Modeling Causal Factors of Food Loss in Fresh Produce Supply Chain: Indonesia

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Abstract

The goal of this research is to identify and analyze the key factors influencing food loss in the fresh produce supply chain in developing countries, particularly Indonesia. This research derived fourteen influencing factors, each representing a specific context, from the literature and as well as data gathered through semi-structured interviews with a select group of experts. In addition, to analyze the identified factors, the Interpretative Structural Modeling Technique (ISM) and Matriced Impacts Analysis of Croise's Appliqués and Un Classement Multiplication (MICMAC) were used as integrated methods. The government's financing support for the food and agriculture sectors has not been maximized along with limited access to capital is the most significant factor, with a high tendency to affect the food loss in the fresh produce supply chain. The study's findings are expected to help business actors and policymakers identify and comprehend key factors. Insights from the findings will aid in the formulation of policies and strategic decisions concerning the reduction of food loss in the fresh produce supply chain, thereby assisting in the achievement of the goals of sustainable development regarding food loss.

Keywords
Food loss, Fresh produce supply chain, Indonesia, Interpretive structural modeling

1. Introduction

Food loss refers to a decrease in the quantity of food in the food supply chain before the consumption stage. Food loss mainly occurs in the upstream supply chain, such as in the production, post-harvest and processing stages. The main drivers of food loss are infrastructure limitations, climatic and environmental factors, and assessments for quality or safety standards (Dora, 2019).

Food loss and waste of fresh produce increases along with the increase in production. During the production and distribution process, fresh produce releases greenhouse gases into the air and continues to the disposal of food waste in landfills (Porter et al., 2018). In addition, food loss and waste has a direct negative impact on the income of producers and consumers (Thyberg and Tonjes, 2016). In addition to environmental and economic impacts, food loss and waste has a negative impact on food security (Mangla et al., 2018).

As much as 44% of waste in Indonesia in 2018 was food waste. Indonesia is estimated to reach 300 kg per capita per year and is claimed to be the second largest producer of food loss and waste in the world (The Economist Intelligence Unit and Barilla Foundation, 2017). The environmental impact caused by food loss and waste in 2000 – 2019 is that the total greenhouse gases are estimated at 1,702.9 Mt CO2-ek. The three main contributors to greenhouse gas emissions are food crop commodities, fisheries, and horticulture with each contributing an average of around 39.67%, 22.32% and 20.21% (Ministry of Environment and Forestry, 2018). The incidence of food loss and waste in Indonesia is 23–48 million tons/year during 2000 – 2019. This has an impact on the occurrence of economic losses of

213–551 trillion rupiah/year or equivalent to 4%-5% of Indonesia's GDP/year (Ministry of National Development Planning/Bappenas, 2021).

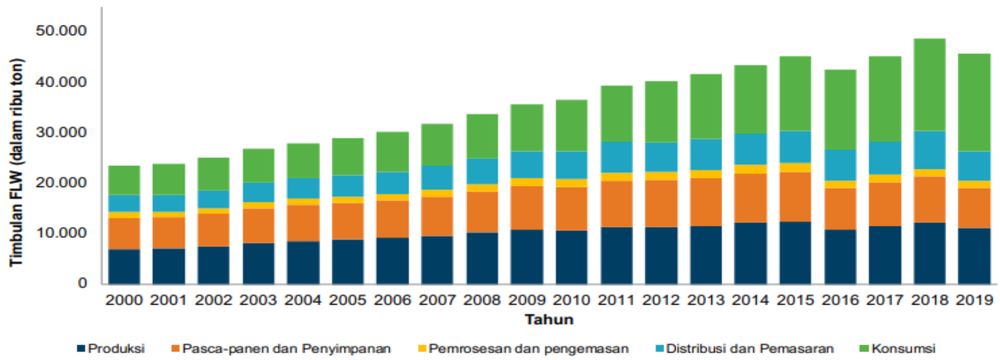

Figure 1. Indonesia's Food Loss and Waste Generation in 2000 - 2019 per Stage of the Food Supply Chain (in thousand tons)
(Source: Ministry of National Development Planning/Bappenas, 2021)

Based on Figure 1, food loss occurs in the first three stages, while food waste occurs in the last two stages. The incidence of food loss in Indonesia at the production stage is 7-12.3 million tons/year, post-harvest and storage stages are 6.1-9.9 million tons/year, processing and packaging stages are 1.1-1.8 million tons /year.

Based on Figure 2, the horticulture sector, especially vegetables, is the most inefficient type of food, with losses reaching 62.8% of the total domestic supply of vegetables in Indonesia.

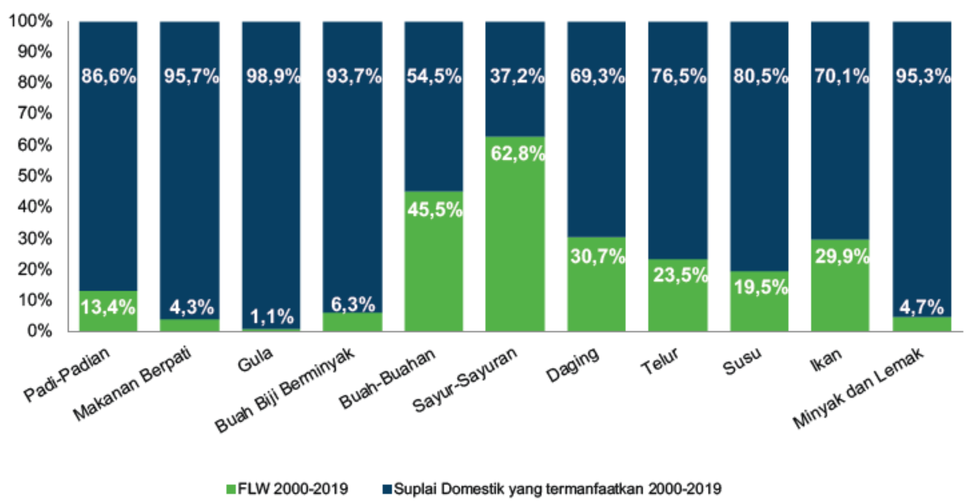

Figure 2. Proportion of Indonesia's Food Loss and Waste Generation compared to Total Domestic Supply 2000 – 2019 in 11 Food Categories
(Source: Ministry of National Development Planning/Bappenas, 2021)

The food crop sector, especially grains, has the greatest economic loss value, but these food crops have good processing efficiency so that the proportion that is wasted is smaller than the proportion of grains consumed. The horticultural sector, especially vegetables, has a low economic loss value compared to food crops, but the efficiency of the processing process is still not good, causing the proportion of vegetables to be wasted to be very high compared to vegetables consumed (Ministry of National Development Planning/Bappenas, 2021).

Several studies related to food loss have been carried out by previous researchers as a comparison with research to be carried out. Therefore, by comparison with previous research, it can be seen the differences from each study along with the weaknesses of previous research so that it can be completed in the research to be carried out.

Gardas et al. (2017), conducted a study in 2017 regarding the factors that cause food loss in India. Through a literature survey and expert opinion, fourteen critical factors were identified, and the Interpretive Structural Modeling (ISM) method was used to determine the relationship between the factors. The results of the analysis of these factors, found the three most significant factors, namely the lack of linkages between industry, government, and institutions, the lack of sophisticated food processing technology and techniques, and the lack of linkages between farmers and processing units. This study has several limitations, in this study only the ISM method was used. To apply the ISM methodology efficiently, the researcher must have in-depth knowledge of the method and need to be sufficiently trained to interpret the data obtained. In overcoming these obstacles and increasing the accuracy of the model for validation purposes, in future research, an integrated approach can be used. Methods that can be used in conjunction with the ISM approach are Technique for Others Reference by Similarity to Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Decision making trial and evaluation laboratory (DEMATEL), Structural Equation Modeling (SEM), Total Interpretive Structural Modeling (TISM).

Raut and Gardas (2018), conducted a study in 2018 regarding the factors causing post-harvest losses that occur in the fruit and vegetable transportation phase in India. The most significant obstacles identified with the multi-criteria decision-making approach (MCDM) namely Interpretive Structural Modeling and MICMAC Analysis were the unavailability of refrigerated vehicles, excessive vehicle loads, poor road conditions, and the absence of radiation shielding on top of the vehicle.

Raut et al. (2018), conducted a study in 2018 on the main causes of post-harvest losses in the fruit and vegetable supply chain in India. From a comprehensive literature review and expert opinion, sixteen causal factors were identified, and the Analytical Hierarchy Process (AHP) was applied. The three main significant contributing factors are the lack of linkages between institutions, industry, and government, climate and weather conditions, and the lack of linkages in marketing channels from agriculture to markets.

Parashar et al. (2020), conducted research in 2020 on the key enabling factors for reducing inefficiency across India's food supply chain. Interpretive Structural Modeling and MICMAC Analysis were applied to understand the interrelationships of the selected supporting factors. Findings from both ISM and MICMAC analyzes indicate that regulation and governance have the highest driving force.

Gokarn and Choudhary (2021), conducted a study in 2021 on the development of a comprehensive framework by identifying and analyzing the key factors influencing the reduction of food loss and waste in the food supply chain of fresh produce in developing countries, particularly India. In this study, data were collected from experts in developing ISM-based models and applying MICMAC analysis. As this input is subjective and based on expert judgment, there is a possibility of bias that might affect the final result. This can be overcome by collecting data from relevant respondents through a questionnaire-based survey and applying exploratory factor analysis (EFA) as a statistical technique to group similar factors into factor super-sets. In this study, the eight factors were categorized into four categories, but the strength of the relationship was not measured. The eight factors are flexibility, responsiveness, performance measurement metrics, logistics management, information and communication technology, relationship management, market infrastructure, food regulations and policies.

Magalhaes et al. (2021), conducted a study in 2021 on the factors causing food loss and waste in the supply chain of fresh food products in Portugal using an approach with a holistic supply chain perspective to map factor relationships and guide the selection, design, and implementation of appropriate mitigation strategies. Focus group discussions were used in this study to gather information and enable a holistic understanding of the causes of food loss and waste in the supply chain of fresh food products. Seven experts were selected based on their experience in producing, distributing and selling fruits and vegetables. In this study, 14 causes of food loss and waste in the supply chain of fresh food products were identified and divided into seven levels of influence, using the Interpretive Structural Modeling (ISM) methodology, which shows that logistics-related causes have a major influence on other causes. Furthermore, five root causes identified by the MICMAC analysis (inadequate transportation system, inadequate packaging, lack of storage facilities, poor handling and operational performance, and lack of coordination and information sharing) are used to serve as a reference for mitigation strategies that should be implemented to reduce food loss and waste.

Chauhan et al. (2021), conducted research in 2021 on the state of the art in food loss and waste in the food supply chain. This study uses a systematic literature review (SLR) approach to examine and synthesize existing literature findings and identify the main research themes, research gaps and future research directions related to food loss and waste. Based on literature analysis, the main factors that influence food loss and waste in the food supply chain are improper management of perishable products, bad stakeholder attitudes, inappropriate agreements between buyers and suppliers, and supply chain disruptions.

Previous research has focused on identifying the causes of food loss and waste in various countries. The limited research and information related to the factors causing food loss of the horticultural sector in the supply chain of fresh food products in Indonesia has become a research gap. This gap occurs from the limitations in previous research. Therefore, the proposed research will fill the gap of previous research in the supply chain of fresh food products. This study focuses on the factors causing food loss in the supply chain of fresh food products that have a short shelf life, are easily damaged, have seasonal production with long production times and have a variety of products in Indonesia. The method used is a combination of Interpretive Structural Modeling (ISM) and MICMAC analysis which will be used to identify and analyze the factors causing food loss.

1.1 Objectives

The goal of this research is to identify and analyze the key factors influencing food loss of the horticultural sector in the fresh produce supply chain in developing countries, particularly Indonesia.

2. Literature Review

Some of the factors that cause FLW are structural, related to infrastructure, and the application of best practices in each supply chain stage, while others are systematic and also related to regulations and policies (Sawaya, 2017).The distinctive characteristics of production and the complexity present in the fresh produce supply chain have a significant negative impact on the reduction of food loss in each stage such as production, harvesting, storage, distribution and consumption (Kaipia et al., 2013).

Bhattacharya and Fayezi (2021), conducted a study in 2021 on multi-stakeholder collaboration contributing to the reduction of food loss and waste across the supply chain through a collaborative orientation across vertical and horizontal collaborations. This study uses a multi-method approach that combines systematic literature review (SLR) and case studies based on secondary data. The finding of this study is that multi-stakeholder collaboration contributes to the reduction of food loss and waste throughout the supply chain through a collaborative orientation across vertical and horizontal collaborations. An example of vertical cooperation to reduce food loss and waste is between consumers and farmers. The Fruta Feia project in Lisbon gives customers the opportunity to purchase defective products from farmers at lower prices. Not only customers and farmers benefit directly, society as a whole also benefits indirectly (Ribeiro, Sobral, Peças, & Henriques, 2018). This study also recommends developing collaboration between the private and public sectors where farmers, retailers/ wholesalers, NGOs, and the government work together to reduce food loss and waste as a form of horizontal collaboration. For example, Matzembacher et al. (2020) discusses the Refresh Project (Resource Efficient Food and Drink for the Entire Supply Chain) in Brazil, which develops strategic agreements between the government, the business sector, and other stakeholders to address food loss and waste through national policies. The project brings together 26 partners from 12 European countries and China to develop horizontal collaboration between different governments and core stakeholders.

Dora et al. (2021), conducted research in 2021 on the main causes of food loss and waste in the supply chains of developed and developing countries. The root cause/cause analysis method was carried out and mitigation strategies were identified by systematically analyzing and synthesizing previous research published over the last 20 years (1998 to 2018) in the field of food loss and waste in the supply chain. The findings in this study are that in developed countries large amounts of food loss and waste occur at the retail stage due to high quality standards, the consumer stage due to inefficient purchase planning, wrong interpretation of best-before and expiration, overcooking food, and underutilization of food waste. In developing countries, large amounts of food loss and waste occur due to poor harvesting techniques, lack of storage and refrigeration facilities, and inadequate infrastructure and packaging.

Surucu-Balci and Tuna (2021), conducted research in 2021 on food loss drivers related to logistics as a whole in the supply chain of fresh food products in Turkey. This study aims to identify, classify, and weight the triggering factors for food loss related to logistics, which have a major influence on the amount of food loss in the fruit and vegetable supply chain. In this study, a literature review was conducted to identify the potential causes of food loss related to logistics, semi-structured interviews were conducted with industry experts, the Analytical Hierarchy Process (AHP) method was used to rank factors that have an influence on food loss. Interviewees included three farmers, ten fruit and vegetable processors, one wholesaler, four logistics service providers, a packaging company manager, a food safety certificate inspector, and a member of the board of a fruit and vegetable exporters association branch. Based on the research results, the drivers related to warehousing and transportation are the drivers that have the most influence on the amount of food loss, while lack of coordination and inappropriate packaging materials are the two sub-drivers that have the most influence. This study has some limitations because Turkey is a developing country, the results may apply to other developing countries, but the results cannot be generalized to developed countries.

3. Methods

This study adopted a multi-criteria decision-making approach to achieve the research objectives. Therefore, we have used literature review, semi-structured interviews, and ISM-MICMAC. A literature review is carried out to reveal an overview of the latest literature. Semi-structured interviews are conducted to gain a deeper understanding of a topic. In this research work, a two-stage approach was followed to determine the significant enablers. In the first stage, research papers related to supply chain, food supply chain and food loss in food supply chain are referred. The authors compiled several research articles related to the food supply chain and the factors that influence the occurrence of food loss in the food supply chain. Initially, through a literature review, 21 factors have been identified that have a significant impact on food loss (Table 1).

Table 1. Causal factor of food loss based on an extensive literature survey

Food Loss Sector	Causal Factor	Reference
Agriculture	• Overproduction • Poor agricultural infrastructure • Low quality equipment for harvesting • Lack of agricultural knowledge, quality seeds • Inadequate agricultural techniques • Failing to meet the quality standards set by stakeholders	1. Dora, M., Biswas, S., Choudhary, S., Nayak, R., & Irani, Z. (2021).
Postharvest Process	• Loss of crop yields due to inefficient processing techniques • Food loss on visually defective products • Use of poor packaging • Lack of knowledge about post-harvest technology • Lack of processing facilities (waxing, washing, etc.)	1. Dora, M., Biswas, S., Choudhary, S., Nayak, R., & Irani, Z. (2021). 2. Gardas, B. B., Raut, R. D., & Narkhede, B. (2017).
Storage	• Improper storage • Inadequate refrigeration storage facilities • Lack of dry storage facilities • Poor storage infrastructure	1. Surucu-Balci, E., & Tuna, O. (2021).
Warehouse	• Inadequate logistics infrastructure • Delivery Delays • High transportation costs • Poor handling of transportation • Lack of refrigerated transport/trucks	1. Surucu-Balci, E., & Tuna, O. (2021).
Distribution	• Lack of linkages between industry and government	1. Gardas et al. (2017),

The identified factors were selected with the help of input from a panel of experts consisting of professionals from industry, government, farmers and academia. The experts consist of an academic expert with a doctoral degree since ten years in a leading institute in the food supply chain, an industry practitioner who is an inventory controller of a company supplying raw materials/materials in the hotel industry with almost 5 years of experience contacted for assessment, a farmer and governments with more than 5 years of experience in the food supply chain. Several forum group discussion sessions were held with individual and collective experts for detailed discussion of the identified causes of food loss. Prior to each session, experts and practitioners were provided with a brief explanation (including definitions) of the factors causing food loss identified from the literature. However, after several meetings, the experts reached a consensus and selected 15 factors (Table 2) from the 23 factors causing food loss that were identified earlier.

Table 2. Causal factor of food loss based on expert

Sector	Causal Factors	Code
Agriculture	Unstable amount of agricultural production	E1
	Inappropriate harvesting time	E2
	Inadequate harvesting techniques	E3
	Limited access to capital	E4
	Inadequate fresh produce transportation facilities	E5
Handling, Warehouse and Distribution	Lack of knowledge about post-harvest technology	E6
	Inefficient post-harvest handling techniques (Good Handling Practice)	E7
	Insufficient storage facilities	E8
	Inappropriate mode of transportation	E9
	Distribution distance and time is too long	E10
External	Unstable market price	E11
	The implementation of regulations regarding food and organic waste management has not yet maximum	E12
	Food and agriculture sector financing support from the government has not been maximum	E13
	High market quality standards	E14
	Lack of integrated studies and data collection related to food loss	E15

4. Data Collection

ISM is a well-established MCDM technique for classification and categorization of contextual relationships between factors (Agrawal, 2020). The ISM technique facilitates the separation and prioritization of the factors under consideration. In this paper, the causative factors of food loss are identified and modeled. The ISM methodology is applied to the sector being studied. The various steps towards the formulation of the ISM model are discussed below.

First of all, related factors are selected and then their direct or indirect contextual relationships are developed. he activities carried out are making a pairwise comparison matrix, developing a structural self-interaction matrix, examining transitivity and finally making a matrix model (Raut et al., 2019). All stages of this technique take both theoretical and contextual knowledge into account in order to decipher the possible interrelationships. Because this approach involves input from practitioners, it bridges the gap between theoretical recommendations and industry practice.

5. Results and Discussion

5.1 Structural Self-Interaction Matrix (SSIM)

To develop a structural self-interaction matrix (SSIM), a group discussion forum was held. The experts were asked to respond to each relationship in terms of yes or no (Gorane and Kant, 2013). Furthermore, the relationship between these factors was analyzed and converted into SSIM using VAXO. Four symbols (VAXO) are used to indicate the path of the relationship between factors (i and j). Where i represents the factors in the row, and j represents the factors in the column.

V: factor i will contribute to making factor j.
A: factor j will help to make element i
X: factor i and j will help to achieve each other
O: fctors i and j are not related

Table 3 shows the results of the SSIM from the expert through the forum group discussion.

Table 3. Structural self-interaction matrix (SSIM)

No	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
E1		X	X	X	V	O	V	X	O	X	X	O	A	A	O
E2			X	A	O	A	V	O	O	O	X	X	A	V	O
E3				A	O	A	V	O	O	O	X	X	A	V	O
E4					V	V	V	V	V	O	O	V	A	O	O
E5						A	V	O	O	O	V	A	A	V	A
E6							V	V	V	V	V	A	A	V	A
E7								V	V	V	V	X	A	V	O
E8									O	O	V	A	A	V	A
E9										V	V	A	A	V	A
E10											V	A	A	A	A
E11												X	A	X	X
E12													X	O	X
E13														V	X
E14															X
E15															

5.2 Reachability Matrix of The Causal Factors of Food Loss

The reachability matrix was developed in two steps: the initial reachability matrix and the final reachability matrix. In the first step, the SSIM is reformed into a binary matrix, known as the initial reachability matrix, changing V, A, X, and O with '1' and '0' as per the case. At this stage, the symbols in the SSIM matrix are converted into a binary matrix with the following rules:

- If the relationship Ei to Ej = V in SSIM, then the elements Eij = 1 and Eji = 0 in RM
- If the relationship Ei to Ej = A in SSIM, then the elements Eij = 0 and Eji = 1 in RM
- If the relationship Ei to Ej = X in SSIM, then the elements Eij = 1 and Eji = 1 in RM
- If the relationship between Ei and Ej = O in SSIM, then the elements Eij = 0 and Eji = 0 in RM

Initial reachability matrix shown in Table 4.

Table 4. Initial reachability matrix

No	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
E1	0	1	1	1	1	0	1	1	0	1	1	0	0	0	0
E2	1	0	1	0	0	0	1	0	0	0	1	1	0	1	0
E3	1	1	0	0	0	0	1	0	0	0	1	1	0	1	0
E4	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0
E5	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0
E6	0	1	1	0	1	0	1	1	1	1	1	0	0	1	0
E7	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0
E8	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
E9	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
E10	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
E11	1	1	1	0	0	0	0	0	0	0	0	1	0	1	1
E12	0	1	1	0	1	1	1	1	1	1	1	0	1	0	1
E13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
E14	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1
E15	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0

The initial reachability matrix was modified to show all direct and indirect reachability, i.e. if Eij = 1 and Ejk = 1, then Eik = 1. The examination is done by checking the cells that are worth 0 whether they meet the transitivity rules or not. For example: Cell (3,2) = 0, because cell value (3,5) =1 and cell (5,2) =1, then cell (3,2) = 1 (Transitivity Rule).

Table 5. Final reachability matrix

No	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	Driver Power
E1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	14
E2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E5	1	1	1	0	1	0	1	1	1	1	1	1	0	1	1	12
E6	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	13
E7	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	14
E8	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	12
E9	1	1	1	0	0	0	0	0	1	1	1	1	0	1	1	9
E10	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	12
E11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
E15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Dependence	15	15	15	11	14	11	14	14	13	15	15	15	9	15	15	206

5.3 Level Partition

Level Partition is done to classify elements in different levels of the ISM structure. For this purpose, two sets are associated with each Ei element of the system:

• Reachability Set (Ri), is a set of all elements that can be achieved from the element Ei.

• Antecedent Set (Ai), is a set of all elements where the element Ei can be achieved. In the first iteration all elements, where Ri = Ri Ai, are level 1 elements.

In subsequent iterations the elements identified as level elements in previous iterations are removed, and new elements are selected for the next levels using the same rules. Furthermore, all system elements are grouped into different levels. In this study, five iterations were obtained, level can be seen in Table 6.

Table 6. Level Partition

Code	*Reachability Set*	*Antecendent Set*	*Intersection Set*	*DP*	*D*	Level
E1	1,2,3,4,5,6,7,8,9,10,11,12,14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,14,15	14	15	1
E2	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1
E3	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1
E4	4,13	4,13	4,13	15	11	5
E5	5,7	4,5,6,7,13	5,7	12	14	3
E6	6	4,6,13	6	13	11	4
E7	5,6,7,13	4,5,6,7,13	5,6,7,13	14	14	3

E8	1,2,3,4,5,7,8,10,11,12, 14,15	1,2,3,4,5,6,7,8,10,11,12,13, 14,15	1,2,3,4,5,7,8,10,11,12, 14,15	12	14	1
E9	9	4,5,6,7,9,13	9	9	13	2
E10	1,2,3,4,5,7,8,10,11,12, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,7,8,10,11,12, 14,15	12	15	1
E11	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1
E12	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1
E13	4,13	4,13	4,13	15	9	5
E14	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1
E15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10, 11,12,13, 14,15	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15	15	15	1

5.4 Causal Factor of Food Loss Analysis

Based on the results of the classification of the elements causing food loss, the hierarchical structure of the causes of food loss consists of 5 levels. The hierarchical structure of the causes of food loss is shown in Figure 3.

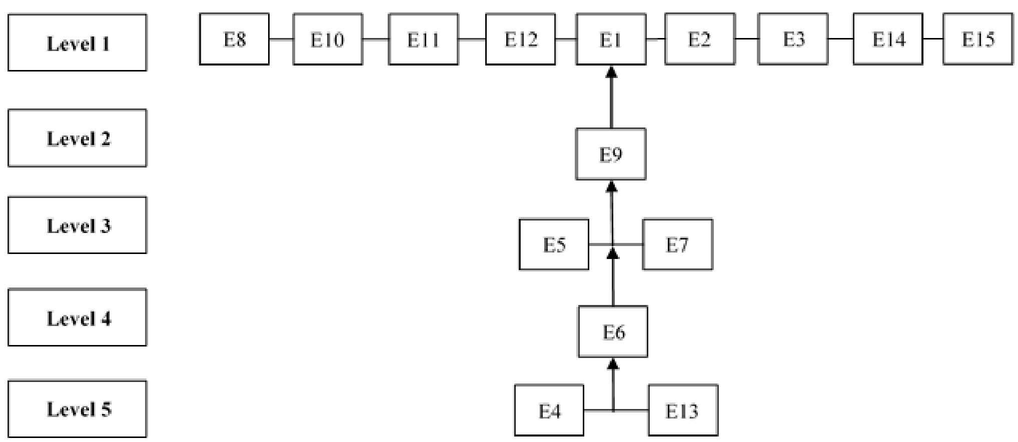

Figure 3. Hierarchical Structure Causal Factor of Food Loss

Based on Figure 4, it can be seen that the sub-element of food and agriculture sector financing support from the government has not been maximum (E13) and limited access to capital (E4) is at level 5. These are the main problems facing Indonesia today. If the causal elements (E13) and (E4) as the main problem have been resolved, then the other causal elements at the next level will be able to be overcome.

The sub element of lack of knowledge about post-harvest technology (E6) is at level 4, namely the next food loss problem faced by Indonesia. Problems that are at the next level are related to inadequate fresh product transportation facilities (E5) and inefficient post-harvest handling techniques (Good Handling Practice) (E7). Then at the next level the problem occurs in the inappropriate mode of transportation (E9). The last problems are inadequate storage facilities (E8), distribution distance and time are too long (E10), unstable market prices (E11), implementation of regulations regarding food and organic waste management has not been maximized (E12), the amount of agricultural production has not been stable (E12). E1), Inappropriate harvesting time (E2), Inadequate harvesting technique (E3), High market quality standards (E14), Lack of integrated study and data collection related to food loss (E15).

Classification of the elements that cause food loss can be classified into 4 sectors as shown in Figure 5. The placement of these elements is based on the coordinates obtained from the Driver Power value and the Dependence Power value in the revised RM table.

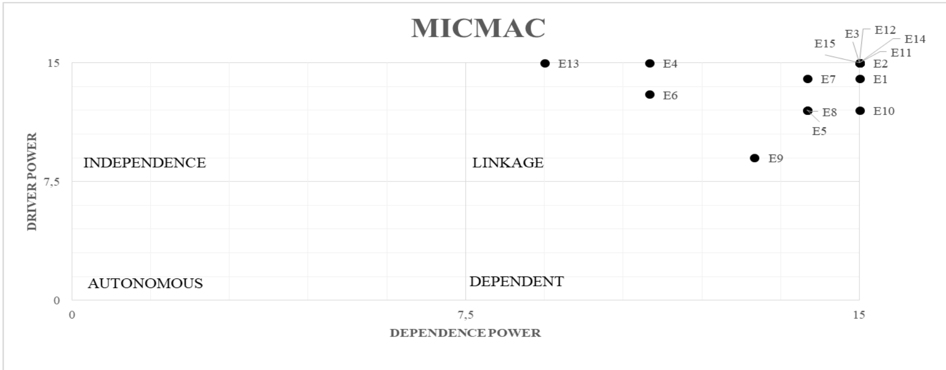

Figure 4. MICMAC Matrix

Based on Figure 4, it can be seen that all elements are in the Linkage sector. These elements have high driver power and high dependence. The characteristic is that any action on the element will have an effect on the variables above their level and a feedback effect on the element itself. Based on the results of the discussion of the ISM-MICMAC analysis with experts, the main factors causing food loss that must be studied are the fifteen elements, namely the amount of unstable agricultural production (E1), inappropriate harvesting time (E2), inadequate harvesting techniques (E3), Limited access to capital (E4), Inadequate fresh produce transportation facilities (E5), Lack of knowledge about post-harvest technology (E6), Inefficient post-harvest handling techniques (Good Handling Practice) (E7), Storage facilities inadequate (E8), Inappropriate mode of transportation (E9), distribution distance and time is too long (E10), unstable market price (E11), implementation of regulations regarding food and organic waste management has not been maximized (E12), financing support Food and agriculture sector from the government has not been maximized (E13), High market quality standards (E14), Lack of integrated studies and data collection related to food loss (E15).

6. Conclusion

In this research work, fifteen important factors that cause food loss were identified, namely the amount of agricultural production is not stable (E1), harvesting time is not right (E2), harvesting techniques are not adequate (E3), limited access to capital (E4), Inadequate fresh produce transportation facilities (E5), Lack of knowledge about post-harvest technology (E6), Inefficient post-harvest handling techniques (Good Handling Practice) (E7), Inadequate storage facilities (E8), Insufficient transportation modes right (E9), distribution distance and time is too long (E10), market price is not stable (E11), implementation of regulations regarding food and organic waste management has not been maximized (E12), food and agricultural sector financing support from the government has not been maximized (E13) , High market quality standard (E14), Lack of integrated study and data collection related to food loss (E15). All elements are in the Linkage sector which has high influence and high dependence. The characteristic is that any action on the element will have an effect on the variables above their level and a feedback effect on the element itself. Based on the results of the ISM-MICMAC analysis discussion with experts, the main factors causing food loss that must be studied are the fifteen elements.

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