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Optimizing FLW Risk Mitigation Strategies in Chili Supply Chains using Fuzzy-ANP

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Abstract

Indonesia's horticultural sector has grappled with a persistent challenge: Food Loss and Waste (FLW). This issue not only represented a drain on resources but also jeopardized food security, diminished farmer incomes, and contributed to greenhouse gas emissions. To confront this, our study introduced a strategic model focused on risk mitigation within the chili supply chain, employing the Fuzzy Analytical Network Process (FANP) approach. This work built upon previous research that integrated Interpretive Structural Modeling (ISM) and Failure Mode and Effect Analysis (FMEA). We fortified the empirical foundation of our FANP analysis with quantitative findings drawn directly from FMEA. The FMEA results pinpointed several critical risk factors that drove FLW in the chili agro-supply chain of Kabupaten Malang, Indonesia: coordination failures (Risk Priority Number/RPN = 630), harvest uncertainty (RPN = 560), and poor post-harvest handling (RPN = 448). These key risks were instrumental in the construction of the FANP decision network, allowing us to map the interdependencies between evaluation criteria and potential mitigation strategies. By leveraging Triangular Fuzzy Numbers, the FANP model navigated the inherent uncertainty in expert judgments and enabled clearer prioritization among the relative importance of various mitigation alternatives. The analysis solidified FANP's capability to systematically rank interrelated strategies, offering crucial decision support in complex, multi-criteria environments. Ultimately, the integrated FMEA–FANP framework provided a robust analytical foundation for minimizing FLW, boosting operational efficiency, and fostering greater supply chain sustainability. These findings were a vital contribution to national endeavors to reduce food loss, build more resilient value chains, and propel Indonesia toward a circular, low-carbon economy.

Keywords
Food Loss and Waste (FLW), Chili Supply Chain, Fuzzy-ANP, Risk Mitigation Strategies, Sustainable Agriculture, and Circular Economy.

Biographies
Rini Oktavera is an Associate Professor specializing in industrial engineering, supply chain management, lean manufacturing, and halal industry development. She earned her bachelor's degree in Chemical Engineering and master's degrees in Industrial Management from Institut Teknologi Sepuluh Nopember (ITS), and is currently pursuing a doctoral dissertation in Agricultural Industrial Technology at Universitas Brawijaya. Her scholarly contributions have focused primarily on supply chain risk management, green business models, logistics and big data analytics, and halal product assurance. She has widely published in national and international journals, including recent works on risk management in the tobacco supply chain (2022), a bibliometric analysis of food loss and waste risk (2024), and lean manufacturing optimization (2025). In addition to her research, she has contributed to books and book chapters addressing supply chain management, ergonomics, entrepreneurship, and disaster mitigation, and frequently shares her expertise at international conferences.

Imam Santoso is an expert in agro-industrial systems and management, specializing in the design and analysis of agro-industrial systems with risk considerations, feasibility assessments for industrial development, and decision support system formulation for strategic management. He holds a bachelor's degree in Agricultural Mechanization and a master's degree in Postharvest Technology from Universitas Brawijaya, as well as a Doctorate in Agro-industrial Technology from IPB University. He has extensive experience as a consultant and subject matter expert in agro-industrial MSME development, product risk mitigation, and community empowerment through locally based agro-industrial initiatives. His research has employed artificial intelligence approaches such as fuzzy theory and artificial neural networks to promote smart and sustainable agro-industrial systems. He has published in accredited national journals (Sinta 2) and internationally recognized journals such as the International Journal of Technology (Q1) and the Journal of Engineering and Technological Sciences (Q2). Internationally, he serves as President of the International Association of Agro Based Engineering and Technology (IAAET) and Secretary of the ASEAN University Consortium on Food and Agro-Based Engineering and Technology (AUCFA). Currently serving as Dean of the Faculty of Agricultural Technology at Universitas Brawijaya, he remains committed to promoting innovation and sustainable policy development in agro-industrial management.

Wike Agustin Prima Dania is the Head of the Bachelor Program in Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Indonesia. She holds a bachelor's degree in Agricultural Industrial Technology from Universitas Brawijaya and completed postgraduate studies at the University of South Australia, earning a master's degree in Manufacturing Management and a Ph.D. in Mechanical and Manufacturing Engineering. Her academic experience includes international teaching roles as a Teaching Assistant (2015–2017) and Adjunct Lecturer (2018–2021) at the University of South Australia. Her expertise spans sustainable supply chain management, risk management in supply chain systems, production planning, and inventory systems. Dr. Dania has published extensively in reputable journals such as Environment, Development and Sustainability, IEEE Xplore, and the International Journal of Productivity and Performance Management. She has also presented at international conferences on topics related to sustainable food supply chains, forecasting, and green innovation. She has been recognized with numerous awards, including Universitas Brawijaya's Citation Award (2019), the Best Implementation of Outcome-Based Education (2024), and multiple CIVA Awards for excellence in teaching and leadership. Through research, teaching, and collaboration, Dr. Dania continues to promote sustainable agro-industrial development and innovative supply chain strategies.

Sujarwo is an Associate Professor of Agricultural Economics at Universitas Brawijaya, Indonesia, and currently serves as the Director of Student Affairs. He earned bachelor's and master's degrees from Universitas Brawijaya, completed a non-degree program at the University of Kentucky, and obtained a Ph.D. in 2017 with a focus on farm efficiency and risk preferences in agricultural insurance. His academic expertise includes agricultural economics, rural development policy, food security, and analyses of farm efficiency. Dr. Sujarwo has produced influential publications, including Production Efficiency of Small-Scale Shallot Producers in East Java (2015) and Changing Technical, Allocative, and Economic Efficiency of Small Farmers in Indonesia (2016), which are recognized as key references in agricultural productivity research. His research on farmers' acceptability of agricultural insurance has also informed

agricultural policy development in Indonesia. He regularly speaks at international forums and holds strategic roles within the Indonesian Agricultural Economics Association (PERHEPI).