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# Multi Criteria Decision Making for Fresh Mango Supply Chain Risk Management: An ISM & TOPSIS-Based approach

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**Abstract**

In Bangladesh, Mango is one of the most demandable fruits as well as called the "King of Fruits" for its exceptional taste and Nutrients. Mango is a perishable fruit that ripens quickly at room temperature. As a result, there are many risks associated with the Fresh Mango Supply Chain (FMSC). The primary goal of our research is to reduce potential mango waste by assessing risk factors and then implementing and evaluating mitigation techniques. Based on the literature review on risk management, several surveys and interviews were carried out to find potential risks and mitigation strategies. ISM (Iterative Structural Model) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) methodologies were applied to assess risks and mitigation strategies, respectively. Both methodologies are very effective MCDM (Multi-Criteria-Decision-Making) analysis techniques. Implementing the proposed risk management framework can help minimize the wastage of mangoes by approximately 15%. This would result in significant economic benefits for growers, shippers, and retailers, and it would also help to maximize the overall sustainability of the mango supply chain. The results indicate that mitigation strategies can significantly reduce wastage and will add value to FMSC. On this basis, by analyzing risk and applying these strategies, firms can earn profit and provide better customer satisfaction, as it will enhance supply chain sustainability and resilience by proactively identifying and addressing potential risks and increasing Bangladesh's economic growth. Minimizing waste eventually obtains the sustainability of a supply chain.

**Keywords: Risks, Risk Management, Mitigation strategy, ISM, TOPSIS, Sustainability, Waste minimization, Fresh Mango supply chain.**

## 1 Introduction

### *1.1 Supply Chain of Perishable Goods*

The movement of activities, information, and resources pertaining to materials from the producer to the consumer is referred to as a supply chain. It is necessary to coordinate and synchronize operations as well as material, financial, and information flow processes. The goal of Supply Chain Management (SCM) is to reduce wastage and expenditures while boosting overall value (Truong et al.,2022). When SCM techniques are used, they must guarantee that data and information are transferred transparently between suppliers, distributors, manufacturers, and consumers (Tajwar et al.,2022). Through a systemic rethinking of the organizations, people, activities, information flow, and resource flow involved in getting a good or service from a supplier to a customer, the supply chain revolution is now changing several industries. In order to increase efficiency by removing repetitive and useless work, supply chain management entails building a highly effective network of business links. As a result, profit-makers are becoming more interested in SCPF operations, commonly known as the farm-to-fork sequence (Yingfeng et al.,2017). The potential to invest more money in lucrative tree-based commodities that take many years to produce fruit increases as Bangladesh develops (Hassan et al.,2022). Sustainable supply chain management includes incorporating naturally and monetarily suitable practices into the total supply chain lifespan (Pritilata et al.,2020). Supply Chain approaches are more complex yet critical approaches toward perishable goods there. These activities, which include farming, processing, inspection, packaging, warehousing, shipping, distribution, and marketing, aim to meet the massive market demand and grow market shares. However, the effectiveness of SCPF is typically hampered by perishable food features and cross-regional logistical operations.

The overall value of unsaleable commodities increased by $3 to $5 billion in 2010, according to the 2008 FMI/GMA Unsaleable Report on Perishable Food. Millions of individuals are increasing their spending on fresh, tasty, but perishable and costly commodities such as fruits, seafood, and so on (Yingfeng et al.,2017). Perishable agricultural products have a limited life, which may deteriorate or demolish quickly if not handled or supplied appropriately. Perishable goods often remain fresh, are highly sensitive to surroundings impacts, and can become unsuitable for eating or usage in a short period. Consumption of fresh fruit has increased in Bangladesh as people become more conscious about living healthy lives. The perishable product supply chain system may be severely disrupted due to uncertain risks. Managing an efficient supply chain network for perishable products is extremely difficult since the time delay in collection or processing and reaching the customer's location reduces quality and lifespan. Globalization, volatile business conditions, and complex interactions among supply chain participants, such as suppliers, manufacturers, service providers, and so on, have made supply networks vulnerable to various risks. A significant percentage of perishable products spoil within the supply and grocery retail business stages. Damage, spoilage, and expiration of lifetime losses average approximately 15 percent of perishable goods (Thomas et al.,2007). According to Asian Development Bank (ADB) research (2022), due to inefficient supply chain management, inadequate transportation, and a shortage of Storage, local farmers receive less than half the price for their goods. On the road and at the market, around 35%-40% of perishable goods are going to waste in Bangladesh. (Food to feed 16cr for 3 months wasted annually [The Business Standard],27 November 2022)

*1.2 Fresh Mangoes Supply Chain (FMSC)*

Mango (Mangifera indica L.) is a popular tropical/subtropical fruit because of its great flavor and savor, as well as its important supply of nutrients and phytochemical components (Truong et al.,2022). Mango is presently the most significant fruit item in tonnage output and is widely grown in all districts of Bangladesh. From local production, mango provides 0.945 million MT (Metric Ton). The fruit is indeed priceless in terms of money and prosperity. It is known as the "King of the Fruit" in Bangladesh. Bangladesh, India, Pakistan, Mexico, Brazil, and the Philippines are significant mango-producing countries (Alexander, 1989). According to FAOSTAT (2014), mango covers around 50,491 hectares in Bangladesh and produced 945049 metric tons in 2011-12. It is presently growing in area by 113.15% and in output by 106.28% in 2011-12 compared to 2008-09 (PEST RISK ANALYSIS (PRA) OF MANGO IN BANGLADESH [Development Technical Consultants Pvt. Ltd. (DTCL) ],2015). Mangoes are a perishable crop that several risk factors can harm. On the other hand, mango is a climacteric fruit that ripens swiftly at room temperature. Mangoes undergo physicochemical changes when they mature, rendering them perishable in environments such as microorganism infection, climacteric respiration, postharvest handling, and Storage. Mango's intrinsic characteristics result in high postharvest losses throughout the supply chain (Truong et al.,2022). A considerable amount of mango is demolished because of insects and other outbreaks and a lack of post-harvesting knowledge. Numerous research was conducted on behalf of different kinds of perishable fruits as well as mango postharvest loss (Kassa et al. 2022) in Southern Ethiopia, mango quality development (Truong et al. 2022), and supply network improvement for both fruits and vegetables (Jouzdani et al. 2022) to reduce risks (Kassa et al.,2022) (Truong et al.,2022) (Jouzdani et al.,2022). Most previous studies focus on supply chain network development, cold chain, value chain constraints, and post-harvesting mango losses in other mango-producer countries. Minimal research has been conducted in Bangladesh on the mango supply chain risk reduction because 23.5 lakh tonnes of mango were produced in the financial year 2021-22. (Amrapali mango production highest among all varieties [The Daily Star],Jul 21, 2023)

The supply Chain of fresh mangoes includes several functional areas such as Harvesting, Packing, Storage, transportation, and Retailing. Fresh mangoes must go through these stages to be presented in the market at the right time. Because of the availability and favorable climate, mango production is considerably large in Bangladesh. Sometimes these favorable conditions are taken for granted, resulting in wastage and spoilage.

### *1.3 Uncertainty (Risk) Regarding the Fresh Mangoes Supply Chain (FMSC)*

In organizational theory and strategic management, the concept of "uncertainty" refers to both a lack of knowledge about these variables and the unpredictability of environmental or organizational factors that have an influence on firm performance. The term "risk" has also been given to components that are either external or internal to the corporation and have an impact on the risk that the company confronts. The term "risk" refers to a source of risk. The term "risk" can refer to unknown external forces that reduce the predictability of performance and the lack of predictability in business results (Miller et al.,1992). Risk can be thought of as a subset of uncertainty. We can estimate risk if we know the odds of various outcomes. Even with the sufficient production of mangoes in Bangladesh, the supply chain has to suffer due to risk. Risk is the possibility that an event or activity will have unintended negative repercussions.

The risk may also be described as a subjective expectation of loss; the more significant the likelihood of this loss, the greater the risk (Surya et al.,2017). Globalization, increased customer awareness, and environmental unpredictability have made the supply chain vulnerable to hazards. Supply chain risk is thus described as "the probability and effect of unanticipated macro and micro-level events or conditions that adversely affect any component of a supply chain, resulting in operational, tactical, or strategic level failures or irregularities. "According to the report, firms should focus on risk within the company and address risk throughout their supply chain. For example, the international automobile sectors have seen an almost 30% rise in interruptions induced by external sources, from 1300 in 2016 to over 1700 in 2017(Umair et al.,2020). Risk is the possibility that an event or activity will have unintended negative repercussions. The risk may also be described as a subjective expectation of loss; the more significant the likelihood of this loss, the greater the risk. Risk management in a supply chain context is a relatively new area of study. Globalization, an unstable economic climate, and complex interactions among supply chain participants, such as suppliers, manufacturers, service providers, and so on, have made supply networks vulnerable to various hazards (Surya et al.,2017). Moreover, a broader analysis of risks related to the mangoes supply chain and mitigating them through this research would financially benefit Bangladesh and contribute to its sustainability.

### *1.4 Methods Statement Related to Risk Analysis and Mitigation Strategy of Perishable Goods*

A supply chain risk index that reflects the degree of risk encountered by a supply chain in a particular circumstance is critical. The decision-making dilemma emerges when there is a need to compare or choose amongst a group of alternatives while considering the influence of many competing criteria. Different multiple criteria decision-making (MCDM) strategies are created in order to find the best choice that will be highly acceptable in light of all applicable purposes. TOPSIS is a multi-criteria decision-making (MCDM) strategy that focuses on ranking and choosing from a range of choices utilizing a number of factors in a hazy and unclear environment (S. M. Sohaeb et al.,2022). The fuzzy analytical hierarchy process (AHP) and fuzzy method for order preference by similarity to the ideal solution (TOPSIS) are two highly prominent approaches previously utilized in comparable scenarios. They offer the advantage of integrating methodologies such as fuzzy theory, designed to handle subjective judgments by definition, with analytical tools like AHP, a proven tool for dealing with multi-criterion decision-making (MCDM) problems. The resultant technology empowers users to make intelligent judgments while remaining imprecise in their inputs.

As a result, approaches like fuzzy AHP are becoming increasingly prevalent nowadays (Avinash et al.,2012). Many decisions are made based on numerous factors. As a result, the judgment can be done by dividing weights to various criteria derived from the groups of experts. Identifying the problem's structure and openly analyzing many criteria is critical. For example, some judgments were made based on several factors when constructing a nuclear power plant. Not all situations are tough and require a number of criteria; some may be affected by certain criteria, but for there to be an ideal solution, all options must share a set of standards that logically result in better and more informed decisions. Multi-Criteria-Decision-Making (MCDM) is concerned with organizing and resolving decision and planning problems incorporating several criteria. The TOPSIS technique posits that each criterion has a propensity to increase or decrease utility monotonically, allowing the positive and negative ideal solutions to be easily defined. To assess how near the alternatives are to the optimum answer. The Euclidean distance method is proposed. Through a series of assessments of their respective distances, the alternatives' preferred order will be discovered. The TOPSIS approach, like the ELECTRE method, first turns the numerous criteria dimensions into non-dimensional criteria. According to TOPSIS, the selected alternative should be the one that is both the farthest from the positive ideal solution (PIS) and the closest to the negative ideal solution (NIS). In multi-criteria decision-making, this approach is used to rank performance and optimize it. All of the criteria are analyzed using the TOPSIS (FUZZY) approach, and they are then ranked by region (Martin et al.,2013).

ISM (Interpretive Structural Modeling) is an approach for determining the interrelationships between components of interest in a given domain by using experts' knowledge of the parts' context. This strategy has been used in a wide number of sectors due to its straightforward philosophy, with sustainability taking the lead. This approach's partially automated or human application has been prone to errors due to a succession of mathematical phases of higher-order computational complexity, as observed in the literature. As a result, this study proposes to develop SmartISM, an end-to-end graphical software package for implementing the ISM approach, as well as MICMAC, which is widely used when combined with ISM to categorize variables (Robiul et al.,2020).

Multiple events threaten to disrupt supply chain operations and imperil productive and effective results in today's global, highly complex, and dynamic surroundings. Because of the worldwide breadth of supply networks, shorter product life cycles, and increasing consumer expectations, businesses are aware that supply chain disruptions will have significant organizational and financial effects. Disruption risks include occurrences caused by natural disasters such as storms, earthquakes, or floods, as well as man-made disasters such as supplier shutdowns, terrorist attacks, significant fires at manufacturing plants, or labor strikes. Building supply chain resilience (SCR) may assist in reducing and resolving risk by establishing procedures that allow the supply chain to return to its original state after a disruption. Building supply chain resilience (SCR) can help to reduce and resolve risk by establishing procedures that allow the supply chain to rebound to its original or even better functional state following an interruption (Robiul et al.,2020).

### *1.5 Objectives of the Research*

1. Identify and analyze key risks to the mango supply chain.
2. To evaluate each risk's possible effects on the mango supply chain, including losses, delays, and other issues.
3. To create an interpretive structural model (ISM) to comprehend better the interdependencies and hierarchical linkages between the identified risks in the mango supply chain.
4. To suggest and create practical mitigation plans for reducing mango fruit supply chain waste.

## 2. Literature Review

Food supply chains (FSCs) are under growing pressure to meet the problems of scarce assets and the requirement for profitable expansion in addition to remaining competitive (Laurent et al.,2022). Postharvest losses take place at each level in the supply chain and enhance with each successive step (Harinder et al.,2019). Supply chain management is commonly recognized as diverse and very complicated, covering different hazards that need adequate supervision (Laurent et al.,2022). Risks are associated with supply systems for perishable items. According to Xiuquan et al.,2019 frequent occurrences of such risks result in multiple interruptions, eventually impacting the sustainability of the supply networks for such perishable items (Xiuquan et al.,2019). Food systems are currently troubled by a major sustainability issue in the form of food waste, which represents a serious problem from economic, environmental, and social perspectives (Federica et al.,2020). The study "Pest Risk Analysis (PRA) of Mango in Bangladesh (2015)" reported mango pests & diseases where nineteen insects were involved in postharvest mango diseases. Then suggests some possible rules & conditions which can reduce postharvest infections (PEST RISK ANALYSIS OF MANGO IN BANGLADESH [Development Technical Consultants Pvt. Ltd. (DTCL)],2015). A huge amount of mango is demolished because of insects and other outbreaks and a lack of post-harvesting knowledge. The implementation of supply chain risk management practices within the Agri-fresh supply chain can generate added value to the products and significantly improve overall productivity (Umair et al.,2020). The analysis indicates that risk management has a significant and positive impact on quality performance (Mohan et al., 2023). To effectively address risk and uncertainty, (Avinash et al.,2012) introduce a risk index that allows for the quantification and assessment of risk within the supply chain. To limit the effect of developing risks, it is critical to identify priority issues that require immediate attention for additional risk mitigation steps (Dwi et al.,2022). Surya et al., 2017 identified four major risk categories: environmental risks, supply risks, demand risks, and process risks.In a research Merveg et al.,2022 identifird the key drivers of spoilage within the context of the study and explore how these insights can be effectively leveraged to mitigate and reduce spoilage occurrences. In a paper by, Kent D. et al., 1991 present a comprehensive framework for classifying the uncertainties encountered by internationally operating firms. (Kassa et al.,2022)(Saurav et al.,2019) evaluate the postharvest losses occurring along the mango value chain while identifying the challenges encountered by actors and stakeholders involved in the process. To achieve the three pillars of sustainability: minimizing total network costs and carbon dioxide emissions related to various network activities while simultaneously maximizing responsiveness to demands (Younis et al.,2020), focused on a closed-loop supply chain (CLSC).

Nadim et al.,(2022) identify possible potential risk mitigation strategies and their sustainability in the long run. The challenge of minimizing transmission time within the supply chain network of perishable products(Jouzdani et al.,2022) addresses a model that incorporates combined transport methods under conditions of uncertainty.(Jouzdani et al.,2022) introduce a novel methodology aimed at creating a resilient logistics plan capable of mitigating demand uncertainty in humanitarian relief supply chains. (Md. Abu et al.,2018) evaluate the potato sector's inventory system in Bangladesh, aiming to identify key solutions for reducing postharvest losses and ensuring fair prices to farmers, thereby motivating increased cultivation. (Md. Abu et al.,2018) (Feng et al.,2021) employ neural network technology to assess the risks associated with the supply chain of fresh grapes. (Min yu et al.,2012) created an integrated network-based food supply chain model that includes perishability, competition, fresh product, and food safety factors. The model uses the arc factors and applies simple computation methods to enhance both accuracy and effectiveness. (Xiuquan et al.,2019) delve into the risk propagation mechanisms prevalent in perishable products supply chains and also propose viable countermeasures to enhance sustainability within these supply chains.

A multi-objective mathematical programming model is devised by (Jaigirdara et al., 2021) to optimize various aspects of supply chain operations, including cost, energy consumption, and traffic congestion. (Md. Sabbir et al.,2022) have proposed a best-worst method (BWM) as a framework to assess the environmental criteria for sustainability of food industries in over the world. (Martin et al.,2013) review and explore the application of Multi-Criteria Decision Making (MCDM) methods in complex decision-making domains, aiming to identify the most robust and effective approaches to select the best alternatives. The goal is to enhance the efficiency and sustainability of the supply chain system.

In order to highlight the best solution based on the given criteria, (Aarushi et al.,2014) summarized three efficient techniques of Multiple Criteria Decision Making (MCDM): the WSM (Weighted Sum Method), AHP (Analytic Hierarchy Process), and TOPSIS (Technique for Ordered Preference). These techniques aid in the optimal selection process and offer valuable insights for decision-making. To identify barriers to supply chain resilience (SCR) in Bangladeshi manufacturing. It uses ISM and MICMAC to guide managers and policymakers in overcoming obstacles and enhancing SCR. (S. M. Sohaeb et al.,2022)employ the Analytic Hierarchy Process (AHP) to identify the optimal location for establishing a super shop in different regions of Bangladesh with a focus on maximizing profits and customer response (M. Ilankumaran et al.,2014) combines the Analytic Network Process (ANP) with a linguistic fuzzy approach, providing a comprehensive and innovative method for assessment.

(V. Raab et al.,2013) introduce a comprehensive process model that outlines how the quality management tool "Failure Mode and Effects Analysis" (FMEA) can be applied to implement preventive measures in the international food trade. (Ali et al.,2012) developed a model that utilizes Interpretive Structural Modeling (ISM) to analyze different risks present in a food supply chain. These risks are classified into five categories, and the paper explores strategies for risk mitigation. A decision framework combining Integrated Interpretive Structural Modelling (ISM) and Analytic Network Process (ANP) has been developed to identify and represent the main challenges to sustainability in PFSCs.(Kumar et al.,2020) (Ebru et al.,2021)use a mixed-method approach to determine, categorize, and prioritize logistics-related factors that significantly contribute to food loss in the fruit and vegetable supply chain.(Emmanuel et al.,2015) The study combines the Failure-Mode and Effect-Analysis (FMEA) framework with the Pareto analytical model to evaluate potential risk (Naim et al.,2021), develop Smart ISM software for effective ISM implementation, assess ISM applications across domains, and enhance modeling interrelationships among variables, leading to informed and effective use of ISM (Kajal et al.,2016)extends TOPSIS to handle uncertainty, validated in the Electronics. This research will improve the risk management of the fresh mango (also perishable fruits) supply chain by using MCDM methodologies, ISM for risk assessment, and TOPSIS for mitigation options evaluation.

## 3 Methodology

This phase introduces the research methodology of risk analysis in the Mango Fruit Supply Chain system (MFSC) and uses two major methods by which linkage risks are identified, and relevant solutions can be designed. Faisal et al. (2006) and Anish Kumar et al. (2020) stated that the majority of research uses ISM to determine hierarchy (levels) and interdependence (Faisal et al., 2006) (Kumar et al.,2020). Researchers' emphasis on using the results of ISM implementation for assessing the efficacy of risk and mitigation techniques is restricted (Prakash et al.,2015). Due to its adaptability, capacity to handle a variety of variables, impartiality, evaluation of trade-offs, and versatility, the TOPSIS technique is crucial for selection. TOPSIS equips decision-makers to act effectively in difficult decision situations by offering a methodical and well-researched framework for decision-making (Zavadskas et al., 2016). This paper covers a methodology based on the Implementation of the Interpretive Structural Model (ISM) and TOPSIS in MFSCs. This paper analyzed the qualitative measures and found the best strategy to mitigate the linkage risks in MFSCs, which are covered in this chapter. Risk management in the mango fruit supply chain is crucial to guarantee a consistent and dependable flow of mangoes from farm to market, maintain product quality, and protect the reputation and financial success of all involved parties. By enabling the supply chain to adjust to uncertainties and difficulties, proactive risk management promotes sustainable business practices and customer satisfaction.

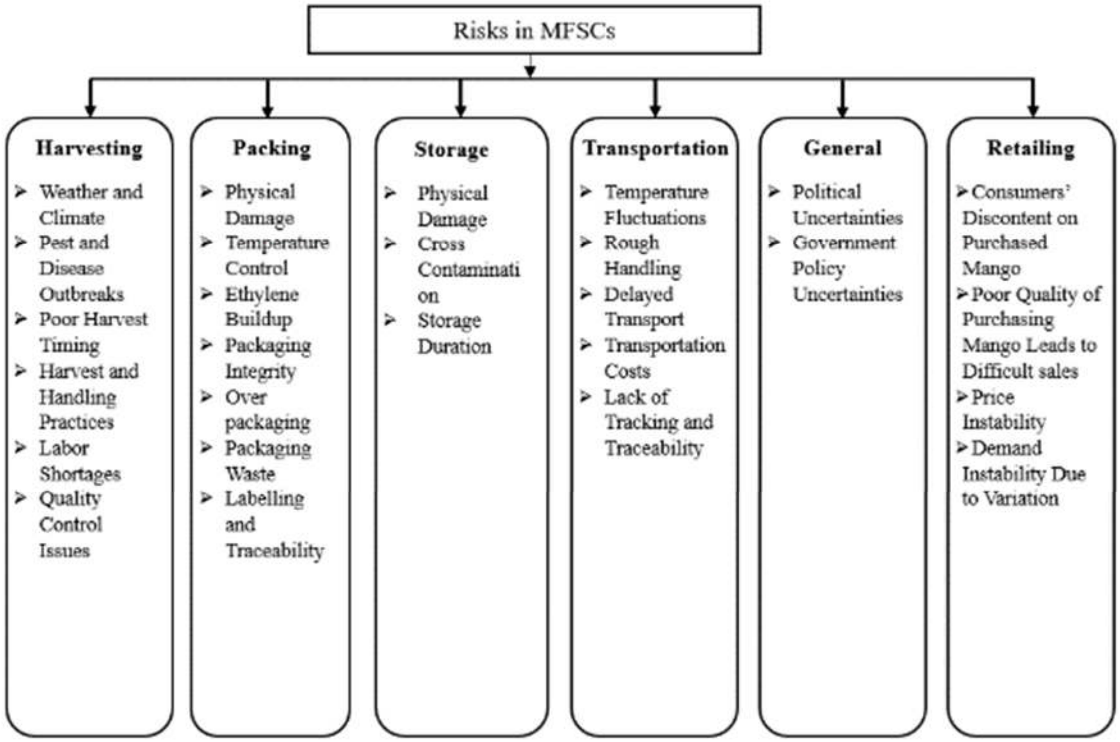



Figure 1: Classification of risk scheme and risk found in each field of MFSCs

*3.1 Stages Involved in the Research*

The study is divided into five phases with the goal of identifying and reducing risks in mango fruit supply networks. In Stage 1, a local survey of mango farmers was carried out to determine and catalog possible risks in the supply chains. Stage 2 required the gathering of data and the creation of contextual linkages, followed by the creation of the SSIM to comprehend how the risks are interdependent. After creating the reachability matrix, MICMAC was used to divide risks into several levels for further investigation. In Stage 3, a final model was built, connection risks were determined, and significant areas of concern were highlighted. The MCDM technique was utilized to develop effective mitigation solutions at stage 4. The TOPSIS technique was used to prioritize the methods in mitigation plans, which in turn helped identify the best approach for mitigating linkage risks. The study findings were then carefully examined and debated in Stage 5, leading to insightful conclusions and consequences for the supply chains for mango fruit. The study offered a thorough and methodical approach to comprehending, dealing with, and managing risks, offering insightful contributions to the area and prospective advantages for the sector.

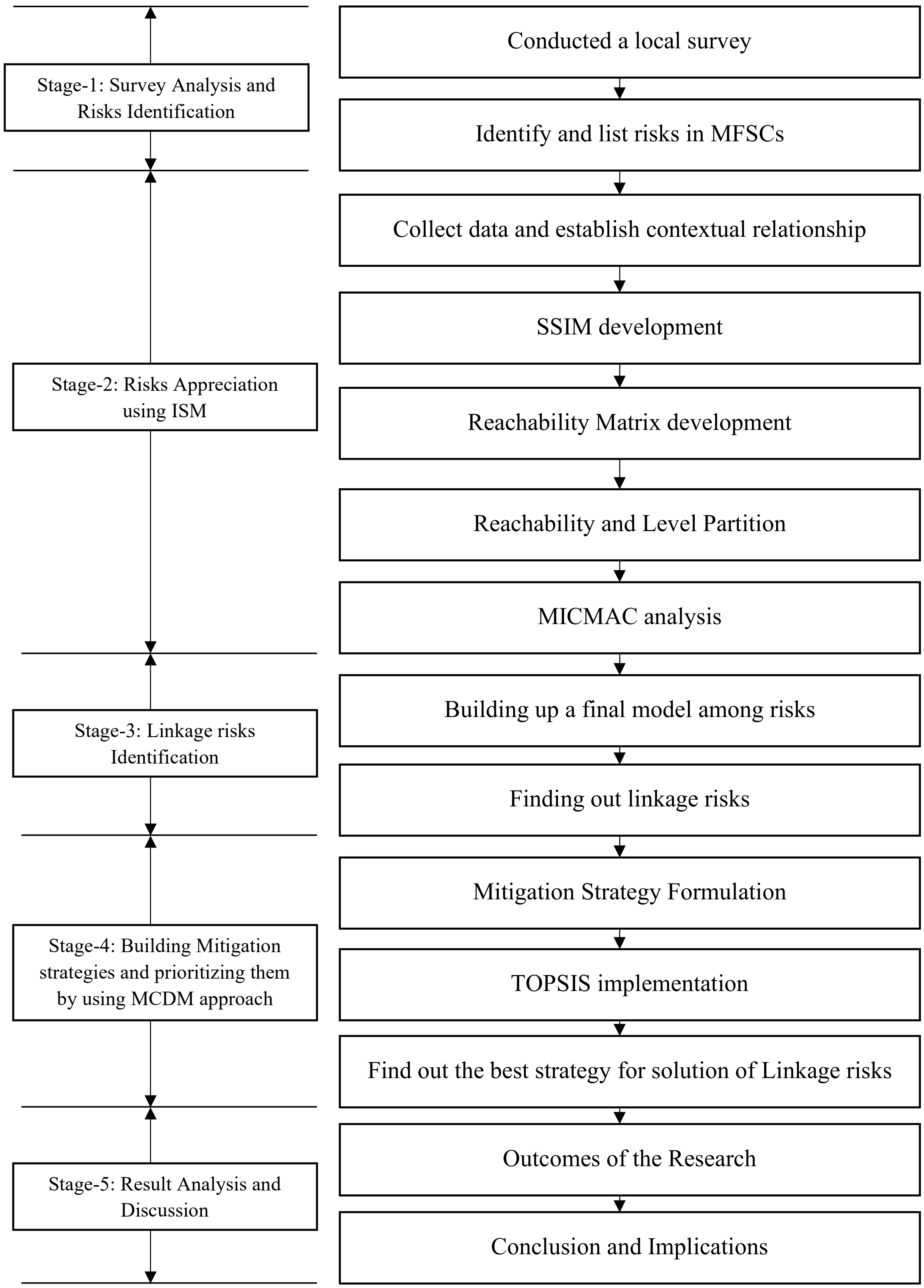

Stage-1: Survey Analysis and Risks Identification
Stage-2: Risks Appreciation using ISM
Stage-3: Linkage risks Identification
Stage-4: Building Mitigation strategies and prioritizing them by using MCDM approach
Stage-5: Result Analysis and Discussion
Conducted a local survey
Identify and list risks in MFSCs
Collect data and establish contextual relationship
SSIM development
Reachability Matrix development
Reachability and Level Partition
MICMAC analysis
Building up a final model among risks
Finding out linkage risks
Mitigation Strategy Formulation
TOPSIS implementation
Find out the best strategy for solution of Linkage risks
Outcomes of the Research
Conclusion and Implications

Figure 2: Flow Diagram of this Methodology

*3.2 Interpretive Structure Model (ISM) Procedures*

The ISM model is a useful tool for determining and enforcing the links between particular system components. The following lists the stages that make up the ISM methodology.

STEP 1: Process of Creating the Adjacency Matrix

The adjacency matrix is used to determine if two nearby factors are connected. Each influencing factor is represented by, the adjacency matrix's members are chosen in line with the Equation, and the adjacency matrix itself is created. The indicated contributing factors' interrelation is therefore assessed.

$$X = A_{if} = \{1, \text{ when } A_i \text{ has an effect on } A_j$$

$$0 \text{ when } A_i \text{ has no effect on } A_j\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

STEP 2: Identifying the reachable matrix

The reachability matrix is made up of any connections between any two items and any path. Based on the existing adjacency matrix, Equation (2) may be utilized to build the reachability matrix.

$$R = (M+1)^{n+1} = (M+1)^n \neq (M+1)^{n-1} \neq \ldots\ldots (M+1)^2 \neq (M+1) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

STEP 3: Addressing the Hierarchy of Connections

This step shows how composition connections between knowledge units in a structure are represented using hierarchical-directed graphs. Both the previous set and the reachable set must be calculated, and this is where the reachable matrix comes into play. Equation(3) is utilized to discover components present at the highest level in order to establish the level of each knowledge element or its hierarchical distribution. The accessible matrix is then modified by removing appropriate rows and columns to create a new matrix, which is then further examined using Equation (2). The system's elements' hierarchical character is established through this procedure, which also makes it easier to see how they relate to one another.

$$L = \{(A_i) \mid\mid P(A_i)\ Q(A_i) = P(A_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

STEP 4: Modeling Structural Systems

The steps for creating a schematic diagram of a multi-level recursive structure are described in this stage. By utilizing directed edges to link nearby levels and factors on the same level, the diagram is constructed depending on the order of the elements. Using this method, a full model of the recursive structure of the associated elements may be built, revealing the system's hierarchical structure and relationships.

*3.3 Introduction to Multi-Criteria-Decision-Making (MCDM) Methods*

Multi-Criteria Decision Making is concerned with structuring and resolving planning and decision-making issues using several criteria. When there are several criteria for alternatives, MCDM (Multi-Criteria Decision Making) gets difficult. A collection of non-dominated solutions is employed rather than a single optimal solution. Non-dominated solutions are the better options since no other solution can outperform them in all criteria without compromising at least one criterion. The collection of non-dominated solutions, however, can be too big for actual usage. Decision-makers can use a variety of MCDM techniques to select the optimal choice by taking into account many different factors. Figure 3 shows these techniques in a hierarchical view. In conclusion, MCDM offers useful tools for navigating difficult decision-making situations and assisting decision-makers in making well-informed decisions.

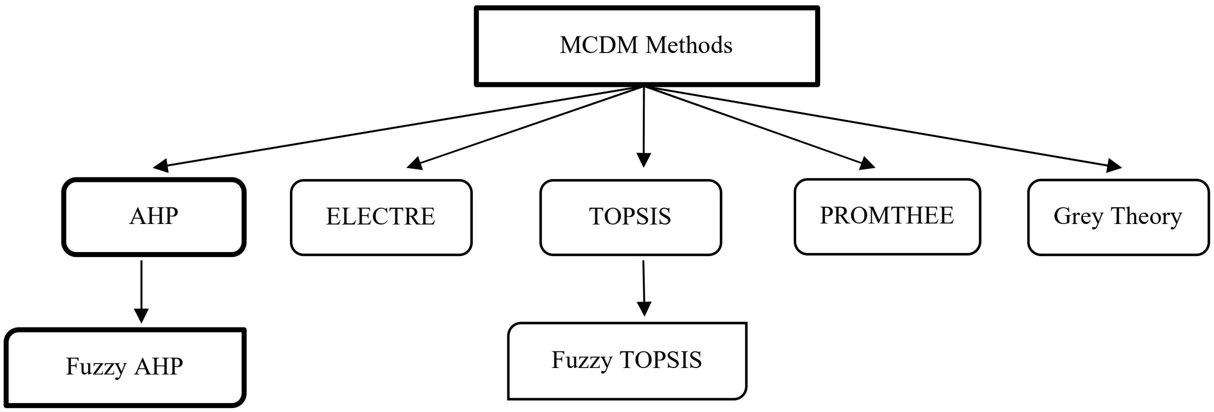
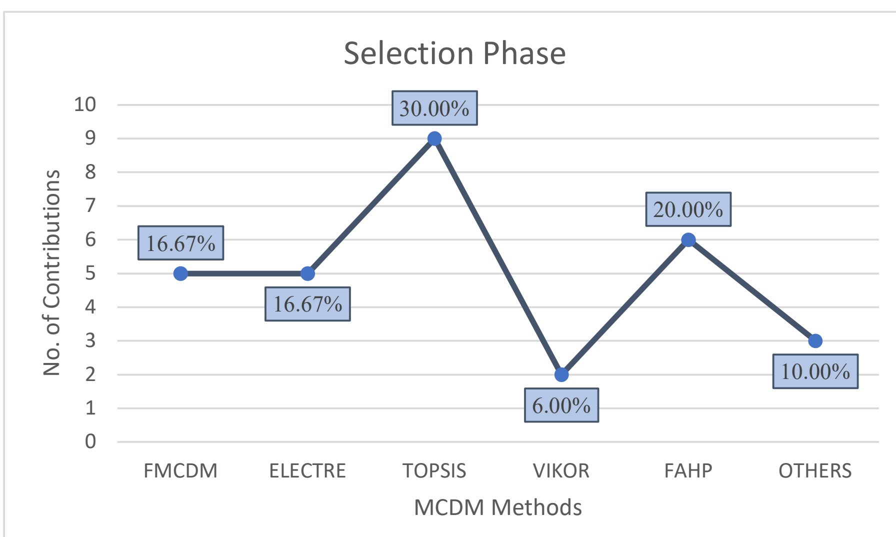



Figure 3: Methods Hierarchy of MCDM

*3.5 Selection of MCDM Technique*

Table 1: MCDM methods and its Contributions (Aruldoss et. al.,2013)

| SI No. | MCDM Methods | Contributions |
|---|---|---|
| 1 | FMCDM | 5 |
| 2 | ELECTRE | 5 |
| 3 | TOPSIS | 9 |
| 4 | VIKOR | 2 |
| 5 | FAHP | 6 |



| | | |
|---|---|---|
| 6 | OTHERS | 3 |

Figure 4: MCDM Methods and its Contributions (Aruldoss et. al.,2013)

The data depicts an overview of the contributions made by several Multi-Criteria Decision Making (MCDM) techniques. It lists the methods' names along with how many contributions to the field they have made overall. ELECTRE and FMCDM both make five(16.67%) contributions. With nine(30.00%) contributions, TOPSIS stands out, highlighting its importance as a commonly applied technique for evaluating alternatives based on resemblance to ideal solutions. VIKOR has two(6.00%) contributions, but FAHP, an AHP extension with fuzzy logic, has six(20.00%). Three(10.00%) contributions total for further MCDM approaches are included in the "OTHERS" category. The results as a whole emphasize the varied contributions of different MCDM approaches, highlighting the significance of these methods in supporting decision-makers in complicated scenarios with many criteria.

As TOPSIS leads a high contribution so for the research purpose TOPSIS is used as an MCDM approach for selecting high-performance mitigation strategies.

*3.6 TOPSIS Methodology*

In multi-criteria decision-making (MCDM), the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) technique is a well-liked approach to ranking and selecting alternatives. The separation in a multidimensional space between each option and both the ideal and worst solutions is measured in this method. The ideal solution represents the highest performance for each criterion, whereas the worst solution represents the lowest performance. The relative proximity score for each alternative is calculated by TOPSIS based on the separation between it and the ideal and non-ideal alternatives. The optimal choice is the one with the highest proximity rating. This method helps decision-makers in a range of industries make well-informed judgments by objectively ranking and selecting the best possibilities, which is especially useful when there are multiple considerations to take into account.

The algorithm for the TOPSIS method is given below,

Step 1: By using the alternatives m and criteria n we calculate the normalized values ($R_{ij}$)

$$R_{ij} = \frac{A_{ij}}{\sqrt{\sum_{i=1}^{m} A_{ij}^2}} \quad i=1,2,3,\ldots\ldots m,\ j=1,2,\ldots.n \qquad (1)$$

Step 2: The normalized values can be obtained by giving weights to the criteria ($V_{ij}$)

$$V_{ij}= W_j * A_{ij},\ \ i=1,2,3,\ldots\ldots m,\ j=1,2,\ldots.n \qquad (2)$$

Step 3: The best performance ( $s^+$ ) and worst performance ($s^-$ ) for every ideal alternative is determined.

$$s^+ = \{v_{1j},v_{2j},v_{3j},\ldots..,v_{mj}\}=\{\max v_{ij} \text{ for } \forall j \in n\} \qquad (3)$$

$$s^- = \{v_{1j},v_{2j},v_{3j},\ldots..,v_{mj}\}=\{\min v_{ij} \text{ for } \forall j \in n\} \qquad (4)$$

Step 4: For all the criteria, every alternatives distance to the best alternative ( $D_i^+$ ) using Equation (3) and the worst alternative ( $D_i^-$ ) using (4)

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^+)^2} \quad \text{for i=1,2,.......m} \qquad (5)$$

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^-)^2} \quad \text{for i=1,2,.......m} \qquad (6)$$

Step 5: The positive ideal solution ($C_i$) is calculated using Equation (5) and (6).

$$C_i = \frac{D_i^-}{D_i^- + D_i^+} \quad \text{i=1,2, .......m and } 0 \leq Ci \leq 1 \qquad (7)$$

The biggest ($C_i$) value is chosen as the best selection and solution for the MDCM problem is obtained through TOPSIS.

**4 Data Collection and Analysis**

This phase mostly emphasizes the variable's collected value, which will be used to conduct the quantitative analysis of the research. The purpose of this research is to address the critical Issue of supply chain volatility in the context of mango production and distribution. Data is collected in the context of risk analysis and mitigation, as outlined in earlier steps.

*4.1 Source and Type of Data*

Most of the data used and collected for this study is from primary sources. This research was conducted by questioning and surveying several entities related to the mango supply chain in the Chapainawabganj district in Bangladesh. Mitigation strategies were collected from both primary and secondary sources. Several farmers, wholesalers, and transporters were questioned in order to identify important risks and mitigation strategies. Several mango stores were polled to get information on mango waste. Secondary data were gathered through a survey of the literature. Then, important issues and mitigation methods were identified using both primary and secondary data.

*4.2 Risk Identification and Analysis*

Risks are identified depending on the different stages of the supply chain of mangoes.

4.2.1 Risks Identification

Table 2: Risks to sustainability in MFSCs

| Risks/Challenges/Cause | Implied Meaning |
|---|---|
| **RH-1**: Weather and Climate | Risks associated with unfavorable weather and climatic trends that impact mango availability and output. |
| **RH-2**: Pest and Disease Outbreaks | Risks connected to the spread of diseases and pests that can harm mango crops. |
| **RH-3**: Poor Harvest Timing | Mango harvesting should be done as soon as possible to avoid risks that might affect quality and availability. |

| | |
|---|---|
| **RH-4**: Harvest and Handling Practices | Risks related to incorrect harvesting and handling techniques that may have an impact on mango quality and shelf life. |
| **RH-5**: Labor Shortages | Risks related to labor availability that have an influence on harvest and supply activities. |
| **RH-6**: Quality Control Issues | Risks associated with difficulties in ensuring constant mango quality along the supply chain. |
| **RP-1**: Physical Damage | Risks of handling and transportation-related physical harm to mangoes. |
| **RP-2**: Uncontrolled Temperature | Temperature-related risks that may impact mango quality and shelf life. |
| **RP-3**: Ethylene Buildup | Mango spoiling and early ripening risks due to ethylene accumulation. |
| **RP-4**: Packaging Integrity | Mangoes may be damaged or contaminated as a result of packing risks. |
| **RP-5**: Over-packaging | Risks associated with excessive packaging, which can raise expenses and raise questions about the environment. |
| **RP-6**: Packaging waste | Risks related to the waste packaging production in the mango supply chain. |
| **RP-7**: Labeling and Traceability | Risks associated with inaccurate labeling and traceability, which have an impact on the methods used to identify and recall products. |
| **RS-1**: Physical Damage | Physical damage risks that might result in quality decline during storage. |
| **RS-2**: Cross-Contamination | Mango cross-contamination risks during storage that might compromise the quality of the product. |
| **RS-3**: Storage Duration | Long-term storage risks that degrade mango flavor and freshness. |
| **RT-1**: Temperature Fluctuations | Mango quality risks resulting from temperature changes during transportation. |
| **RT-2**: Rough Handling | Risks associated with harsh handling during shipping that might result in physical harm. |
| **RT-3**: Delayed Transport | Risks of transportation delays impacting the timely supply of fresh mangoes. |
| **RT-4**: Transportation Costs | Risks associated with changing transportation prices having an influence on supply chain costs. |

| | |
|---|---|
| **RT-5**: Lack of Tracking and Traceability | Risks related to the mango supply chain's lack of efficient tracking and traceability methods. |
| **RGPU-1**: Political Uncertainties | Political risks can have an impact on mango regulations and trade. |
| **RGPU-2**: Government Policy Uncertainties' | Government policy risks can have an impact on the mango supply chain. |
| **RR-1**: Consumers' discontent with purchased mango | Risks brought on by customers being dissatisfied with mango purchases. |
| **RR-2**: Poor quality of purchasing mango leads to difficult sales | The challenge of selling low-quality mangoes creates risks. |
| **RR-3**: Price Instability | Risks related to price swings that might affect mango sales and profitability. |
| **RR-4**: Demand Instability due to Variation | Risks resulting from changes in mango demand that have an impact on supply chain planning and sales. |

Table 3: Data of Wastage in the Hierarchy of Risk

| Field | Risk | Wastage Per 100 Unit | Sources | Data Type |
|---|---|---|---|---|
| Harvesting | RH-1 | 20 | • Farmers<br>• Garden owner<br>• Vendors | Primary |
| | RH-2 | 40 | | |
| | RH-3 | 50 | | |
| | RH-4 | 40 | | |
| | RH-5 | 30 | | |
| | RH-6 | 57 | | |
| Packaging | RP-1 | 30 | • Day laborer<br>• Farmer | Primary |
| | RP-2 | 40 | | |
| | RP-3 | 35 | | |
| | RP-4 | 06 | | |
| | RP-5 | 09 | | |
| | RP-6 | 05 | | |
| | RP-7 | 37 | | |
| Storage | RS-1 | 20 | • Labors<br>• Local Inventory Management Personnel. | Primary |
| | RS-2 | 15 | | |
| | RS-3 | 38 | | |
| Transportation | RT-1 | 38 | • Driver<br>• Labors<br>• Vehicle helper<br>• Courier Services | Primary |
| | RT-2 | 15 | | |
| | RT-3 | 45 | | |
| | RT-4 | BDT. 340 | | |
| | RT-5 | 25 | | |
| General | RGPU-1 | (Considerable) | | Secondary |

| | | | | |
|---|---|---|---|---|
| | RGPU-2 | (Considerable) | • (Miller et al.,1992) | |
| Retailer | RR-1 | 10 | • Garden owner<br>• Wholesaler<br>• Local Vendors | Primary |
| | RR-2 | 25 | | |
| | RR-3 | 14 | | |
| | RR-4 | 08 | | |

4.2.2 Risk Analysis Through ISM

The SSIM incorporates a contextual model of the interaction between various risks, shown in Table 4. The attributes (V, A, X, and O) are used to illustrate the different contextual relationships, and their individual meanings are as follows:

V—Issue (i) is achieved by Issue (j), but not vice versa.

A—Issue (j) is achieved by Issue (i), but not vice versa.

X—Issue (i) and Issue (j) variables influence each other

O—Issue (i) and Issue (j) variables have no relationships

Table 4: Structural Self-Interaction Matrix (SSIM)

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RH-1:Weather and Climate | | O | A | A | O | A | A | A | A | O | O | O | O | A | O | O | A | O | A | A | O | O | O | O | O | A | O |
| RH-2:Pest and Disease Outbreaks | | | V | X | O | A | A | O | O | O | O | O | O | A | A | O | O | O | O | O | O | O | O | O | A | A | O |
| RH-3:Poor Harvest Timing | | | | X | A | A | A | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | A | O |
| RH-4:Harvest and Handling Practices | | | | | V | A | A | O | O | O | O | A | O | A | O | A | O | A | A | O | O | O | O | O | O | A | O |
| RH-5:Labor Shortages | | | | | | A | O | O | O | O | O | O | O | O | O | O | O | A | O | O | O | V | O | O | O | O | O |
| RH-6:Quality Control Issues | | | | | | | X | V | V | V | V | A | O | A | V | V | V | V | V | O | O | O | O | A | A | A | O |
| RP-1:Physical Damage | | | | | | | | V | V | V | V | A | O | A | X | V | V | V | V | A | O | O | O | A | A | A | O |
| RP-2:Uncontrolled temperature | | | | | | | | | A | O | V | A | O | A | O | O | X | O | O | O | O | O | O | A | A | A | O |
| RP-3:Ethylene Buildup | | | | | | | | | | O | V | A | O | A | X | V | X | O | O | O | O | O | O | A | A | A | O |
| RP-4:Packaging Integrity | | | | | | | | | | | X | A | A | A | A | O | O | V | O | O | O | O | O | O | A | A | O |
| RP-5:Over-packaging | | | | | | | | | | | | A | O | A | O | O | A | O | O | O | O | O | O | O | A | A | O |
| RP-6:Packaging waste | | | | | | | | | | | | | O | X | V | V | V | V | V | O | O | V | V | O | A | A | O |
| RP-7:Labeling and Traceability | | | | | | | | | | | | | | O | O | O | O | O | O | O | O | O | O | O | A | O | O |
| RS-1:Physical Damage | | | | | | | | | | | | | | | X | V | O | V | O | O | O | V | O | A | A | A | O |
| RS-2:Cross-Contamination | | | | | | | | | | | | | | | | O | A | O | O | O | O | O | O | A | A | O | O |
| RS-3:Storage Duration | | | | | | | | | | | | | | | | | A | O | A | A | O | V | V | O | A | A | A |
| RT-1:Temperature Fluctuations | | | | | | | | | | | | | | | | | | O | O | O | O | O | O | O | A | O | O |
| RT-2:Rough Handling | | | | | | | | | | | | | | | | | | | O | O | O | O | O | A | A | O | O |
| RT-3:Delayed Transport | | | | | | | | | | | | | | | | | | | | X | O | V | V | A | A | A | O |
| RT-4:Transportation Costs | | | | | | | | | | | | | | | | | | | | | A | V | V | A | O | X | O |
| RT-5:Lack of Tracking and Traceability | | | | | | | | | | | | | | | | | | | | | | O | O | O | O | O | O |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RGPU-1:Political Uncertainties | | | | | | | | | | | | | | | | | | | | | | | A | A | A | A | O |
| RGPU-2:Government Policy Uncertainties | | | | | | | | | | | | | | | | | | | | | | | | O | A | A | O |
| RR-1:Consumers' discontent on purchased mango | | | | | | | | | | | | | | | | | | | | | | | | | A | V | V |
| RR-2:Poor quality of purchasing mango leads to difficult sales | | | | | | | | | | | | | | | | | | | | | | | | | | X | V |
| RR-3:Price Instability | | | | | | | | | | | | | | | | | | | | | | | | | | | X |
| RR-4:Demand Instability due to Variation | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 5: Final Reachability Matrix

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | Driving Power |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 | 1* | 1 | 1 | 1 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 6 |
| 3 | 1 | 1* | 1 | 1 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 6 |
| 4 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 6 |
| 5 | 1* | 1* | 1 | 1* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 6 |
| 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1* | 1* | 1 | 1 | 1 | 1 | 1 | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 7 | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1* | 1* | 1 | 1 | 1 | 1 | 1 | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 8 | 1 | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1 | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 9 | 1 | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1 | 1* | 1 | 1* | 1* | 1* | 1 | 1 | 1 | 1* | 1* | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 10 | 1* | 1* | 1* | 1* | 1* | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 9 |
| 11 | 1* | 1* | 1* | 1* | 1* | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 9 |
| 12 | 1* | 1* | 1* | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 0 | 1 | 1 | 1* | 1* | 1* | 1* | 26 |
| 13 | 1* | 1* | 1* | 1* | 1* | 0 | 0 | 0 | 0 | 1 | 1* | 0 | 1 | 0 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 10 |
| 14 | 1 | 1 | 1* | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1* | 1 | 1* | 1* | 0 | 1 | 1* | 1* | 1* | 1* | 1* | 26 |
| 15 | 1* | 1 | 1* | 1* | 1* | 1* | 1 | 1* | 1 | 1 | 1* | 1* | 1* | 1 | 1 | 1* | 1* | 1* | 1* | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 16 | 1* | 1* | 1* | 1 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 8 |
| 17 | 1 | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1 | 1* | 1 | 1* | 1* | 1* | 1 | 1 | 1 | 1* | 1* | 1* | 0 | 1* | 1* | 1* | 1* | 1* | 1* | 26 |
| 18 | 1* | 1* | 1* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 7 |
| 19 | 1 | 1* | 1* | 1 | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1 | 1 | 0 | 1 | 1 | 1* | 1* | 1* | 1* | 26 |
| 20 | 1 | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1 | 1 | 0 | 1 | 1 | 1* | 1* | 1 | 1* | 26 |
| 21 | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 27 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| 24 | 1* | 1* | 1* | 1* | 1* | 1 | 1 | 1 | 1 | 1* | 1* | 1* | 1* | 1 | 1 | 1* | 1* | 1 | 1 | 1 | 0 | 1 | 1* | 1 | 1* | 1 | 1 | 26 |
| 25 | 1* | 1 | 1* | 1* | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 26 |
| 26 | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1 | 1* | 1 | 1* | 1* | 1 | 1 | 0 | 1 | 1 | 1* | 1 | 1 | 1 | 26 |
| 27 | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1* | 1 | 1* | 1* | 1* | 1* | 0 | 1* | 1* | 1* | 1* | 1 | 1 | 26 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dependence power | 25 | 24 | 24 | 24 | 24 | 15 | 15 | 15 | 15 | 18 | 18 | 15 | 16 | 15 | 15 | 16 | 15 | 19 | 15 | 15 | 1 | 26 | 17 | 15 | 15 | 15 | 15 | 25 |

The changes due to the transitivity rule are shown by 1*

**Level Partitioning (LP)**

Table 6. Levels of supply chain risks

| Elements (Mi) | Reachability Set R(Mi) | Antecedent Set A(Ni) | Intersection Set R(Mi)∩A(Ni) | Level |
|---|---|---|---|---|
| 1 | 1, | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,17, 18, 19, 20, 21, 24, 25, 26, 27, | 1, | 1 |
| 2 | 2,3,4,5, | 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,18, 19, 20, 21, 24, 25, 26, 27, | 2,3,4,5, | 2 |
| 3 | 2,3,4,5, | 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, 27, | 2,3,4,5, | 2 |
| 4 | 2,3,4,5, | 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, 27, | 2,3,4,5, | 2 |
| 5 | 2,3,4,5, | 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, 27, | 2,3,4,5, | 2 |
| 6 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 7 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 8 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 9 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 10 | 10,11, | 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 10,11, | 4 |
| 11 | 10,11, | 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 10,11, | 4 |

| | | | | |
|---|---|---|---|---|
| 12 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 13 | 13, | 6, 7, 8, 9, 12, 13, 14, 15, 17, 19, 20, 21, 24, 25, 26,27, | 13, | 5 |
| 14 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 15 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 16 | 16, | 6, 7, 8, 9, 12, 14, 15, 16, 17, 19, 20, 21, 24, 25, 26, 27, | 16, | 3 |
| 17 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 18 | 18, | 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 24, 25, 26, 27, | 18, | 3 |
| 19 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 20 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 21 | 21, | 21, | 21, | 7 |
| 22 | 22, | 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, | 22, | 1 |
| 23 | 23, | 6, 7, 8, 9, 12, 14, 15, 16, 17, 19, 20, 21, 23, 24, 25, 26, 27, | 23, | 2 |
| 24 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 25 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |
| 26 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |

| | | | | |
|---|---|---|---|---|
| 27 | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 21, 24, 25, 26, 27, | 6, 7, 8, 9, 12, 14, 15, 17, 19, 20, 24, 25, 26, 27, | 6 |

**MICMAC Analysis**

The MICMAC analysis is used to validate ISM findings. Four categories are used in the study to group the risks: independent, linkage, dependent and autonomous. The driving and dependence of risks, as found in Table 4, is used for MICMAC analysis. A lack of Tracking and Traceability (RT-5) is identified in the independent region. They have high driving and low dependence. Weather and Climate (RH-1), Pest and Disease Outbreaks (RH-2),Poor Harvest Timing (RH-3), Harvest and Handling Practices (RH-4), Labor Shortages (RH-5), Packaging Integrity (RP-4), Overpackaging (RP-5), Labelling and Traceability (RP-7), Storage Duration (RS-3), Rough Handling (RT-2), Political Uncertainties (RGPU-1) and Government Policy Uncertainties (RGPU-2) are identified in the dependent region and may be interpreted as "output risks" indicating poor sustainability in MFSCs. Quality Control Issues(RH-6), Physical Damage(RP-1),Uncontrollable Temperature (RP-2),Ethylene Buildup(RP-3), Packaging Waste(RP-6),Physical Damage(RS-1),Cross Contamination(RS-2),Temperature Fluctuations(RT-1),Delayed Transport (RT-3),Transportation Costs(RT-4), Consumers' discontent on purchased mango(RR-1),Poor quality of purchasing mango leads to difficult sales(RR-2), Price Instability(RR-3) and Demand Instability due to variation(RR-4) are identified in the linkage region.

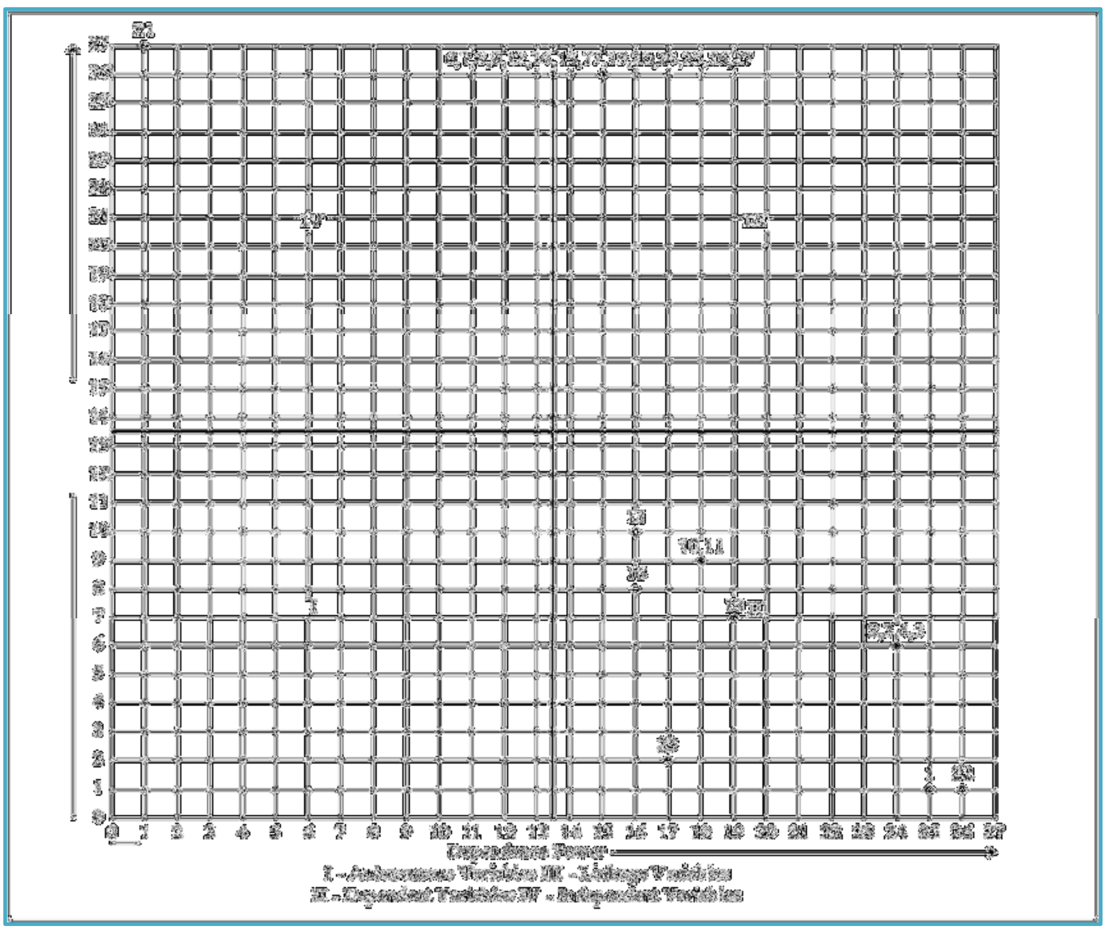



Figure 5: Graph of risks groups

**Final Model**

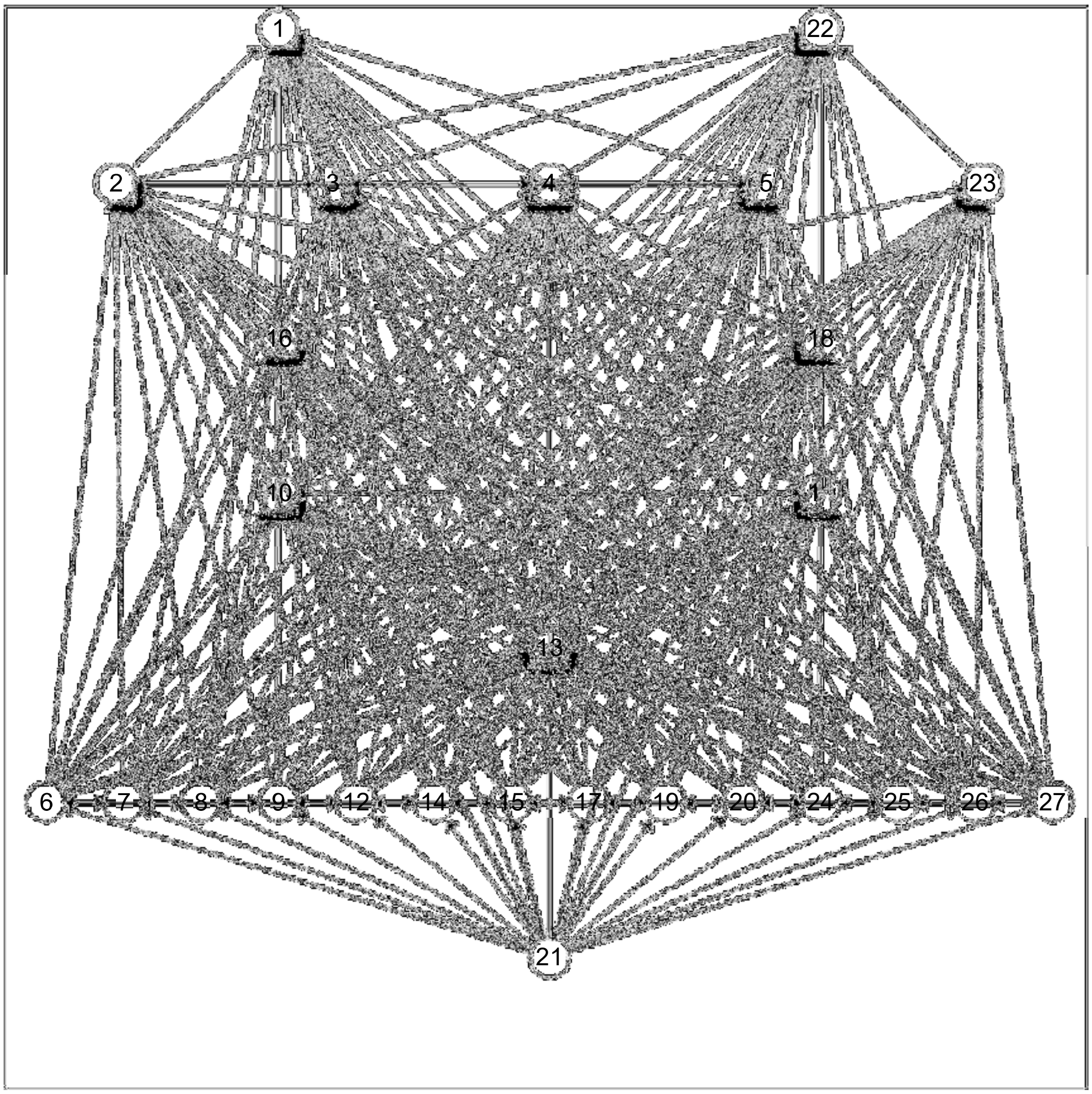



Figure 6. Interpretive Structure Modelling (ISM) model for risks in MFSCs

4.3 Identification of Mitigation Strategies

| Mitigation Strategy | Purpose of the strategy |
|---|---|
| **SH-1**: Variety-wise in time Harvesting. | Mango species have varying life spans. |
| **SH-2**: Use appropriate harvesting devices. | Reduce Mechanical damage. |
| **SH-3**: After picking, wash mango sap as early as possible. | Decrease perishability. |
| **SH-4**: Harvest in cool weather, especially morning or afternoon. | Improve quality. |
| **SH-5**: Trained the workforce for Harvesting. | Improving process. |

Through the analysis of the final model, it was clear which risks created a vital issue for the overall supply chain. By concerning those risks, this research builds up some strategies for each field to create more sustainability in MFSCs.

4.4 Mitigation strategy for each field

Table 7. Mitigation Strategies to Prevent Harvesting related risk

Table 8. Mitigation Strategies to Prevent Packaging-related Risk

| Strategy | Purpose of Strategy |
|---|---|
| **SP-1**: Proper packing material with ethylene absorbing properties. | Use shock-absorbing materials such as bubble wrap or foam. Activated carbon is also used to help lower the quantity of ethylene in the air. |
| **SP-2**:Modified atmosphere packaging(MAP). (Truong et al.,2022) | MAP refers to the introduction of high $CO_2$ and low $O_2$ surrounding fruit inside the packaging. Because of the high $CO_2$ and reduced $O_2$ levels, MAP retards fruit ripening. |
| **SP-3**: Fresh produce packaging | To ensure there is no 'shrinkage,' food inventory is FIFO (First in, First out) managed, and expiring inventory is always monitored. |

| | |
|---|---|
| **SP-4**: Considerations in the use of plastic crates (Postharvest management of mango for quality and safety assurance [FAO], 2018) | Plastic carets are more robust for mangoes, reducing overpackaging and physical damage. |
| **SP-5**: Use a traceability system to track the mangoes from the farm to the consumer. | System or Software like TraceOn, Traceability, MangoTrace, Jolt, etc. |
| **SP-6**: Pre-Quality Control to Prevent Mix-up | Initial checking may be obtained to avoid other fruits from becoming mixed up with the mangoes. |

Table 9. Mitigation Strategies to Reduce Storage-Related Risk

| Strategy | Purpose of the strategy |
|---|---|
| **SS-1**: Handling Guidelines | Reduce the possibility of accidents and damage. |
| **SS-2**: Quality Control | Assist in identifying defective goods early on, reducing future problems. |
| **SS-3**: Monitoring and Regular Inspection | Regular basis check-ups to reduce perishability |
| **SS-4**: Sanitization | To limit the possibility of cross-contamination, thorough cleaning practices for equipment, surfaces, and hands are being implemented. |
| **SS-5**: FIFO (First-In-First-Out) Method | Implementing a FIFO-based inventory management system to ensure that older products are utilized or sold before newer ones arrive. |
| **SS-6**: Storage Atmosphere Control | To safeguard the quality of sensitive items, storage facilities must maintain adequate temperature, humidity, and light conditions. |
| **SS-7**: Inventory Optimization(EOQ) | Analyzing demand trends and modifying inventory levels to reduce excess supply |

Table 10. Mitigation Strategies to Reduce Transportation-related Risk

| Strategy | Purpose of the Strategy |
|---|---|

| | |
|---|---|
| **ST-1**: Pre-Shipment Inspection | Quality is a key concern; pre-shipment inspections are helpful for identifying and removing damaged or low-quality fruits before they reach the supply chain. |
| **ST-2**: Optimum cold chain infrastructure | Mangoes should be carried at a cold temperature, often between 12 and 18 degrees Celsius, to ensure quality. This will keep the fruit from ripening too soon. Considering the cost factor, employing cold chain transportation when the distance factor is high and a traditional transportation system with little distance factor. |
| **ST-3**: Find out the Optimum route | Plan transportation routes carefully to reduce transit time and risk. Utilize technology and data analytics to improve routes, taking into account elements such as road conditions, weather predictions, and traffic patterns. |
| **ST-4**: Best Distributor Selection | Choose reliable and experienced distributors. |
| **ST-5**: Transportation visibility | Establish real-time tracking and monitoring systems (GPS systems) to have visibility into the transportation process. |
| **ST-6**: Protect against uncertainty | It is critical to have a plan of action in place in the case of a transportation disruption, such as a weather catastrophe or an accident. |

Table 11. Mitigation Strategies to Reduce Retailing-related Risk

| Mitigation strategy | Purpose of the strategy |
|---|---|
| **SR-1**: customer-friendly policy | to improve the whole customer experience, establish trust and loyalty, and make consumers feel valued and appreciated |
| **SR-2**: reduce unnecessary intermediaries' level | decrease unnecessary delays, enhance efficiency, cost-effectiveness |
| **SR-3**: Diversify supply and supplier | This strategy aims to reduce the risk of over cost, increase flexibility, and improve the supply chain's overall efficiency and adaptability. |

| | |
|---|---|
| **SR-4**: implement marketing policy, promotion & discount | well-executed marketing policy, promotion, and discount plan may have a major influence on client acquisition and retention, as well as sales growth. |

4.5 MCDM Analysis Through TOPSIS for Mitigation Strategy

The TOPSIS method, which is an MCDM approach, here used to find out the best mitigation strategy among other alternative strategies. For implementing TOPSIS, linkage-wise risks have been given the highest weight. The TOPSIS method is run through MATLAB software. By calculating the collected value, MATLAB provides a performance score and then ranks the mitigation strategy consecutively.

Table 12. TOPSIS of Harvesting related risk mitigation strategy

| | | Harvesting related risk | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | RH-1 | RH-2 | RH-3 | RH-4 | RH-5 | RH-6 | Performance score | Rank |
| Mitigation Strategies | SH-1 | 95 | 88 | 98 | 80 | 70 | 87 | 0.6642 | 1 |
| | SH-2 | 80 | 86 | 50 | 93 | 92 | 96 | 0.45287 | 4 |
| | SH-3 | 80 | 95 | 59 | 89 | 70 | 92 | 0.44895 | 5 |
| | SH-4 | 87 | 65 | 92 | 60 | 70 | 93 | 0.47177 | 3 |
| | SH-5 | 80 | 90 | 65 | 97 | 86 | 94 | 0.55654 | 2 |
| | Weight | 0.156 | 0.156 | 0.156 | 0.156 | 0.156 | 0.22 | | |

Table 13. TOPSIS of Packaging related risk mitigation strategy

| | | Packaging related risk | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Risk | RP-1 | RP-2 | RP-3 | RP-4 | RP-5 | RP-6 | RP-7 | Performance score | Rank |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Mitigation Strategies | SP-1 | 97 | 72 | 98 | 97 | 93 | 99 | 63 | 0.53691 | 3 |
| | SP-2 | 97 | 74 | 95 | 94 | 93 | 95 | 63 | 0.54692 | 2 |
| | SP-3 | 96 | 80 | 95 | 94 | 95 | 96 | 63 | 0.59276 | 1 |
| | SP-4 | 98 | 62 | 92 | 96 | 98 | 99 | 63 | 0.44245 | 4 |
| | SP-5 | 72 | 60 | 95 | 94 | 91 | 95 | 95 | 0.39218 | 5 |
| | SP-6 | 77 | 71 | 98 | 94 | 91 | 95 | 63 | 0.31892 | 6 |
| | Weight | 0.175 | 0.175 | 0.175 | 0.1 | 0.1 | 0.175 | 0.1 | | |

Table 14. TOPSIS of Storage related risk mitigation strategy

| | | Storage related risk | | | | |
|---|---|---|---|---|---|---|
| | | RS-1 | RS-2 | RS-3 | Performance score | Rank |
| Mitigation Strategy | SS-1 | 95 | 93 | 85 | 0.69683 | 2 |
| | SS-2 | 90 | 97 | 68 | 0.46827 | |
| | SS-3 | 97 | 96 | 82 | 0.71072 | 1 |
| | SS-4 | 92 | 85 | 68 | 0.36226 | 5 |
| | SS-5 | 94 | 85 | 98 | 0.63247 | 4 |
| | SS-6 | 93 | 89 | 93 | 0.67128 | 3 |
| | SS-7 | 80 | 85 | 85 | 0.2971 | 6 |

| | Weight | 0.4 | 0.4 | 0.2 | | |
|---|---|---|---|---|---|---|

Table 15. TOPSIS of Transportation related risk mitigation strategy

| | | Transportation-related risk | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | RT-1 | RT-2 | RT-3 | RT-4 | RT-5 | Performance score | Rank |
| Mitigation strategy | ST-1 | 62 | 85 | 55 | 300 | 75 | 0.17849 | 6 |
| | ST-2 | 97 | 85 | 92 | 350 | 75 | 0.62402 | 2 |
| | ST-3 | 77 | 85 | 98 | 250 | 75 | 0.65713 | 1 |
| | ST-4 | 62 | 96 | 91 | 290 | 88 | 0.49802 | 3 |
| | ST-5 | 62 | 85 | 85 | 340 | 98 | 0.4134 | 5 |
| | ST-6 | 82 | 85 | 67 | 310 | 88 | 0.41853 | 4 |
| | weight | 0.23 | 0.155 | 0.23 | 0.23 | 0.16 | | |

Table 16. TOPSIS of Retailing related risk mitigation strategy

| | | Retailing related risk | | | | | |
|---|---|---|---|---|---|---|---|
| | | RR-1 | RR-2 | RR-3 | RR-4 | Performance score | Rank |
| strategy | SR-1 | 86 | 81 | 85 | 92 | 0.38286 | 2 |
| | SR-2 | 81 | 86 | 87 | 88 | 0.3996 | 3 |
| | SR-3 | 81 | 78 | 88 | 94 | 0.29735 | 4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | SR-4 | 91 | 88 | 92 | 93 | 0.94678 | 1 |
| | weight | 0.25 | 0.25 | 0.25 | 0.25 | | |

**5.Outcomes of the Research**

*5.1 Result of ISM and MICMAC*

This study uses ISM to determine the relationship between risks related to mango's supply chain and exhibit the most responsible risk which needs to be mitigated to reduce overall food waste. This method uses the risks as the variable of input and divides them into four categories. At Level 1, the prominent risks are Weather and Climate, which can significantly impact mango production and distribution, along with Political Uncertainties that affect trade and regulations. At Level 2, factors like Pest and Disease Outbreaks, Poor Harvest Timing, Harvest and Handling Practices, Labor Shortages, and Government Policy Uncertainties form the next tier of risks. Moving further down, Level 3 consists of Storage Duration and Rough Handling risks. Level 4 includes Packaging Integrity and Over-Packaging, while Level 5 is marked by Labeling and Traceability risk. At Level 6, the study finds an extensive cluster of interconnected risks, including Quality Control Issues, Physical Damage (RP-1), Uncontrolled Temperature, Ethylene Buildup, Packaging Waste, Physical damage(RS-1), Cross-Contamination, Temperature Fluctuations, Transportation Costs, Consumer' Discontent on Purchased Mango, Poor Quality of Purchasing Mango Leads to Difficult Sales, Price Instability, and Demand Instability due to Variation. Those risks are shown as linkage risks; it means these risks can also provide an effect on the other risks. Finally, at Level 7, the solitary risk is Lack of Tracking and Traceability.

In-depth knowledge of the risks in the mango supply chain is provided by this ISM result, which also highlights how they are interconnected and arranged hierarchically. Stakeholders can prioritize and resolve the most important risks at higher levels as a result of the study, which may have a cascade effect on risks at lower levels.

Additionally, the MICMAC analysis has categorized the risks into four regions based on their driving and dependence powers. In the independent region, Lack of Tracking and Traceability (RT-5) stands out, with high driving power and low dependence on other risks. The first quadrant is called the autonomous which has no risks contains because this quadrant depicts very weak driver power and reliance and mostly out of the system. In the dependent region, Weather and Climate (RH-1), Pest and Disease Outbreaks (RH-2), Poor Harvest Timing (RH-3), Harvest and Handling Practices (RH-4), Labor Shortages (RH-5), Packaging Integrity (RP-4), Over-Packaging (RP-5), Labelling and Traceability (RP-7), Storage Duration (RS-3), Rough Handling (RT-2), Political Uncertainties (RGPU-1), and Government Policy Uncertainties (RGPU-2) are identified, suggesting that these risks are influenced by other factors in the system. In the linkage region, risks like Quality Control Issues (RH-6), Physical Damage (RP-1), Uncontrollable Temperature (RP-2), Ethylene Buildup (RP-3), Packaging Waste (RP-6), Physical Damage (RS-1), Cross Contamination (RS-2), Temperature Fluctuations (RT-1), Delayed Transport (RT-3), Transportation Costs (RT-4), Consumers' Discontent on Purchased Mango (RR-1), Poor Quality of Purchasing Mango Leads to Difficult Sales (RR-2), Price Instability (RR-3), and Demand Instability due to Variation (RR-4) that have a significant reliance as well as a strong driving force. These variables are particularly unstable since any change in one of them will have an impact on all the others as well.

In the mango supply chain, this study uses these integrated analyses to determine where to focus on risk management efforts. In order to successfully fulfill customer demand, it is important to address the significant risks at higher levels and comprehend how they relate to other risks. This will improve sustainability, optimize supply chain operations, and guarantee a consistent supply of high-quality mangoes.

*5.2 Output of the TOPSIS*

The TOPSIS results show that the following mitigation strategies are the best for each stage of the supply chain:

1. Harvesting: Variety Wise in time Harvesting (performance score of 0.6642)
2. Packaging: Fresh produce packaging (performance score of 0.59276)
3. Storage: Monitoring and regular inspection (performance score of 0.71072)
4. Transportation: Find out the optimum route (performance score of 0.65713)
5. Retailing: Implement Marketing Policy Promotion & Discount (performance score of 0.94678)

Overall, the TOPSIS results suggest that the best mitigation strategies are those that are specific to each stage of the supply chain. To cite an example, Variety Wise in Time Harvesting is the best strategy for mitigating risks during Harvesting because it ensures that fruits and vegetables are harvested at the right time and in the right way. Fresh produce packaging is the best strategy for mitigating risks during packaging because it helps to protect fruits and vegetables from damage. Monitoring and regular inspection is the best strategy for mitigating risks during Storage because it helps to ensure that fruits and vegetables are stored in the right conditions. Find out the optimum route is the best strategy for mitigating risks during transportation because it helps to ensure that fruits and vegetables are transported in the most efficient and safe way. Implementing Marketing Policy Promotion & Discount is the best strategy for mitigating risks during retailing because it helps to increase demand for fruits and vegetables.

It is important to note that these are just the best mitigation strategies according to the TOPSIS results. The specific mitigation strategies that are best for a particular supply chain will vary depending on the specific risks that the supply chain faces.

*5.3 Comparison between Current and Improvement Scenario*

The primary objective of our paper is to reduce wastage through risk management of the fresh Mango Supply Chain. For that, at first, we identified key risks and then applied mitigation strategies. These observed data were collected from several primary sources such as farmers, Retailers, Distributors, etc. The amount of wastage related to key risks is given in the table 18 From the table, we can see that there is a large amount of wastage in Harvesting, Packaging, Storage, Transportation, and Retailer, with an amount of 40,23,24,31 and 17 per 100 units, respectively. But after applying mitigation strategies, the amount of mango wastage is reduced to 14,12,8,16 and 9 units, respectively. The column chart makes it evident how the two scenarios compare, emphasizing the huge reduction in waste brought about by improvement initiatives. It is clear that the supply chain optimization measures have significantly reduced waste, which has improved productivity, reduced costs, and raised sustainability overall.

Table 17. Comparison of Sustainability in Fresh Mango Supply Chain

| Field | Current Wastage | Improvement |
|---|---|---|
| Harvesting | 40 | 14 |

| | | |
|---|---|---|
| Packaging | 23 | 12 |
| Storage | 24 | 8 |
| Transportation | 31 | 16 |
| Retailer | 17 | 9 |

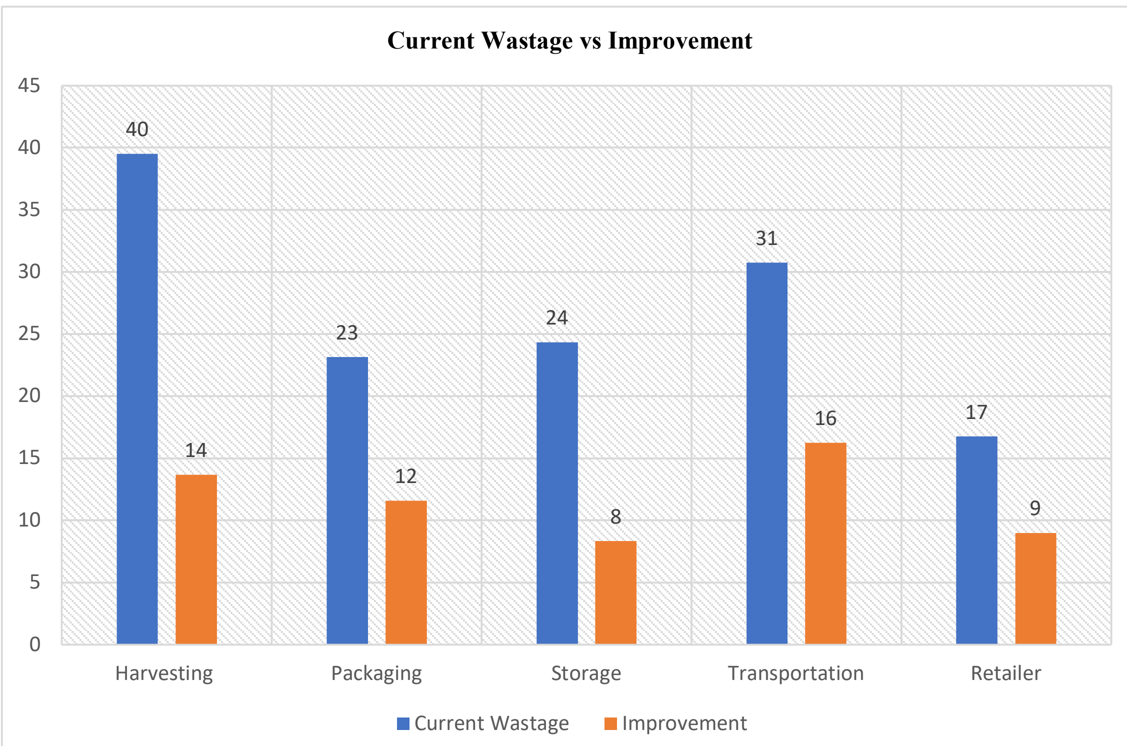



Figure 7. Chart of Two scenarios

*5.4 Discussion*

This paper aims to study the risks of the mango fruit supply chain and their impact and to find the best strategies to mitigate these uncertainties. Mango fruit is a perishable good that might be exposed to numerous dangers all throughout the supply chain. The mango supply chain has a great level of wastage at each step, from harvesting to reaching the consumer, by these risks. In all, we have seen a total of 27 risks in our survey for each field. Weather and Climate, pests and diseases, delays in transportation, and price instability are a few examples of these risks. Risks that are leveled as general (Political Uncertainty & Government Policy Uncertainty) contribute indirectly to almost every supply chain stage. Government policy regarding transportation, storage guidelines, and relating can increase overall supply chain surplus and maximize profit for every functional stage. Currently, courier services in Bangladesh are charging inadequately the wholesalers or garden owners regardless of any appropriate reason. Implementing government policy regarding transportation can minimize such behavior. Government concern about storage methods and applicable retailing policies can reduce quality defects and overall wastage. Political uncertainty is more of pure uncertainty than risk. as it can't be controlled. Some cold storing or on-hand inventory practices may defend against such uncertain variations. As the methodology of this study is based on primary data, data regarding such risk couldn't be quantified from the sources. But the impact of it cannot be unseen.Retailers are directly connected with the end customers. They can quickly identify market fluctuation, demand fluctuation or instability, and custom buying patterns. The selected strategy would help retailers to incorporate with the market and increase availability by minimizing waste. Other than that, the return policy to Storage can also prevent such fluctuations. Such practice would eventually increase supply chain surplus,

It's crucial to recognize these risks and create effective mitigation plans in order to reduce them. The ISM approach can be used to identify major risks in the mango fruit supply chain through survey analysis from the local people. In order to mitigate these risks, it is important to identify them and develop appropriate mitigation strategies. In the end, we have given the five best mitigation strategies by using the TOPSIS method, then depicted the improvement of the overall mango supply chain by reducing wastage.Bangladesh is considered one of the leading countries in the production of mangoes. Higher availability may result in unseen wastage impact. Reducing wastage in suggested percentages can help businesses export mangoes in large quantities and generate higher revenue.

## 6 Conclusion

Each step of the mangoes supply chain is critical as a perishable fruit. Fresh mangoes can be demolished and wasted at any stage due to avoidable or unavoidable uncertainties. This paper inspects the risk related to FMSC and studies the relationship between them through ISM. As risks are interrelated, their solving techniques are also connected with many criteria. Interpretive Structural Model (ISM) aids this study in structuring the risk associated with FMSC. An MCDM approach is made to evaluate the possible mitigation strategy. Because every risk is interconnected, the strategies also adversely affect each. TOPSIS is implemented in this research to select the best strategy for the risk at a particular FMSC functional stage.

This study undoubtedly will facilitate waste minimization of the Fresh Mango Supply Chain (FMSC). Every year Bangladesh faces large waste of fresh mangoes due to unmanaged uncertainty. During summer, the country exhibits a large amount of mango production, which doesn't make them enough concern to consider the waste of 27% of total FMSC. Our approach offers strategies that will eventually minimize the waste to 15% with an improved FMSC of 12% wastage. Waste reduction of any perishable foods would contribute to maintaining sustainability in the overall supply chain and increases its surplus. Though we have performed deep research on FMSC, we couldn't select every possible solution because of the limitation of the Methods. We have evaluated the most severe risk through this investigation, but other mitigation strategies, such as ours, may reduce more wastage for a particular risk. Our results may vary in time as we have performed a local survey and questioning. Each functional area of FMSC can be investigated in future research individually, which will offer more definite outcomes. The implementation of blockchain in FMSC can be another opportunity for future studies.

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