

CHAPTER 6

CONCLUSIONS

Risk modeling of the agro-industrial supply chain in Asian countries was conducted based on two case studies: a banana supply chain in India and bamboo shoot supply chain in Thailand. This study is to deal with uncertainties and imperfect information to determine the appropriate strategies and achieve sustainable supply chain profit. Summary of the work is given in this chapter.

6.1 A STUDY ON THE BANANA SUPPLY CHAIN IN INDIA

This work commenced with interviews and discussion with banana growers, traders, commission agents, wholesalers and faculty members and researchers involved in the banana supply chain. Risk issues and risk factors were obtained through interviews and discussion. Causal Loop Diagram (CLD) a tool from systems dynamics (SD), was developed after interviews and discussion. The Fuzzy Delphi Method (FDM) was used to obtain the value of elementary risk factors. The Analytic Hierarchy Process (AHP) was applied for selection the of most appropriate post-harvest technology alternative. Dynamic Programming (DP) was used to tackle the quality attributes and to find the optimal route for the supply chain. Multistage fuzzy goal programming (MFGP) approach was employed to deal with uncertainty in price, quality attributes, and operation costs of post harvest technological action in order to achieve the maximum profit and the most reasonable risk in profit/loss.

6.1.1 Risk Identification and risk assessment was initiated through interview and discussion with growers, commission agents, wholesalers and researchers from the state of Tamil Nadu and Karnataka in India. Risk issues and risk factors were obtained through interview and discussions. A Causal Loop Diagram was developed for analysis of relation among risk issues and influential elementary risk factors. FDM was used for obtaining the value of elementary risk factors. Price fluctuation was found as the first priority over other risk issues followed by demand risk, production loss risk, competition risk, cost risk and quality risk respectively.

6.1.2 Six possible post-harvest technological alternatives were evaluated with nine criteria which influence the selection of best post-harvest technology. Through FDM and AHP it is found that the availability of products and comparable products is ranked as the most significant criteria with the weightage of 0.1485 and the modified atmospheric packaging as recommended as the highly preferred post-harvest technology with the weightage of 0.234.

6.1.3 Data related to quality and uncertainty risk issues in the banana supply chain (color attributes, defect attributes, operation cost, and selling price) were obtained from FDM and used through DP for analysis of the optimal post-harvest handling route of the banana supply chain. Both quality states of color development attributes and quality state of defect attributes are determined by handling or operation conditions and throughput time. Decision variables are defined with respect to handling or operation which affects color development and defect development state. Through FDM and DP, the optimal route with maximum profit and most preferred quality state was found.

6.1.4 Multistage fuzzy goal programming approach was employed to deal with uncertainty in price, quality attributes, and operation cost of post harvest treatment. Relevant data was obtained from FDM, in order to achieve the maximum aspiration level of profit and risk preference level for profit loss. DP was extended with preferences and profit aspiration levels for providing alternative in order to achieve higher profit.

6.2 A STUDY ON THE BAMBOO SHOOT SUPPLY CHAIN IN THAILAND

Interviews and discussions were made in the initial state of this study. FDM was used in order to obtain values from elementary risk factors (operation cost, delivery time, price, carrying cost, etc.) Risk with respect to different enablers in the chain can result in different values. Fuzzy Inference System (FIS) was applied to quantify the sustainable risk value that contributes risk to every party in the entire supply chain in the long term. System Dynamics (SD) approach was used to construct the bamboo shoot supply chain and helps in proposing higher profitability for bamboo shoot growers. The Analytic Hierarchy Process was applied to find the most appropriate post-harvest treatment.

6.2.1 Major risk issues and elementary risk factors were identified through interviews, discussions and FDM. The Chemical Hazard Risk caused by post-harvest treatment done by commission agents was found to be the major risk issue for consumer's health. Samples of bamboo shoots from bamboo shoot farms and wholesale markets were randomly selected and stored at two different conditions (ambient and chill temperature) at the laboratory of the faculty of agro-industry, King Mongkut's University of Technology North Bangkok, Thailand to study shelf life. The samples collected from commission agents and wholesalers were found with the

highest sulfur dioxide levels (92.91 mg/kg). Based on results from physical experiments and value obtained from FDM, FIS was developed to quantify sustainable risk value in the bamboo shoot supply chain. Production loss or yield loss risk is another risk faced by bamboo shoot growers. The data on elementary risk factor influencing the yield loss risk were obtained through FDM. FIS was developed and applied for predicting the yield loss risk index.

6.2.2 From risk issues obtained in 6.2.1, four major risks (chemical hazard risk, biological hazard risk, product appearance risk and economic risk) were considered for mitigation. The chemical hazard risk is the major risk issue that affects the consumer's health. AHP was employed for selection of post-harvest technology in order to reduce risk for consumers without increasing risk for the other enablers in the chain. Food safety found to be the important criteria with weight 0.536 while the blanching was ranked best post-harvest treatment with the most significant recommended weight of 0.403.

6.2.3 Production or yield loss was identified as the first prioritized risk issue with respect to growers. The production and distribution simulation model (PDSM) was developed to act as a baseline in this risk analysis. The complex model for risk management process was developed by employing a SD modeling software known as 'VENSIM Plus 5.9e'.

6.2.4 Different policy scenarios were simulated using PDSM. Through analysis of the simulated results, the best policy that maximizes the revenue for bamboo shoot grower is selected.

6.3 CONTRIBUTIONS OF RESEARCH

6.3.1 In both the case studies of the banana supply chain in India, and the bamboo shoot supply chain in Thailand, there are several risk factors causing agro-industrial supply chain failures but the enablers are forced to make decisions with insufficient information. Obtaining reliable information is very difficult and costly. A study of risk identification and risk assessment from this research defined an appropriate method to be used in this situation. Integrated method of interview, discussion and the fuzzy Delphi technique is recommended to obtain data and to identify risk issues and factors. FIS or CLD can be used as a tool for quantification.

6.3.2 A risk profile for each case was developed containing useful information from growers, traders, wholesalers, manufacture, wholesaler, retailers and consumers. Decision makers, for example, government agencies or enablers involved in supply chains can apply this information to mitigate their risks.

6.3.3 The risk issues, risk factors, risk value, and other data related to supply chain risk identified can be used as guidelines by any partner in the chain to design the supply chain with and higher performance. Selection of post-harvest technology alternatives by using AHP can be recommended for commission agents, wholesalers, or government agencies to increase the capability of sustainable agro-industry in India, Thailand, and other countries of similar nature.

6.3.4 For integrating quality issues into supply chain management for enhancing performance of postharvest supply chain, DP is used to take quality attributes like ripeness and defect which are affected by postharvest handling methods. Profit and quality attributes from postharvest handling method

scenarios are quantified. It is found that the application of FDM and DP is very useful and more flexible to deal with uncertainties in order to reach desire state.

6.3.5 When the aspiration level on profit and acceptable risk level with respect to different goals at different stages in supply chain are referred, analysis of post-harvest harvest supply chain networks using multistage fuzzy goal programming (MFGP) was applied. Practically, in different seasons, with different customers, different market channels, enablers in supply chain may expect profit and try to avoid severity of risk at different levels. MFGP is very useful and more flexible for making decisions when enablers have different aspirations of profit and risk. Profit and loss risk from post-harvest handling method scenarios are quantified through this method. FDP is used by taking into account quality attributes like ripeness and defect which are affected by post-harvest handling methods. These attributes are analyzed simultaneously in order to reach the desired quality state in a particular stage in the supply chain. Addressing quality problems in supply chain management not only help improve benefits for partners in the chain but also for consumers by providing better product quality alternatives.

6.3.6 In the case study of the bamboo shoot supply chain, the SD based simulation model was developed to understand the whole picture of bamboo production and distribution. This is very useful tool to help people in the supply chain understand and verify the supply chain. SD based simulation models facilitate the decision maker to analyze the scenarios of interest. The effectiveness of alternative response scenarios may be employed to mitigate the negative impacts of the risk through system dynamics models. Farmer's income with respect to alternative risk management policies was analyzed using proposed the fuzzy SD approach. The output from fuzzy-SD was applied through response surface methodology. These proposed integrated

approaches are useful for production and distribution of horticultural products with uncertain and imperfect information.

6.4 LIMITATIONS OF RESEARCH

6.4.1 Distance and Travelling

In order to interview and have discussion with all players involved in the supply chains of two case studies, travelling from place to place is required. This involves long distance travelling to reach farmers and other partners in India. Period of interview and discussion are longer than scheduled. Availability of participants from various firms is also another problem.

6.4.2 Cooperation and Participation

Some participants did not understand the purpose of interview and the usefulness of information. They might have provided unreliable information. Data from some experts was removed due to inconsistency. Moreover, because the research scholar foreigner, visiting and interviewing officials at National Agriculture Research Institutes in India is sometimes not allowed. Food manufacturing in India is also restricting the visits.

6.4.3 Communications

Bananas were transferred across different states in India. There are more than three languages used by various players from different parts of the countries. Local languages (Tamil, Kannada, Hindi, and Malayalam) are required for communication with farmers and local traders.

This thesis address the risk issues related to quality in the dedicated (Banana, Bamboo Shoot) supply chain only. This proposed approach as it is will not be applied to the agro industrial supply chains that deals with the multiple products.

6.5 FURTHER STUDY

6.5.1 Risk assessment models used in this study can be extended with the traceability issues to promote an organic food supply chain.

6.5.2 The proposed approaches from this work can be applied for other agricultural products. There are only two case studies: bananas and bamboo shoots for this work. There are various agricultural commodity products in Asia such as such as Mango, Rambutan, Mangosteen, Durian, Palm, Cassava, etc.

6.5.3 The framework used in the study can also be extended for international agro-industrial supply chains.