supply chain. Prioritization of post-harvest improvement strategies for tomatoes using the Analytical Network Process (ANP) method. This shows that the largest post-harvest losses in tomatoes are at the farmer level. Alternative priority A2 has the highest ideal value, namely 1, related to counseling or directing tomato farmers so that they get the desired amount of harvest and the quality of the product produced.

Keywords: *Tomato 1, Supply Chain 2, Analytical Network Process 3*

INTRODUCTION

Horticultural commodities are perishable goods. This perishability renders them unsuitable for sale and reduces market supply, thereby driving up their prices (Nugrahapsari and Arsanti, 2018). One horticultural product consumed by the public almost daily is the tomato. Tomatoes are a leading agricultural commodity considered highly important due to their strong market prospects. A supply chain is a system characterized by organized components, interdependence among these components, and specific objectives (Saptana, 2017). Generally, the post-harvest stages for horticultural products include harvesting, collection, sorting, grading, packaging, transportation, and distribution (Wigati, 2020).

The Jember Regency Statistics Data Center indicates that the development of tomato production and productivity in Jember Regency tends to fluctuate annually; according to BPS data, in 2021 the harvested area of tomato crops in Jember Regency was 130 hectares, yielding a total tomato production of 13,720 kg, while in 2022 the harvested area was 139 hectares with a production of 10,051 kg (Jember Regency Central Statistics Agency, 2022). The areas in Jember Regency experiencing a decline in tomato production are the villages of Sumberjambe, Sukowono, and Kalisat. Most farmers in Indonesia store their harvests in open spaces and handle them carelessly because there are no dedicated storage facilities. This causes the tomatoes to ripen and rot quickly (Restian, A., 2022). Therefore, special post-harvest handling is required to maintain the physical and chemical quality of the tomatoes. Agricultural commodities have different characteristics, so proper handling is necessary to minimize damage to the produce. Prioritizing strategies for improving tomato post-harvest management must be established to minimize or eveneliminate the negative impacts of inadequate handling. The Analytical Hierarchy Process (AHP) method, which considers the interdependence among hierarchical elements. The prioritization of tomato post-harvest improvement strategies involves several decisions that cannot be arranged hierarchically.

METHOD

Modeling Phase

Define the problem and determine the criteria for the desired improvement strategy by identifying clusters and nodes and describing the network model.

Weighting Phase

Weighting is performed using a pairwise comparison method between two elements on a nine-point scale until all elements are covered. The priority weight vector (w) is then calculated using the following formula:

$$Aw = \lambda_{max} w$$

Where:
w : Eigenvector
A : Matrix A
λmax : Largest eigenvalue of matrix A Determination of Interconnection Weights Between Nodes and Clusters

The matrix results are acceptable if the consistency ratio (CR) is ≤ 0.1. If the CR value is > 0.1, corrections must be made to the questionnaire responses. The Consistency Index (CI) and
Consistency Ratio (CR) of the pairwise comparison matrix can be calculated using the formula

Where:
n: the number of elements
RCI: Random Consistency Index
λmax: the largest eigenvalue of matrix A

Cluster matrix and unweighted supermatrix stage

The priority weights resulting from the weighting of inter-cluster relationships are organized in the cluster matrix. The priority weights resulting from the weighting of inter-node relationships are organized in the corresponding matrix (unweighted supermatrix). In general, the importance relationships between elements within a network can be represented using a supermatrix.

Weighted supermatrix stage.

According to Ascarya (2016), the weighted supermatrix is created by multiplying each entry of the unweighted supermatrix by the criteria comparison matrix.

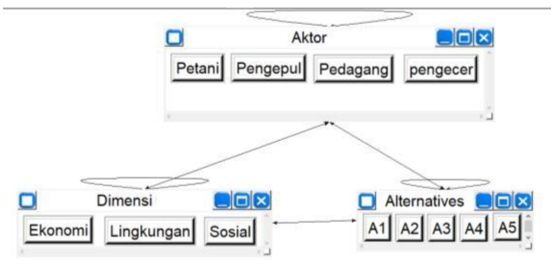
Limiting supermatrix stage

The limiting supermatrix is obtained by repeatedly raising the weighted supermatrix to a power until the numbers in every column of a row are equal; the limiting matrix is then normalized.

RESULT AND DISCUSSION

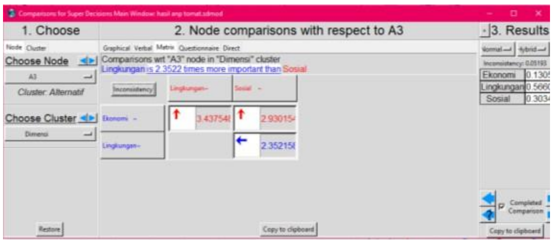
The criteria and subcriteria obtained through the questionnaire were then used to identify the relationships between them. This identification was conducted by distributing a questionnaire designed to determine the influence between subcriteria, using a "yes or no" response to indicate whether or not there was an influence between one subcriterion and another. It is evident that subcriterion 1 (retailers) influences the actor and dimension subcriteria, while the alternative subcriteria are only influenced by subcriteria A2 and A4. Expert respondents assessed that the actor does not influence the presence of criteria A1, A3, and A5. Subcriteria 2 (retailers) and 3 (collectors) influence almost all subcriteria, except for subcriterion A5. Subcriterion 4 (farmers) influences all subcriteria under the actor and dimension criteria and only influences alternatives A2 and A4.

Vendors need to receive training on post-harvest handling of tomatoes (A2) so they can learn proper and correct handling methods for tomatoes; supervision (A4) is also influenced by subcriteria 1 and 2 to ensure that vendors and retailers consistently apply the training outcomes. Subcriteria 5 and 7 influence all subcriteria in clusters A, B, and C, whereas subcriterion 6 does not affect criterion A1. According to Sarjan, M., et al. (2023), to ensure the quality of agricultural products from post-harvest processes—ensuring high competitiveness and safety—it is essential for relevant government agencies to play a role in conducting supervision, training, and inspections.



Creating a pairwise comparison matrix

Expert respondents were asked to assign ANP scale values ranging from 1 to 9. The values obtained from Questionnaire 3 were then averaged using the geometric mean. The geometric mean was used because the values provided by the expert respondents were comparative in nature, making it more appropriate than the arithmetic mean. The results of Questionnaire 3, for which the geometric mean has been calculated, are then entered into the ANP model in the software. Example of data input in the Super Decision software



Inconsistency values will automatically appear when data is entered. If the inconsistency value exceeds 0.1, the data must be re-verified, as this indicates that the data is inconsistent. Re-evaluation must be performed until all comparison results have an inconsistency value below 0.1. In the completion of Questionnaire 3, all comparison matrices have an inconsistency ratio of less than 0.1; if the value exceeds 10% or 0.1, re-verification must be performed, but if the value is already less than 0.1, it can be considered consistent (Anissa F, et al. 2020). This means that all completed questionnaires yield reliable results.

Forming the supermatrix

Once all the comparison values have been entered, the values of the unweighted matrix, weighted matrix, and limit matrix will be obtained. The values in the limit matrix represent the priority values that indicate the weight of each subcriterion. Three supermatrices are formed: the unweighted matrix, the weighted matrix, and the limit matrix.

Unweighted Supermatrix

Super Decisions Main Window: Unnamed file 0: Unweighted Super Matrix

Cluster Node Labels		Alternatif					Dimensi		
		A1	A2	A3	A4	A5	Ekonomi	Lingkungan	Sosial
Aktor	Petani	0.510873	0.516715	0.533814	0.490090	1.000000	0.519229	0.516715	0.504763
Alternatif	A1	0.000000	0.249311	0.225361	0.750000	0.000000	0.176135	0.000000	0.494040
	A2	0.666667	0.000000	0.502339	0.000000	0.000000	0.482683	0.482683	0.000000
	A3	0.000000	0.593634	0.000000	0.250000	0.750000	0.247248	0.112927	0.269729
	A4	0.333333	0.157056	0.094200	0.000000	0.250000	0.000000	0.146972	0.154422
	A5	0.000000	0.000000	0.178101	0.000000	0.000000	0.093934	0.257418	0.081809
Dimensi	Ekonomi	0.250000	0.249311	0.139648	0.157056	0.157056	0.000000	0.750000	0.250000
	Lingkungan	0.000000	0.593634	0.527836	0.593634	0.593634	0.800000	0.000000	0.750000

Done

Alternatives A2, A3, A4, and A5 are influenced by environmental subcriteria with respective values of 0.482683, 0.112927, 0.146972, and 0.257418.

The unweighted supermatrix shows that when a subcriterion is influenced by only one subcriterion within a cluster, the resulting value is one

Weighted Supermatrix

Weighted supermatrix is the product of an unweighted supermatrix and the influence values of the criteria. The comparison of the influence values of one subcriterion relative to another in the weighted supermatrix is no different from the comparison of influence values in the unweighted supermatrix. This is because, in the weighted supermatrix, the influence values are multiplied by the same weight for each criterion.

Limit Supermatrix

Super Decisions Main Window: hasil anp tomat.sdmod: Weighted Super Matrix

Super Decisions Main Window: hasil anp tomat.sdmod: Limit Matrix

Cluster Node Labels		Aktor				Alternatif			
		Pedagang	pengecer	Pengepul	Petani	A1	A2	A3	A4
Aktor	Pedagang	0.039631	0.039631	0.039631	0.039631	0.039631	0.039631	0.039631	0.039631
	pengecer	0.062720	0.062720	0.062720	0.062720	0.062720	0.062720	0.062720	0.062720
	Pengepul	0.089993	0.089993	0.089993	0.089993	0.089993	0.089993	0.089993	0.089993
	Petani	0.133138	0.133138	0.133138	0.133138	0.133138	0.133138	0.133138	0.133138
Alternatif	A1	0.052911	0.052911	0.052911	0.052911	0.052911	0.052911	0.052911	0.052911
	A2	0.133556	0.133556	0.133556	0.133556	0.133556	0.133556	0.133556	0.133556
	A3	0.070382	0.070382	0.070382	0.070382	0.070382	0.070382	0.070382	0.070382
	A4	0.056856	0.056856	0.056856	0.056856	0.056856	0.056856	0.056856	0.056856

Done

The results show that the cell values of each row of the matrix are convergent. The values of the limiting supermatrix cells are obtained by increasing the weights of the unweighted supermatrix by multiplying the supermatrix by itself several times. When the weights in each column have the same value, the values of the limiting supermatrix are obtained. These values in the limiting supermatrix are the results of ANP processing and serve as the basis for determining the priority of post-harvest tomato handling improvements.

Analysis of Subcriteria Weights and Improvement Priorities Subcriteria weights determine the priority of each existing subcriterion. The subcriteria and alternative weights can be seen in Table 4.15. There are two types of weighting in Table 4.15: global weights (limiting values) and cluster weights (normalized by cluster). The global weight (limiting value) indicates the weight of that subcriterion compared to other subcriteria in the overall model, while the cluster weight is the result of normalizing the global weight to reflect the subcriterion's weight within the cluster.

Based on the data processing results using the Super Decision software, it is known that the subcriterion in the actor cluster with the highest weight is farmers, with a value of 0.133138. The highest subcriterion in the dimension cluster is the environmental subcriterion, with a value of 0.167054. Based on the ANP data processing results in Table 4.15, it is known that alternative A2 has the highest limiting value among the other alternatives, namely 0.133556.

The farmer subcriteria are prioritized (assigned the highest weight) in efforts to improve postharvest handling because it is the farmers who determine the quality of the tomatoes. The primary factor to consider in the postharvest process is the condition or quality of the produce immediately after harvest. Farmers, as the first actors handling post-harvest tomatoes, play a crucial role in determining tomato quality all the way to the end of the supply chain. The environmental subcriteria have the highest weight (0.167054) within the dimension cluster. The environment plays a significant role in determining the quality of the tomatoes produced. Post-harvest handling is inseparable from environmental aspects such as weather, climate, season, soil fertility, and water availability. Factors influencing plant growth include both external and internal factors, such as nutrients, temperature, humidity, light, water content, genes, and hormones. (Pudjiwati & Murtilaksono, 2021)

Environmental conditions require action or measures to address factors that determine tomato quality; such measures can be taken to minimize damage to tomatoes caused by actors or farmers, such as reducing the use of inorganic fertilizers by combining them with organic fertilizers. According to Hardiana (2018), the application of organic fertilizer combined with inorganic fertilizer can increase crop productivity and fertilizer use efficiency, both in paddy fields and dryland. Post-harvest losses of tomatoes typically occur more frequently during the rainy season because tomatoes rot more easily. These challenges often lead to a decline in tomato crop production, both in terms of quality and quantity; if not addressed promptly, they can result in crop failure (Harefa, D., 2020).

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	A1	0.0529	0.1569	0.3962	4
	A2	0.1336	0.3960	1.0000	1
	A3	0.0704	0.2087	0.5270	2
	A4	0.0569	0.1686	0.4257	3
	A5	0.0236	0.0698	0.1764	5

Alternative A2 ranks first in terms of improvement priority because it has the highest ideal score of 1. Alternative A2 involves providing extension services or guidance to tomato farmers to help them achieve the desired harvest volume and produce high-quality crops. This includes extension services on proper crop cultivation methods and advancements in appropriate cultivation technologies. However, farmers sometimes still rely on traditional methods and are reluctant to adopt new practices. In this context, post-harvest handling training will have an impact on the commodities managed by farmer actors. As an educational process, training empowers farming communities to become self-reliant in their efforts to increase production and productivity.

Farmer mentoring is a priority activity in the cultivation sector. One way to empower farmers and enhance their capabilities is through mentoring programs (Setyaningtyas M.N., 2016). Farmers must be consistently supported so they feel valued and receive backing from government representatives.

Extension activities can be conducted by

Relevant parties, such as the Jember Regency Office of Food Crops, Horticulture, and Plantations. These activities can involve hands-on field training on proper post-harvest handling of tomatoes, enabling farmers to fully grasp the information provided by extension officers. According to Effendy & Diantoro (2020), extension activities are not limited to the learning process alone, but also involve interaction between extension workers—acting as facilitators and catalysts—and farmers to exchange ideas or opinions in solving the problems they face.

The provision of good and sustainable inputs (A3) is the second priority with an ideal value of 0.5270 and is an important aspect. The provision of appropriate agricultural inputs in terms of type, quantity, and price is a key effort in food crop development. The input resources respondents consider most important are the provision of seeds and the procurement of fertilizers; however, in this regard, the role of the government has not yet been felt by tomato farmers in Jember Regency.

Regular monitoring by the relevant agency (A4) of the post-harvest process for tomatoes is a follow-up measure that must be implemented. This monitoring is conducted with the aim of ensuring consistency among agricultural stakeholders regarding the post-harvest handling of tomatoes. Based on interviews with respondents and relevant agencies that have been conducted, it was found that there is currently no supervision specifically dedicated to post-harvest handling; therefore, it is hoped that in the future the government will be able to implement a supervision program as a strategy to reduce the impact of post-harvest losses in tomatoes.

Intensifying the government's role in technology, management, and financing capacity-building programs (A1) has a value of 0.3962, ranking fourth, while support for infrastructure and facilities for business partners and relevant agencies (A5) ranks fifth with an ideal value of 0.1764. Alternatives A4 and A5 have nearly identical roles, both involving the government or relevant agencies. The government's role is primarily focused on preparing infrastructure, facilities, and equipment that support agricultural business development, as well as drafting regulations. It also involves fostering cooperation/partnerships between farmers/farmer organizations and financial institutions, private sector entities, and producers of production inputs.

CONCLUSIONS

The results of the ANP analysis using Super Decision software indicate that the top priority for improving tomato postharvest management is to provide training to agricultural stakeholders on proper postharvest handling practices and their impact on tomatoes. This information is presented in paragraph form rather than as a detailed list.

AUTHOR CONTRIBUTIONS

In this study, MNF was responsible for sample preparation, sensor fabrication, and data analysis, as well as writing the report. NWU was responsible for sensor fabrication and writing the article, conducting the research, and compiling the report.

CONFLICT OF INTEREST

In this study, the authors declare no conflict of interest

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