A Risk Management Framework for Aquaculture: The Case of Vietnamese Catfish Farming

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the degree of Doctor of Philosophy

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CANDIDATE'S CERTIFICATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and ethics procedures and guidelines have been followed.

Signed: ______________________

Name: Cong Tru Le

Date: ________________________

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(In Vietnamese)

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ABSTRACT

Aquaculture plays an increasingly important role in providing food for human beings as a result of declining stock of ocean fish. According to the FAO, aquaculture output accounted for 29% of total fisheries production and it more than doubled its production in the past decade. Vietnamese aquaculture, in general, and Vietnamese catfish farming, in particular, has also experienced a rapid growth in the past decade to meet the increasing demand both domestically and internationally. The fast growing catfish industry is troubled by many problems, challenges and uncertainties such as: environmental and edaphic issues, losses due to disease, strict quality and safety regulations, export-import restrictions, increasing production costs, sustainability, oversupply and other global and regional socioeconomic problems. All these uncertainties are potentially detrimental risks to the catfish industry and they need to be managed in a systematic way for the sustainable development of the industry. A sound and solid risk management framework, as well as a risk management tool, is very much needed for Vietnamese catfish farming.

The purpose of this study is to develop a risk management framework for Vietnamese catfish farming. Three objectives are proposed: (1) to examine the perceptions of risks and risk management in catfish farming; (2) to develop a risk management framework for Vietnamese catfish farming; and (3) to develop a decision support system (DSS) as an implementation tool for risk management in Vietnamese catfish farming. The significance of this study is in providing a framework as well as a useful tool to Vietnamese catfish farmers for systematically managing risks in their farming efforts.

In seeking an understanding about the importance as well as the development of Vietnamese aquaculture and catfish farming in the Vietnamese economy, historical data were used and analysed. Simple descriptive statistical methods were used to understand the developments and fluctuations of the main indicators of Vietnamese aquaculture as well as the catfish industry in the past decade. The development of the industry was analysed in terms of: catfish

production (including farming area, yield, and prices); export (including export volumes, values, and prices); and the development of input markets for catfish farming (including labour, seeds and fingerlings, feed, and medicine). Based on the analyses conducted on the development of the industry, the opportunities and challenges facing the Vietnamese catfish industry were derived.

Prior to the development of the risk management framework, Vietnamese catfish farmers' perceptions of risks and risk management were examined using the data collected from a questionnaire survey of 261 catfish farmers in the Mekong Delta, where most of the Vietnamese catfish are produced. Descriptive statistics methods were used to evaluate the perceptions of risk and risk management. Next, exploratory factor analysis (EPA) and multivariate regression methods were used to determined the influences of farm socioeconomic characteristics on the perceptions of risks and risk management in Vietnamese catfish farming.

A risk management framework was developed as a combination of the catfish business process model and the risk management process introduced by AS/NZS 4360. The seven (7) steps in the risk management process were subsequently applied on each of the sub-processes in the catfish farming business. The data used for the development of the risk management framework were collected from a survey of 261 catfish farmers in three provinces of Can Tho, An Giang and Dong Thap, which accounted for more than 80% of the total catfish production, in the Mekong Delta. The risk management framework developed in this study was then used as the foundation for the development of the DSS as an implementing tool for risk management in Vietnamese catfish farming.

Once the risk management framework was developed, a DSS for risk management was then built upon as a tool implementing the proposed framework for practical risk management activity. The developed DSS has three main components: a model system, a data system, and a user interface. The data system allows users to manage both input and output data of the system, including input data on risk and risk management, predetermined probability functions of risk consequences and likelihoods, calculated outputs, etc. The model system conducts all the calculation and analyses required by the system goals and provides appropriate outputs for risk decision making. A graphical user interface allows user to interact with the system. Due to the low computer literacy of catfish farmers and software accessibility, the system was designed and developed with ease of use in mind. To achieve that objective, the system was written in Visual Basic for Application on the Microsoft Excel platform.

Finally, a modified UTAUT model was built to evaluate the acceptance of the DSS for risk management in Vietnamese catfish farming. The model was assessed using data collected from a fresh survey of 55 catfish farmers and local aquaculture staff in three provinces of Can Tho, An Giang, and Dong Thap in the Mekong Delta. The findings of this part of the study provide insights into the role of traditional UTAUT factors and other demographic variables influencing the intention to use an information technology innovation.

Chapter 1

INTRODUCTION

As part of a developing economy, Vietnamese agriculture, including fisheries and aquaculture, still plays a very important role in the economy in terms of GDP contribution and employment. By the year 2009, the sector accounted for 21% of the country's total GDP and used 52% of the country's total labour force (Vietnam GSO 2011). Therefore, the development of the agricultural sector is a key factor for the success of poverty reduction and rural development. Within the agricultural sector, the fisheries and aquaculture subsector has experienced a much higher growth rate than the agricultural sector as a whole due to the high demand for aquatic products both domestically and internationally. The total output value of fisheries and aquaculture has increased from 6,664 VND billions in 1995 to 61,756 VND billions in 2009 (Vietnam GSO 2011), a more than 9 fold increase.

Within the fisheries and aquaculture subsector, catfish is a major product that has contributed significantly to the development of the Vietnamese fisheries and aquaculture in the last decade, both in terms of output values and export revenue. In the last ten years, Vietnamese catfish farming has experienced an impressive development, with a growth rate of 40.23% annually (Le & Cheong 2010a). The fast development of the Vietnamese catfish industry brings both positive and negative impacts to the economy. In terms of the positive impacts, the industry generates opportunities for generating high income for catfish producers, processors, and exporters; earning foreign exchange for the country; and creating employment and poverty reduction. On the other hand, the fast growth of the industry also brings in many negative impacts and problems, such as environmental pollution, disease outbreaks, food safety and hygiene problems, increasing production costs, and decreasing prices. All of these are potentially detrimental risks threatening the sustainability of the Vietnamese catfish industry and they need to be managed in a systematic and efficient way. Therefore, a sound and solid risk management framework, as well as a practical risk management tool, is definitely a need for mitigating risks in Vietnamese catfish farming.

This research is aimed at developing a risk management framework for Vietnamese catfish farming. Background on the development of the industry is introduced. The research objectives and significance are then described to outline the research aims. The methodology section provides a brief discussion about the ways in which this research was conducted. Finally, a summary of the organisation of this thesis is presented.

Although the research objectives of this research are specifically aimed to developing a risk management framework for Vietnamese catfish farming, the results of this study can be generalized and adapted to other aquacultural products or other types of activities in agriculture and aquaculture. To concentrate on the stated research objectives, hereafter, the research will focus on the developing of a risk management in Vietnamese catfish farming.

1.1 Background

Catfish farming in Vietnam has grown at an impressive rate in the last few years: farming area has increased from about 560 ha in 2000 to 5,600 ha in 2007, a 10-fold increase, and production jumped from about 264,000 tons in 2004 to a total output of 1.5 million tons in 2007. In 2007, earnings from catfish export passed the $1 billion threshold to reach the value of $1.2 billion (MOFI 2005; Pham 2008; VnEconomy 2007). The catfish product is Vietnam's second largest single foreign exchange-earning aquacultural product after shrimp, and according to some projections, this fast growing trend will continue in the future due to increasing demand both domestically and internationally, following the admission of Vietnam into the World Trade Organization (WTO).

Highly intensive catfish farming generates high revenue, and thus profits for producers, but it also brings more risks to the farms. Price fluctuations due to oversupply and also marketing difficulties and yield losses caused by disease and environmental deterioration, have both occurred very frequently in recent years. As a result, catfish farmers are facing serious risks of severe financial losses, or even bankruptcy (Tu 2006). These factors suggest that the fast growth of the catfish industry might not be sustainable. To enhance the ability of risk tolerance, a risk management system that can protect farmers against financial losses, as well as maintaining the sustainability of the business, is a valuable tool for catfish farming in Vietnam.

Risk management is widely applied in the financial and banking sectors to prevent financial losses from the impacts of market, credit, and operational risks. However, in agriculture and aquaculture, risk management is applied to a much lesser extent due to the diversified and unstandardized production activities, especially in developing countries.

1.2 Research Aims and Objectives

The main aim of this research is to develop a risk management framework for Vietnamese catfish farming. Specifically, the research aims to define a framework for risk management by identifying, categorizing and assessing risks faced by catfish farmers and also to propose risk management strategies to mitigate risks. Based on the developed risk management framework, a decision support system (DSS) will then be developed as an implementing tool for risk management.

The proposed framework is a combination of a business process model and a risk management process. The business model defines the generic catfish farming business processes as well as activities used by the industry and identifies the risks associated with each activity. The multi-dimensional nature of the risk factors and losses will be reflected in the business model to cover both external or unknown and uncontrollable events that affect the earnings of the value-adding processes and the risk factors stemming from people, processes, and systems that can be directly assigned to losses.

The risk management process will provide a method for calculating risk measures for the business unit. State-of-the-art tools and techniques based on international standards and latest research will be used to predict losses. Risk measures can then be used to support management decisions to avoid, control, or mitigate losses in accordance with the selected risk strategy. Specifically, the research aims to achieve the following research objectives:

1. Examining the perceptions of risk and risk management in Vietnamese catfish farming. This part of the research provides empirical insights about how Vietnamese catfish farmers perceived risks and risk management in catfish farming. Farm socioeconomic characteristics and demographic variables are also included in the analysis to distinguish the differences in the perceptions of risks and risk management with respect to the differences in farm characteristics and demographic factors.

2. Developing a risk management framework for Vietnamese catfish farming. Farming is a risky business due to the many uncontrolled factors that can affect the revenue or income of farming activities. Generally, market (price) risks, institution (e.g. law and regulation) risks, and credit (financial) risks can affect farm returns. Farm producers, however, often take these factors as given, and try to mitigate those risks by some risk-mitigating strategies, such as production contract or hedging. This research focuses on all the risks that a catfish farm may face, including production (yield) risk, price (market) risk, institutional risk, human or personal risk, and financial risk. In this part of the research, a step-by-step guidance framework for farms is built to identify risks involved in catfish production, to assess the risks, and to treat the risks in the most economically efficient way, taking into account the sustainability of environment.

3. Developing a Decision Support System (DSS) for risk management. Based on the developed risk management framework, a DSS is developed as a tool implementing the proposed framework to facilitate risk management by farmers. Because the end users of this DSS are catfish farmers and/or aquacultural staff, the software should be user friendly and easy to use, yet it must provide enough tools for the risk management task.

In summary, to address the research aims, three research objectives are proposed: (1) to examine the perceptions of risks and risk management in Vietnamese catfish farming; (2) to develop a risk management framework for Vietnamese catfish farming; and (3) to develop a DSS as an implementing tool for risk management in Vietnamese catfish farming.

1.3 Significance of Research

Catfish production in Vietnam has grown at a very fast rate and quickly become an important foreign exchange earner for the country in recent years. The high profitability of catfish farming attracts more and more producers to the industry without any caution about the risky nature of aquacultural farming. Until recently, when frequent unfavourable events occurred that seriously damaged farm productivity and selling prices, more warnings have been made to the catfish farming industry. Highly populated farming areas and high-density fish stock make disease spread quicker, more serious, and more difficult to control. Large output volume causes oversupply problems in peak harvesting seasons, and as a result, the selling price usually falls sharply during this time. Deteriorated water quality causes product quality problems and yield loss that affects the selling price and might disqualify the product for export standards. Technical and trade barriers from importing countries also bring in chaos in domestic catfish production. Increasing feed costs that take a major proportion of production costs, hamper fish farmers' profit. All of these are risks to farmers and only a few are mentioned. Surprisingly, in practice, the Vietnamese catfish farmers almost have no tool to shield against these unfavourable events. Consequently, the farmers are the ones who bear all the risks and take all financial losses in the industry.

Therefore, there is a need to develop a risk management framework for Vietnamese catfish farming. This is not primarily because the literature about risk management in the catfish industry is limited, but mainly because of the economic benefit and the sustainability of the Vietnamese catfish industry. The developed framework provides the necessary guidance and tools for farmers to select specific strategies on risk reduction, thus reducing production volatility and financial losses. In addition, although the framework is originally aimed at risk management in catfish farming, it can be generalized and adapted to other activities in the catfish industry, such as brood stock, hatchery, fingerling production, catfish processing, or to different aquacultural and agricultural products such as shrimp or other kinds of fish.

1.4 Research Scope

The catfish industry consists of many related business activities, including brooding, fingerling nursing, food-fish (growing out) farming, processing, and exporting. Owing to the time and resource limitations, the scope of this research is restricted the catfish food-fish farming stage in Vietnam. We define our population as all catfish farmers, regardless of the production scale. Commercial catfish production only takes place in the Mekong Delta, in South Vietnam. Our research scope is thus centred on catfish farmers in the Mekong Delta, Vietnam.

1.5 Methodology

The purpose of this study is to provide a better understanding about the perceptions of risk and risk management and to develop a risk management framework for Vietnamese catfish farming. In this regards, both semi-quantitative and quantitative data were used to provide a comprehensive analysis and to construct a risk management framework and tool for Vietnamese catfish farmers. The main phases undertaken to conduct this research were as follows:

- First, examining the perceptions of risks and risk management in Vietnamese catfish farming. A 5-point Likert scale is first used to rate the importance of 40 risks and 50 risk management strategies in Vietnamese catfish farming. Next, factor analysis and multivariate linear regression are then used to examine the relationship between perceptions of risk and risk management with catfish farmers' socioeconomic characteristics

- Second, developing the risk management framework for Vietnamese catfish farming. Business process modelling is used to identify risks and risk management strategies associated with each sub-process and activities in the catfish farming process. The general risk management process is then applied on each sub-process of the catfish business process model to manage all the risks systematically to form the risk management framework. Primary semi quantitative (on a 5-point Likert scale) data are used to measure the levels of risk and risk management efficacy. Estimated cumulative density functions (CDF) of risk consequences and likelihoods are used to convert semi-quantitative (discrete) rating to continuous rating for risk measurements. Risks and risk management are ranked and prioritized based on the levels of risk and risk management efficacy or net benefit.

- Last, based on the developed risk management framework, a DSS for risk management is then developed as an implementing tool for risk management. A system approach is used to develop the DSS. Data collected from fresh surveys and interviews are used to test and evaluate the system. SEM is used to examine the influences of factors on the acceptance of the DSS. Data used for this evaluation are collected by a face-to-face interviewing survey, using a questionnaire for data recording.

1.6 Contributions

Risk mitigation has become a critical issue in Vietnamese catfish farming. Protecting catfish farmers against risks is a crucial factor for the sustainable development of the Vietnamese catfish industry. Our aim is to provide a risk management framework as well as a risk management tool (DSS) for the Vietnamese catfish farmers to improve their ability in dealing with risks in catfish farming. Given the aim of our research, this thesis offers contributions to the field based on four perspectives:

A comprehensive review of the Vietnamese catfish industry provides a general understanding about the development of the industry in the past decade. This provides the policy makers with an understanding of how the industry has been developing and points out the opportunities and challenges facing the industry. This provides policy makers with necessary and important information for policy decisions in promoting the sustainability of the industry in the future.

A rigorous examination of the perceptions of risks and risk management provides empirical insights about how Vietnamese catfish farmers perceive risks and risk management in catfish farming. Understanding how catfish farmers perceive risks and risk management may help the policy makers, credit lenders, input providers, and catfish processors to adjust their policies in relation to catfish farmers. In this regard, this contributes to the improvement of the market efficiency.

In regard to developing the risk management framework, a combination of Business Process Modelling (BPM) and Risk Management Process (RMP) is used to identify all the possible risks and risk management strategies that can occur along all stages of the whole catfish farming process. Business process modelling and risk management process are well known in business and risk management fields, but have not yet been applied in a combined way to study risk management in agriculture or aquaculture in general, and in catfish farming in particular. This contribution is marked by an innovative approach by using BPM in combination with general risk management process to develop a risk management framework for Vietnamese catfish farming.

Based on the developed risk management framework, a decision support system (DSS) for risk management has been built. The DSS is developed as an implementation tool for actual risk management activity in catfish farming. This research can thus contribute to practical aspects of research activity. Specifically, the outcome of this research can be transferred into practice for use and makes the research become practically useful.

1.7 Outline of Thesis

The remainder of this thesis consists of six parts:

- **Chapter 2** presents the background to the development of the Vietnamese catfish industry and to risk and risk management in agriculture and aquaculture. Firstly, the development of Vietnamese catfish industry is reviewed to provide a general picture of the current status of the industry. Secondly, the theoretical and empirical foundations of risk and risk management and its applications are discussed. Next, background on DSS and IT innovation acceptance is presented. Lastly, the proposed conceptual frameworks and models of this research are explained.

- **Chapter 3** outlines the research design and procedures. The research is broken down into several phases. For each phase, this chapter describes the data collection and analysis techniques used.

- The third part consists of **Chapter 4**, and is related to the research objective, which is to examine the perceptions of risk and risk management in Vietnamese catfish farming, using exploratory factor analysis (EFA) and multiple linear regressions. The primary data collection procedures are reported, and the research methods justified. This part of the thesis empirically provide empirical insights about perceptions of risk and risk management in Vietnamese catfish farming, taking into account the differences in farm socioeconomic characteristics and demographic variables.

- The fourth part contains **Chapter 5**. This part is dedicated to the main research objective: developing a risk management framework for Vietnamese catfish farming. In this chapter, all steps of a risk management process are described and analysed. The risk management process/framework, following the Australia/New Zealand Risk Management standard (AS/NZS 4360:2004), includes the following seven steps: (1) communicate and consult, (2) establish the context, (3) identify the risks, (4) analyse the risks, (5) evaluate the risks, (6) treat the risks, and (7) monitor and review. Each step of the risk management process requires specific data processing and analysing techniques. Details on data and analysing techniques for all steps in a risk management process are presented in chapter 3 and chapter 5.

- The fifth part includes **Chapter 6 and Chapter 7**, which present the development and evaluation of the DSS for risk management. This part achieves the research objective of developing a DSS as an implementing tool for risk management and evaluating the user acceptance of the DSS for risk management in Vietnamese catfish farming. Specifically, chapter 6 describes in details the architecture of the DSS in terms of the system design and the user interface. In chapter 7, we examine the influences of factors on the acceptance of the DSS for risk management using a modified UTAUT model. The Structural Equation Modelling (SEM) technique is used to reveal the relationships between factors. SmartPLS Version 2.0 software is used to obtain the path coefficients of the model, and bootstrapping procedure is used to obtain the standard errors and the t-statistics of the path coefficients. The instrument of the questionnaire survey and sampling is designed and included. After the developing of the model and the questionnaire, face-to-face interviews are then conducted to collect data using the questionnaire for recording.

- The sixth and last part of this thesis includes **Chapter 8**, which concludes the thesis with a summary of the research work, a discussion of the limitations of this research and suggestions for future work.

This thesis also contains five appendices:

- **Appendix A** contains the survey questionnaire for perceptions of risk and risk management

- **Appendix B** contains the survey questionnaire for evaluating the acceptance of the DSS for risk management in Vietnamese catfish farming

- **Appendix C** contains the estimated probability distribution functions for risk consequences.

- **Appendix D** contains the estimated probability distribution functions for risk likelihoods

- **Appendix E** contains the calculation results for the levels of risk using Microsoft Excel and the DSS

Chapter 2

BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Vietnamese aquaculture, in general, and catfish industry, in particular, has been experiencing a strong development in the past decade. It has, however, also faced a sharp fluctuation in the recent years. In this chapter, a review of the development of the Vietnamese aquaculture and Vietnamese catfish industry is provided in section 2.2. In particular, as our research is aimed at developing a risk management framework for Vietnamese catfish farming, we first provide the basic background of the contribution of the aquaculture and catfish industry to the Vietnamese economy and the development of the catfish farming sector and its exports.

As catfish farming is a highly risky business, producers need to understand the risk, and risk management strategies to mitigate risks. Concepts of risk and risk management in agriculture and aquaculture are discussed in section 2.3. A risk management framework is considered an important tool to manage risks systematically and efficiently. As such, we review existing risk management frameworks. Especially, the risk management framework based on the Australia Standard / New Zealand standard for risk management (AN/NZS 4360:2004) is discussed in detail. Justification for using AS/NZS 4360:2004 for this research is provided in section 2.4. This forms the foundation for the development of the risk management framework for Vietnamese catfish farming. The discussion of the risk management framework and its applications is presented in sections 2.4 and 2.5.

DSS has been applied extensively as an implementing tool in risk management. We present the review of the basic structure of a DSS and its applications in section 2.6. An extensive body of empirical research already exists around examining the influences of factors on IT acceptance. In this research, we adapt the unified theory of user acceptance and use of technology to assess the impact of factors on the acceptance of the DSS for risk management in Vietnamese catfish farming. As such, we present the well-known UTAUT model of IT acceptance and its applications in different contexts in section 2.7.

In light of the knowledge obtained from the literature reviewed in this chapter, we present the proposed conceptual framework and models for this research in section 2.8, including a conceptual risk management framework, a conceptual structure for the DSS, and a conceptual model for assessing the DSS acceptance.

2.2 Development of Vietnamese Aquaculture and Catfish Industry

Vietnamese aquaculture including catfish farming has grown phenomenally in the past decade. This brings both positive and negative impacts to Vietnamese aquaculture, in particular, and to the Vietnamese economy in general. The positive impacts could be job creation, income and foreign exchange earning, poverty alleviation, and rural development. The industry, however, also causes many negative impacts to the economy, e.g. environmental degradation, disease outbreaks, and increasing cost of inputs. To provide an insight into the industry, this section will review the development of the Vietnamese aquaculture and catfish industry in terms of production and exports. In addition, the development of input markets for catfish farming is also analysed. Finally, risk issues facing the Vietnamese catfish industry will then be identified.

2.2.1 Role of Vietnamese Fisheries and Aquaculture

The fisheries and aquaculture sector plays an important role in the Vietnamese economy, especially in exports. Although the sector only contributed less than 4% of the total GDP in the past 15 years, it accounted for approximately 10% of the country's total exports. This implies that the sector is an important foreign exchange earner for the economy. Fisheries and aquaculture exports increased steadily in the last 15 years, starting from USD 621 million in the year 1995. By the year 2009, export revenue from fisheries and aquaculture reached to the value of 4.25 USD billion and accounted for 7.4% of the total export of the country (Vietnam GSO 2011). Within this, catfish export values also reached the threshold of USD 1 billion by the year 2008 (Le & Cheong 2010a), accounting for 25% of the total export of fisheries and aquacultural products. Therefore, catfish farming plays an important role in the development of Vietnamese aquaculture. Figure 2-1 below presents the contribution of the fisheries and aquaculture sector to the Vietnamese economy in the last 15 years.

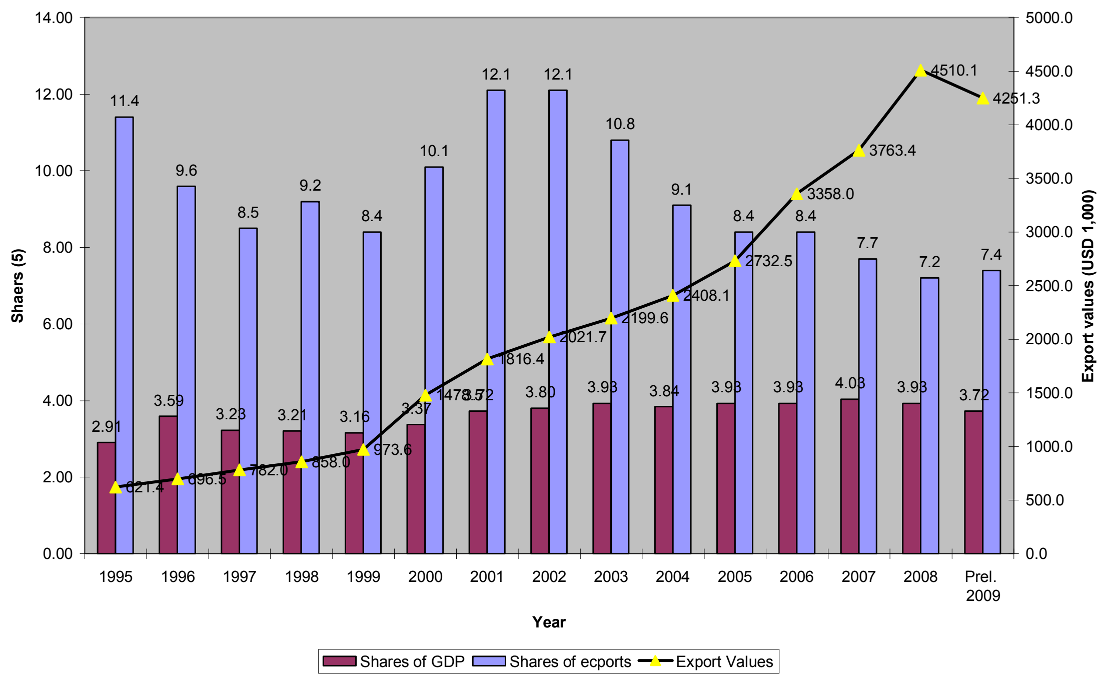

Figure 2-1 Contribution of Fisheries and Aquaculture

2.2.2 Catfish Farming in Vietnam

Raising catfish in the Mekong Delta has hundreds of years of history, mostly in ponds at the household level and mainly for household consumption. Only a small amount of catfish was exported to outside markets in Hong Kong, Singapore, and Taiwan before 1975. Since the mid-1980s, catfish began to be exported again, initially in the form of fillets to Australia.

Markets later expanded to Hong Kong and Singapore in the early 1990s and to North America and the European Union (EU) in the mid 1990s. The expansion of markets and demand led to a phenomenal development in catfish farming (Tu 2006). Before 2002, just before the "catfish war" with the USA, most of the catfish were produced in cages, ponds, and enclosures and at a relatively small scale, with an average productivity of 32 tons/cage and 12.96 tons/ha of pond (Tu 2006). Before 2003, the main market for the Vietnamese catfish export was the USA. The market share of Vietnamese catfish imports in the US market has grown from 0.14% in 1996 up to 17.34% in 2002. This strongly shocked the US catfish industry and led to the anti-dumping trial of Vietnamese catfish in the US market in 2003 (Schultz 2006; Tu 2006).

After 2003, the catfish industry went through a period of difficulty, as exports to the US market dropped by almost 50% due to a higher anti-dumping tax. This seriously affected the fragile local economy and the livelihood of catfish farmers and other stakeholders. There was an increase in rural unemployment, due to the fact that many fish producers could not sell their products. They ran into financial losses, which in turn led to bankruptcy, as catfish farming was their main occupation (Tu 2006). However, the industry recovered quickly by the end of 2004, due to expansion of international markets to other regions in the world; especially, the European Union and other ASEAN countries. By the end of 2005, the EU became the largest export market for the Vietnamese catfish industry, accounting for 37.6% of total Vietnamese catfish exports and equivalent to 28,219 tons. The second important market was the ASEAN market, with 15.6% of total export value and equivalent to 22,435 tons, followed by the US market with 11.7% total exports and equivalent to 21,229 tons. The quick adaptation to the challenges in the world market led to a continuing increase in catfish production after 2003 (Tu 2006). The areas for catfish farming grew by up to 5,600 hectares, a 10-times increase from the year 2000. Catfish output has increased from 264,436 tons in 2004 to 825,000 tons in 2006, and, according to the latest estimations, the total catfish production can reach to 1.5 million tons with an export value of $1.2 billion for the year 2007 (Pham 2008; VnEconomy 2007). The following sections will describe in more detail the driving forces for the development of the Vietnamese catfish farming in the last decade.

2.2.2.1 Catfish Production

Catfish rearing has been a traditional activity of many rural households in the Mekong Delta region, primarily for individual household consumption purposes. Production at a commercial scale in its present form is a relatively new development in the Mekong Delta since the artificial propagation of the catfish species *Pangasius bocourti* Sauvage (basa catfish) was developed and adopted for *P. hypopthalmus* (tra catfish) (Phan et al. 2009). This technological breakthrough enabled the traditional, small-scale production practice that was dependent on wild-caught stock to shift to a more intensified system that relies entirely on hatchery-produced seed (Trong, Hao & Griffiths 2002). As a result, Vietnamese catfish farming has experienced phenomenal growth in the period 2000–2008.

The total output of catfish production has grown at an accelerated rate, both in terms of output volumes and output values. Figure 2-2 depicts the development of total output volumes and total output values of Vietnamese catfish farming in the period 1997 to July 2008. Within this 10-year period, catfish output increased from around 23.5 thousand tons to 835.564 thousand tons, a 35-fold increase. The annual growth rate of total catfish production output during this period was 40.23%. Concurrently, the output values for this period grew from VND 220 billion to VND 10,793 billion, a 46-fold increase. These phenomenal increases can be attributed to increases in farming area, yield per hectare and farm-gate price.

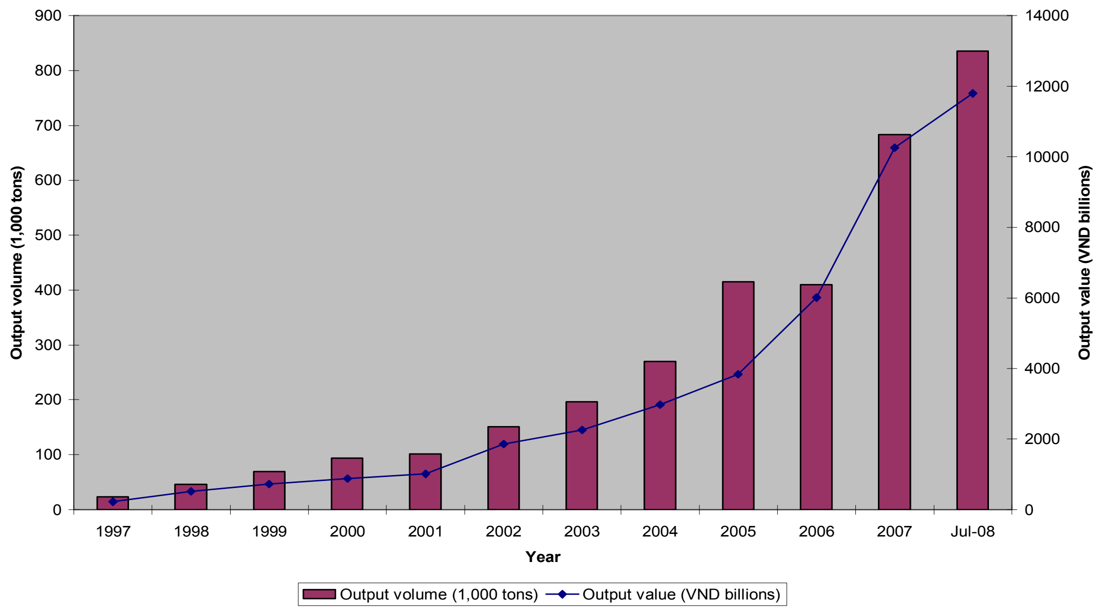

Figure 2-2 Vietnamese Catfish Production

2.2.2.2 Farming Area

Figure 2-3 shows the development in the total surface area of catfish farming in Vietnam in the period 1997–2008. The surface area for catfish farming increased from 1,290 hectares in 1997 to 5,350.8 hectares in the year 2008—a growth of more than four times. The average annual growth rate for this period was 15.46%. However, the annual growth rate of the total area has fluctuated significantly between the two periods before and after 2003, the year the Vietnamese catfish anti-dumping trial took place in the US. Vietnamese catfish farming grew at an annual growth rate of 13.34% and 18.09% for the periods 1997–2002 and 2003–2007, respectively.

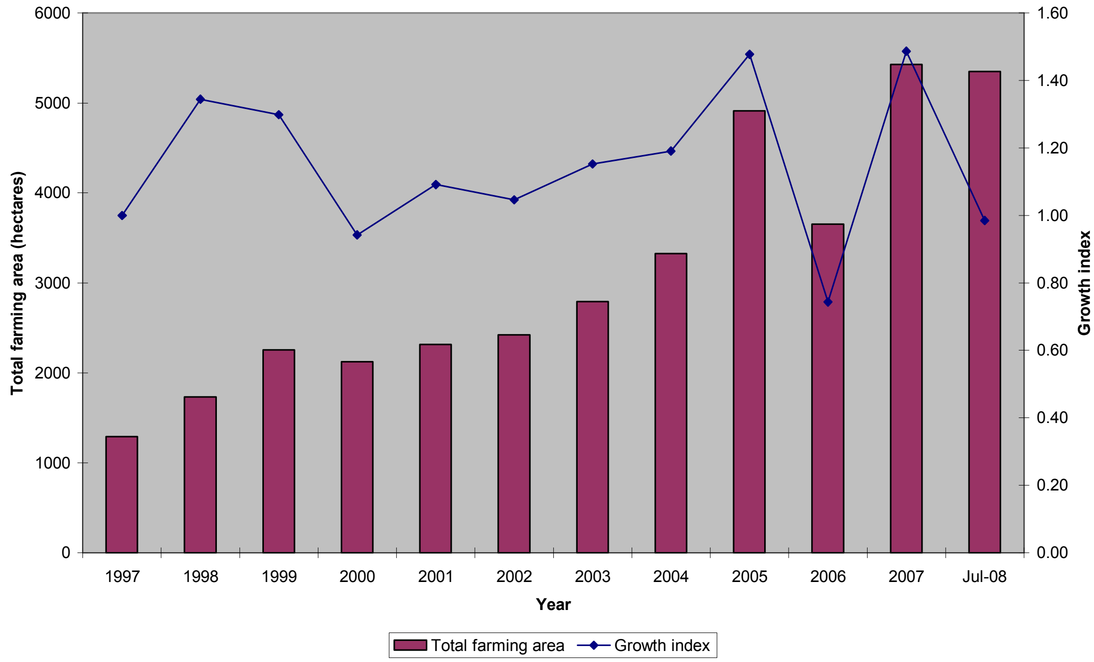

Figure 2-3 Vietnamese Catfish Farming Area

2.2.2.3 Catfish Farming Yield

Besides the rapid increase in the catfish farming area, yield increase has been another important factor driving the phenomenal growth of total catfish output in the period 2000–2008. In pond farming, yield per hectare increased steadily from 24.6 tons/ha in the year 2000 to 157 tons/ha in 2008. This achievement is the result of advances in farming technology, including disease control, water management, feed production and fingerling availability. Catfish farmers have shifted from a low-density extensive farming system to a highly intensive farming system. While pond farming experiences a steady trend of yield increase, cage farming yield shows a strong fluctuation and decrease over time. The opposite trends in yield of the two types of catfish farming system are shown in Figure 2-4.

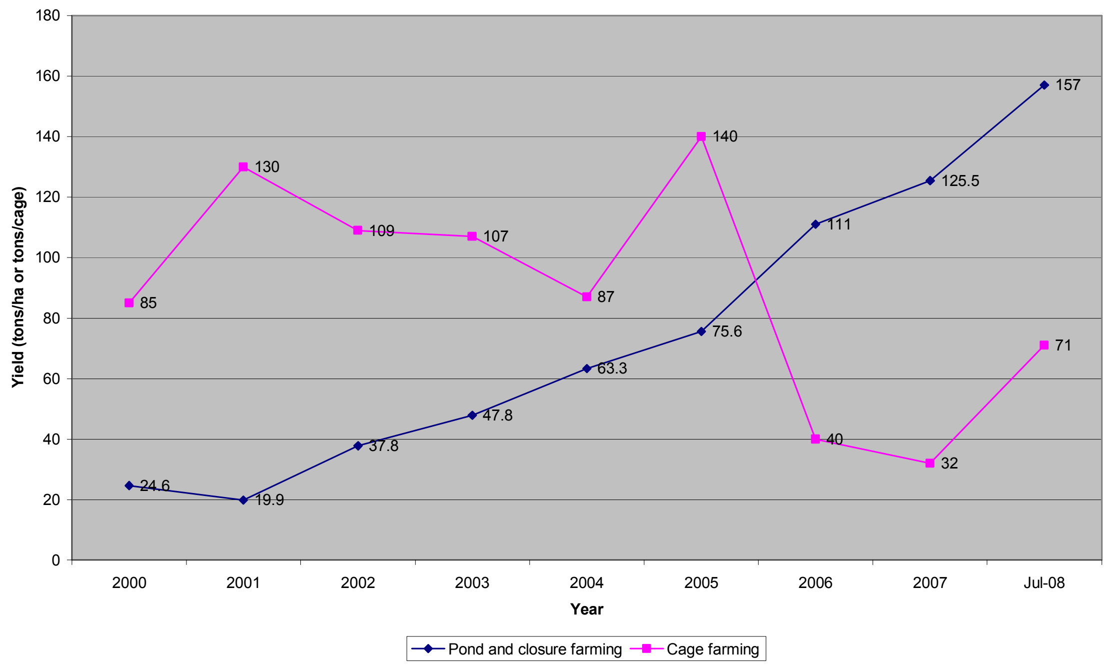

Figure 2-4 Catfish Yield by Types of Production

2.2.2.4 Average Farm-gate Unit Price

Another factor underlying the increase in total output value is the increase in average farm-gate prices over the period 1997–2008. The current average price fluctuates significantly over time, due to variation in the supply and demand of the market. In particular, before 2003 (the year in which the US anti-dumping trial took place) the average price of catfish was quite stable and slowly increased to its peak in 2003. After the trial, the US imposed a heavy anti-dumping tariff (ranging from 36.84% to 53% across export companies) on Vietnamese catfish imports to the US (Tu 2006). This caused a major drop in catfish exports to the US market in subsequent years. As a result, the average farm-gate price of catfish dropped sharply in 2004 and 2005. However, after 2005 the price rose again due to higher demand from international markets other than the US—specifically, the EU, Russia, and the Middle East.

Although the current price continues to increase, the real farm-gate price of catfish decreased over the period 1997–2008, which was a result of high inflation in Vietnam. This has also been a common phenomenon for the agricultural/aquacultural commodity price over time. The supply of food usually increases at a much higher rate than does the demand for food due to the application of new technological advances to production. The variations and trends of the average Vietnamese catfish farm-gate prices are presented in Figure 2-5.

Figure 2-5 Vietnamese Catfish Farm-gate Prices (1997-2008)

2.2.3 Catfish Exports

Approximately, 90% of Vietnamese catfish output was processed and exported to foreign markets (VASEP 2008). Therefore, development on the world market is very important to the development of the Vietnamese catfish industry. Variations of world market demand significantly impact on Vietnamese catfish exports. Sections below review the development of Vietnamese catfish exports in the period 2000 to 2008.

2.2.3.1 Export Volumes, Values, and Average Prices

Figure 2-6 depicts the development of Vietnamese catfish exports over the past ten years. In 2000, Vietnamese catfish exports started the year with a small amount of 689 tons of frozen catfish fillet per year with an export earning of USD 2.6 million. However, by the end of 2007 the total export volume had reached 386,870 tons, with an export value of approximately USD 1 billion (VASEP 2008)—an increase of 561 times the export volume and 377 times the export value. According to a recent estimate, the total catfish export value may reach USD 1.4 billion in 2009, despite the global economic crisis and the fall of the export price. It is worth noting that Vietnamese catfish export volumes and values have increased constantly over the period 2000–2007 despite the US anti-dumping trial in 2003. It was expected that Vietnamese catfish exports would face a serious downturn after the catfish 'war' took place because the US was the main market for Vietnamese catfish exports at that time.

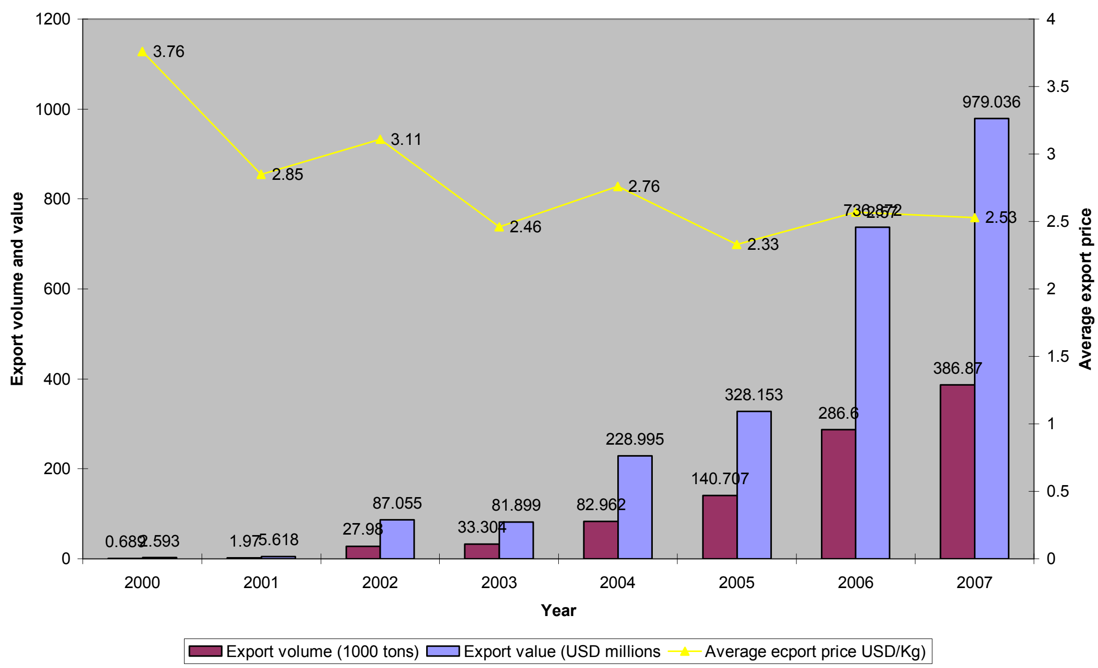

Figure 2-6 Vietnamese Catfish Exports

Although catfish exports volume and value have increased significantly in the period 2000–2007, the average export price has decreased constantly over the same period. The average export price decreased by 33%, from its highest price of USD 3.87 per kilogram in

2000 to USD 2.53 per kilogram in 2007. This is considered to be the main reason for the decrease in profits over the same period in both the processing and farming sectors.

2.2.3.2 Export Market Shares

In terms of market shares, there was a big shift from the main and traditional markets to newly developed markets from 2003 onwards. Before 2003, the main market for Vietnamese catfish export was the USA, which accounted for 77%, 77%, and 63% of total catfish exports (in term of export volumes) in the years 2000, 2001, and 2002 respectively. In terms of export values, these figures were 82%, 74%, and 6% for the years 2000, 2001, and 2002 respectively. In 2003, the US market share for Vietnamese catfish export dropped dramatically to 31% and continued to decline to only about 7% by May 2008. Unlike the expectation for a decline in the Vietnamese catfish export due to the impact of the US anti-dumping trial, Vietnamese catfish exports continued to grow at an impressive rate after 2003. Vietnamese catfish exporters have quickly switched to new markets such as the EU, Russia, and Middle East countries. The developments of change in export markets for Vietnamese catfish are presented in Figure 2-7 and 2-8.

After 2003, the EU replaced the US to be the most important market for Vietnamese catfish exports. The EU market share has increased from only 5% in 2001 to 48% in 2007. Most of the loss in export volume to the US has been replaced by the increase in exports to the EU. In addition, Vietnamese catfish exports have explored new markets in Russia, Ukraine, and Middle Eastern countries. By the end of 2008, Vietnamese catfish products had been exported to more than 100 countries and territories around the world. This quick reaction of the Vietnamese catfish industry not only has helped to prevent a serious downturn of catfish exports but has also increased the total catfish exports in terms of both volumes and values.

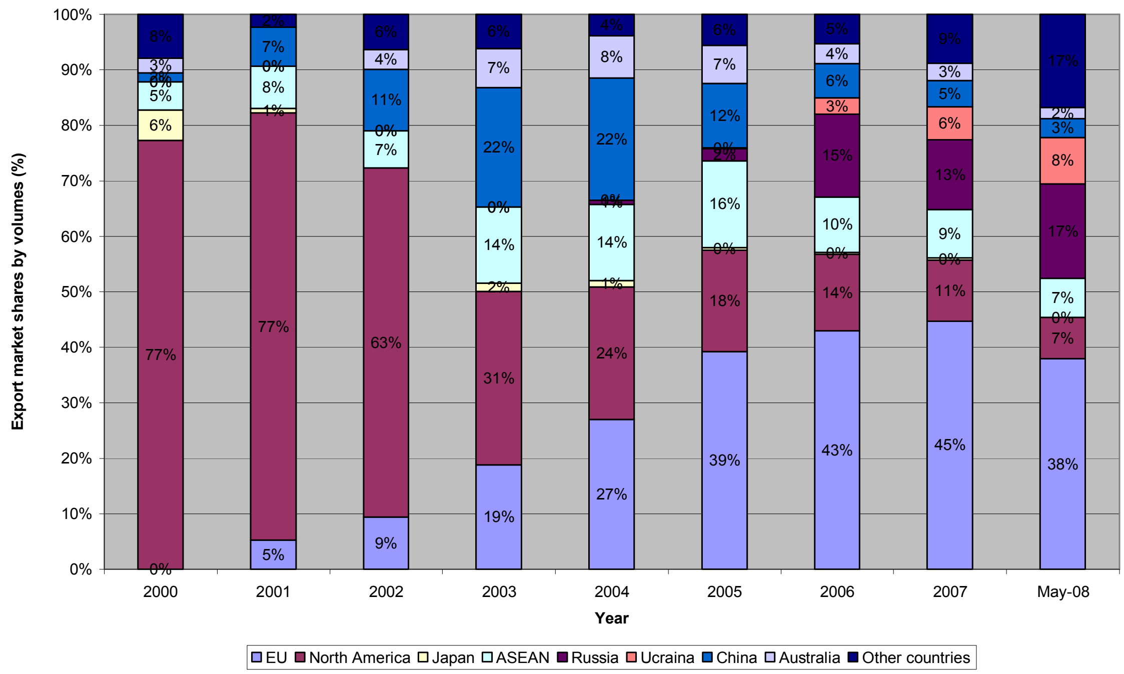

Figure 2-7 Vietnamese Catfish Export Market Shares (by Volume)

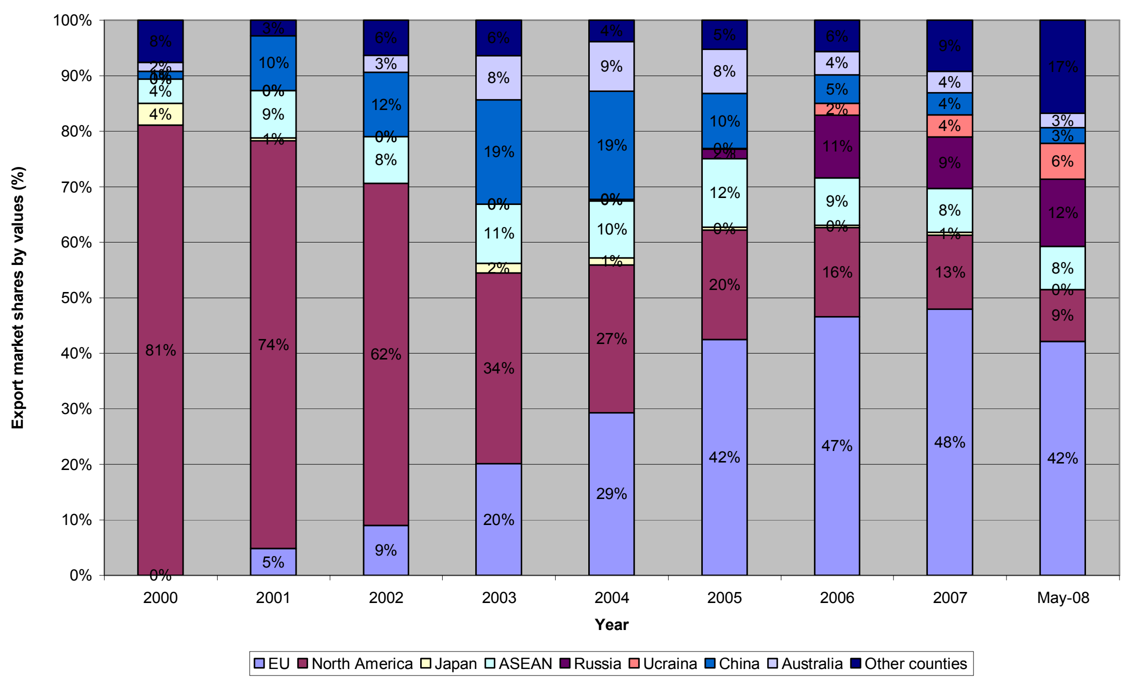

Figure 2-8 Vietnamese Catfish Export Market Shares (by Value)

2.2.4 Development of Input Markets for Catfish Production

Rapid growth in the catfish farming sector also led to a strong development in input markets for catfish farming. This can be considered the multiplier effect of the development of the catfish industry. The following sections present the development of the major input markets supporting the development of the Vietnamese catfish farming.

2.2.4.1 Labour Market

Together with the increases in farming area and production, more labour has also been used for catfish production process. The development of the catfish farming industry has significantly created jobs, increased income and reduced poverty in the region. The amount of labour involved in catfish grow-out farming increased from 6,470 persons in 1997 to 101,314 persons in 2007, an increase of 15.66 fold. By July 2008, this number was 105,535 persons, mainly in the three top provinces producing catfish: An Giang, Dong Thap, and Can Tho. The increase in the labour force used in the catfish farming industry is presented in Figure 2-9. The labour used for farming in 2006 abruptly jumped up to 71,158 persons from 23,341 persons a year before. This could the consequence of the increase in both farming area and intensification of farming. Generally, each hectare of catfish farm requires about three regular labours to take care of the farm if using pellet feed. The demand for labour is higher if homemade feed is used.

Besides generating many jobs directly related to farming activity, the development of the catfish farming industry has also created employment in many fields related to catfish farming, such as fingerling production, feed production, catfish processing, and seasonal employment in pond preparation and harvesting. According to the research done by the Vietnam Ministry of Agriculture and Rural Development (MARD 2008), the labour demand for fingerlings and seasonal work is about 8-12% of the total labour used in the catfish farming sector.

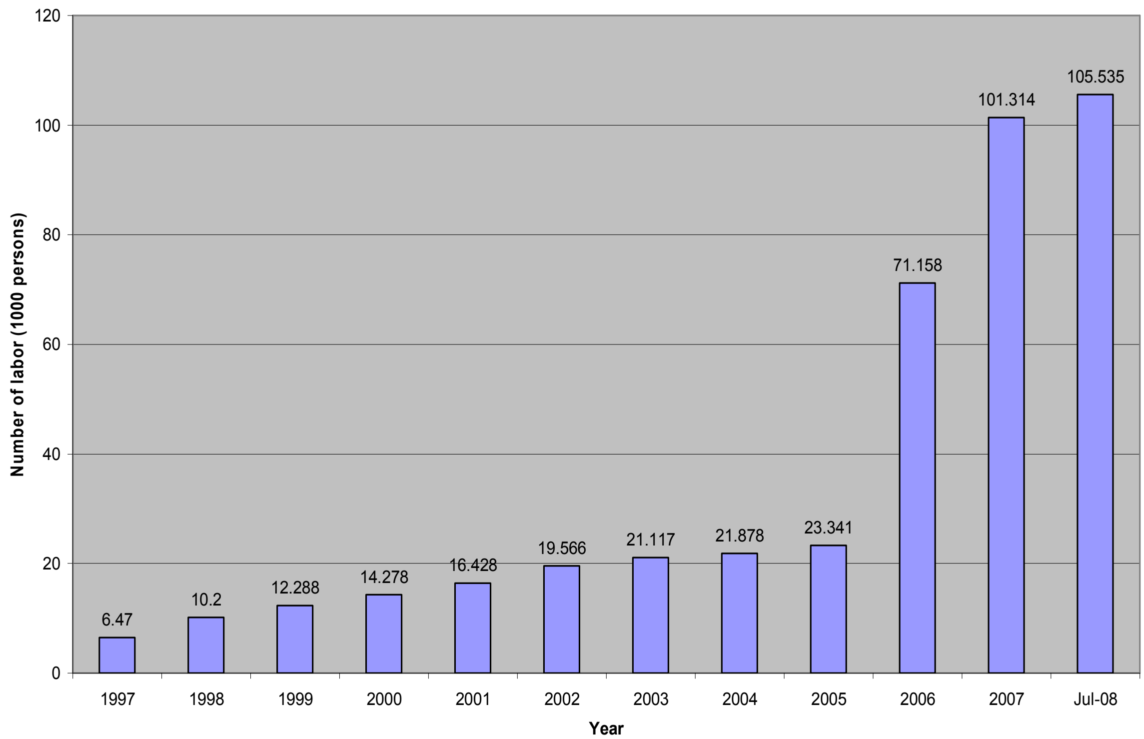

Figure 2-9 Amount of Labour Used in Catfish Farming

The average age of farm owners is about 40-55 years old, while hired labour has a lower average age of 20-35 years old. More than 80% of labours in catfish farming are male. Female labours often do logistic work serving male labours, who do most of the work in catfish farming. Most of labour has some training in aquacultural techniques by the Aquacultural Extension Service. Seed and fingerling producers often have a higher technical training than grow-out farmers do. In some cases, producers can have a bachelor or even higher degree in aquaculture. Younger labour tends to have a higher education level in comparison to older labour. About 80% of them have finished secondary school (junior high school). About 10% of the catfish labour force has secondary school level education. The remaining 10% of the labour force can read and write.

2.2.4.2 Seeds and Fingerlings Production

Concurrent to the development of catfish grow-out farming, fingerling production also had tremendous growth during the same period to meet the increasing demand of fingerlings. The fingerling production has grown quickly, in number of hatcheries and total fries and also in fingerling output.

In 1999, there were only three hatcheries in the region, located in An Giang province. One year later, this number was 46, with 43 hatcheries in Dong Thap and three hatcheries in An Giang province. In the period 2001-2007, the number of hatcheries has increased rapidly from 82 hatcheries in 2001 to 5,171 hatcheries in 2007, a 63-fold increase, with an average annual growth of 80.76%. Most of this increase happened in Dong Thap and An Giang provinces, where natural conditions are suitable for catfish breeding, hatching, and nursing activities. An Giang and Dong Thap provinces are located in the upstream part of the Tien and Hau rivers so industrial waste, agricultural pesticides, and aquacultural effluents do not pollute the water. This is the most important factor for fingerling production. An Giang and Dong Thap accounted for 94.24% of the total number of hatcheries in the whole Mekong Delta region. Only a small number of hatcheries are located in other provinces, such as Tien Giang, Hau Giang, Ben Tre, Vinh Long provinces; those are mainly nursery farms. Figure 2-10 presents the development of catfish fingerling production in terms of number of hatcheries, fries, and fingerlings output in the period 1997-2008.

Although the number of hatcheries has increased very quickly, most of these hatcheries are small. Average production of hatcheries in the region is about one million fingerlings per year, which requires 10-15 million fries (post larvae) per year. The average surface area is between 3,000 and 5,000 square metres.

Together with the fast increase in number of hatcheries, the total output of fry and fingerlings are also increasing rapidly. Total fry production has increased from 466 million fries in 2000 to 11.8 billions fries in 2007, a 25-fold increase. Similarly, fingerling output has reached 1.9 billion fingerlings in 2007 from a very low of 32 million fingerlings in 2000, a 60-fold increase in the same period of time.

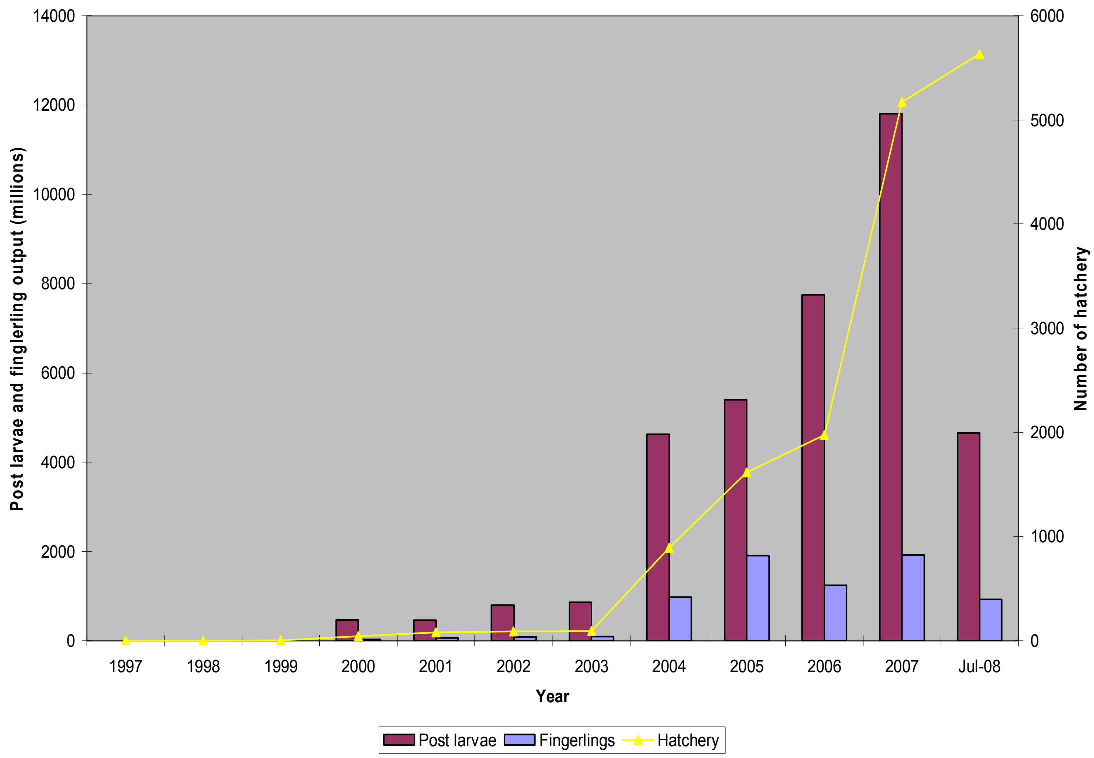

Figure 2-10 Number of Hatcheries and Fry and Fingerling Production

An important point worth making is the increase in the nursing survival rate (the number of fingerlings collected from 100 fries in the nursing stage) in this period. In the early 2000s, the survival rate was quite low, around 10%. By the end of the 2000s, the survival rate has significantly improved and reached about 20%. This is the result of applying scientific and technological advances to production practices. The survival rate reached 35%, the highest survival rate in nursing activity to date.

In the period 2001-2006, the catfish farming area was expanded continuously. In addition, farming technology shifted from extensive or semi-intensive farming to highly intensive farming (with very high stock density). The demand for fingerlings was extremely high. To meet this high demand for fingerlings, many hatcheries and nursing farms have been established. This phenomenal development is somewhat beyond the control of the government. Taking advantage of high market demand for fingerlings, many hatcheries and nursing farms did not follow the required technical standards to maximize profits. As a result, lots of fingerlings provided to the market were low quality, and had weak resistance to the environment, slow growth, and a high death rate in the grow-out stage.

2.2.4.3 Feed, Chemicals and Medicines

Feed is the most important and also the highest cost input in catfish farming, which usually accounts for about 80% of total production cost. Therefore, the increase of feed price is one of the most important concerns of catfish farmers. Two types of feed are used in catfish farming: homemade feed and pellet feed (factory made). Due to different nutritional content in each kilogram of feed, the unit cost and the feed conversion rate (FCR) of these two types of feed are different.

Statistics on feed prices and volumes used in catfish farming is generally not available in official statistics. However, through personal communication with local staff in the aquaculture field, the price of feed and feed-using practice can be described as follows. In the period 1997-2000, most of catfish farmers used homemade feed for their production. The advantage of this type of feed was low cost and the availability of materials for feed processing. The average feed cost in this period was about VND 4,000-4,200. The FCR of this type of feed is about 1.7-2.2 (meaning it takes about 1.7-2.2 kilogram of feed to produce one kilogram of fish). The major disadvantage of this type of feed is its high effluent rate that pollutes the water, both in pond and environment.

Since 2001, most catfish farmers have used pellet feed for their production due to stricter regulations and requirements on environment protection. The price of feed has constantly increased since then. It increased from VND 5,000-5,500 per kilogram in the period 2001-2003 to VND 5,000-6,000 per kilogram in the period 2004-2006. However, feed price reached a record high, up to 8,000-8,500 per kilogram, in the period 2007-2008. The FCR of this type of feed is about 1.5-1.6.

Chemicals and medicines used in catfish farming are usually provided together with feed. Chemicals are mostly used in pond treatment before stocking and after harvesting, for water management, while medicines are used for disease treatment. All of the chemicals and medicines used for catfish farming must be approved by Ministry of Aquaculture (formerly) or the Ministry of Agriculture and Rural Development (currently). Figure 2-11 presents the development of the number of feed and medicine providers in some selected provinces. Dong Thap, Tien Giang, Can Tho, and Vinh Long provinces have large number of feed and medicine providers because of their advantages in transportation.

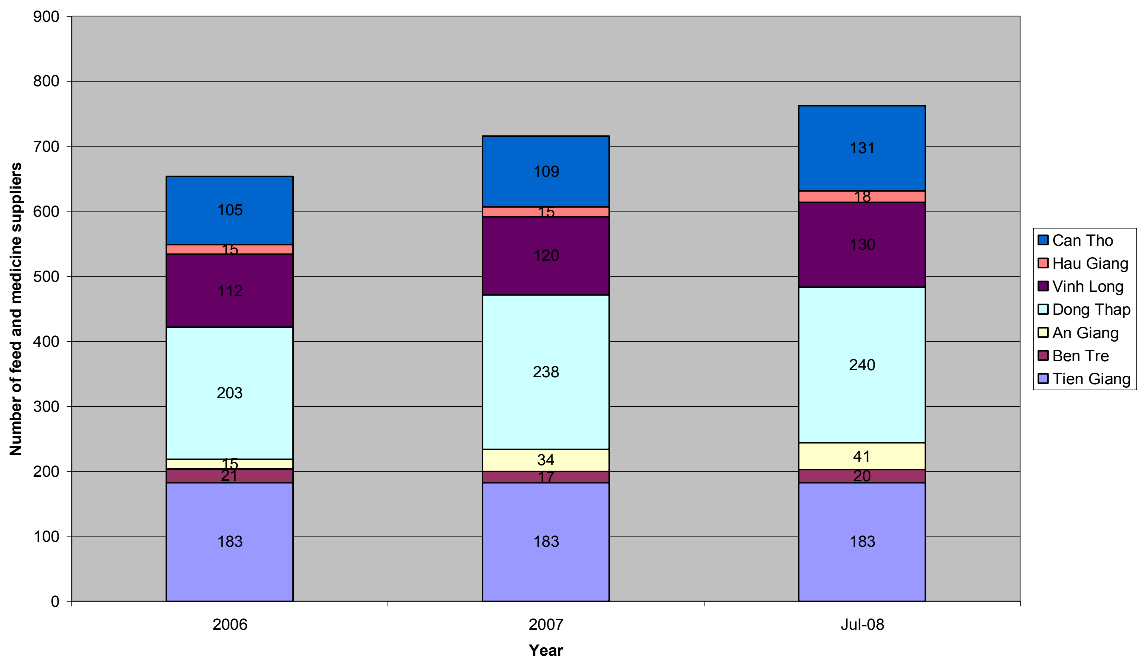

Figure 2-11 Number of Feed and Veterinary Medicine Providers

2.2.5 Risk Issues Relevant to the Vietnamese Catfish Farming Industry

Risk is defined as the possibility of adversity or loss, and refers to “uncertainty that matters”. Consequently, risk management involves choosing among alternatives to reduce the effects of risks. Understanding risk is a starting point to help producers make good management decisions in situations where adversity and loss are possibilities. Generally, risk in agriculture and aquaculture are classified into five main categories: (1) production or yield risk; (2) price or market risk; (3) institutional risk; (4) human or personal risk; and (5) financial risk (Harwood et al. 1999).

Among these types of risk, Vietnamese catfish farmers are most concerned about price risk, production risk and financial risk in their production. Catfish prices have fluctuated significantly over time as a result of the market for the produce being underdeveloped. Sale contracts with processors are made without a predetermined price and are easily broken in the face of unfavourable market conditions. The law governing sale contracts between catfish farmers and processors is weak and unreliable. Under intensified production systems, disease outbreak is another concern. There are 15 reported symptoms and/or diseases that affect catfish culture, with the cumulative mortality varying from farm to farm as well as throughout the production cycle. The level of mortality rises up to 30% during the early stages of the production cycle and less than 10% in the later months (Phan et al. 2009).

Most catfish farmers borrow money from banks and/or relatives to finance their production. The risk of under-financing is high due to a lack of access to funds and regular changes in government monetary policy.

2.3 Risk and Risk Management in Agriculture and Aquaculture

Risk and risk management in agriculture are discussed extensively in the literature. However, there is much less discussion of risk and risk management in aquaculture. In this section, we specifically review risks, and risk management strategies available to mitigate those risks, in agriculture and aquaculture. The typical risks, and risk management strategies applied, in aquaculture are emphasised.

2.3.1 Risk and Risk Management in Agriculture

The results from the Agricultural Resource Management Survey (ARMS), done by the US Department of Agriculture (USDA), indicated that the degree of producers' concern (on a scale from 1 to 4, with 1 for "not concerned" and 4 for "very concerned") varies across groups of commodities. More specifically, producers producing wheat, corn, soybean, tobacco, cotton, and certain other crops were more concerned about price and yield risks than any other factors. The degree of concern about more specific crops, such as greenhouse crops and livestock producers, was greatest regarding factors including changes in laws and regulations (with a score of 3.02), decreases in crop yields or livestock production (with a score of 2.95), and uncertainty regarding commodity prices (with a score of 2.91). The study also found out that, in general, producers of major field crops tend to be more concerned about price and yield risks, while products of livestock and specialty crop are relatively concerned about changes in law and regulations (Harwood et al. 1999). This may imply that different crops are subjected to different marketing conditions and government policies controlling the market for these commodities. In the case of aquacultural products, food safety requirements might put an even stronger constraint on production and this issue will be reviewed in more details later in this section.

Major strategies for risk management in US farming are: marketing contracting (including hedging, forwards, and futures and options), production contracting, enterprise diversification, vertical integration, and crop insurance. Study results on risk management in the US farms showed mixed results in the effectiveness of enterprise diversification as a strategy for risk mitigation. While enterprise diversification can be an efficient strategy for risk reduction in smaller farms (measured by cropped acreages) and younger operators, this is not necessarily the case for large-scale farms and wealthier operators. The degree of diversification in farming also varies significantly across regions and farm sizes. The reasons that could account for this situation are: the differences and limitations in farm resources, expertise, market outlets, weather conditions, and farmers' risk aversion (Harwood et al. 1999). The next two sections review the production contracts and marketing contracts that are commonly used in agriculture for risk mitigation.

Production contracting is an important instrument for risk prevention used by farmers. Farmers commonly enter into production contracts with firms (processing or marketing firms) when the products need a timely delivery, with rigid quality levels and uniform characteristics, and are highly perishable (Barry, Sonka & Lajili 1992; Kliebenstein 1995). There are two basic types of production contracts depending on the degree of control, risk, and uncertainty. They are: production management contracts and resource-providing contracts. Under a production management contract scheme, the contractors gain additional control over farming decisions, which are normally solely made by the farmer in cases without a contract. Under this contract scheme, production risks are totally shifted to contractors. However, growers still face some risks, related to the quality of products or production loss. The second type of contract is the resource-providing contract, which usually offers contractors a greater degree of control than does the production management contract. This type of contract is often used when production requires specific inputs and management to ensure the specific attributes of the final product. In this contract scheme, growers bear no risk on the price of the products, but still bear the "idiosyncratic" risks that are related to the efficiency of farm operation (Harwood et al. 1999).

Marketing contracts are another major tool used by farmers for price risk mitigation. Marketing contracts are either verbal or written agreements between a buyer and a producer that set a price and/or an outlet for a commodity before harvest or before the commodity is ready to be marketed (Perry 1997). There are many forms of marketing contracts, including: flat price contracts, basic contracts, price later contracts, hedge to arrive (HTA), and futures contracts. Although most of the marketing contracts guarantee producers a minimum price for the harvest delivery based on futures price quotes at the time the contract is established, they are slightly different in the final pricing formula that allows producers to obtain a higher price if the futures prices increase before the contract expires (Catania 1992). A detailed comparison of these different marketing contracts can be found in Harwood et al. (1999). Most types of contracts do not completely remove price risk except the "flat price contract".

A study on risk perceptions and management responses of 149 crop and livestock producers in 12 states in the US found that farmers' perceptions of sources of risk and management responses were significantly different across farm categories and product types. For crop producers, in general, weather conditions, crop price and government program were the most important sources of risk. However, a small group of ranchers considered variability in price as relatively unimportant. Mixed farming and small grain producers considered diseases and pests an important source of variability. Cotton producers were less concerned about diseases and pests than other farmers. They gave the greatest importance to the cost of operating inputs. Midwest corn, soybean, and hog producers placed greater importance on credit availability and the cost of credit than any other groups. A similar pattern for risk perceptions was also found in livestock production and risk management responses. The findings suggest that risks and management responses vary across geographical regions and by farm types. As a result, risk modelling should be adapted to the unique conditions of the domain being investigated and go beyond price and yield risks. As a minimum requirement, production (including inputs), marketing, and financial considerations must be integrated into a realistic decision-making framework (Patrick et al. 1985).

In a study on risk and risk management of Dutch livestock farmers (Meuwissen, Huirne & Hardaker 2001), it was found that meat price, epidemic diseases, and milk price were the most perceived important risks. The most relevant risk management strategies were producing at the lowest possible cost, and buying of business and personal insurance (in this order). The study also pointed out that, although price risks were perceived as a major source of risk, risk management strategies to deal with price risks, such as price contracts and futures and options markets were not perceived as important.

Beef producers in the Texas and Nebraska states of the US rated drought and price variability as the greatest two concerns, with average responses of 4.4 and 4.3 on a 5-point Likert scale, respectively. The next cluster of the sources of risk between a scale of 2.5 and 3.0 included extremely cold weather and disease. Finally, four sources of risk that were rated between 2.0 and 2.5 included: land price variability, variation in rented pasture availability, labour availability, and labour price. In terms of risk management strategies, maintaining animal health was viewed as the most effective strategy (mean score of 4.2). This finding is somewhat paradoxical because disease was ranked relatively low as a source of risk. Being a low-cost producer, maintaining financial or credit reserves, and off-farm investments were also considered important strategies (mean of 3.8, 3.6, and 3.6, respectively). Forward contracting and use of futures and options markets were considered least effective in risk mitigation. Again, this was a paradoxical finding, considering beef producers' perceptions of the high potential of price variability to affect ranch or farm income (Hall et al. 2003).

In comparing risk and risk management perceptions of organic and conventional dairy farming in Norway, organic dairy farmers had the least risk aversion perceptions. Both groups of dairy farmers rated institutional and production risks as major sources of risk, with farm support payments at the top. In contrast, organic farmers put more weight on institutional factors than production systems, in comparison to their conventional colleagues. Conventional farmers were more concerned about the cost of purchased inputs and animal welfare policies. However, both groups had similar responses on the efficacy of risk management strategies.

Financial measures such as liquidity and cost of production, disease prevention, and insurance were perceived as important ways to handle risks (Flaten et al. 2005).

2.3.2 Risks and Risk Management in Aquaculture

In aquaculture, besides other risks similar to agriculture, yield risk and quality risk are the most important issues due to the sensitivity of aquaculture to the environment. The success of aquaculture is greatly dependent on the quality of the cultivating environment. To meet the increasing demand of aquacultural products on the world market, semi-intensive and highly intensive aquacultural farms are common in the world, especially, in Asia, where approximately 90% of global aquacultural production is based (Giuffrida 2003). These models of cultivation use a large amount of artificial feed as the main source of food for the fish stock. Consequently, a large amount of effluent from fish ponds or fish cages is dumped into natural water resources (Le 2003). This causes serious problems for both the environment itself and the fish quality and yield, due to disease spread out and contamination of toxic substances in the product that might be harmful for human health. Research on risk management in aquaculture emphasizes the importance of the sustainability of the industry and the environment, and call for the application of good aquacultural practices.

Fish grown in large quantities are a major source of environmental disturbance. The wasted fish feed and fish faeces settle at the bottom and lead to a heavy accumulation of both beneficial and deleterious bacteria, and finer particles increase the turbidity in the water column and perhaps affect fish respiration (Doupe, Alder & Lymbery 1999). The enrichment of nutrition causes a reduction in farm holding capacity and adverse biological and chemical conditions for fish growth. Many studies have aimed at reducing the impact of fish effluents on the environment and at the same time improving the economic efficiency of fish farming. Most previous work on effluents of fishponds was largely related to channel catfish in the USA (Boyd 1978; Ellis, Tackett & Carter 1978; Hollerman & Boyd 1985). Tucker and Lloyd (1985) recognized that effluents from channel catfish ponds were an important source of pollution, particularly for total nitrogen (TN) and chemical oxygen demand (COD) (Lin & Yi 2003).

The effect of agricultural animals on water pollution is a growing concern for policy makers in all countries around the world. For sustainable growth of the industry, the adoption of “win-win” best management practices (BMP) is a common strategy in today’s aquaculture. An innovative aspect of many BMPs is their focus on pollution prevention by reducing the quantity of inputs used that cause run-off and emissions. Such cost-saving strategies should be profitable or profit neutral to businesses (Stanley 2000). The following six best management practices could reduce marine culture water effluents while maintaining farm profitability: (1) on-farm intake or effluent treatment plants (settling basins or constructed wetlands); (2) sludge removal; (3) co-production schemes; (4) improved feed and fertilizer management; (5) lower stocking rates; and (6) reduced water exchange or even closed recycling systems (Dieberg & Kiattisimkul 1996; Hopkins, Sandifer & Browdy 1995). The first three options are “structural BMPs” that require substantial fixed investment and significant capital outlay while the last three are “managerial” BMPs requiring changes in the variable inputs used. Better feed management lowers costs while reducing pollution. For example, feeding trays are a small investment likely to lower feed conversion ratios (Stanley 2000).

Another concern in aquacultural production is food safety, and one of the methods for controlling food safety and quality is the application of the Hazards Analysis and Critical Control Points (HACCP) system. While the implementation of HACCP-based safety assurance programmes are well advanced in the fish processing sector, the application of such programmes at fish farms, to enhance food safety, is in its infancy. There are few examples of applying HACCP principles in animal husbandry because of the lack of scientific data regarding the appropriateness of on-farm control of pathogenic micro-organisms. However, national and international agencies continue to recommend and promote the HACCP-based approach for all stages of the food chain, including the farm (Reilly & Kaferstein 1997; Vo 2006). The central goal of the HACCP rule is to stimulate improvement in food-safety practices by setting public health-oriented targets or standards that all food establishments must meet. The system establishes targets or standards to reduce risk from all sources of food-borne hazards—biological, chemical, and physical—while simultaneously providing a tool for holding establishments accountable for achieving acceptable levels of food-safety performance (Hulebak & Schlosser 2002).

Reilly and Kaferstein (1997) suggested a generalized model for the application of HACCP to aquacultural production. In this model, a flow diagram describes all the steps included in the production process, and through that diagram, critical control points (CCPs) are identified. At each CCP, the application of HACCP based on seven principles tries to clearly identify the following issues: hazards, control measures, critical limits, monitoring procedures, and corrective action. This is a generalized model for applying the HACCP to aquaculture production it must be modified substantially to meet specific fish farm conditions. However, it provides a useful guideline for application in practice.

In short, studies about risk and risk perceptions within conventional agriculture have been conducted extensively. For example, a rigorous study was conducted by the US Department of Agriculture (USDA) on risk and risk management in grain crops, cash crops, greenhouse crops, and livestock production in the United States (Boggess, Anaman & Hanson 1985; Hall et al. 2003; Harwood et al. 1999; Patrick & Musser 1997); research has been conducted on livestock production in the Netherlands (Meuwissen, Huirne & Hardaker 2001); and a study was undertaken on dairy production in Norway (Flaten et al. 2005). These studies have provided useful information for policy makers and the industry. Similar studies within the aquaculture sector have been carried out but to a far lesser extent. Some work has been done on the impact and management of price risk (Guttormsen 1999), on marketing contracts (Quagraine, Kuethe & Engle 2007), on potential insurance solutions (Harvey 1998), and on futures markets (Bergfjord 2007; Vassdal 1995). However, none of these studies has provided empirical information about sources of risk and which risk management strategies (RMS) farmers might use to manage the risks they face in their aquacultural production (Bergfjord 2009). Until recently, Bergfjord (2009) was a pioneer in conducting a complete survey on risk and risk perceptions in Norwegian aquaculture. In this study, besides general firm-related issues, the focus was on the perceptions of the sources of risk and risk management strategies of Norwegian salmon producers.

In aquaculture, in addition to traditional risks, which are similar to those faced in agriculture, much attention has been paid to environmental sustainability and food safety and hygiene risks. Some research has been conducted into the impact of the use of artificial feed, effluents, and waste water exchange in intensive fish farming on water resource disturbance and degradation as well as on potential strategies to minimise these impacts on the environment

(Boyd 1978; Dieberg & Kiattisimkul 1996; Doupe, Alder & Lymbery 1999; Giuffrida 2003; Hopkins, Sandifer & Browdy 1995; Le 2003; Lin & Yi 2003; Stanley 2000). Regarding food safety and hygiene risks, Hazards Analysis and Critical Control Points (HACCP) is considered an important tool for food safety and quality management in aquaculture and aquacultural product processing (Hulebak & Schlosser 2002; Reilly & Kaferstein 1997; Vo 2006)

2.4 Risk Management Standards

There exist quite a few risk management standards in the world, such as Australian Standards/New Zealand Standards 4360, ISO 9000, ISO 14000, COSO Enterprise-wide Risk Management (COSO ERM), Risk Management Standard (IRM-AIRMIC-ALARM, UK), HACCP, etc. Although these standards generally provide guidelines for the risk management process in businesses and institutions, they are slightly different in terms of the size, scope, and activities of businesses they are intended for. AS/NZS 4360 provide generic guidelines for developing risk management framework across various types and sizes of organizations while COSO ERM mostly focuses on risk management in multinational and multifunctional corporations. An ISO-based quality system, on the other hand involves all activities and handling being established in a procedural way, which must be followed by ensuring clear assignment of responsibilities and authority (Vo 2006). For this research, we use the Australia standard for risk management (AS/NZS 4360:2004) as the foundation for the development of the risk management framework for Vietnamese catfish farming due to its appropriateness to the scale of the Vietnamese catfish farms, which are mostly at small and medium scale farming levels; its coherence; and ease of application. The following section briefly reviews steps involved in the risk management process according to AS/NZS 4360:2004.

2.5 Risk Management Frameworks and Applications

A risk management framework is a set of elements of an organization's management system concerned with managing risk (Standards Australia & Standards New Zealand 2004a, 2004b). Within this framework, a risk management process is applied to mitigate risks. A risk management process is the systematic application of management policies, procedures, and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring, and reviewing risk (Standards Australia & Standards New Zealand 2004b). Risk management processes have been applied to various fields of business, including manufacturing, construction, industry, agriculture, aquaculture, banking, and health care service. The following sections first review the steps in the risk management process and then its applications in different industries.

2.5.1 Risk Management Process

The risk management process consists of a series of steps that, when undertaken in sequence, enable continuous improvement in decision making (Standards Australia & Standards New Zealand 2004b). According to AS/NZS 4360, the risk management process consists of seven steps, which are closely related to each other, namely: (1) communicate and consult, (2) establish the context, (3) identify the risk, (4) analyse the risk, (5) evaluate the risk, (6) treat the risk, and (7) monitor and review. The paragraphs below provide a brief description of the content of each step of the risk management process. At the end of this section, the general process will be summarized in a diagram for an overall view.

Step 1: Communicate and consult. This step aims to identify who should be involved in the assessment of risk, including identification, analysis, and evaluation). It should engage those who will be involved in the treatment, monitoring and review of risk. There are two main aspects of this step that should be identified in order to establish the requirements for the remainder of the process: eliciting risk information and managing stakeholder perceptions for the management of risk.

Step 2: Establish the context. The main purpose of this step is to identify specifically the boundaries within which risk management will apply. AS/NZS 4360 provides a five-step process to assist with establishing the context within which risk will be identified, i.e. establish the internal context, establish the external context, establish the risk management context, develop risk criteria, and define the structure for risk analysis.

Risk assessment is an integral part of a risk management process that consists of the next three steps of the process.

Step 3: Identify the risks. The aim of risk identification is to identify possible risks that may affect, either negatively or positively, the objectives of the business and activity under analysis. Identifying risks is the work of answering the following questions: What can happen? How can it happen? And, why could it happen? There are two main ways to identify risk: retrospectively and prospectively. Retrospective risks are those that occurred previously, such as incidents or accidents, and it is easier to identify and quantify the impacts of retrospective risks. On the other hand, prospective risks are often more difficult to identify. These are things that have not yet happened, but might happen sometime in the future. Among other methods of prospective risk identification, a "strengths, weaknesses, opportunities, and threats" (SWOT) analysis is a common tool used in planning and identifying areas of negative or positive risk at the business level.

Step 4: Analyse the risk. The objective of this step is to identify the possible consequences, or impact, of an event. And as a result, the level of risk can be determined; that is, *level of risk = consequence x likelihood*. The level of risk can then be used for making decisions about resources to commit to control the risk. The techniques for determining the consequence and likelihood of risk include descriptors, or mathematically determined values (Global Risk Alliance 2005). The purpose of risk analysis is to provide information to business owners to make decisions regarding priorities and treatment options, or balancing costs and benefits. Three categories or types of risk analysis can be used to determine the level of risk: qualitative, semi-quantitative, and quantitative.

Step 5: Evaluate the risks. The result of this step is a prioritized list of clearly identified risks: which risks need treatment and which risks are going to be accepted by the business (accept the risks). Business can choose between treating the risk and accepting the risk. Risks can be accepted if the level of risk is low and the cost of treating the risk outweighs the benefit, or maybe there is no reasonable treatment that can be implemented.

Step 6: Treat the risks. Risk treatment is about considering the options for treating the risks that are not acceptable or tolerable at Step 5. This step identifies the options for treating or controlling risk, in order to reduce or eliminate negative consequences or to reduce the likelihood of an adverse occurrence. Risk treatment should also aim to enhance positive outcomes. AS/NZS 4360 identifies the following options that may assist in the minimization of negative risks or an increase in the impact of positive risk: avoid the risk, change the likelihood of occurrence, change the consequences, share the risk, and retain the risk.

Step 7: Monitor and review. Monitor and review is an essential and integral step in the risk management process. Businesses must monitor and review the effectiveness of their risk treatment plan and ensure that changing circumstances do not alter the risk priority. At a business level, the risk management plan should be periodically (at least on an annual basis) reviewed to ensure the effectiveness of current risk treatment as well as to capture new risks into the risk management plan (Global Risk Alliance 2005).

Figure 2-12 summarises the elements of the risk management process based on the AS/NZS 4360 standard.

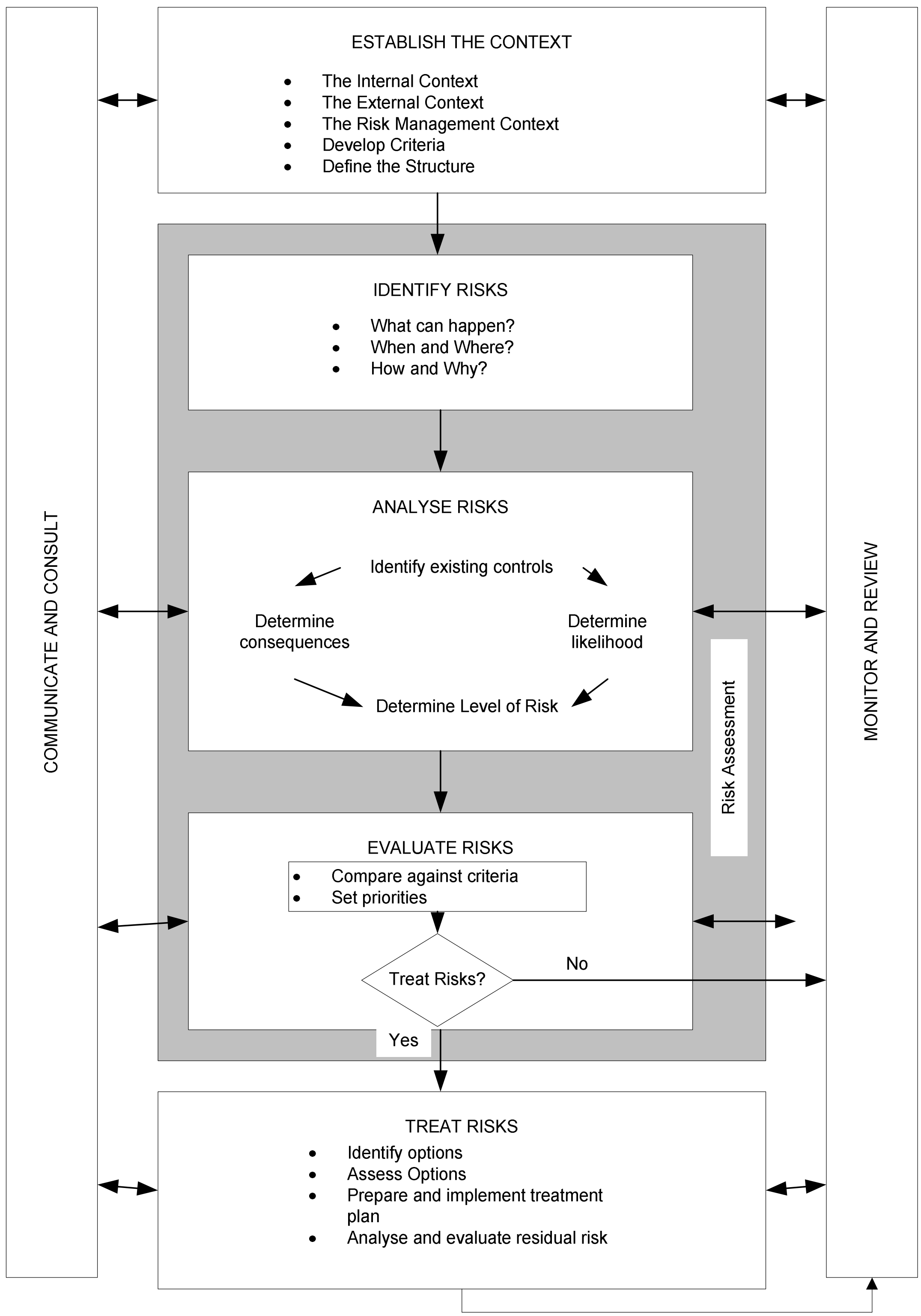

Figure 2-12 Risk Management Process (AS/NZS 4360:2004)

Similar to the risk management developed by AS/NZS 4369:2004, (Haimes 2009) developed a methodological framework to identify, prioritize, assess, and manage scenarios of risk to a large-scale system from multiple overlapping perspectives. The framework described the guiding principles and the eight phases of the risk filtering, ranking, and management (RFRM) methodology, followed by several examples, including applying the framework to a mission in support of an operation other than war (OOTW).

The Haimes' RFRM framework is a modified and much-improved version of risk ranking and filtering (RRF), originally developed by NASA for the space shuttle (CRMES 1991; Haimes et al. 1992). The key aspects of the RFRM methods are: (1) a hierarchy of five major contributors to program risks, which constitute the criteria for ranking; (2) a quantification of the program risk by measurable attributes; (3) a graphical risk "fingerprint" to distinguish among critical items; (4) a telescoping filter approach to reduce the critical item list to the most critical number of sources of risk, often referred as the top n-; and (5) a weighted score method, adapted from the analytic hierarchical process (AHP) developed by Saaty (1988), augmenting the criteria hierarchy and risk fingerprint to support interactive prioritization of the top n. To illustrate the application of the RFRM framework, an example of the application of the RFRM was developed for risk management for mission of an operation other than war (OOTW), conducted by (Haimes 2009; Haimes, Kaplan & Lambert 2002).

The hierarchical holistic model (HHM) is constructed based on the two major components; namely, the *head topics* and the *sub-topics.* The *head topics* constitute the major visions, concepts, and perspectives of success, and the *sub-topics* provide a more detailed classification of requirements for the success scenarios, or sources of risk for the risk scenarios.

Thus, by nature and construction, the HHM methodology generates a comprehensive set of sources of risk, i.e., categories of risk scenarios, commonly in the order of hundred of entries. To systematically discriminate between these sources of risk with respect to severity (consequences) and likelihood (probabilities) of risk on the basic of principled criteria and sound premises, the proposed framework must take into account the following considerations:

- It is impractical (e.g. due to time and resource constraints) to apply quantitative risk analysis to hundreds of sources of risk. In such cases, qualitative risk analysis may be adequate for decision purposes under certain conditions.

- All sources of evidence should be harnessed in the filtering and ranking process to assess the significance of the risk sources.

- Six basic questions characterize the process of risk assessment and management and serve as the compass for the RFRM approach. For risk assessment processes, there are three questions: What can go wrong? What is the likelihood of that happening? What are the consequences? (Kaplan and Garrick, 1981). For the risk management process: What can be done and what are the available options? What are the associated trade-offs in terms of costs, benefits, and risks? What are the impacts of current decisions on future options? (Haimes 1991).

To deploy the RFRM effectively, we must consider the variety of sources of risk, including those representing hardware, software, organizational, and human failures. Programmatic risks are also addressed.

An integration of empirical and conceptual, descriptive and normative, quantitative and qualitative methods is always superior to “either-or” choice. The trade-offs that are inherent in the risk management process manifest themselves in the RFRM methodology.

The RFRM consists of the following eight major phases:

a. Phase I: Scenario Identification: A hierarchical holographic model (HHM) is developed to describe the system “as planned” or “success” scenario.

Most sources of risk are identified through the HHM methodology. These sources of risk describe “what can go wrong” in the “as planned” or “success” scenario. Each sub-topic represents a category of risk scenarios, i.e., description of what can go wrong. Through the HHM we generate a diagram that organizes and displays a complete set of system success criteria from multiple overlapping perspectives. Each box in the diagram represents a set of sources of risk, or requirements for successful operation of the system. A more detailed HHM yields a more accurate picture of the success scenario, and consequently leads to a better assessment of the risk situation. In other words, having more levels in the hierarchy describes the system structure in greater detail and facilitates identifying failure modes. However, a more detailed HHM is also more expensive to construct in terms of time and resources (Haimes 2009; Haimes, Kaplan & Lambert 2002).

b. Phase II: Scenario Filtering: The risk scenarios identified in Phase I are filtered according to the responsibilities and interests of the current system user.

In Phase II, filtering is done at the level of "subtopics" or "sources of risk". The large number of sources of risk identified in Phase I (commonly hundreds of sources of risk) can be overwhelming. Clearly, not all of these subtopics can be of immediate concern to all the levels of decision making at all times. At this phase, the sources of risk are filtered according to the interest and responsibility of the individual risk manager or decision maker. The filtering criteria include decision making level, scope, and temporal domain. This phase often reduces the number risk sources from several hundreds to around 50.

c. Phase III: Bi-criteria Filtering and Ranking: The remaining risk scenarios are further filtered using qualitative likelihoods and consequences.

In this phase, risk filtering is also at the level of subtopics. However, the process moves closer to quantitative treatment. A joint contribution of two different types of information – the likelihood of the risk and the associated consequences is estimated based on available evidence. The likelihoods and consequences are combined into a joint concept called "severity" using the ordinal version of the matrix procedure adopted from US Military Standard (MIL-STD) 882, US Department of Defence.

d. Phase IV: Multi-criteria Evaluation: Eleven criteria are developed that determine the ability of a risk scenario to defeat the defences of the system.

This phase takes a further step in filtering risks by reflecting on the ability of each scenario to defeat three defensive properties of the underling system: *resilience, robustness, and redundancy*. *Redundancy* refers to the ability of extra components of a system to assume the function of failed components. *Robustness* refers to the insensitivity of system performance to external stresses. *Resilience* is the ability of a system to recover following an emergency.

Scenarios able to defeat these properties are of greater concern, and thus are scored as more severe.

e. Phase V: Quantitative Ranking: Filtering and ranking continue based on quantitative and qualitative matrix scales of likelihood and consequences.

This phase quantifies the likelihood scenario using Bayes' theorem and all the relevant evidence available. The value of quantification is that it clarifies the results, disciplines the thought process, and replaces opinion with evidence.

Calculating the likelihoods of scenarios avoids possible miscommunication when interpreting verbal expression such as "high", "low", and "very high". This approach yields a matrix with ranges of probability on the horizontal axis. This is a "cardinal" version of the "ordinal" risk matrix deployed in Phase III. Filtering and ranking the risk scenarios through this matrix typically reduces the number of scenarios from about 20 to about 10.

f. Phase VI: Risk Management: Identifying risk management options for dealing with filtered scenarios, and estimating the costs, performance benefits, and reduction of each.

In this phase, we focus on the risk management strategies to mitigate the risks identified in Phase V. Basically, we try to answer the following questions: "What can be done, and what options are available?" and "What are the associated trade-offs in terms of cost, benefits, risks?"

g. Phase VII: Safeguarding Against Missing Critical Items: Evaluating the performance of the options selected in Phase VI against the scenarios previously filtered in Phase II to V.

Phase VI aims at providing added assurance that the proposed RFRM methodology creates a flexible reaction plan if indicators signal the emergence of new or heretofore undetected critical items. In particular, in this phase of the analysis, we:

- Ascertain the extent to which the risk management options developed in Phase VI affect or are affected by any of the risk scenarios discarded in Phase II to V.
- From what was learned in Step 1 above, make appropriate revisions to the risk management options developed in Phase VI.

h. Phase VIII: Operational Feedback: Using the experience and information gained during application to refine the scenario filtering and decision processes of earlier phases.

The RFRM can be improved on the basic of feedback accumulated during its deployment. The following are guiding principles for the feedback data collection process:

- The HHM is never considered finished; new sources of risk should be added as additional categories or new topics.
- Be cognizant of all benefits, costs, and risks to human health and the environment.

2.5.2 Existing Risk Management Frameworks in Agriculture and Aquaculture

The literature on risk management frameworks in agriculture and aquaculture is widely diverse in terms of scale, extent, and target. It can be focused on the control of the food safety problems, environmental sustainability, and animal health and disease management, etc. The well known food safety risk management framework is the Hazard Analysis and Critical Control Points (HACCP) system that provides procedures and principles for applying the framework for food safety control (USDA 1993). The US catfish industry is a good example of the application of HACCP system to aquacultural production including both catfish farming and processing. The Mississippi State University has developed training programs for food industries that provides trainees six steps for applying the seven principles (including: conduct hazard analysis, identify critical points, set critical limits for each hazard at each critical control point, devise monitoring system, establish a correction plan, verify the HACCP system, and keep records) of the HACCP system (Kim 1993; USDA 1993).

According to the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), risk management comprises of four steps: risk evaluation, risk management option assessment, implementation of management decision, and monitoring and review (FAO/WHO 1997). In this process, the risk evaluation process combined with the management options evaluation should result in a decision on the risk management strategy. In this system, the primary consideration in arriving at a management decision is human health protection, with other factors such as cost, feasibility, and risk perception (Schlundt 1999).

McDaniels, Longstaff & Dowlatabadi (2006) applied a value-based framework for risk management decisions involving multiple scales for the salmon aquaculture industry in the British Columbia area. In their study, risk management decisions could be divided, in conceptual and practical terms, into local, national, regional, and international scales. The approach tries to reach key decisions that arise at each level and the diverse relationships among them. For example, while regulatory decisions concerning the global role of salmon aquaculture are found solely at the international scale, others can be found at multiple levels. This model mainly focuses on the analysis of the aquacultural industry and aims at developing regulatory policies for environment and industry sustainability.

In short, although there are different existing risk management frameworks in the literature, they are either too specific or too general for particular aims. The HACCP framework for example is specified for food safety issues, while the value-based framework for environmental sustainability is too general. Currently, to the best of our knowledge, there is no existing framework that provides a complete treatment of the risks faced by farmers at the farm level, which covers all risk factors that can affect farm profitability and sustainability. This research aims to achieve this goal by balancing the scope and the scale in risk management for catfish farming in Vietnam.

2.5.3 Applications of Risk Management Framework

A general risk management framework has been applied widely across industries in the economy. Due to the variability involved in developing a specific risk management framework for a specific targeting object, it is difficult to provide a common process for developing different risk management frameworks for different purposes. The following paragraphs will first provide some examples of risk management frameworks in different industries. Then a short discussion about the similarity and differences of these risk management framework is provided.

In the construction industry, Wang, Dulaimi & Aguria (2004) developed a risk management framework for construction projects in developing countries. The aim of this research was to help international construction firms, especially those in Singapore, identify the risks foreign construction firms may face operating in developing countries and to develop a risk management framework to aid their efforts in mitigating such risks. Specifically:

- To develop a model for identifying, categorizing, and representing the risks associated with international construction projects;
- To validate the model through an international survey to identify and evaluate critical risks associated with construction projects in developing countries, with an emphasis on China;
- To identify and evaluate practical measures for mitigating these risks;
- To formulate a risk management framework that can be adopted by international construction firms, including Singaporean firms, seeking work in developing countries.

To reach the research objectives, four research tasks were carried out, mainly through a literature review, interviews and discussions, as well as an international survey.

The literature review tasks were extensively conducted to compile the list of risks of construction projects and the list of mitigation measures for each of the risks identified, as well as to examine existing risk models. Then the risks and risk mitigation measures identified were filtered and a risk model and risk management framework was proposed. To validate the proposed risk model and risk management framework, an international questionnaire survey was carried out. After analysing the survey results, the risk model and risk management framework were improved and documented.

The study adopted the three level (country, market, and project) framework developed by Hastak and Shaked (2000) to categorize risks involved in the study. A seven-degree rating system scale was used for the criticality of risk and the effectiveness of risk mitigation measures. Total Criticality Index and Mean Critical Index were used for measuring and ranking the criticality of risk and the effectiveness of risk mitigation measures.

The study also used the Alien Eyes' Risk Model to model the inter-relationship of risks across different levels. For example, the country level risks influence both the market and project level risks, while the market level risks influence the project level risks. Therefore, the country level risks are considered the most dominant and at the highest hierarchical level while the project level risks are relatively the most dormant and at the lowest hierarchical level in the model. From this model, it follows that the risk mitigation strategy should prioritize with respect to dominance, i.e., the dominant risks should be mitigated before, or with higher priority over, the dormant ones. By doing so, this not only mitigates the dominant risks but also influences the dormant risks, which ultimately minimize the dormant risks as well.

Finally, the study proposed a qualitative risk mitigation framework for risk management in construction projects in developing countries. The framework made use of all the steps identified above; namely, risk and risk mitigation measure identification, evaluation, ranking, and prioritizing.

A risk management framework is also developed to mitigate risks in different activities in the electricity industry, i.e., a risk management model for improving operation and maintenance activities in electricity transmission networks (Tummala & Mak 2001), and a risk management model for cost risk management (Tummala & Burchett 1999).

In the former example, the study aimed at formulating a risk management model to identify and assess potential risk factors so as to improve the performance of the operation and maintenance activities involved in the transmission of electricity in Hong Kong. The model is formulated based on the five core elements of risk management process (RMP); namely, risk identification, risk measurement, risk evaluation, and risk control and monitoring.

In the risk identification and risk assessment phases, the authors have tried to identify potential risk factors affecting project success and enumerate the associated consequences and assess their severity levels (consequence severity levels), and probability of occurrence (risk probability levels).

To measure the risks, the authors used a qualitative approach of enumerating the risk consequence severity levels (1-4) and risk probability levels (1-5), based on US Military Standards 882c. The risk exposure level is defined as the product of consequence severity level and probability level. The ranking of risk factors consists of finding risk exposure values and prioritizing the identified risk factors based on the risk exposure values

Similarly, developing a risk control action plan involves possible risk response actions to contain and control the identified risk factors based on the five risk control approaches, namely: accept, reduce, avoid, spread and transfer. The stage of establishing risk control costs consists of examining the resources needed and associated costs to fully implement and formulate risk response action plans.

The Hazard Totem Pole (HTP) is used to integrate these costs along with the consequent severity and risk probability levels by means of an HTP diagram in order to prioritize the identified risk factors with respect to risk control plans. The HTP indexes are determined as the algebraic sum of index values of the three attributes of the identified risk factors, namely, consequences severity, risk probability, and cost levels (1-4), without imposing weighting factors to any one of the attributes.

For managing cost risks, Tummala & Burchett (1999) applied a risk management process (RMP) to manage cost risk for an EHV[1] transmission line project. Specifically, this study examined the role of the application of RMP in capital budgeting. It also examined how

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[1] EHV stands for Extremely High Voltage.

critical success factors, project structure, work breakdown structure, range estimation, and management control systems are used in developing an RMP based risk management model to allow potential risks to be identified and assessed in order to improve the evaluation and control costs. A risk management process (RMP) is used to formulate a risk management model incorporating transmission line costs for capital budgeting and apply it to an existing EHV transmission line project.

In this study, the authors used RMP in developing a risk management model to estimate EHV transmission line project costs. The RMP provide a systematic framework to enumerate and assess the consequences and the likelihood of the occurrence of all potential risk factors associated with a given project. Furthermore, it is useful in identifying the resources needed and choosing appropriate response actions to control and manage the identified risk factors.

Similar to other RMP, the RMP in this study consists of the five core elements, including risk identification, risk measurement, risk assessment, risk evaluation, risk control, and monitoring. RMP begins with identifying the strategic importance of the project and the corresponding project mission, aims, and objectives. Risk identification, risk measurement, and risk assessment form a system that includes several tools to identify all potential risk factors and to enumerate the consequences and their severity of the identified risk factors. It also includes several techniques for assessing the uncertainty associated with the consequences in the form of probability distributions for project critical success factors.

The risk evaluation phase of the RMP involves several decision alternatives and evaluating them based on the risk profiles obtained in the risk assessment phase, and taking necessary corrective actions if the project outcomes are at variance with the planned outcomes.

In the risk control and monitoring phase, the project manager can examine the progress as well as any decision that might occur and the corrective action required for achieving the desired objectives of the project. This phase also facilitates periodic communication between senior manager and other personnel who are involved with project execution.

In project risk management, Dey (2002) combined analytic hierarchy process (AHP) and a decision tree approach to develop a project risk management model. The objective of this study was to model a decision support system (DSS) through risk analysis for making objective decisions on project planning, design, engineering, and resource deployment for completing a project on time, within budget, and in line with project objectives, organizational policy and present business scenarios.

The study demonstrates a quantitative approach to construct risk management through an analytic hierarchy process (AHP) and decision tree analysis (DTA). The entire project is classified to form a few work packages. With the involvement of project stakeholders, work packages are classified. As all the risk factors are identified, their effects are quantified by determining probability (using AHP) and severity (guess estimate). Various responses are generated, listing the cost implications of mitigating the quantified risks. The expected monetary values are derived for each alternative in a decision tree framework and the subsequent probability analysis helps to make the right decision in managing risks. The methodology of the study is explained in the following steps:

- Identifying the work packages for risk analysis
- Identifying the factors that affect the time, cost, and quality achievement of a specific work package.
- Analysing the effect by deriving the likelihood of the occurrences in an AHP framework
- Determining severity of failure by guess estimation
- Deriving various alternative responses for mitigating the effect of risk factors
- Estimating the cost of each alternative
- Determining the probability and severity of an failure of a specific work package after a specific response
- Forming a decision tree
- Deriving expected monetary value (EMV) or the cost of risk response in this case.
- Selecting the best option through statistical analysis.

For illustration of the application of the risk management model, the entire methodology was applied to a case study of a cross-country petroleum pipeline project in India. A details example of applying the methodology can be seen in Dey (2002).

Finally, the case of applying risk management in an infrastructure protection is provided. Leung, Lambert & Mosenthal (2004) developed a risk base approach to setting priorities in protecting bridges against terrorist attacks. This study aimed to address some of the issues in critical infrastructure protection against wilful attack; namely, critical asset classification, risk scenario identification and prioritization, and risk management. It presents insights on multi-objective evaluation of management options, as well an illustration of extreme-value event analysis and the value this adds to the problems involving catastrophic consequences. This study employs risk filtering, ranking and management (RFRM) developed by Haimes, Kaplan & Lambert (2002) as the methodological framework in assessing the threat of terrorist attacks. This risk assessment is conducted at two levels: (1) system level, and (2) asset specific level. The system level assessment involves identifying the critical assets of a highway transportation infrastructure. This is complemented by the asset specific risk assessment, which allows for a more in-depth analysis of a particular infrastructure asset. The study used the HHM to constitute a comprehensive framework for identifying real and perceived sources of risk. It is employed to be able to capture the many perspectives from which to view the system or problem.

Table 2-1 summarises the applications of the general risk management framework in developing a risk management model in different industries.

Table 2-1 Studies on Applying Risk Management Frameworks

	Methods used in risk management steps		
Research title/reference	Risk identification and measurement	Risk evaluation and prioritization	Risk management prioritization
Risk management framework for construction projects in development (Wang, Dulaimi & Aguria 2004)	• Literature review • Three levels (country, market, and project) breakdown • Seven-degree rating system	• Total Criticality Index and Mean Criticality Index • Alien Eyes' Risk Model	• From the most dominant risks to the dormant risk
A risk management model for improving operation and maintenance activities in electricity transmission networks (Tummala & Mak 2001)	• Examining past equipment fault records or defect histories • Supplier' recommendation • Using 'loss of revenue" to measure the seriousness and five-degree scale (1-5) to measure probability of risk occurrence	• Risk exposure = risk consequence * risk probability • All risks are important • The Hazard Totem Pole (HTP)	• HTP Index (sum of risk consequence (1-5), risk probability (1-5) and cost level (1-4))
Applying a risk management process (RMP) to manage cost risk for an EHV transmission line project (Tummala & Burchett 1999)	• The work breakdown structure (WBS), top down approach • Risk check list • Range of costs • Probability distribution	• Probability distributions (triangle, logistics) • Simulations	• Maximize profit by minimizing risks using risk reduction, risk retention, and risk transfer
Project risk management: a combined analytic hierarchy process and decision tree approach (Dey 2002)	• Work package breakdown • Historical data and guess estimate of risk consequences and probabilities • Cost over-run	• Analytic hierarchy process (AHP • Weighted verbal scale	• Decision tree analysis (DTA) • Expected monetary value of the cost of risk response

2.6 Decision Support Systems in Aquaculture

A decision support system (DSS) is used extensively in almost any type of business. As the name suggested, it provides a tool for decision makers to make decision based on the information managed and processed by the DSS. Related to this research, in this section, we review the designs of some DSS used in aquacultural management in terms of DSS architecture, user interface, and development platform. A summary of these DSS is provided last.

In marine fisheries, a DSS was developed for fishery management in the North-eastern Sea of the US (Azadivar, Truong & Jiao 2009). The authors developed a decision support system (DSS) for fishery management using operations research and systems science approach. A general framework, using systems science approach, was used to develop the DSS. The DSS combined a fishery model and operation research methods to provide information for the designs of fishery management policies. Fishery models consider multiple stocks and fisheries simultaneously in balancing catch among targeted and protected fish abundances. The core component of this DSS applies operation research techniques of simulation and optimization to determine the optimal inter-annual and intra-annual fishery plans in terms of fishing efforts in each of sub-area and time period.

The systems science approach was used to develop the DSS. An effective fishing management system should link together three fundamental phases of given activities. Specifically, these are: (i) system description, which includes data collection and processing; (ii) system analysis, which provides parameter estimation, and (iii) system optimization/implementation, which is used to estimate parameters to provide the measures for policy design. The DSS is linked to a GIS for graphical representation and spatial analysis in terms of stock status in a given period. In addition, the graphical user interface (GUI) of the DSS helps the users to define inputs, to set constraints, and sub-area boundaries, and to visualize the output.

In short, their DSS structure consists of three main components: (1) the data management component, (2) the functional component, and (3) the implementation component; and can be presented as in Figure 2-13 below.

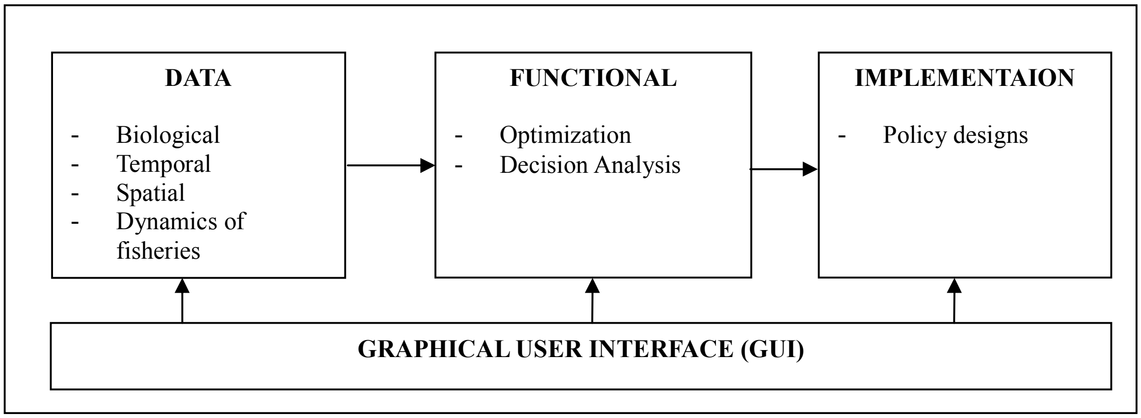

Figure 2-13 Structure of the DSS for Fisheries Management (Azadivar, Truong & Jiao 2009)

For the purpose of aquacultural farm management, Halide et al. (2009) developed a decision support system for sustainable cage aquaculture. The system enabled managers to perform four essential tasks: (1) site classification, (2) site selection, (3) holding capacity determination, and (4) economic appraisal.

Based on measurement of water and substrate qualities, hydrometeorology, and socioeconomic factors, a cage site is classified as poor, medium, or good. Then, the study uses the AHP tool to evaluate the best site for cage sitting. A simplified version of Modelling on Growing Monitoring (MOM) is developed to determine the optimal fish stock to be grown without harming the environment. Break-even point and Rate of Investment (ROI) indicators are calculated using other input data and culture practice variables.

All models are integrated into a user's friendly interface in Java called CADS_TOOL (Cage Aquaculture Decision Support Tool) as an implementing tool for supporting a manager decision-making process. In terms of the DSS structure, the CADS_TOOL DSS consists of four tabs that provide users information and hence support manager making decision on the four essential tasks as mentioned above: (1) site classification, (2) site selection, (3) holding capacity determination, and (4) economic appraisal. Figure 2-14 presented the general structure of the CADS_TOOL DSS.

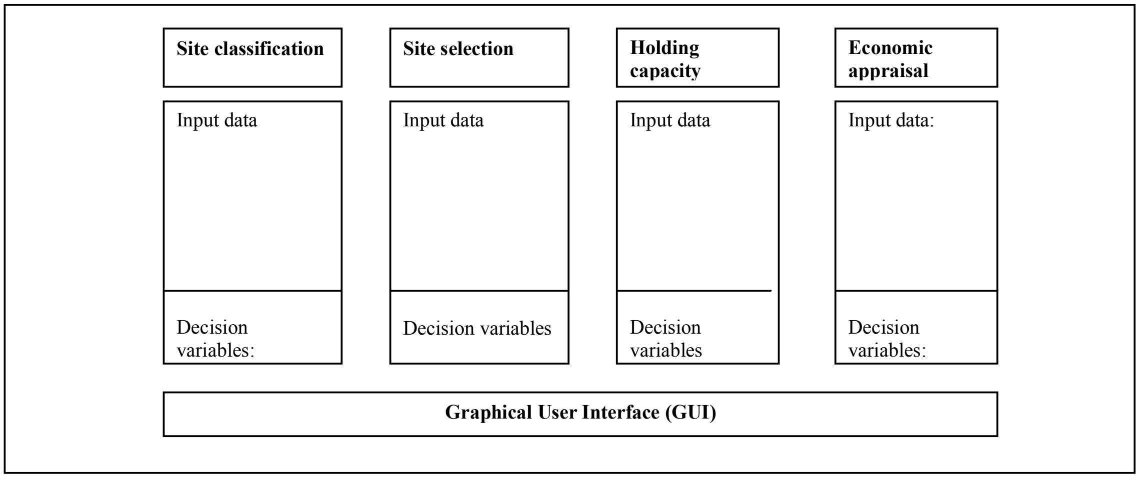

Figure 2-14 Structure of the DSS for Sustainable Cage Aquaculture (Halide et al. 2009)

Bourke, Stagnitti & Mitchell (1993) developed a DSS for Aquaculture Research and Management. The DSS was developed to facilitate the collection, manipulation, and analysis of physio-chemical and biological data generated in aquaculture research. The system allowed researchers to measure the impact of environmental variables to: (1) production failure, (2) increase in biomass, and (3) survival rate of seeds. The system also allowed researchers to simulate the results according to different environmental variables inputs prior to actual experiments being carried out.

To meet the proposed objectives, the DSS consists of three main components: (1) the Dialog, (2) the Data Based Management System (DBMS), and (3) the Model Based Management System (MBMS). The system allows managers or researchers to assign important values for environmental variables or aquacultural practices to determine the probability of specific experiment outcomes. The structure of the DSS for Aquaculture Research and Management is presented in Figure 2-15.

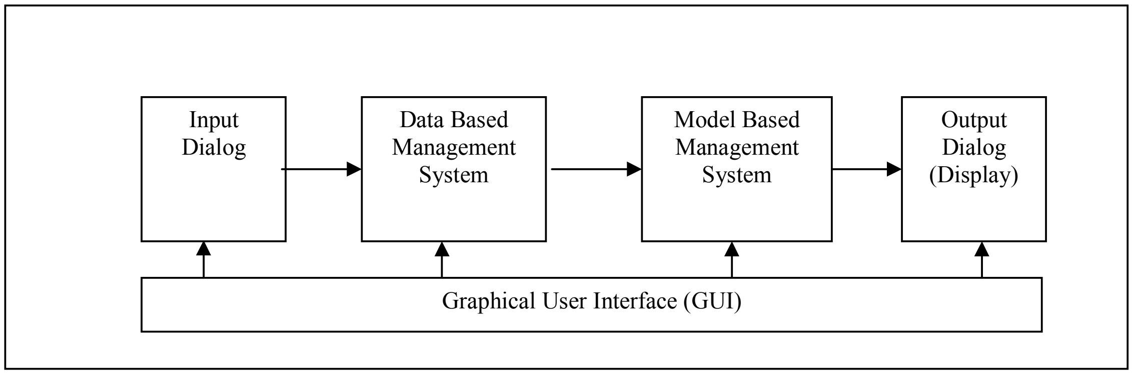

Figure 2-15 Structure of the DSS for Aquaculture Research and Management (Bourke, Stagnitti & Mitchell 1993)

A sophisticated DSS developed for aquacultural management in the US is called POND (Bolte, Nath & Ernst 2000). The architecture of POND included a series of mini-databases, a number of knowledge-based components (experts), models of pond eco-system, and various support features. The POND includes of the following four main services: (1) basic time flow synchronization of system component; (2) data storage, collection, display, and output; (3) linear programming tools for optimization; and (4) parameter estimation methods to determine the best fit model parameters. The object-oriented programming approach is used for developing the software. Figure 2-16 presents the general structure of the POND DSS.

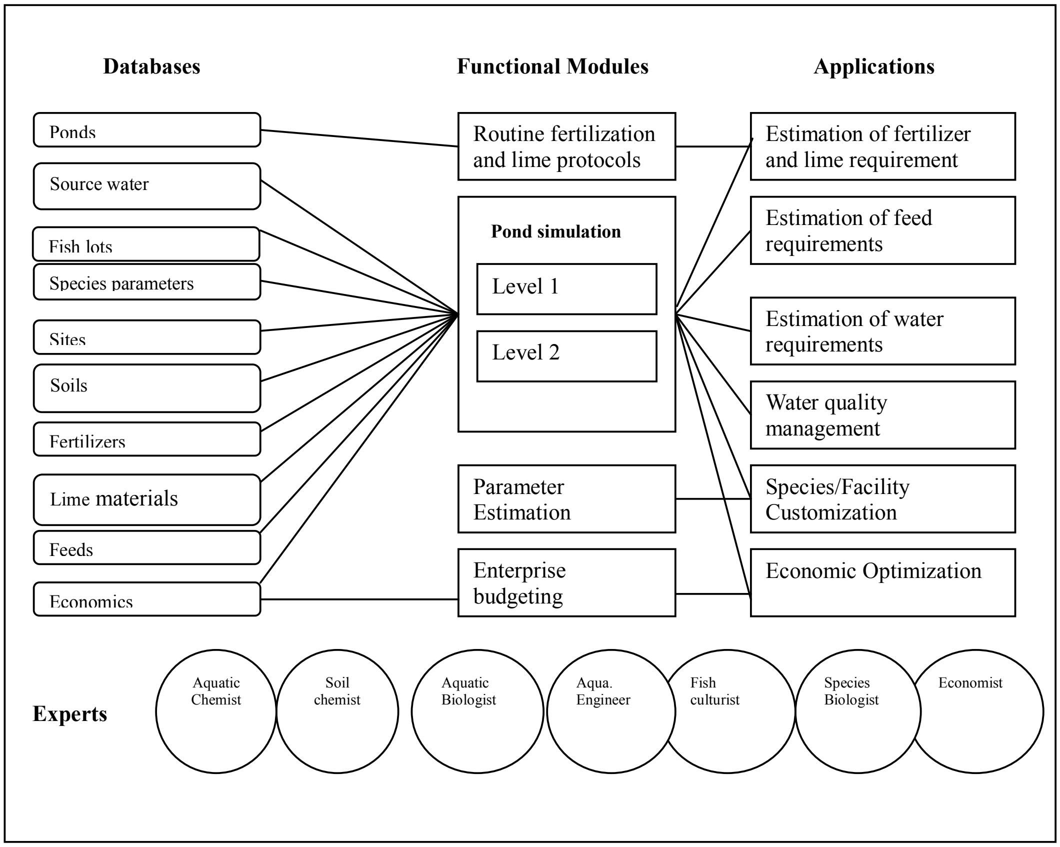

Figure 2-16 Structure of the POND DSS (Bolte, Nath & Ernst 2000)

Besides the general issues related to the structure of the DSS, the study made some important comments on what should be noted when developing a DSS, as follows:

- Different target groups have different needs.
- An appropriate interface for users is desired, as most users are aquaculture managers. They care about the economic results, not what the underlining processes to produce those results are. Showing underlining process causes the users' interface to become somewhat burdensome.
- There is a need for adding components on financial feasibility and launching an aquaculture venture.
- A feature to develop a least cost fertilizer mixed (a linear programming problem) is required.

- Issues of software development effort depend on how well the product addresses user need, not how complicated the system is.

In short, although DSS's are different in purposes of usage as well as DSS architecture, most of the DSS's have three main components: a database system, a model system, and a graphical user interface (GUI). The database system is aimed at managing all the input and output data of the DSS. The model system is designed to conduct the calculation or computation tasks of the DSS. The graphical user interface is the mean of interaction between user and the system. Depending on the objectives of the DSS, the database system, the model system, and the user interface can be as simple, complicated, or sophisticated as possible. Table 2-2 bellows provides a summary of the components of the DSS reviewed above.

Table 2-2 Summary of the Reviewed DSS

DSS/reference	**Structure of the DSS**		
	Database System	**Model System**	**Applications**
DSS for fishery management (Azadivar, Truong & Jiao 2009)	• Biological data • Temporal data • Spatial data • Data on dynamics of sea • GIS	• Optimization • Decision analysis	• Policy design
CADS_TOOL (Cage Aquaculture Decision Support Tool) (Halide et al. 2009)	• Water and substrate qualities • Hydrometeorology data • Socioeconomic data	• AHP • Modelling-on growing-monitoring (MOM)	• Site classification • Site selection • Holding capacity • Economic appraisal
DSS for Aquaculture Research and Management (Bourke, Stagnitti & Mitchell 1993)	• Online monitoring data (tanks/ponds data) • Past experiments/Historical data/offline retrieval	• Statistical analysis • Simulations	• Statistical summaries • Decision support (AHP) in three ways: (1) cause and effect; (2) probability analysis, and (3) interaction of components • Display
POND (Bolte, Nath & Ernst 2000)	• Ponds • Source water • Fish lots • Species parameters • Sites • Soils • Fertilizers • Lime materials • Feed • Economics • Weather • Simulation parameters	• Routine fertilization and liming protocols • Pond simulation • Parameter estimation • Enterprise budgeting • Experts: aquatic chemist, soil chemist, aquatic biologist, aquacultural engineer, fish culturist species biologist, economist	• Estimation of fertilizer and lime requirements • Estimation of feed requirements • Estimation of water requirements • Water quality management • Species/facility customization • Economic optimization

2.7 Unified Theory of Acceptance and Use of Technology

The literature on theory of IT acceptance is extensive. Historically, the most prominent theories in the field of information could be: (1) the theory of reasoned action (TRA), (2) the technology acceptance model (TAM), (3) the motivational model (MM), (4) the theory of planned behaviour (TPB), (5) a model combining the technology acceptance model and the theory of planned behaviour, (6) the model of PC utilization, (7) the innovation diffusion theory, (8) and the social cognitive theory (SCT). Venkatesh et al. (2003) introduced a unified theory of user acceptance and use of technology by reviewing and unifying the eight above-mentioned prominent existing theories of user technology acceptance, called the UTAUT model. In this research, we are going to adapt the UTAUT model to develop a conceptual model to examine the influences of factors on the acceptance of the DSS for risk management in Vietnamese catfish farming. Thus, the following subsections will review the theoretical foundations of the UTAUT model and its applications in assessing the acceptance of IT innovation.

2.7.1 UTAUT Model

The unified theory of user acceptance and use of technology was introduced by Venkatesh et al. (2003) as a result of reviewing and unifying of the eight prominent existing theories of user technology acceptance. To achieve that goal, that study: (1) reviewed user acceptance literature and discussed the eight prominent models, (2) empirically compared the eight models and their extensions, (3) formulated a unified model that integrates elements across the eight models, and (4) empirically validated the unified model (Venkatesh et al. 2003).

After reviewing the eight use acceptance models extensively, the authors used the data from four organizations over a six-month period with three points of measurements to estimate the relationships of predictors and user's intention to use information technology, using partial least squares (PLS) technique. Empirical results show that the eight models explained between 17% and 53% of the variance in user intentions to use the information technology.

Next, a unified model which is an integration of the eight reviewed models was formulated, called the Unified Theory of User Acceptance and Use of Technology (UTAUT). This included the four core determinants of intention and usage, with four moderators of key relationships. The UTAUT model was then tested using the original data. Statistical results showed that UTAUT model explained about 69% of variance in intentions and usage and was found to outperform the eight individual models.

The UTAUT model has four core constructs; namely, performance expectancy, effort expectancy, social influence, and facilitating conditions. It also has four moderating variables; i.e. gender, age, experience, and voluntariness, affecting the key relationships in the model. The UTAUT structural model is presented in Figure 2-17.

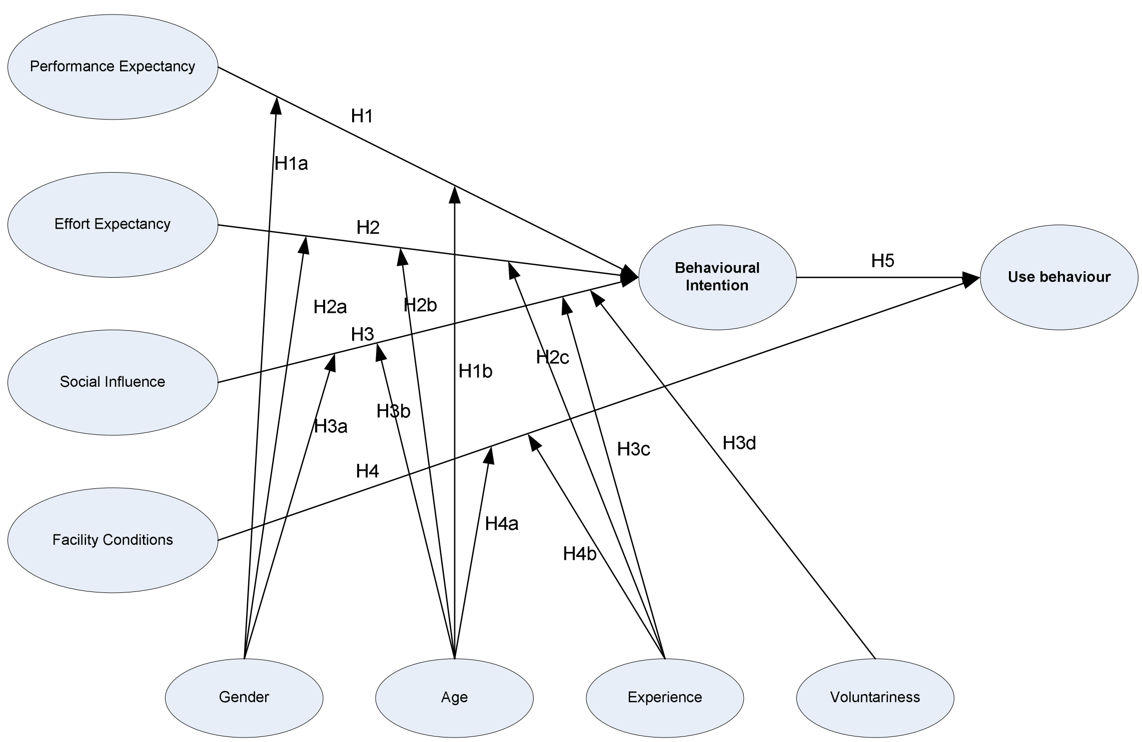

Figure 2-17 UTAUT Model (Venkatesh et al. 2003)

The UTAUT model is formulated to test the following hypotheses:

Direct effects:

- H1: Performance expectation will have a positive impact on the user intention to use the IT system
- H2: Effort expectancy will have a positive impact on the user intention to use the IT system
- H3: Social influence will have a positive impact on the user intention to use the IT system
- H4: Facilitating conditions will have a positive impact on the use behaviour
- H5: Behaviour intention will have a positive impact on behaviour use.

Moderating effects:

- H1a: The influence of performance expectation on behaviour intention will be moderated by ***gender,*** such that the effect will be stronger for men.
- H1b: The influence of performance expectation on behaviour intention will be moderated by ***age,*** such that the effect will be stronger for younger.
- H2a: The influence of effort expectancy on behaviour intention will be moderated by ***gender***, such that the effect will be stronger for women
- H2b: The influence of effort expectation on behaviour intention will be moderated by ***age,*** such that the effect will be stronger for younger.
- H2c: The influence of effort expectation on behaviour intention will be moderated by ***experience,*** such that the effect will be stronger at early stages of experience.
- H3a: The influence of social influence on behaviour intention will be moderated by ***gender***, such that the effect will be stronger for women
- H3b: The influence of social influence on behaviour intention will be moderated by ***age***,

such that the effect will be stronger for older.

- H3c: The influence of social influence on behaviour intention will be moderated by ***experience***, such that the effect will be stronger in the early stages of experience.
- H3d: The influence of social influence on behaviour intention will be moderated by ***voluntariness***, such that the effect will be stronger for mandatory settings
- H4a: The influence of facilitating conditions on behaviour use will be moderated by ***age***, such that the effect will be strong for the older worker
- H4b: The influence of facilitating conditions on behaviour use will be moderated by ***experience***, such that the effect will be strong for the more experienced worker.

2.7.2 Applications of UTAUT and TAM models

Since the introduction of the UTAUT model in 2003, this model has been used extensively in the field of information system to assess the acceptance of IT innovation in different contexts. The remainder of this section will first provide a review of the studies adapting the UTAUT and TAM models as the research model. A summary of these studies is then provided for ease of comparison.

A modified UTAUT structural model was employed by Kijsanayotin, Pannarunothai & Speedie (2009) in a study to understand factors that influence health IT adoption in community health centres in Thailand and to validate this extant IT adoption model in a developing country's healthcare context. In this study, besides traditional hypotheses, as in Venkatesh et al (2003), the authors set voluntariness and experience as constructs directly influencing intention to use the system and IT use, respectively; rather than as moderators, as in the original Venkatesh et al (2003) study. In addition, IT experience was hypothesised as a predictor for facilitating conditions that in turn influences IT use behaviour.

Data was collected from a cross-sectional survey of 1607 randomly selected community healthcare centres in Thailand, with a response rate of 82%. A partial least squares (PLS) path modelling technique was used to assess the research structural model.

The study results suggested that IT acceptance is influenced by performance expectancy, effort expectancy, social influence, and voluntariness. The use of a health IT system is significantly predicted by previous IT experience, intention to use the system, and facilitating conditions. The model explained about 54% and 27% of variance in intention to use the system and health IT use, respectively.

In another study in the field of health IT, Aggelidis & Chatzoglou (2009) attempted to use a modified technology acceptance model to test whether hospital personnel are willing to use state of the art information technology while performing their tasks. The original TAM model was modified to include some exogenous variables, in order to examine HIS (Hospital Information System) acceptance by Greek hospital personnel.

In this study, the research model was based on the UTAUT model developed by Venkatesh et al. (2003) and covered three major contexts: (a) individual, (b) technological, and (c) implementation. The individual context of this research model contained: (a) anxiety, (b) self efficacy, and (c) computer attitude. The technological context in this study was made up of two concepts: (a) perceived usefulness (performance expectancy), and perceived easy of use (effort expectancy). The organizational (implementation) context of the research model contained: (a) subjective norms (social influence), (b) facilitating conditions, and (c) training. In this study, the construct of training was included in the model as an independent construct rather than included in the facilitating conditions, because of its prevailing importance in the study.

A sample of 341 of respondents was surveyed and the results of 281 of them collected, with an effective response rate of 83%. Data analysis was first conducted using descriptive statistics to extract specific statistics (central tendency and dispersion). Structural model analysis was performed using Structural Equation Modelling (SEM) method.

A modified structural equation model was introduced after the initial model showed mixed results. The coefficient of determination (R^2) indicated that the model explained 87% of variance associated with behaviour intention, 58% of variance associated with perceived ease of use, 45% of variance associated with perceived usefulness, 64% of variance associated with attitude toward use, 21% of variance associated with self-efficacy, 32% of variance associated with facilitating conditions, 27% of variance associated with anxiety, and finally 17% of the variance associated with social influence (Aggelidis & Chatzoglou 2009).

IT systems have been introduced widely in the field of education. The success of the introduction of new technology to the classroom depends largely on the acceptance of this new technology by end users such as staff and students. Birch & Irvine (2009) applied the UTAUT model to predict the acceptance of ICT integration in the classroom. The objective of this study was to explore the factors that influence pre-service teachers' acceptance of information and communication technology (ICT) integration in the classroom, using the UTAUT model from Venkatesh et al (2003). The role of the UTAUT variables (performance expectancy, effort expectancy, social influence, and facilitating conditions) was examined using a multiple regression model.

A sample of 85 pre-service teachers was surveyed on UTAUT variables and used for conducting statistical analysis. Descriptive statistics analysis was used to explore the central tendency and dispersion of the variables. Multivariate regression was used to estimate the relationship among the constructs and the dependent variable, the intention to use of ICT in the classroom.

Statistical results show that the model explained about 33% of variance associated with intention to use ICT in the classroom, and only effort expectancy was shown to be a significant predictor of behavioural intention. Besides the main four constructs of the UTAUT model, variables such as age, gender, and voluntariness were also included and tested as moderators. The results show that only age (as an independent variable) had a significant impact on behaviour intention, with the coefficient of -0.26. This indicates that as age increases, behavioural intention decreases. All of the interaction terms were insignificant. The study's findings have important implications for teaching and learning. Since only effort expectancy had a significant impact on behavioural intention, this must be a focus in teacher education. Ease of use of an ICT system is an important factor for its integration into future teaching activities (Birch & Irvine 2009).

To assess the acceptance and use of a virtual learning environment (VLE) in China, van Raaij & Schepers (2008) developed an extended TAM2 model including subjective norms, personal innovativeness in the domain of information technology, and computer anxieties. Data collected from 45 Chinese participants in an Executive MBA program was used to test hypotheses in the proposed model using PLS technique. Statistical results indicated that perceived usefulness has a direct effect on VLE (Virtual Learning Environment) use. Perceived ease of use and subjective norms had only indirect impacts on the use of VLE via perceived usefulness. Both personal innovativeness and computer anxiety have direct effects on easy of use only. The model explains about 31% variance in use, 54% variance in perceived usefulness, and 59% variance of perceived ease of use. These results were considered comparable with previous studies on the acceptance and use of e-learning systems. The study results imply that program managers in education should explicitly address individual differences between VLE users rather than be concerned with the basic system design alone (van Raaij & Schepers 2008).

In considering cultural context, Al-Gahtani, Hubona & Wang (2007) examined the relative power of a modified UTAUT model in determining the “intention to use” and “behaviour use” of desktop computers in Saudi Arabia. A sample of 722 workers using computers on a voluntarily basic was used for statistical analysis. The research model was analysed using PLS path modelling method. In the model, without the interacting moderator variables, statistical result show that the model explained 35% of intention to use variance and 25% of usage variance. All the beta path coefficients are positive and statistically significant (at $p < 0.05$). When moderator variables are included, the model explained for 39% and 42% for the variance of intention to use and usage, respectively. Only performance expectancy and subjective norms had significant influence on intention to use. The impacts of effort expectancy on intention to use and of facilitating conditions on usage were not statistically significant.

For the moderating effects, age has significant effects on moderating the impacts of subjective norms on intention to use. Experience was shown to be significant in moderating the impacts of effort expectancy and subjective norms on intention to use. Similarly, experience had a significant moderating effect on the influence of facilitating conditions on use behaviour (Al-Gahtani, Hubona & Wang 2007).

To examine the moderating effect of user experience in terms of internet experience and website experience on the user future intention to revisit a website, Castañeda, Muñoz-Leiva & Luque (2007) used a Web Acceptance Model (WAM). The WAM, based on the Davis's Technology Acceptance model (TAM) was used to predict a user's intention to revisit a website and how this changed over time as the user gained more experience of the internet and the website. In this study, users' experience was assumed to play a moderating role. Study results showed that, for less experienced users, perceived ease of use was a more important factor in deciding to revisit the website, whereas perceived usefulness had more effect on experienced users.

To achieve the study goal, a structural multi-group model was estimated and the results were compared for the differences between non-experienced and experienced groups. Statistical results showed a significant difference in estimated coefficients between the two user groups at the level of significance less than 1% ($P<0.01$). The model explains for 68% for the variance of future intention to revisit the website, for both internet non-experienced and experienced groups of users. In case of website experience, the model explains 68% and 69% of variance in future intention to revisit the website for non-experienced and experienced user groups respectively.

Based on the study results, the authors have claimed the following statements:

- 'Perceived usefulness is the main determinant of the intention to revisit a website, irrespective of the level of experience of user, its direct influence being greater than in frequent users of the internet.'
- 'In users with high experience of the internet or a website, the influence of perceived usefulness on the process of forming attitudes to the website is substantially greater than in users with low experience.'
- 'In users with high experience of the internet or a website, the influence of perceived ease of use on the attitude toward the website is substantially smaller than in users with low experience.'

Another example of using the UTAUT model to examine IT acceptance can be found in Lin, Chan & Lin (2004). The authors applied the UTAUT model to study acceptance and use of instant messaging among college students. The study aimed to validate the UTAUT model in a non-work environment. Besides traditional hypotheses from the UTAUT model, the study also tests hypotheses on the direct impact of functional capability (the presence of various functions in the application) on behaviour intention as well as on performance expectancy and effort expectancy. Social influence was replaced by peer influence as a direct determinant on behaviour intention, to reflect the specific impacts of friends on using the application. Social influence became a moderator on the impact of peer influence on behaviour intention. Age moderator was also removed from the model due to the narrow group of respondents who were college students.

Data from 300 respondents, all of them students, were analysed using Partial Least Squares (PLS) technique. The analysis results showed that the model explained about 62% and 56% of variances of behaviour intention and use behaviour respectively. Most of the hypotheses are consistent with Venkatesh et al (2003).

Functional capability was shown to have significant direct effect on the factors of performance expectancy, effort expectancy, and behavioural intention. However, unlike in most other IT acceptance research, performance expectancy had no significant direct impact on behavioural intention. This difference may be attributed to the different environment under study. Specifically, the study by Venkatesh et al (2003) was in the work environment, whereas this study was in a non-work environment, individual communication (Lin, Chan & Lin 2004).

In modelling the acceptance of the mobile wallet – besides traditional constructs of perceived usefulness, perceived ease of use, and attitude toward use – the UTAUT model includes constructs of security, trust, social influence, and self-efficacy. The structural equation modelling method was then used to construct a predictive model of attitudes toward mobile wallet. The study results showed that perceived security and trust are significantly influenced to user attitude and intention, besides classical factors such as perceived usefulness and perceived ease of use (Shin 2009). The summary of the applications of the UTAUT and the TAM models are presented in Table 2-3.

Table 2-3 Studies on the Applications of the UTAUT and TAM Models

Research/reference	Variables	Findings
Factors influencing health information technology adoption in Thailand's community health centres: Applying the UTAUT model (Kijsanayotin, Pannarunothai & Speedie 2009)	• Intention to use, IT use, performance expectancy, effort expectancy, social influence, facilitating conditions, voluntariness, experience, and IT knowledge	• Performance expectancy, effort expectancy, social influence, and voluntariness were significant influences on IT acceptance • IT experience, intention to use, and facilitating conditions were significant predictors of use of IT

Using a modified technology acceptance model in hospitals (Aggelidis & Chatzoglou 2009)	• Behavioural intention, perceived usefulness, ease of use, social influence, facilitating conditions, attitude toward use, self efficacy, and anxiety	• Strongest direct effects:
		  o From perceived usefulness to attitude
		  o From training to facilitating conditions and ease of use
		  o From facilitating conditions to ease of use and self efficacy
		  o Anxiety negatively affected self efficacy
		• Training had strong indirect impact on behavioural intention through facilitating conditions and ease of use

Pre-service teachers' acceptance of ICT integration in the classroom: applying the UTAUT model (Birch & Irvine 2009)	• Intention to use, performance expectancy, effort expectancy, social influence, facilitating conditions, • Moderators: voluntariness, age, and gender	• Effort expectancy and age had significant impact on behavioural intention • All the interaction terms (moderators) had no significant impact on behavioural intention

Web Acceptance Model (WAM): Moderating the effects of user experience (Castañeda, Muñoz-Leiva & Luque 2007)	• Future intention to visit, attitude towards website, perceived ease of use, perceived usefulness
	• Moderators: internet experience and website experience
		• Performance expectancy significantly influenced intention
		• For the more experienced user
		  o the impact of performance expectance on attitude was substantially greater than that of low experienced user
		  o the impact of effort expectance was smaller than that of low experienced user

Research/reference	Variables	Findings
Information Technology (IT) in Saudi Arabia: Culture and the acceptance and use of IT (Al-Gahtani, Hubona & Wang 2007)	• Use behaviour, behavioural intention, performance expectancy, effort expectancy, subjective norms, facilitating conditions • Moderators: gender, age, experience	• Performance expectancy and subjective norms had significant impacts on behavioural intention • Behavioural intention and facilitating conditions were not significant predictors of usage of computers • Age significantly moderated the impact of subjective norms on behavioural intention • Experience significantly moderated the impact of effort expectancy and subjective norms on behavioural intention • Experience positively increased the influence of facilitating conditions on use behaviour
The acceptance and use of a virtual learning environment in China (van Raaij & Schepers 2008)	• System usage, perceived usefulness, perceived ease of use, social norms, personal innovativeness in the domain of IT (PIIT), computer anxiety	• Perceived usefulness significantly influenced use • Perceived ease of use and subjective norms had significant indirect effects on use via perceived usefulness
Towards an understanding of the consumer acceptance of mobile wallet (Shin 2009)	• Use behaviour, intention, attitude, social influence, perceived security, trust, self efficacy, perceived usefulness, perceived ease of use	• Perceived security and trust had significant impacts on attitude and intention • Perceived usefulness had significant impact on intention
Instant messaging acceptance and use among college students (Lin, Chan & Lin 2004)	• Use behaviour, behavioural intention, performance expectancy, effort expectancy, peer influence, facilitating conditions, functional capacity • Moderators: gender, social influence, experience	• Functional capacity had significant impact on performance expectancy and effort expectancy • Effort expectancy, peer influence, functional capacity, and experience were significantly predictors of behavioural intention • Behavioural intention and experience significantly influenced use behaviour

2.8 Proposed Conceptual Frameworks

In light of the literature review, we propose three conceptual framework and models for our research to achieve the research objectives 2 and 3: specifically, a conceptual framework for risk management, a conceptual architecture of the DSS, and a conceptual model for examining for the DSS acceptance. The sections below will explain these conceptual frameworks in more detail.

2.8.1 Proposed Conceptual Framework for Risk Management

The proposed conceptual framework for risk management in Vietnamese catfish farming is a combination of the catfish farming business process and the risk management process based on the Australia/New Zealand standard for risk management (AS/NZS 5360:2004). In our proposed framework, the catfish farming business process is presented horizontally and the risk management process is depicted vertically. The business process is further broken down into sub-processes. All steps in the risk management process will then be applied on each sub-process of the catfish farming process. Figure 2-18 presents the conceptual framework for risk management in Vietnamese catfish farming.

2.8.2 Proposed Conceptual Structure of the DSS

Like most of other decision support systems, our proposed DSS also consists of three main components: a database system, a model system, and a graphical user interface. The database system allows users to manage the input for and the output from the DSS. In our DSS, the database model includes: a database for risk data, a database for risk management strategy data, a database for predetermined probability distribution functions for risk consequences and likelihoods, and a database for cost and benefit of risk management strategies. The model system is built to conduct the risk analysis and risk management, including: calculating the levels of risk, risk ranking and prioritizing, risk management cost-benefit analysis, and suggesting the most effective risk management selection. The user interface allows the user to

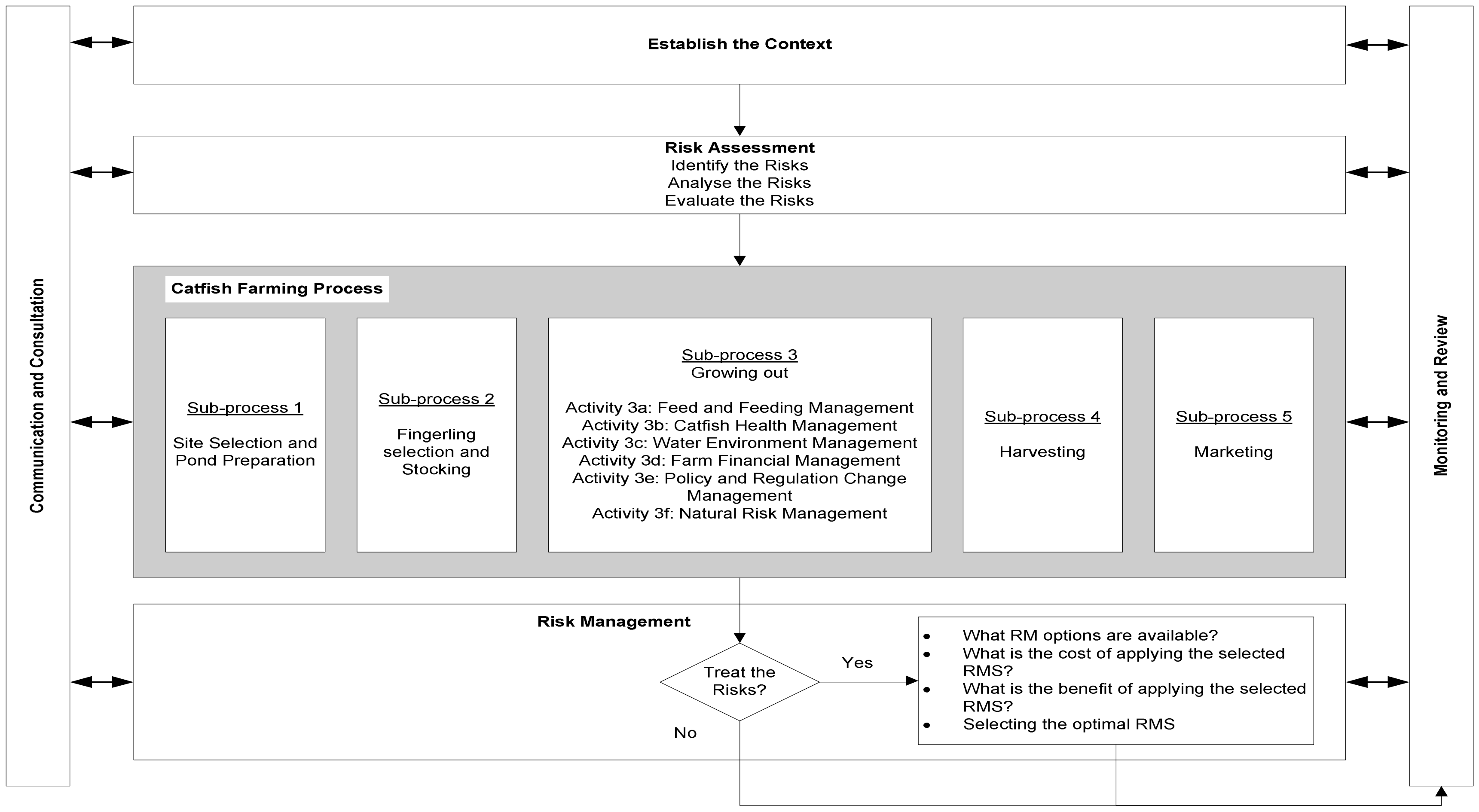

Figure 2-18 Proposed Framework for Risk Management

interact with the system and connect the database system with the model system. The proposed structure of the DSS is presented in Figure 2-19.

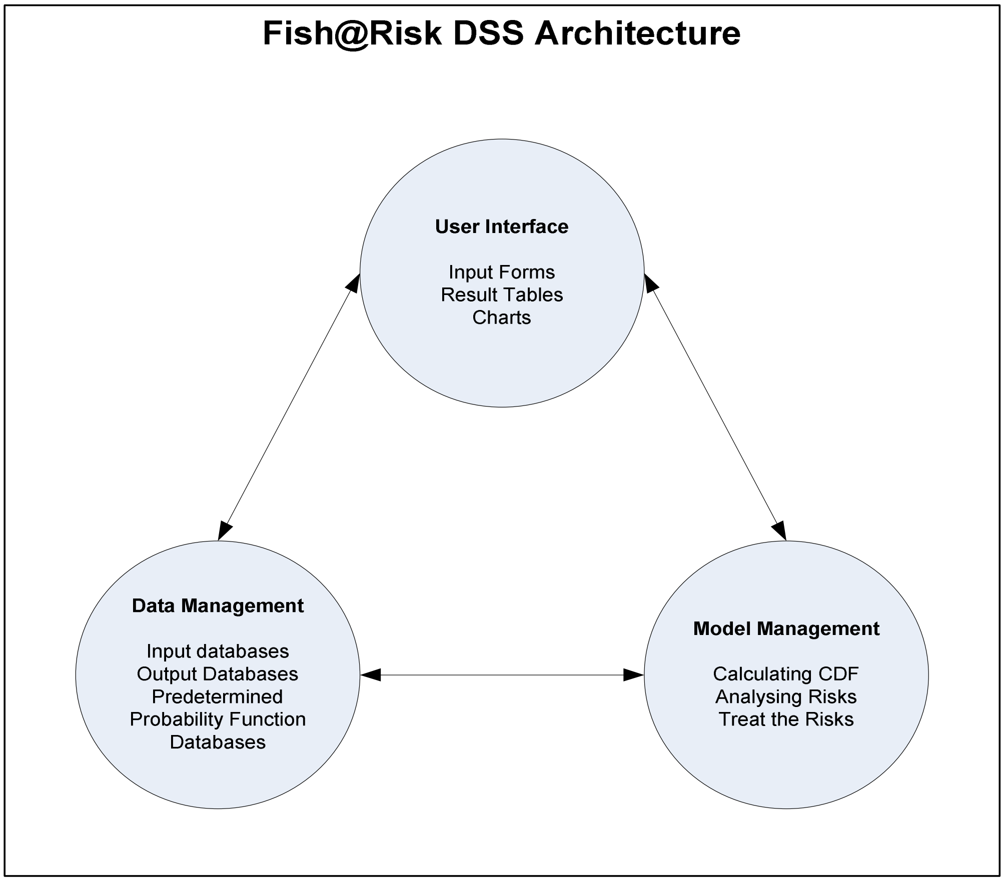

Figure 2-19 Proposed Architecture for the DSS

2.8.3 Proposed Conceptual Model for Evaluating DSS Acceptance

In order to examine the influences of factors on the acceptance of the DSS, we developed a modified UTAUT model. In our proposed model, besides the presence of traditional UTAUT variables such as performance expectancy, effort expectancy, and social influence, computer anxiety, self efficacy, and other demographical variables were also included. Figure 2-20 presents the proposed model for testing DSS acceptance.

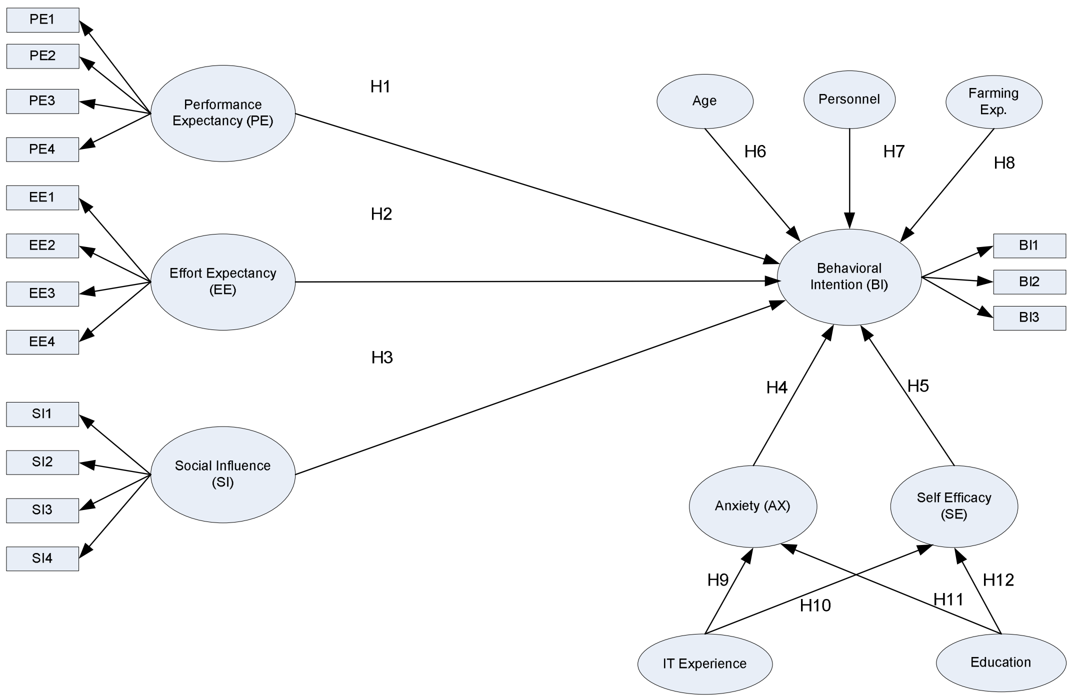

Figure 2-20 Proposed Model for Evaluating DSS Acceptance

2.9 Summary

The purpose of this chapter was to provide an understanding of the development of the Vietnamese catfish industry, issues related to risk and risk management, and DSS for risk management. In the period of 1997-2008, Vietnamese catfish farming has grown quickly in terms of output volumes, values, and export. The industry is facing many problems, challenging its sustainable development in the future. Oversupply, increasing operating costs, decreasing selling price, higher technical barriers from importing countries, disease and water pollution are major risks to Vietnamese catfish farmers. Thus, mitigating risks has become an important concern for the Vietnamese catfish farming sector.

In regarding to the development of live catfish production, both output volumes and output values have grown at impressive rates. Specifically, in the period of 1997-2008, the increases in total output volume and total output values were 23.5 and 46 times respectively. This fast development of industry production was accounted for the significant increases in Vietnamese catfish farming area, yield, and farm-gate price. In the same period, the catfish farming area increased from 1,290 hectares in the year of 1997 to 5,350 hectares in 2008, a four-fold increase. At the same time, yield (output per hectare) also increased from about 15 tons/ha in the year 1997 up to 157 tons/ha in 2008. The increase in yield of catfish farming was considered the result of technology advancements in farming techniques, disease control, water management, feed quality improvement, and seed and fingerling availability. Due to the high inflation rate in Vietnam during that period, although the current prices of catfish farm-gate prices showed a steadily increasing trend over the period of 1997-2008, the real farm-gate prices decreased over time. This significantly decreased the effect of the increase in farm-gate prices on the increase of total catfish output values.

More than 90% of Vietnamese catfish production is for export market. In the period 2000-2008, export volumes and export values of Vietnamese catfish increased dramatically. Export volumes increased from 689 tons in 2000 to 386,870 tons in 2008, a 377-fold increase. Similarly, export values also grew quickly in the same period, with the total export earnings of USD 2.6 millions in 2000 and approximately USD 1 billion in 2008, a 377-fold increase in total export values. The export price, however, decreased steadily over the same period, from USD 3.87/kg in 2000 to USD 2.35/kg in 2008, a decrease of 33%. In terms of the export market shares, there was a major shift from the US market to other markets, such as the EU, Russia, and the Middle East. Before 2003, the US market accounted for approximately 77% (2001) of total Vietnamese catfish exports. After 2003, due to the effect of the US anti-dumping trial on Vietnamese catfish, the US market share dropped sharply to 7% by March 2008. After 2003, the EU, Russia, and the Middle East replaced the US to be the most important importers of the Vietnamese catfish product.

The fast expansion of the Vietnamese catfish industry led to significant growth in the input markets for catfish farming, including labour, seed and fingerling, feed and medicine markets. The number of labours employed in the catfish farming increased significantly from 6,470 persons in 1997 to 101,314 persons in 2007, an increase of 15.66 fold. Besides the contribution of the catfish farming to the GDP, the industry has becomes an important driver in job creation and poverty alleviation in the rural regions. The impact of catfish farming in job creation is further multiplied via creating jobs in related industries such as fingerling production, feed and veterinary medicine production, fish processing, and seasonal employment in pond preparing and harvesting.

The number of seed and fingerling producers increased proportionally with the increase of catfish farming area. The number of catfish hatcheries increased 63 times, from only 82 hatcheries in 2001 to 5,171 hatcheries in 2007. The total number of fingerlings provided to the grow-out farming sector increased from 32 million in 2000 to 1.9 billion in 2007, a 60-fold increase. The number of feed and veterinary medicine providers also increased significantly to meet the high demand of inputs for catfish farming. In 2008, there were about 763 providers providing feed and veterinary medicine for the catfish farming sector in the region, most of them located in the three provinces of Can Tho, Dong Thap, and Tien Giang.

Risk and risk management in agriculture and aquaculture are diverse and usually classified into five main categories: (1) production or yield risk, (2) price or market risk, (3) institutional risk, (4) human or personal risk, and (5) financial risk. In aquaculture, besides all the risks similar to those in agriculture, yield risk and quality risk are the most important risks due to the sensitivity of aquaculture to the environment. The success of aquaculture greatly depends on the quality of the cultivating environment. Thus, a risk management framework that can help catfish farmers to manage the risks systematically is needed for the sustainable development of the industry.

A review of popular risk management frameworks was presented. According to the AS/NZS 4360:2400, a risk management process will include seven steps, namely: (1) communication and consult, (2) establish the context, (3) identify the risks, (4) analyse the risks, (5) evaluate the risks, (6) treat the risks, and (7) monitor and review.

A discussion of the DSS for different purposes was presented. In most of the DSS, there are three main components, specifically: a model system, a database system, and a user graphical interface. Depending on the purpose of the DSS, it can be a simple system or a complicated system that can integrate many different sub-systems and/or databases. Finally, the UTAUT model and its applications were reviewed extensively.

After reviewing the related work, the proposed conceptual framework and models were presented, including: the proposed conceptual framework for risk management in Vietnamese catfish farming; the proposed conceptual structure of the DSS for risk management; and the proposed conceptual model for evaluating the acceptance of the DSS for risk management in this research.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter outlines the methodology used in this research, including research design, data collection methods and justification for methods used. To address the research objectives, four phases are designed. Given the central objective of this research, which is to develop a risk management framework for Vietnamese catfish farming, we first analyse the perceptions of risk and risk management in Vietnamese catfish farming. Understanding how catfish farmers perceive risk and risk management in catfish farming is an important factor to the success of developing a risk management framework. This phase is to provide empirical insights about the perceptions of risk and risk management in Vietnamese catfish farming, taking into account the differences in farmer socioeconomic characteristics. This forms the goal of phase 1 of the research.

Phase 2 of this research is designed to develop a risk management framework. The first step of this phase is to identify all the sources of risk and corresponding risk management strategies associated with the catfish production process in Vietnam, using a business process modelling technique. After the sources of risk and risk management strategies are identified, other steps of a risk management process will then be conducted. Based on the Australia/New Zealand Risk Management Standard (AS/NZS 4360: 2004) and the catfish business process modelling, the risk management framework for Vietnamese catfish farming will then be built. This forms the goal of Phase 2 of the research.

Once the risk management framework has been developed, phase 3 of this research is designed to develop a decision support system for Vietnamese catfish farming as an implementing tool for risk management in practice.

Finally, modelling the acceptance of the DSS is conducted in phase 4 of this research. A modified UTAUT model is developed to examine the influences of factors on user acceptance of the DSS for risk management, using data from a fresh face-to-face interview survey and the structural equation modelling (SEM) technique.

3.2 Research Design

The research aims of this study are to develop a risk management framework and a decision support system as an implementing tool for conducting risk management tasks in Vietnamese catfish farming. Four phases are designed to achieve the research aims, which are presented in Figure 3-1.

For simplification, these four research phases are outlined in terms of research objectives below:

Research objective 1: to examine the perceptions of risk and risk management in Vietnamese catfish farming

- Phase 1: Examining the perceptions of risk and risk management in Vietnamese catfish farming

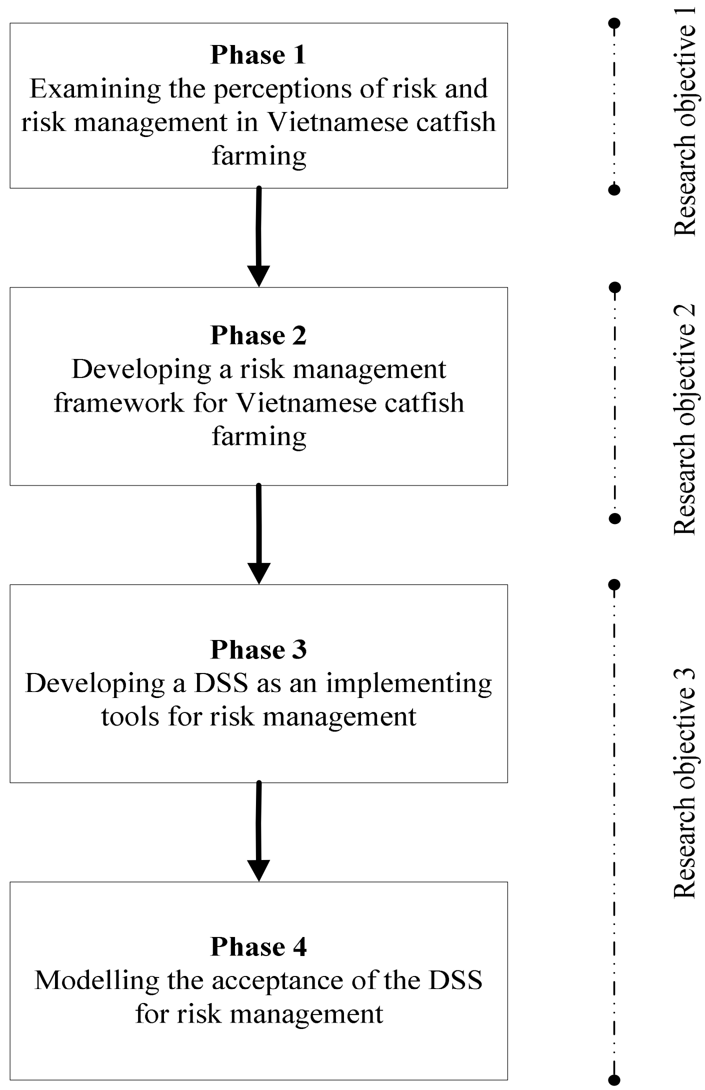

Figure 3-1 Research processes

Research objective 2: to develop a risk management framework for Vietnamese catfish farming

- Phase 2: Developing the risk management framework, including:
    - Communicating and consulting
    - Establishing the context

- Identifying sources of risk and risk management strategies
- Analysing the risks and risk management strategies
- Evaluating the risks
- Treating the risks
- Monitoring and reviewing the risks

Research objective 3: to develop a decision support system as an implementing tool for risk management in Vietnamese catfish farming

- Phase 3: Developing a decision support system for risk management
- Phase 4: Modelling the acceptance of the DSS in risk management

After introducing the research design, the methodology used to carry out the research is described. We then discuss the data collection, justify the methods used in each phase, and briefly describe the steps used in the research. These descriptions of the data and methods used in each phase are summarised in Table 3-1.

Table 3-1 Data Collection and Research Methods

Phase	Objective	Data collection	Analysis method
1	Examining the perceptions of risk and risk management	**Fresh survey** • Numbers of records: 261 catfish farmers • Location: An Giang, Can Tho, and Dong Thap provinces • Year 2008	**Descriptive Analysis** • Variables: 40 sources of risk and 50 risk management strategies • Exploratory Factor Analysis (EFA) • Multiple linear regression o Dep. variables: factor scores of 6 categories of risk and factor scores of 6 categories of risk management o Indep. variables:

Phase	Objective	Data collection	Analysis method
			farmers' socioeconomics characteristics
2	Developing the risk management framework	**Fresh surveys** • Number of records: 261 catfish farmers, year 2008 • 8 in-depth interviews for cost and benefit of applying risk management strategies, year 2009	• Focus group workshop • Business Process Modelling • Australia Standard AS/NZS 4360:2004 Risk Management • Variables: 40 sources of risk and 50 risk management strategies • Descriptive statistics • Cost-Benefit Analysis • Probability Distribution Function Estimation
3	Developing the DSS for risk management	**Data from previous phases**	• Consultation and literature review • System approach • Visual Basic for Application • Case Testing
4	Modelling the acceptance of DSS for risk management in catfish farming	**Fresh survey** • Number of records: 55 including 45 catfish farmers and 10 aquacultural extension staff • Year 2010	**Structural Equation Modelling (SEM)** Dep. variable: behavioural intention, anxiety, and self efficacy Indep. variables: performance expectancy, effort expectancy, social influence, anxiety, self efficacy, and other demographical attributes Path analysis using Smart PLS 2.0

3.3 Phase 1: Examining perceptions of risk and risk management

In the first phase, we examine the perceptions of risk and risk management in Vietnamese catfish farming using the data collected from a fresh survey of 261 catfish farmers on perceptions of risk and risk management. Exploratory factor analysis and multivariate regression techniques are used for the analysis.

First, the 40 original sources of risk and 50 risk management strategies are reduced into six categories of risk and six categories of risk management, respectively, using exploratory factor analysis. Factor scores are saved for subsequent regressions. To maximize the independency of the factors, Jointed Varimax Rotated Extraction methods are used.

In regarding to the regressions, two regression models are built to measure the impact of the farmer socioeconomic characteristics on the perceptions of risk and risk management. The first model measures the impacts of farm characteristics on the perceptions of risk. The second model examines the impacts of farm characteristics and the perception of risk on the perceptions of risk management.

3.4 Phase 2: Developing a Risk Management Framework

As mentioned in Table 3-1, this phase of the research aims to develop a risk management framework for Vietnamese catfish farming, following the Australian risk management standard AS/NZS 4360:2004. According to the AS/NZS 4360:2004, a risk management process consists of seven steps which are closely related to each other, namely: (1) communicate and consult, (2) establish the context, (3) identify the risk, (4) analyse the risk, (5) evaluate the risk, (6) treat the risk, and (7) monitor and review. The following sections will elaborate in more detail how each of the steps in this phase can be done and what data is used for the analysis.

3.4.1 Step 1: Communicate and Consult

This step of the research aims to improve stakeholders' understanding of risks and the risk management process, ensure that all the different views of stakeholders are considered, and ensure that all participants are aware of their roles and responsibilities. To achieve this goal, the researcher communicates and consults with different stakeholders in our research, including aquacultural academics, aquacultural staff and managers, and most importantly, catfish farmers. Communication and consulting can be conducted via the mean of personal talks, interviews, and focus group workshops. In our research, several interviews with aquacultural academic and managers were made before organizing a focus group workshop. At the focus group workshop, all involved stakeholders discuss and exchange ideas about risks and risk management in Vietnamese catfish farming.

3.4.2 Step 2: Establish the Context

The purpose of this step in the risk management process is to set the boundaries for the scope of risks and risk management in the organization. Establishing the context is concerned with understanding the background of the organization and its risks, scoping the risk management activities being undertaken, and developing a structure for the risks management tasks to follow (Standards Australia & Standards New Zealand 2004b). In this research, personal interviews and focus group workshop will be used to establish the context for risk management in Vietnamese catfish farming. As a result, the organization objectives will be defined: the business environment; the main scope and objectives of risk management; a set of criteria against which the risks will be measured; and a set of key elements for structuring the risk identification and assessment process.

3.4.3 Step 3: Identify Risk and Risk Management Strategies

The purpose of this research step is to identify sources of risk and risk management strategies in Vietnamese catfish farming. In identifying these risks and risk management strategies, a business process modelling method will be used. The entire catfish farming process will be broken into five continuing production stages (called sub-processes). In each sub-process, we will describe all the activities in each sub-process and identify all the possibly associated risks and risks management for each activity. Identified risks and risks management will then be listed and classified into groups for easy of monitoring and management in the later phases of the research.

To identify all the possible sources of risks and risk management strategies involved in catfish farming process, we break down the farming process into five sub-processes, i.e. (1) pond location selecting and preparing, (2) selecting and stocking fingerlings, (3) growing out, (4) harvesting, and (5) marketing. A list of sources of risks and risk management strategies gathered from the literature is developed for discussion and comment in a focus group workshop.

The focus group workshop is organized at the early stage of the research in order to verify the list of risks and risk management strategies in practical perspectives. The workshop includes catfish farmers, aquacultural extension staff, aquacultural management officers, and aquacultural academics. Discussion and comments from the focus group workshop will then be incorporated into the survey questionnaire, used later to collect data on catfish farmers' perceptions of risks and risk management in catfish farming. Before the actual survey is conducted, a pilot survey will be carried out in order to check for the relevancy and correctness of all the survey questions. The survey questionnaire is then revised and made ready for the survey. In our research, the survey will be conducted on a face-to-face interview basis. As most of catfish production is concentrated in three main provinces in the Mekong Delta—An Giang, Dong Thap, and Can Tho—our survey will focus only on these three provinces. Specifically, a sample of 270 farmers from these three provinces of An Giang (150), Dong Thap (60), and Can Tho (60) will be randomly selected and interviewed. After screening for completeness, the questionnaires of 261 farmers will be available for statistical analysis, equating an effective rate response of 97%.

Data collected from the survey will be used to analyse the perceptions of risk and risk management in catfish farming and to determine the relationships between farmers' perceptions of risks and risk management and their socioeconomic conditions, using descriptive statistical analysis (mean and standard deviation), exploratory factor analysis (EFA) and multiple regressions.

Descriptive statistical analysis is first used to evaluate the perceptions of catfish farmers' about risks and risk management in their catfish farming. Given the risks and risk management strategies are measured by a Likert scale, ranging from one (not important) to five (very important), means and standard deviations of all 40 sources of risk and 50 risk management strategies will be calculated to reflect the perceptions of the importance of risk factor and risk management strategies. All risks and risk management strategies are then ranked by means in a descending order to reflect the relative importance of risk factors or risk management strategies among the lists.

To gain more understanding about the perceptions of risks and risks management in Vietnamese catfish farming, exploratory factor analysis and multivariate regression analysis are applied. First, factor analysis is applied to reduce the large number of sources of risks (40) and risk management strategies (50) to a sensible and meaningful number of factors that can present the underlining problems. Factor scores will then be saved and used for further analysis—i.e. multivariate regressions—to explore the relationship between the perceptions of risks and risk management with socioeconomic characteristics of catfish farmers.

3.4.4 Step 4: Analyse the Risks

The objective of this step is to identify the possible consequences, or impacts, of an event. In other words, this step will aim to determine the level of risk of all the sources of risk identified in the previous step. According to AS/NZS 4360, risk consequence or likelihood can be determined by using descriptors or mathematically determined values. Depending on how risk consequence and likelihood are measured, the categories or types of risk analysis can be applied to determine the level of risk: qualitative, semi-quantitative, and quantitative. In general, the level of risk can be defined as a function of risk consequence and risk likelihood, i.e., in the form of *level of risk = f(risk consequence, risk likelihood)*. In our research, we will use the simplest function form for the level of risk, specifically, *level of risk = risk consequence * risk likelihood.*

In analysing the risks, we use both semi-quantitative and quantitative risk analysis types. In semi-quantitative types of risk analysis, the level of risk of a specific source of risk is calculated as the product of the mean values of that risk's consequence and likelihood. Because the level of risk for each source of risk is calculated from the mean values of risk consequence and likelihood, we can compare the levels of risk of different sources of risk. Given that approach for computing the level of risk, the value for level of risk will range from the minimum of 1 to the maximum of 25.

While the mean scores for risk consequences and likelihoods can present the perceptions of risks for a sample of observations, the Likert scale rating can be a problem in rating risks on an individual (farmer) basis. First, average scores of risk consequences or risk likelihoods might not reflect exactly what an individual farmer might perceive about the risk. Consequently, these wrong perceptions about risks will affect what he/or she might want to do with the risk. Second, rating risks using Likert scale increases the chance of binding occasions in which two different risks with different risk consequences and likelihoods may have the same levels of risk. If this is the case, ranking and prioritizing risks might be misleading. To overcome these problems, the quantitative risk analysis approach is used. In this approach, first, probability distribution functions (PDF) for risk consequences and risk likelihoods will be estimated using the collected data from the survey. Because the original data are on a 5-point Likert scale, discrete probability distribution functions will be used. Chi-squares criteria will be used to select the best-fit probability distribution functions. Second, cumulative probability density functions (CDF) are then used to measure the risk consequence and likelihood. After the risk consequence and likelihood are determined, the level of risk will then be determined as the products of the two calculated probability of risk consequence and risk likelihood. Under this approach for computing the levels of risk, the values for level of risk will vary continuously from the minimum of 0 to the maximum of 1.

3.4.5 Step 5: Evaluate the Risks

The result of this step is a prioritized list of clearly identified risks: which risks need treatment and which risks are going to be accepted by the business (accept the risks). Business can choose either treating the risk or accepting the risk. Risks can be accepted if the level of risk is low and the cost of treating the risk outweighs the benefit, or may be there is no reasonable treatment that can be implemented.

In this step, all sources of risk involved in Vietnamese catfish farming will be ranked and prioritized by the levels of risk calculated in Step 4. Risk factors with higher level of risk are set at higher priority for treatment. Given the way we calculate the levels of risk, all sources of risk will be sorted by the levels of risk in a descending order. Risks listed at the top of the list have higher levels of risk and so should receive more attention in treating them.

To determine which risks are going to be treated and which risks are going to be accepted, we use the "as low as acceptable risk" (ALAAR) criteria. Given that selection criteria, a risk factor with either the risk consequence or risk likelihood rating of 1 in a 5-point Likert scale (negligible or very low) will be determined as ALAAR. As a consequence, that risk receives no further consideration in risk management or treatment.

3.4.6 Step 6: Treat the Risks

This step determines for treating or controlling the risks identified as "to be treated risks" in Step 5. Risk management strategies identified in Step 3 are going to be matched with specific relevant risk. A risk management strategy can be selected based on the following criteria: risk management efficacy or/and cost-benefit analysis.

For the former case, each risk will be matched with all available risk management strategies for that risk. The risk management strategies are prioritized according to the efficacy of the options in reducing the risk. Risk management strategy with higher efficacy will be considered as a higher priority risk management strategy to be used.

For the latter case, a risk management strategy is selected according to the cost-benefit efficiency. The net benefit criterion is used to decide which risk management strategy to use for risk mitigation. The net benefit of applying a risk management strategy is defined as the monetary benefit (revenue/income) obtained by applying a risk management strategy minus the total cost of applying that option.

3.4.7 Step 7: Monitor and Review

Monitoring and reviewing is an essential and integral step in the risk management process. This step will review the effectiveness of the risk treatment plan and ensure that the changing circumstances do not alter the risk priority. At a business level, the risk management plan should be periodically (at least on an annual basis) reviewed to ensure the effectiveness of current risk treatment as well as to capture new risks into the risk management plan.

3.5 Phase 3: Developing a Decision Support System (DSS)

This phase of the research aims to develop a decision support system (DSS) as an implementing tool for risk management for Vietnamese catfish farming. The DSS development process consists of the following five steps: (1) DSS conceptualization, (2) data collection and analysis, (3) DSS design, (4) implementation, and (5) testing/evaluating. The following sections will described the methodology and data (if applicable) used for each of the five steps of the DSS development process.

3.5.1 DSS Conceptualization

At the start of the development process, in the conceptualization stage, the potential uses of the DSS by stakeholders are assessed based on the risk management framework developed in the previous chapter. From the consultation process and literature review, several concepts are developed. Using the DSS, the user will be able to conduct all steps of a risk management process, consisting of risk identifying, risk measuring, risk evaluating, risk treating, and risk monitoring and reviewing.

Also from the consultation stage, the type of the DSS is obtained. The development team decides to build a prototype DSS over the period of 2 months, which can then be used to get more feedback from different stakeholders. This prototype DSS allows user to conduct a complete risk management process, including: (1) to enter input data on risks and risk management strategies, (2) to conduct a risk analysis section, and (3) to choose the best risk management strategies. After a prototype DSS is developed, it is introduced to potential users for trying and evaluating. Comments and feedbacks from them are then used for DSS improvement, both in terms of functionality and the user interface.

3.5.2 Data Collection and Analysis

The relevant data for the DSS to work on are the data on risks and risk management strategies evaluated and entered by the user. The input data are then converted into appropriate form for risk measuring using built-in probability distribution functions.

3.5.3 DSS Design

The design of the DSS depends on several factors, including the system desired functionalities, ease of use, and IT accessibility. To achieve the DSS desired goals, the system development approach will be applied. As a result, the proposed DSS will consist of three main components: a database system, a model system, and a graphical user interface. Use case technique is used to define the needed functionalities. The system is coded using Microsoft Visual Basic Application for Excel, which is available on any personal computer, for ease of use and also easy IT accessibility.

3.5.4 DSS Implementation

In the implementing step, a software programmer, using Visual Basic for Application (VBA) on the Microsoft Excel platform, codes the design. The first prototype DSS is an Excel file that includes 10 separate sheets including: (1) the DSS main screen, (2) the risk data, (3) risk management strategy data, (4) risk probability distribution functions, (5) risk management strategy cost and benefit, (6) risk analysis results (Table of Levels of Risk), (7) view matrix of risk and risk management strategies (by efficacy), (8) view matrix of R&RMS (by net benefit), (9) risk scatter diagram, and (10) language sheet for the language translation. Several versions of this spreadsheet will be developed during the development process to reach the most satisfying prototype. The last version of the prototype will then be introduced to the stakeholders for testing, trying, and evaluating.

3.5.5 DSS Testing and Evaluating

Testing and evaluating is an important step in the DSS development process. This step ensures that the system is error free and achieves all the required goals. Thus, the prototype DSS is introduced to the end users for testing and evaluating. Comments and suggestions from this testing stage will be used for system improvement both in terms of system functionalities and user interface. Data used for the evaluation step are collected from a fresh survey of 55 catfish farmers and local aquacultural staff. The DSS is first introduced to the users by the researcher and then users will have about a half an hour to try with the system. A survey questionnaire is used to collect the data on the evaluation of the system.

3.6 Phase 4: Modelling the Acceptance of the DSS

A fresh survey will be conducted to collect data on potential users' evaluation of the DSS. To obtain better understanding of the impacts of influencing factors on the users' acceptance of the DSS, partial least squares techniques (PLS) will be applied. The survey will focus on catfish farmers and local aquaculture extension staff, who are considered the most likely users of the system. The aim of this phase is to develop a model and test it on users' acceptance of the DSS. Identifying factors influencing the users' acceptance of the DSS will help to improve the system development process, including improvement in usefulness, ease of use, and completeness of the system.

Based on the literature review, we develop a proposed conceptual model, which is a modification of the well-known UTAUT model developed by Venkatesh et al. (2003), by including the self efficacy, computer anxiety, and some other demographical factors. Our model consists of the following five main factors: performance expectancy, effort expectancy, social influence, computer anxiety, and self efficacy. In addition, age, personnel, farming experience, computer experience, and education level are included in the model to capture the impact of demographic factors on the acceptance of the DSS. Based on the proposed conceptual model, a survey questionnaire will be developed, tested and used for data collecting.

The survey measurement items are mainly based on the survey instrument developed by Venkatesh et al. (2003). Survey data will be collected to statistically model the effects of influencing factors on the acceptance of the DSS in Vietnamese catfish farming by catfish farmers and aquaculture extension staff. A sample of 55 participants, including 45 catfish farmers and 10 aquaculture extension staff, will be selected and interviewed. The sample is evenly distributed across the three provinces of An Giang, Dong Thap, and Can Tho, with 15 catfish farmers and three to four extension staff in each province.

PLS analysis is one of the statistical methods for structural equation modelling (SEM), a modelling procedure that assesses the inter-relationships among latent variables (unobserved variables) (Kijsanayotin, Pannarunothai & Speedie 2009). SEM is a multivariate technique that can deal with multiple relationships simultaneously and explain the relationships among multiple variables comprehensively (Hair et al. 2006). SEM validates a relationship between two factors while the impacts from other factors are take into account, and shows the reliability of findings by evaluating measurement errors (Hoyle 1995). However, SEM is considered a covariance-based estimation while PLS is a variance-based technique. Specifically, PLS is a least squares regression-based technique that can analyse structural models with multiple-item constructs with direct and indirect paths. PLS provides all the necessary output to assess the measurement and structural models, including loadings between items and constructs, standardized regression coefficients between constructs (path coefficients), and R^2 values for dependent constructs. Bootstrapping procedure will provide the standard error and the t-statistics of the path coefficients. In addition, PLS is considered a robust estimation method with respect to distributional assumptions regarding the underlying data and tests of normality (Chin 1998a; Chin & Newsted 1999; Fornell 1982).

SEM has been used extensively in the IT acceptance literature, in particular, and in IS literature, in general, both under theoretical and empirical perspectives. Under a theoretical perspective, SEM is used widely as a confirmatory method to provide researchers with comprehensive means for assessing and modifying theory (see for examples, (Becker & Schmidt 2001; Compeau, Higgins & Huff 1999; Davis 1989; Davis, Bagozzi & Warshaw 1989; Durndell & Haag 2002; Koufaris 2002; Venkatesh et al. 2003; Wixom & Todd 2005); (Szajna 1996)). Empirically, SEM has also been used extensively to evaluate the impacts of influencing factors to the end users' acceptance of IT innovation in different perspectives, such as culture (developed vs. developing countries), professions (education, health, government services, social use, or general work related use), sex (male vs. female), computer experiences, etc. (see for example, (Aggelidis & Chatzoglou 2009; Al-Gahtani, Hubona & Wang 2007; Birch & Irvine 2009; Castañeda, Muñoz-Leiva & Luque 2007; Kijsanayotin, Pannarunothai & Speedie 2009; Lin, Chan & Lin 2004; Loo, Yeow & Chong 2009; Marchewka & Liu 2007; Raaij & Schepers 2008; Shin 2009)).

SEM has also been used to identify direct and indirect effects of variables on user IT acceptance theory, and to examine the moderating effects of other demographical factors on dependent variables. Take the UTAUT model (Venkatesh et al. 2003), for instance: the study results revealed that performance expectancy, effort expectancy, and social influence directly affect user behavioural intention, and indirectly affect use behaviour via behavioural intention. Facilitating conditions were assumed to have direct effect on behavioural use. Apart from the results of the effects on behavioural intention and behavioural use, the moderating effects of other demographical characteristics on the dependent variables were also revealed. Gender and age were assumed to have moderating effects on the impacts of performance expectancy, effort expectancy, and social influence on behavioural use. Experience was hypothesised to have moderating effects on the impacts of effort expectancy, social influence, and facilitating conditions on behavioural intention and use. Besides the capability to assess the directional effects of one or more independent variables to one or more dependent variables, SEM is also able to examine the interrelationships among variables.

3.7 Summary

The aim of this chapter was to explain how this research was conducted. To achieve the research goals, four research phases were presented aimed at meeting the research objectives. The section on research design explained the reasons for dividing the research into four phases. Descriptive analysis, factor analysis, multivariate linear regression, business process modelling (BPM), system approach, SEM and face-to-face survey methods were adopted for data collection and analysis.

Each phase was briefly described in terms of data collection and justification for methods used. In outlining the methods used for each research objective, descriptive and inferential statistics were used to address the first research objective, which is: to examine the perceptions of risk and risk management in Vietnamese catfish farming. Specifically, descriptive statistics were used to describe the perceptions of risks and risk management in Vietnamese catfish farming. Factor analysis and multivariate linear regression methods are used to determine the relationships between perceptions of risks and risks management with the socioeconomic characteristics of Vietnamese catfish farmers.

For the second research objective (2), which is to develop a risk management framework for risk management in Vietnamese catfish farming, several methods have been used to achieve different specific sub-objectives. BPM was first used to identify risk and risk management strategies associated with each sub-process of catfish farming. Descriptive statistics and estimated probability distribution functions were used to measure the risks and the risk management efficacy. Ranking and prioritizing methods were applied to identify risks needing treatment. Finally, cost and benefit analysis was used for selecting risk management strategies.

To achieve the third research objective (3), which is to develop a decision support system (DSS) for risk management in Vietnamese catfish farming, the system approach was used for developing the DSS and the SEM method was used for modelling the acceptance of the DSS for Vietnamese catfish farming.

Chapter 4

PERCEPTIONS OF RISKS AND RISK MANAGEMENT IN VIETNAMESE CATFISH FARMING[†]

4.1 Introduction

The objective of this chapter is to provide empirical insights into: (1) Vietnamese catfish farmers' perceptions of risk and risk management strategies; and (2) the relationships between the farms' and farmers' socioeconomic characteristics and farmers' perceptions of risks and risk management in catfish farming. The results of this study will form a foundation for developing a risk management framework for Vietnamese catfish farming.

Data collected from a fresh survey of 261 catfish farmers in the Mekong Delta were used for analysis in this study. Descriptive statistics were used to measure the perceptions of risks and risk management in Vietnamese catfish farming. Exploratory factor analysis (EFA) and multivariate linear regression were used to determine the relationship between perceptions of risks and risk management with farmers' socioeconomic characteristics.

This chapter is divided into four sections. First, the procedures used for data collection are described, followed by an outline of the data analysis. Second, the results of analysis are then presented. The discussion and the summary of this chapter are presented last.

[†] Part of the work presented in this chapter has been previously published (Le & Cheong 2010a, 2010b).

4.2 Data Collection

Data for this study were collected using a questionnaire survey. Prior to designing the survey, a focus group workshop consisting of major stakeholders (catfish farmers, government staff, extension workers, aquacultural specialists and university researchers) in catfish farming was organized in An Giang province, a major catfish production area in the Mekong Delta, to collect comments, opinions and suggestions about sources of risk and risk management strategies in Vietnamese catfish farming. Together with information gathered from a literature review, a survey questionnaire was developed to include questions aimed at gathering information on: (1) farm and farmer socioeconomic characteristics; (2) catfish farmers' perceptions of risk; and (3) catfish farmers' perceptions of risk management strategies. The questionnaire was pre-tested through a pilot survey of 10 catfish farmers classified into three categories of farm size—small (<5,000 m^2), medium (5,000–20,000 m^2), and large (>20,000 m^2)—in order to check the relevance of questions and detect ambiguous or missing questions. The questionnaire was revised and improved based on the comments and suggestions offered by farmers. The survey was conducted by direct (face-to-face) interviews with farmers conducted on their farms and the questionnaire was used for data recording. The survey was carried out in the three provinces of An Giang, Dong Thap and Can Tho, which account for more than 80% of the total catfish production in the Mekong Delta, the lower part of the Mekong River Basin. A sample of 270 catfish farmers from these three provinces of An Giang (150), Dong Thap (60), and Can Tho (60) was randomly selected and interviewed. The population of catfish farmers surveyed from An Giang, Dong Thap, and Can Tho provinces were from 2,891, 636, and 780 farms, respectively. On average, the sample accounted for about 6.2% of the total Vietnamese catfish farmer population. After screening for completeness, the questionnaires of 261 farmers were available for statistical analysis, equating to an effective response rate of 97%.

4.3 Data Analysis

This study made use of descriptive statistical methods, a factor analysis method, and multiple regression methods for data analysis. First, standard descriptive statistical methods, using the means and standard deviations of the studied variables, were used to measure the perceptions of Vietnamese catfish farmers of the impacts of sources of risk and the efficacy of risk management strategies. The impacts of risks and the efficacy of risk management strategies were then ranked by their means in descending order to evaluate the perceived importance of sources of risk and risk management strategies.

Next, the relationships between the perceptions of risk and risk management and farm and farmer socioeconomic characteristics were explored using factor analysis and multivariate regression methods. Due to the large number of sources of risk and risk management strategies examined in the study, it was deemed sensible to reduce the number of variables and group them into a smaller number of factors that could be more readily interpreted and evaluated empirically. In factor analysis, the orthogonal (varimax) rotation extraction method was used to ensure maximum independence of the resulting factors. Prior to conducting factor analysis, the application condition of factor analysis was checked using the correlation coefficient matrix, the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy, and Bartlett's test of sphericity.

Standardized factor scores for each farmer and factor were saved for subsequent regression analysis. In regression analyses, the standard factor scores achieved from the factor analyses of both sources of risk and risk management strategies were then regressed on farms' and farmers' socioeconomic characteristics to identify the impact of these characteristics on the farmers' perceptions of risks and risk management in their catfish farming. Specifically, the regression models can be represented in the form of Eq. 1 and Eq. 2 as shown below.

$$RF_{i,t} = f(Consult_t, D\_large_t, D\_medium_t, Age_t, Education_t, Experience_t, Gender_t, \varepsilon_t) \quad (1)$$

and

$$RMF_{j,t} = f(Consult_t, D\_large_t, D\_medium_t, Age_t, Education_t, Experience_t, Gender_t, RF_{i,t}, e_t) \quad (2)$$

where

- $RF_{i,t}$: standardized factor scores for sources of risk factors (i=1, 2, 3, …, 6), achieved from the factor analyses of sources of risk

- $RMF_{j,t}$: standardized factor scores for risk management strategy factors, achieved from the factor analyses of risk management strategies (j = 1, 2, …, 6)
- Consult: Dummy variable, 1 denotes farm taking external technical consultancy, 0 denotes not.
- D_large: Dummy variable, 1 denotes large-scale farm, which has a total pond area of greater than 2 hectares, 0 denotes otherwise.
- D_medium: Dummy variable, 1 denotes medium-scale farm, which has a total pond area of between 0.5 and 2.0 hectares, 0 denotes otherwise.
- Age: Age of farm head (farm decision maker), measured in years.
- Education: Education level of farm head, measured in years.
- Experience: Number of years in catfish farming.
- Gender: Dummy variable, 1 denotes male farm head, 0 denotes female farm head.
- ε_t and e_t are the error terms of Eq. 1 and Eq. 2, respectively.

It was assumed that standard parametric statistical procedures were appropriate for ordinal values in the form of Likert scales (Flaten et al., 2005; Meuwissen et al., 2001; Patrick & Musser, 1997). Missing values were treated before conducting factor analysis. Observations with missing values for more than 15 variables on sources of risk or more than 20 variables for risk management strategies were deleted prior to factor analysis. The remaining missing values were replaced by the mean values of the variables before conducting further statistical analyses. All factor analyses were conducted using SPSS for Windows (v16.0) and regressions were estimated using EViews for Windows v.6.0.

All of the regression models were tested for possible violations of the basic assumptions of a linear regression model. Specifically, a simple correlation matrix of all independent variables was inspected to detect any potential multicollinearity. Heteroscedasticity was checked using the White test with cross terms to maximize the detection of misspecification. Durbin-Watson statistics were used to check the first order autocorrelation problem. After estimating the original regression models, the regressions that violated the assumption about homoscedasticity of the error terms were then re-estimated using the White's consistent standard error and covariance estimators.

4.4 Results

4.4.1 Perceptions of Sources of Risk

In total, 40 sources of risk were presented to the respondents. To measure the catfish farmers' perceptions about the potential impacts of sources of risk, catfish farmers were asked to rate (on a 5-point Likert scale) the potential of the risk to affect their income/profit on each of the 40 risk factors. The consequence of risk was rated on a scale of 1 to 5, with 1 representing very low or minor impact, and 5 representing very high or severe impact. The third and fourth columns of Table 4-1 show the average ratings of the consequences of risk factors and their ranks, respectively. Due to the large size of the table, the standard deviations were suppressed for space conversion. Table 5-2 in chapter 5 presents detailed means, standard deviations, and corresponding ranks of the 40 sources of risk variables in descending order in terms of the impacts of these sources of risk.

Table 4-1 Mean Scores and Jointed Varimax Rotated Factor Loadings for Sources of Risk

Risk ID	Sources of risk	Mean	Rank by mean	Factor loading: most important factors [a]					
				1	2	3	4	5	6
3	Pond does not have waste treatment system	3	27	**0.65**	0.16	0.12	-0.16	0.15	0.02
16	Inability to control diseases caused by environmental sources	3.54	15	**0.72**	0.08	0.05	0.11	0.01	0.05
17	Low level of awareness of disease prevention among farmers	3.18	23	**0.66**	0.07	0.18	0.21	0.17	-0.25
20	Applying chemicals and medicines improperly	3.07	25	**0.56**	0.25	**0.33**	0.2	0.1	0.15
21	Farm has no reserved area for waste water and mud treatment	3.06	26	**0.53**	**0.32**	0.01	-0.03	0.12	0.16
22	Pond water is under-managed	3.74	10	**0.4**	**0.37**	-0.12	-0.04	0.3	0.21
23	Waste water treatment system is under-invested	2.74	36	**0.74**	-0.01	0.1	0.18	0.13	0.13
24	Lack of awareness about community environmental protection	2.94	28	**0.73**	0.11	0.21	0.03	0.11	0.04
30	Consequence of high level of technical barriers imposed by importing countries	2.91	29	**0.41**	0.24	**0.34**	0.04	0.22	0.2
35	Changes in government policy on product development strategy	2.83	33	**0.61**	-0.12	0.29	0.18	**0.3**	0.24
4	Pond not treated before stocking	3.83	8	**0.36**	**0.49**	-0.06	0.01	0.09	-0.06
5	Low quality fingerlings	3.85	7	0.18	**0.49**	0.09	0.26	-0.02	0.21
12	Low quality of feed	3.62	12	**0.38**	**0.49**	0.13	0.27	0.08	-0.04
13	Uncontrolled/unstable homemade feed quality	3.45	18	0.14	**0.52**	-0.1	0.2	-0.2	**0.49**
14	Overfeeding causing pollution and waste accumulation	3.7	11	0.02	**0.64**	0.02	0.13	-0.02	0.17
19	Use of prohibited chemicals and medicines	4.06	2	0.04	**0.66**	0.07	-0.05	0.17	0.07
28	Inaccessibility to the market	4.04	3	0.01	**0.58**	0.1	0.1	0.17	**0.31**
29	Weak legislation on sale contracts between farmers and processors	3.47	17	0.28	**0.43**	0.19	0.28	0.17	-0.13
37	Drought	2.11	40	0.14	-0.07	**0.84**	0.13	0.03	0.12
38	Flood	2.17	39	0.13	0.03	**0.85**	0.08	-0.02	0.02
39	Lack of water supply	2.62	37	0.22	0.06	**0.8**	0.12	0.05	0.01
40	Technical failure	2.28	38	0.23	0.25	**0.65**	0.04	0.15	-0.15
6	Fingerlings from unknown origin	3.27	21	0.06	**0.31**	0.08	**0.52**	-0.02	0.18
18	Limited knowledge about use of chemicals and medicines	3.34	19	0.16	**0.53**	0.09	**0.42**	-0.03	0.29
27	Fish price variability	4.49	1	0.17	**0.35**	-0.25	**0.47**	0.24	-0.12
31	High costs of operating inputs	3.95	5	**0.37**	0.28	0.03	**0.45**	**0.31**	-0.02
32	Under-financing by own capital for the whole crop cycle	3.75	9	0.05	0.01	0.07	**0.6**	**0.33**	0.11
33	Under-financing by credits from banks/credit institutions	3.62	13	0.02	0.03	0.14	**0.64**	0.24	**0.38**

Risk ID	Sources of risk	Mean	Rank by mean	Factor loading: most important factors [a]					
				1	2	3	4	5	6
34	High interest rate for loans	3.57	14	0.01	0.11	0.21	**0.76**	-0.02	-0.05
10	Over (density) stocking fingerlings	3.49	16	0.27	0.26	0.03	0.04	**0.42**	-0.02
11	Use of undersized/oversized fingerlings	2.8	35	0.29	-0.03	0.25	0.14	**0.55**	-0.18
15	High death rate due to disease	3.96	4	0.08	**0.31**	0.09	0.09	**0.44**	0.07
25	Inappropriate size of harvested fish	2.88	30	0.25	-0.02	0.04	0.06	**0.57**	**0.34**
26	Inappropriate method of harvesting	3.19	22	0.13	0.06	-0.07	0.22	**0.75**	0.08
1	Pond outside planning area	2.87	31	0.03	**0.31**	-0.24	0.08	0.01	**0.67**
2	Pond near residence	2.86	32	**0.42**	0.07	0.07	-0.01	0.14	**0.53**
7	Fingerlings infected by diseases	3.9	6	-0.01	**0.39**	0.08	0.19	**0.33**	**0.43**
8	Fingerlings treated by antibiotics during fingerling production process	3.32	20	-0.18	0.28	0.27	0.09	0.2	**0.45**
9	Epidemic checking for the fingerlings not conducted	2.8	34	0.29	0.08	0.24	0.13	-0.12	**0.36**
36	Changes in environmental policy	3.1	24	0.23	0.12	0.06	**0.38**	0.28	**0.4**
	Percentage of total variance explained			24.66	8.77	6.08	4.94	4.04	3.32
	Cumulative percentage of the variance explained by the most important factors			24.66	33.44	39.52	44.46	48.51	51.83

[a] Factors 1 to 6 are: disease and environment; production; natural conditions; price and credit; legislation; and pond location. Loadings of ≥ 0.3 are in bold.

Variability in prices, usage of prohibited medicines and chemicals, and inaccessibility to the market were the greatest concerns, with average scores of 4.49, 4.06 and 4.04, respectively. The second cluster included 12 sources of risk, for which the average scores ranged from 4.0 to 3.5 and ranked from 4 to 15 in the list. The third cluster consisted of the next 12 risk factors, rated from 3.5 to 3.0 with the ranks varying from 16 to 27. The next 10 sources of risk, which were rated from 3.0 to 2.5 with corresponding ranks of 28 to 37, constituted the fourth cluster of risks. Finally, three sources of risk were rated between 2.5 and 2.0, belonging to the fifth cluster, which included technical failure, flood, and drought (refer to Table 5-2 in chapter 5 for the complete list of risk factor rankings).

Clearly, these catfish farmers were very concerned about factors affecting their incomes such as variability in the price of catfish, usage of prohibited medicines and chemicals, and inaccessibility. Concern about the variability of price reflects the fact that catfish farmers were producing their product without any guarantee of a sale price. Variations in catfish sale prices in the last few years have caused big losses for farmers, especially in 2008. Most of the farmers had to sell their catfish at a price 10–15% lower than the production cost. It is important to understand the underlying reasons for this phenomenon as well as the perceptions of farmers about the risk management strategies they use to mitigate the price risk. The next section of this paper will discuss this issue in greater detail.

Usage of prohibited medicines and chemicals was ranked second in the list. This indicates that this risk factor can have a severe impact on the income and profits of farms. One possible reason for this finding is that the bulk of Vietnamese catfish are produced for export markets, where standards and regulations on food hygiene and safety are very strict. In these markets, there is almost zero tolerance for residues of prohibited medicines and chemicals in the imported food, such that Vietnamese catfish processors and exporters will never buy catfish containing prohibited medicines or chemicals. When catfish are impure in this way, catfish farmers cannot sell their products to any markets, causing big losses, and potentially bankruptcy, for such farmers.

The third most important risk factor affecting catfish farmers' income was found to be inaccessibility to the market. This source of risk causes a similar problem for the farmers to that created by the use of prohibited medicines and chemicals. However, the reason for this problem is based in the imbalance between market supply and demand; that is, the oversupply problem. In recent years, total catfish output has increased rapidly, far exceeding the growth in demand and processing capacities, and as a result catfish processors have not been able to buy all of the catfish produced in this period. This created a loss for catfish producers because they could not stop feeding the fish, and were forced to reduce the selling price of their fish due to the over-sizing of fish and the reduction in fish meat quality.

To gain a deeper understanding of the perceptions of catfish farmers regarding sources of risk impact, the total of 40 sources of risk variables was reduced using joint orthogonal (varimax) rotation factor analysis. Prior to conducting the factor analysis, the application conditions of the factor analysis were verified using a correlation matrix, the KMO measure of sample adequacy, and Bartlett's test of sphericity. Due to its large size, the correlation matrix is not presented in this paper. However, there are a substantial number of correlation coefficients with absolute values of greater than 0.3. The KMO measure of adequacy is 0.850, and Bartlett's test of sphericity is statistically significant at the 1% level of significance ($\chi^2 = 3.371E^3$, df = 780, Sig. = 0.000). All of these results indicate that the sample data satisfied the application conditions for factor analysis (Hair et al. 2006).

The latent root criterion suggested the use of 12 factors (with Eigenvalue > 1) for data reduction with a total explained variance of 68.93%. However, the six-factor solution was considered to produce the most meaningful and interpretable factors in terms of the current types of sources of risk that affect catfish farming. Given this justification, 40 original risk-source variables were reduced to six factors, which accounted for 51.83% of the total variance. Variables that did not load significantly on any factor (i.e. loadings < |0.3|) were considered for possible deletion (Flaten et al. 2005; Hair et al. 2006). The last six columns in Table 4-1 present the six factors and their respective loading items (grouped by factor). After checking for non-significant loadings, no variable was removed.

Factors 1–6 can best be denoted as: 'disease and environment'; 'production'; 'natural conditions'; 'price and credit'; 'legislation'; and 'pond location'. Factor 1, disease and environment, loads significantly from a range of variables related to disease and environmental issues. Variables such as investment in waste-water treatment systems, lack of awareness of environmental protection issues, and inability to control disease caused by environmental sources have the highest loadings on this factor.

Factor 2 constitutes a wide range of production variables and covers several aspects of catfish production, including: disease control; quality of feed and feeding practices; and the use of medicines and chemicals. Factor 3 is ‘natural conditions’, which reflects the very high loading of the four specific variables: drought, flood, lack of water supply, and technical failure.

Factor 4, ‘price and credit’, has high loadings on the ‘price of output’; ‘cost of operating input’; and ‘interest rate and credit availability’ variables. Factor 5 consists of high loading variables related to ‘changes in government policy’ so has been called ‘legislation’. Heavy loading of pond location–related variables suggested ‘pond location’ as Factor 6.

4.4.2 Perceptions of Risk Management Strategies

In this study, 50 risk management strategies were rated by catfish farmers in regards to their efficacy for mitigating each risk factor. The efficacy of the risk management strategies was rated on a 5-point Likert scale, with 1 as negligible effect, and 5 as very significant effect. The average scores of the efficacy of strategies and their ranks are presented in the third and fourth columns of Table 4-2. Due to the large size of the table, the standard deviations were suppressed from the table. Details of the means, standard deviations and ranks of the 50 risk management strategies, ranked in descending order in terms of efficacy, are presented in Table 5-8 in the next chapter.

Table 4-2 Mean Scores and Joint Varimax Rotated Loadings for Risk Management Strategies

RMS ID	Risk management strategies	Mean	Rank by mean	Factor loading: most important factors [a]					
				1	2	3	4	5	6
1	Locate pond in designated (planning) area	3.38	30	**0.37**	-0.02	0.12	0.12	**0.33**	**0.35**
14	Regularly update list of prohibited chemicals and medicines	3.5	18	**0.58**	0.07	0.5	**0.32**	-0.06	0.01
23	Use labour that has knowledge of aquacultural veterinary matters	3.37	32	**0.51**	0.28	**0.35**	-0.03	0.29	0.18
24	Consult people who have knowledge of aquacultural veterinary matters	3.41	27	**0.55**	0.06	**0.46**	-0.01	0.08	0.29
25	Sale and production contract with processor	3.37	31	**0.5**	**0.35**	0.22	**0.39**	0.02	0.2
26	Collect information about favourable catfish size from processors	2.72	44	**0.57**	**0.36**	**0.33**	0.23	-0.13	0
27	Choose proper size of pond	3.13	38	**0.54**	**0.45**	0.12	0.19	-0.03	-0.08
28	Vertical integration (be a member of a fish association that processes the fish itself)	3.48	20	**0.41**	**0.36**	0.22	0.18	**0.37**	0.27
32	Buy insurance for crops	2.75	43	**0.6**	**0.42**	0.18	0.13	-0.17	0.19
33	Request government support	3.78	9	**0.47**	0.17	**0.46**	-0.15	0.22	0.04
36	Reduce farm size to appropriate scale	3.15	37	**0.6**	**0.41**	0.09	-0.03	0.03	0.03
39	Ensure credit arrangement before cropping	3.43	25	**0.42**	0.14	0.09	0.25	-0.03	0.08
45	Choose location near good source of water supply	4.1	4	**0.7**	0.09	0.03	-0.16	0.24	-0.11
47	Regularly check and maintain the dyke	3.44	24	**0.67**	**0.39**	0.07	-0.07	0.24	0
48	Maintain a good relationship with the community	3.94	8	**0.71**	0.08	0.1	0.15	0.26	-0.13
49	Surplus machinery capacity	3.13	39	**0.66**	0.01	0	0.34	0.18	0.14
50	Regularly check equipment	3.22	36	**0.64**	-0.17	0	**0.42**	0.03	0.04
5	Apply farming system that minimises water replacement	3.03	40	**0.3**	**0.48**	0.02	0.15	0.13	0.14
10	Only buy fingerlings from certified producers	3.42	26	0.21	**0.53**	0.24	0.1	0.08	0.12
15	Use large-sized fingerlings	3.45	23	0.03	**0.71**	0.01	0.16	0.18	0.08
17	Self-processing to ensure feed quality and reduce cost	3.39	29	-0.08	**0.62**	0.18	-0.17	-0.12	0.16
18	Choose good quality raw materials	3.65	15	0.15	**0.56**	0.39	-0.19	0.22	-0.04
19	Use only factory-made (pallet) feed	3.68	14	0.2	**0.55**	0.05	0	**0.46**	0.04
35	Production at lowest possible cost/keep fixed costs low	3.62	17	0.17	**0.53**	0.29	0.27	0.27	0.21
37	Increase solvency ratio	3.35	33	0.1	**0.56**	-0.05	**0.35**	-0.04	-0.08
41	Use economic consultancy services	2.54	46	0.26	**0.56**	-0.1	0	-0.11	**0.34**
42	Keep cash on hand for farming	3.46	22	0.26	**0.76**	-0.12	0.01	0.14	-0.12

RMS ID	Risk management strategies	Mean	Rank by mean	Factor loading: most important factors [a]					
				1	2	3	4	5	6
4	Regularly check quality of water supply	3.7	13	0.22	0.23	**0.6**	-0.01	**0.33**	0.26
8	Select good fingerlings	4.14	3	0.11	-0.07	**0.68**	0.13	0.06	-0.21
11	Carefully check fingerlings when buying	3.71	12	0.2	**0.47**	**0.62**	0.16	0.04	0.04
3	Develop a separate water supply system	3.46	21	0.16	0.24	**0.42**	**0.47**	0.27	0.05
7	Attend extension workshop	3.31	34	**0.48**	0.27	**0.36**	**0.51**	0.17	0.17
9	Buy fingerlings from reliable sources	4.04	6	0	-0.24	0.3	**0.5**	0.09	-0.12
12	Strictly follow government regulations and technical guidelines	3.72	11	**0.42**	0.18	0.36	**0.53**	**0.35**	-0.05
22	Develop aquacultural water treatment pond	3.48	19	0.02	0.28	-0.02	**0.56**	**0.45**	0.05
44	Increase investment in environmental protection	3.25	35	**0.32**	0.14	0.02	**0.67**	0.14	0.05
2	Change to other activity	2	49	0.04	-0.11	-0.02	0.11	**-0.42**	0.24
6	Strictly treat the pond before stocking	4.34	1	0	0.18	**0.46**	0.17	**0.51**	-0.04
13	Reduce density of fingerling stocking	3.63	16	**0.35**	0.22	0.12	**0.32**	**0.46**	0.11
20	Manage water environment in pond well	4.29	2	0.05	-0.27	**0.43**	0.1	**0.51**	0.01
21	Prevent disease or infection by regular checking and observation of pond	3.94	7	0.22	0	0.41	0.22	**0.46**	0.03
34	Apply quality management program (e.g. HACCP, Global-GAP)	3.72	10	0.1	0.01	0.04	**0.36**	**0.59**	0.17
43	Apply new technology in production	3.41	28	**0.32**	0.16	0.15	0.18	**0.46**	0.07
16	Choose good brand of feed	4.06	5	**0.34**	-0.12	0.2	0.27	**0.35**	**-0.39**
29	Enterprise diversification	2.04	48	-0.04	0.11	-0.03	-0.14	-0.15	**0.71**
30	Cooperative marketing	3.02	41	0.17	0.22	0.09	0.04	0.26	**0.69**
31	Off-farm work	1.97	50	-0.12	0.03	0.1	0.15	-0.15	**0.71**
38	Cooperate with others in financing production	2.7	45	0.02	0.07	-0.17	0.12	0.18	**0.57**
40	Solvency-debt management	2.8	42	0.11	0.25	-0.04	**0.37**	0.11	**0.45**
46	Spatial diversification	2.17	47	0.25	-0.24	0.14	-0.28	-0.02	**0.58**
	Percentage of total variance explained			27.17	7.65	5.70	4.94	4.33	3.30
	Cumulative percentage of the variance explained by the most important factors			27.17	34.82	40.52	45.46	49.80	53.10

[a] Factors 1 to 6 are: farm management; financial/liquidity; input quality; extension and education; disease prevention; and diversification. Loadings of ≥ 0.3 are in bold.

The first cluster consists of six strategies with an average score of above 4.0, and these were rated as very efficient in mitigating catfish farming risks. These strategies are, in order of decreasing importance: strictly treat the pond before stocking, manage water environment in pond well, select good fingerlings, choose pond location near good water supply, choose good brand feed, and buy the fingerlings from reliable sources; with scores of 4.34, 4.29, 4.14, 4.10, 4.06, and 4.04, respectively. The second cluster consisted of 12 of the suggested strategies with average scores of between 4.0 and 3.5, which were considered to be highly effective strategies. Next, there were 23 strategies rated as having moderate effects on risk mitigation, scoring from 3.5 to 3.0. Finally, the fourth cluster included the remaining nine risk management strategies for which the average scores were below the median of the measuring scale (3) and can be considered as minimally efficient strategies. In this cluster, off-farm work was rated as the least efficient strategy in the list, with a score of 1.97. Table 5-8 in chapter 5 presents a complete list of risk management strategies with their average scores of efficacy and corresponding ranks.

Although price risks were perceived as the most important source of risk on average (see Table 5-2 in chapter 5), risk management strategies to deal with price risks (sale and production contract, vertical integration, enterprise diversification, cooperative marketing, and off-farm work) were not perceived as important strategies (see Table 5-8 in chapter 5). This finding is similar to the case of Dutch livestock farmers' perceptions of risk and risk management examined in a study by (Meuwissen, Huirne & Hardaker 2001). The highest-rated risk management strategies were those related to cultivation techniques, pond location selection, disease control and water management rather than price risk management strategies. This can be explained by the fact that farmers in different countries generally prefer to rely on the everyday activities that they do best in order to maximise their income or profit, in contrast to price risk mitigation measures that they often consider to be beyond their control, either due to their complicated nature (forwards and futures), reliability (marketing contract), and/or availability (forwards and futures, insurance).

Similarly to the sources of risk, using factor analysis reduced the number of risk management strategy variables, and again an orthogonal (varimax) rotation factor analysis was applied. Application conditions for the factor analysis were checked prior to conducting the analysis. There were a substantial number of correlation coefficients with absolute values of greater than 0.3. The KMO measure of adequacy was 0.886, and Bartlett's test of sphericity was statistically significant at the 1% level of significance ($\chi^2 = 4.410E^3$, df = 1,225, Sig. = 0.000). All of these results indicate that the sample data satisfied the application conditions for factor analysis.

Although the latent root criterion suggested 11 factors (with a total explained variance of 67.62%), the six-factor solution was selected for best interpretability and feasibility, and accounted for about 54.86% of the total variance. Based on the factor loadings, Factors 1–6 and their respective loadings (grouped by factor) are presented in Table 4-2 and are named: 'farm management'; 'financial/liquidity management'; 'input quality control'; 'extension and education'; 'disease prevention'; and 'diversification'.

Factor 1, farm management, has high loadings of variables related to everyday farm management activities, such as regularly checking the dyke, maintaining good relationships with the community, maintaining surplus machinery capacity, regularly checking equipment, establishing sale contract with processors, and buying crop insurance. Factor 2 is named financial/liquidity management because of the heavy loadings of keeping cash on hand for farming, increasing solvency rations, and producing at the lowest possible cost. Some high cross loadings of homemade feed producing and choosing good raw materials for feed processing suggested that self-processed feed for catfish is a cost-effective means of achieving better financial management.

Factor 3, input quality, includes large loadings of variables related to water and fingerling quality management, such as: selecting good fingerlings, careful checking of fingerling quality, and regularly checking water supply quality. Developing a separate water supply system also shows a high loading for this factor. Factor 4 is described as extension and education, which has heavy loadings of the following variables: attending extension workshop, and strictly following regulations and technical guidelines. Factor 5 included variables that directly or indirectly affect disease control. High loading variables on this factor are: applying a quality management program (e.g. HACCP, Global-GAP); developing water treatment pond; applying new technologies in production; managing the water environment in pond well; reducing stocking density; and regularly checking for disease and infection. Finally, enterprise diversification, cooperative marketing, off-farm work and cooperative financing all loaded highly on Factor 6, which is named 'diversification'.

4.4.3 Relationship between Perceptions of Risk and Farm and Farmer Socioeconomic Characteristics

Relationships between 'perceptions of sources of risk' and 'farm and farmer socioeconomic' variables were determined using multiple regressions, the results of which are shown in Table 4-3. For each of the independent variables, the table depicts the partial regression coefficients and the levels of significance for the two-tailed t-tests. The goodness-of-fit of the models is indicated by R^2 and adjusted R^2. All of the models have relatively low R^2 and adjusted R^2. As shown in Table 4-3, all of the models are statistically significant at a 1% level of significance except the equation for the risk factor 4, which was not statistically significant at any level of significance less than 30%.

Table 4-3 Results of Multiple Regressions for Sources of Risk

Independent variables	Sources of risk					
	Disease and environment	Production	Natural conditions	Price and credit[a]	Legislation	Pond location[a]
Intercept	*0.92	-0.42	0.07	0.42	**1.32	**-0.98
Consult	*-0.28	**0.34	***0.52	-0.06	-0.12	**0.51
D_large	**0.35	***0.52	-0.16	0.26	***-0.64	***0.55
D_medium	**0.42	*0.25	0.06	0.26	-0.10	**0.31
Age (years)	**-0.02	0.00	0.00	*-0.01	**-0.01	**0.02
Education (years)	0.03	0.01	-0.01	-0.01	-0.02	-0.01
Experience (years)	0.00	0.00	***-0.04	0.00	***0.04	-0.02
Gender	*-0.29	0.13	-0.25	0.22	-0.32	-0.09
R-squared	***0.12	***0.08	***0.08	0.04	***0.10	***0.10
R-squared adjusted	0.09	0.05	0.05	0.01	0.07	0.07
White heteroscedasticity statistics[b]	29.45 (0.4937)	35.83 (0.2137)	36.93 (0.1791)	46.79 (0.0260)	30.25 (0.4530)	49.87 (0.0128)
Durbin-Watson statistics	1.98	1.91	1.36	1.61	1.64	1.65

Note:

'*', '**' and '***' denote levels of significance of 10%, 5% and 1% respectively for variables and models.

[a] White Consistent Standard Error and Covariance Estimation.

[b] White statistics of the original regressions and numbers in parentheses are P-values.

White heteroscedasticity tests revealed that the regressions of Factor 4 (price and credit risks) and Factor 6 (pond location risks) on the farm and farmer socioeconomic characteristics violated the assumption of homoscedasticity of the regression. So these two equations were re-estimated using the White's consistent standard errors and covariance estimators. All Durbin-Watson statistics for the six regression models ranged from 1.5 to 2.5, suggesting that autocorrelation is not a problem for these models. Furthermore, the data used for the regressions are cross-sectional data, and the autocorrelation seems not to be a serious issue in these estimations.

The regression results demonstrate that the farmers' perceptions about sources of risk related to disease and environment had a greater impact among farmers from medium and large farms compared to those from small farms. This implies that medium and large farms are more concerned about disease and environmental risks. Obviously, the impact of disease or an environmental pollution will hurt the larger farms more seriously than smaller farms. Younger farmers also tend to be more concerned about disease and environmental risk sources than do older farmers. This may be explained by the fact that younger farmers are less experienced in catfish farming and also that they might have more access to disease and environment education/extension work.

In the case of production risks, the results show that the bigger the farm, the higher the risk perceptions about production risk will be. This is probably because larger output volumes are more sensitive to production risks. The larger the output, the larger the potential loss will be should something bad occur on a farm. External technical consultation also has a significant positive impact on the perception of production risks.

The education variable does not have a significant impact on any sources of risk. However, farmers' experience in catfish farming has a significant impact on perceptions of risks related to natural conditions, and legislation. Large farms are significantly less concerned about changes in legislation than are smaller farms.

All explanatory variables except age of the farmer showed no significant impacts on the perceptions of price and credit risks across farm size, education levels, farming experience, and sex. That might be explained by the fact that all catfish farmers in the Mekong Delta face the same market conditions for their production and most of these market conditions are beyond their control. Older farmers were slightly less concerned about price and credit risk than that the younger farmers were.

Perceptions of legislation risks are significantly impacted by farm size, age of farmer and level of farming experience. Larger farms and older farmers are less concerned about legislation risks than are smaller farms and younger farmers. However, more experienced farmers tend to be more concerned about changes in government policy regarding catfish farming.

Pond location is a source of risk strongly influenced by consultancy, medium-farm size, large-farm size, and age of farmer variables. Medium- and large-scale farmers are more concerned about choosing an appropriate location for their farms due to the high costs of farm investment. Better external technical consultation has a positive impact on the perceptions of catfish farmers regarding pond location selection and capital investment risk.

4.4.4 Relationship between perceptions of risk management strategies and farm and farmer socioeconomic characteristics

As with the sources of risk, the relationships between the perceptions of risk management and farms' and farmers' socioeconomic characteristics were determined using multivariate regression. All of the models are statistically significant at the 1% level of significance, with R^2 varying from 0.22 to 0.64. White heteroscedasticity tests were conducted to detect any misspecification. The test results show that all regressions for the risk management factors indicate a problem of heteroscedasticity, except for risk management Factor 2 (financial). To correct the heteroscedasticity problem, these equations were re-estimated using the White's consistent standard errors and covariance estimators. The final regression coefficients and goodness-of-fit measures for the six risk management factors are presented in Table 4-4.

In terms of the impact of farm and farmer characteristics on the perceptions of risk management strategies, medium and large farm sizes, catfish farming experience, and farm head gender were revealed to have a statistically significant impact on the perceptions of farm management factors. Large farm size had a strong impact on perceptions of the efficacy of education and extension work. Experienced farmers rated the role of financial risk management highly. However, they rated the efficacy of extension/education strategies as significantly less important compared to less experienced farmers.

Table 4-4 Results of Multiple Regression for Risk Management Strategies

Independent variables	Risk management strategies					
	Farm management [a]	Financial	Input quality [a]	Extension/ Education [a]	Disease prevention [a]	Diversification [a]
Farm/farmer characteristics						
Intercept	-0.31	-0.04	-0.62	***1.14	**-0.89	-0.60
Consult [a]	0.12	-0.11	**0.42	-0.20	-0.07	**0.52
D_large [b]	*0.31	-0.13	-0.23	***0.76	0.17	0.23
D_medium[c]	***0.39	-0.04	-0.17	0.10	*0.26	-0.04
Age	-0.00	0.00	0.00	-0.01	*0.01	-0.00
Education	-0.00	0.00	0.02	-0.01	*0.05	0.00
Experience	**-0.02	**0.02	0.02	**-0.03	*-0.02	*-0.02
Gender [d]	0.20	0.11	-0.09	***-0.65	-0.12	0.25
Sources of risk						
(1) Disease and environment	0.00	***0.46	**0.14	***0.14	***0.27	***0.28
(2) Production	0.06	***-0.3	***0.33	**0.13	**0.20	**-0.19
(3) Natural conditions	***0.44	***0.4	-0.03	-0.07	-010	**-0.15
(4) Price and credit	***0.22	-0.03	***0.17	***0.37	*-0.14	***-0.27
(5) Legislation	**0.13	***0.16	-0.09	***0.23-	*-0.11	**0.10
(6) Pond location	***0.28	***-0.18	***0.24	***-0.28	-0.07	0.03
R-squared	***0.46	***0.56	***0.25	***0.45	***0.23	***0.25
R-squared adjusted	0.43	0.53	0.20	0.42	0.18	0.21
White heteroscedasticity statistics [b]	145.03 (0.0014)	109.16 (0.2071)	146.03 (0.0012)	130.92 (0.0147)	151.60 (0.0004)	143.12 (0.0020)
Durbin-Watson statistics	1.50	1.88	2.04	1.53	1.84	1.86

‘*’, ‘**’ and ‘***’ denote variables and models significant at the level of significance of 10%, 5% and 1%, respectively.

[a] White Consistent Standard Error and Covariance Estimation.

[b] White statistics of the original regression and numbers in parentheses are P-values.

There were no differences in perceptions of risk management strategies across farmers’ ages and education levels. Female farm heads tended to be more concerned with the role of extension and education as a risk management strategy. Diversification was not perceived to be an important strategy by farmers across all farm sizes and with all farmer characteristics, other than farmers who received external technical consultancy, who did perceive diversification as an effective risk management strategy. This finding is consistent with the results presented in the previous section (Perceptions of Risk Management Strategies), which revealed that catfish farmers rated as relatively low the effectiveness of diversification (i.e. enterprise diversification, spatial diversification, and off-farm work) as risk mitigating strategies.

The last independent variables were the sources of risk. As shown in the lower part of Table 4-4, most of the risk sources were found to be highly associated with multiple risk management strategies. Previous studies have also observed the multidimensional relationships between the sources of risk and the responses to risk (Meuwissen, Huirne & Hardaker 2001; Patrick & Musser 1997).

Disease and environment risk is highly associated with multiple risk management strategies, including: financial, input quality, extension/education, disease prevention, and diversification. It may also be related to the selection of non-diseased fingerlings, attending extension workshops to improve knowledge of disease treatment, and the high costs of disease and environment treatment.

Production risks were found to be highly associated with multiple risk management strategies, including: financial management, input quality, disease prevention, and diversification. Farm management is an important response to natural risks; price and credit risks; legislation risks; and pond location risks. Surprisingly, financial risk management strategy appears significantly influenced by all of the risk sources other than price and credit risks. This might be the result of the perceptions of low efficacy of financial risk management strategies in catfish farming in Vietnam, where financial instruments are still very underdeveloped and farmers have limited access to financial resources.

Price and credit risks are strongly associated with multiple risk management strategies, such as farm management, input quality, extension/education, and diversification, although not financial and disease prevention strategies. As previously mentioned, financial risk management strategies were not considered to be important tools for price and credit risk management, and currently catfish farmers can only use other practices to minimise price and credit risks. For example, good farm management practices or careful selection of inputs such as good fingerlings and raw materials for feed processing can be used to reduce the cost of production, and are strategies to be considered when output price is low or fluctuates.

Natural risk sources are significantly associated with multiple risk management strategies, including: farm management, financial management, and diversification. While regular checking of the pond dyke system can significantly reduce the potential effects of storms and floods, building a strong pond dyke system and investing in a good and reliable water supply system for aquaculture are costly endeavours, requiring financial support from financial institutions. Clearly, diversification, including enterprise and spatial diversification, can reduce the loss of income in the event of natural disasters like drought, flood or storm.

Extension and education was found to constitute an important strategy for most of the risk sources, except for natural condition risks. This suggests that knowledge plays an important role in successful catfish farming. In practice, extension activities in Vietnamese rural areas is the major channel for delivering new technological progress and regulations to farmers, besides other traditional channels such as radio, television and technical guides.

4.5 Discussion

4.5.1 Perceptions of Risks and Risk Management

In measuring and interpreting farmers' perceptions of risks and risk management strategies in catfish farming, we used the average scores of all catfish farmers included in the analyses. There were considerable variations in the answers given on risk sources, as indicated by the large standard deviations of most variables (refer to Table 5-2 in chapter 5). This suggests that perceptions of risk sources are very personal and specific among farmers. However, catfish farmers were in overall agreement when evaluating the impacts of some sources of risks, such as price variability, cost of operating inputs, high death rates due to disease, and low quality of fingerlings. This fact is indicated by the rather low value of standard deviations of these variables, being 0.80, 0.88, 0.92 and 0.94, respectively. These are also the sources of risks that were rated with the highest scores in terms of their potential to affect the income or profits of catfish farmers. This might suggest that these sources of risk are clearly evident and significant risks that all catfish farmers face in their production activities.

Conversely, the standard deviations of risk management strategies showed much less variation in comparison to the sources of risk. Most of them had a standard deviation of less than 1, and the highest standard deviation was for ‘collecting favourable size of fish at harvesting time from the processors’ (refer to Table 5-8 in chapter 5). The risk management strategies that had the lowest standard deviations were: strictly follow government regulations, attending extension workshop, strictly treat the pond before stocking, reducing the density of stocking, and managing pond water environment well. However, compared to previous studies that also used a 5-point Likert scale (Boggess, Anaman & Hanson 1985; Meuwissen, Huirne & Hardaker 2001; Patrick & Musser 1997), this study’s standard deviations were found to be relatively low. This suggests that the catfish farmers included in our survey are fairly homogeneous in terms of their risk management perceptions. Other aspects of risks and risk management perceptions are difficult to compare with the results of previous studies because of the differences in the type of product, differences in questions, and differences in farming practices and the risk environment.

4.5.2 Relationships between perceptions of risk and risk management and farm/farmer socioeconomic characteristics

The relationship between sources of risk and risk management strategies on the one hand and farm/farmer socioeconomic characteristics on the other were determined using a number of multiple regression models. All of the models that represented this relationship showed low goodness-of-fit and non-significant regression coefficients. This suggests that the farmers’ perceptions of risks are very personal or farm specific and/or that the models might be missing important variables that explain the farmers’ perceptions of risks. Given the wide range of questions in the questionnaire, the latter case is not very likely. The low goodness-of-fit of these regression models is similar to that of previous studies (Boggess, Anaman & Hanson 1985; Meuwissen, Huirne & Hardaker 2001; Wilson & Luginsland 1988).

The relationships between risk management strategies and sources of risk, however, are significant. The multidimensional relationship between them suggests that there is no one-to-one risk management strategy for a specific type of risk source. To reduce a specific type of risk, farmers need to make use of a range of strategies and conversely a risk management strategy can be applied to mitigate different types of risk.

Our results indicate that there is a mismatch between farmers' perceptions of price risk and the risk management strategies adopted to reduce price risk. Specifically, sale contract, price insurance and diversification are not perceived as relevant strategies for price risk reduction. This suggests either that farmers are not aware of the benefits of price risk protection tools or that these tools are not feasible in practice. Further studies are needed to clarify this issue, as price risks are the most important concerns for catfish farmers, in particular, and for agricultural/aquacultural farmers in general.

4.6 Summary

The purpose of this chapter was to provide empirical insights into Vietnamese catfish farmers' perceptions of risk and risk management and the relationships of these perceptions with farm and farmer socioeconomic characteristics. The analyses were performed on a sample of 261 catfish farmers in the Mekong Delta. Our results suggest that, in general, price and production risks were perceived as the most important sources of risk. However, price risk reduction strategies such as sale contracts, insurance and diversification were not perceived as relevant strategies for price risk management. Instead, catfish farmers perceived farm management, disease prevention and selecting good quality inputs (such as water source, feed and fingerlings) as the most relevant risk management strategies.

In terms of the relationships between perceptions of risk and farm and farmer socioeconomic characteristics, farmers from medium- and large-scale farms are more concerned about the potential impact of disease, environment and production risks than are those from small farms. Younger farmers also showed more concern about disease and environmental risks than did older farmers. However, education was found to have no significant impact on the perceptions of risk in catfish farming. Consultancy had an important impact on farmers' perceptions of pond location and natural risks. Experienced farmers perceived natural and legislation risks as significant.

Farm management and extension/education were perceived as more relevant and important risk management strategies among farmers from medium- and large-scale farms. Insurance and diversification were not considered to be relevant risk management tools among farmers from across the range of farm sizes, age, education levels, farming experience, and gender differences. The impact of extension/education on risk management was highly valued by farmers from large-scale farms, experienced farmers and female farm heads.

There is no one-to-one relationship between source of risk and risk management strategy; instead, a multidimensional relationship exists. This finding is consistent with the results of previous studies. Several risk management strategies—financial, input quality, extension/education, disease prevention and diversification—were perceived as relevant for managing production risks. One risk management strategy, for example, farm management, can be used for mitigating the potential impact of several sources of risk, such as natural risks, price and credit risks, legislation risks, and pond location risks.

Extension/education was perceived to be an important risk management strategy for most of the risk sources. This might be a result of the technical difficulties faced in—and the complexity of—catfish farming in particular (and aquaculture in general). In aquaculture, farming activities are strongly affected not only by internal factors like farm resources and management but also by external environmental factors such as water resources, disease spread and natural conditions.

Chapter 5

RISK MANAGEMENT FRAMEWORK FOR VIETNAMESE CATFISH FARMING [†]

5.1 Introduction

While the previous chapter provided empirical insights about Vietnamese catfish farmers' perceptions of risks and risk management in their catfish farming, this chapter will develop a framework for risk management in Vietnamese catfish farming. The following sections will describe in detail all activities done in each of the seven (7) steps of a risk management process, based on the AS/NZS 4360: 2004 Risk Management standard, including: (1) communicate and consult, (2) establish the context, (3) identify the risks, measure the risk, (4) analyse the risks, (5) evaluate the risks, (6) treat the risks, and (7) monitor and review.

The chapter started with a description of the general catfish farming business process. The general risk management process developed by AS/NZS 4360:2004 was then applied to the catfish farming business process to provide the proposed risk management framework for Vietnamese catfish farming. The remaining sections of the chapter described in detail all the steps of the proposed risk management process in the context of Vietnamese catfish farming.

Data used for the analysis or illustrations in this chapter were collected from a face-to-face questionnaire survey. A sample of 270 Vietnamese catfish farmers from three provinces of Can Tho, An Giang, and Dong Thap in the Mekong Delta were randomly selected and

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[†] Part of the work presented in this chapter has been previously published (Le & Cheong 2009).

interviewed. After data cleaning, 261 observations were usable for analysis, an effective rate of 97%.

5.2 Business Process and Associated Risk and Risk Management Strategies

The catfish primary production process can be separated into two main stages: the fingerling production stage and the growing out stage. The end products of these two stages are catfish fingerlings and food size catfish. While fingerlings are used as an input for the growing out production, food size catfish are sold live to domestic markets or catfish processors. Only a small proportion of the total catfish production is sold live in the domestic market for home consumption. The major proportion of catfish production is processed into different types of products, mainly for export purpose.

This section will describe in detail each step or activity of the growing out stage of the catfish farming process, in terms of sub-steps/activities, and illustrate them by business process diagrams, using BPMN v 1.0 from Object Model Group (OMG). At the same time, steps or activities associated with sources of risk and risk management strategies will be identified for later use in risk management framework development.

Combining comments from aquacultural experts and on-field observation, the general catfish farming process for the growing out stage can be divided into five main steps or sub-processes: (1) selecting pond location and pond preparation, (2) selecting fingerlings and fingerling stocking, (3) growing out, (4) harvesting, and (5) marketing. Figure 5-1 presents an overview of the general catfish farming business process.

The general catfish faming business process starts with the sub-process of selecting pond location and pond preparation. The second step is to select fingerlings for the crop and stock the fingerlings into ponds for rearing. The third step is called the growing out sub-process. This is the most important activity in catfish farming and takes a period of six to seven months to complete. There are many sub-activities that catfish farmers have to take care of simultaneously in this stage of the production. When the fish reach the food size, the next

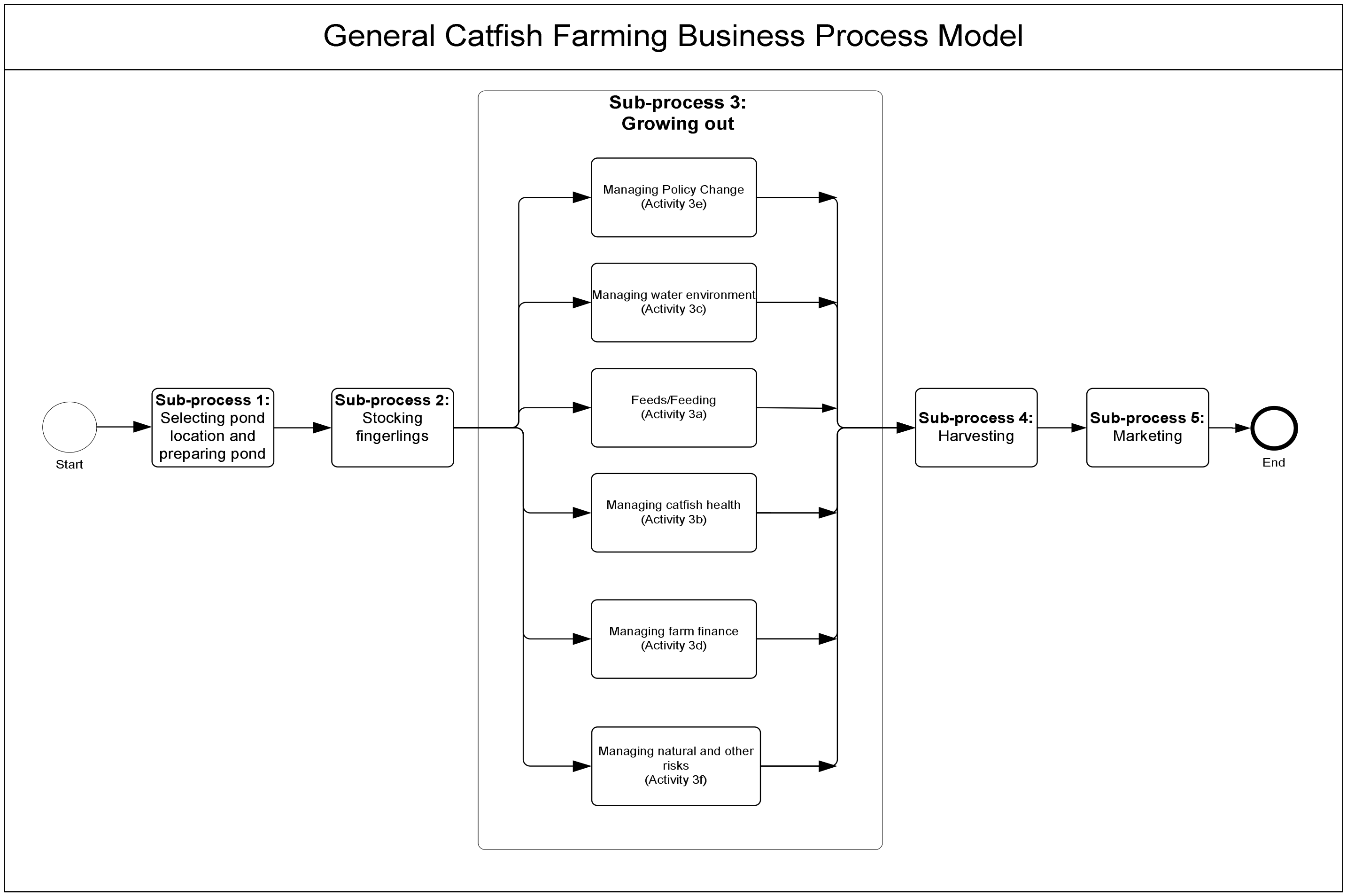


Figure 5-1 General Catfish Business Process Model

activity in the general process is harvesting. Then, the final activity in the catfish farming process is marketing. The following sections will describe each of these five steps/activities in detail and identify risks and risk management strategies associated with each of these activities in the process.

5.3 Proposed Risk Management Framework for Vietnamese Catfish Farming

Using the business process for Vietnamese catfish farming developed in the previous section, the general risk management process described in Section 2.4.2 will then be applied to each of the production steps. At each production step, associated risks will be assessed (including risk identifying, evaluating, and analysing) and the corresponding risk mitigating strategies will be developed. Thus, the approach for the development of the proposed risk management framework is to combine the GBPM and the risk management process together.

In the framework, the risk management process (including the seven steps) will be applied to each step or activity of the catfish farming process. Although catfish farming practices may vary from farmer to farmer, and country to country, a general catfish production process includes the following stages: maintaining brood stock, a hatchery phase, fingerling production, and food-fish (grow out) production (MSUCares 1993). In Vietnam, practically, almost 100% of the Vietnamese catfish farmers only conduct the food-fish production stage at their farms. The hatchery and fingerling production stages are done by other private or state hatcheries, who sell the fingerlings to fish grow-out farmers. Due to the scope of this research, the proposed framework is focused on the food-fish (grow-out) production stage.

The food-fish production stage includes the following five main sub-processes: site selection, pond/cage preparation, grow-out production, harvesting, and marketing (Ficen 2002). Applying the general risk management process to the catfish farming business process, a proposed risk management framework for Vietnamese catfish farming was developed and presented in Figure 5-2.

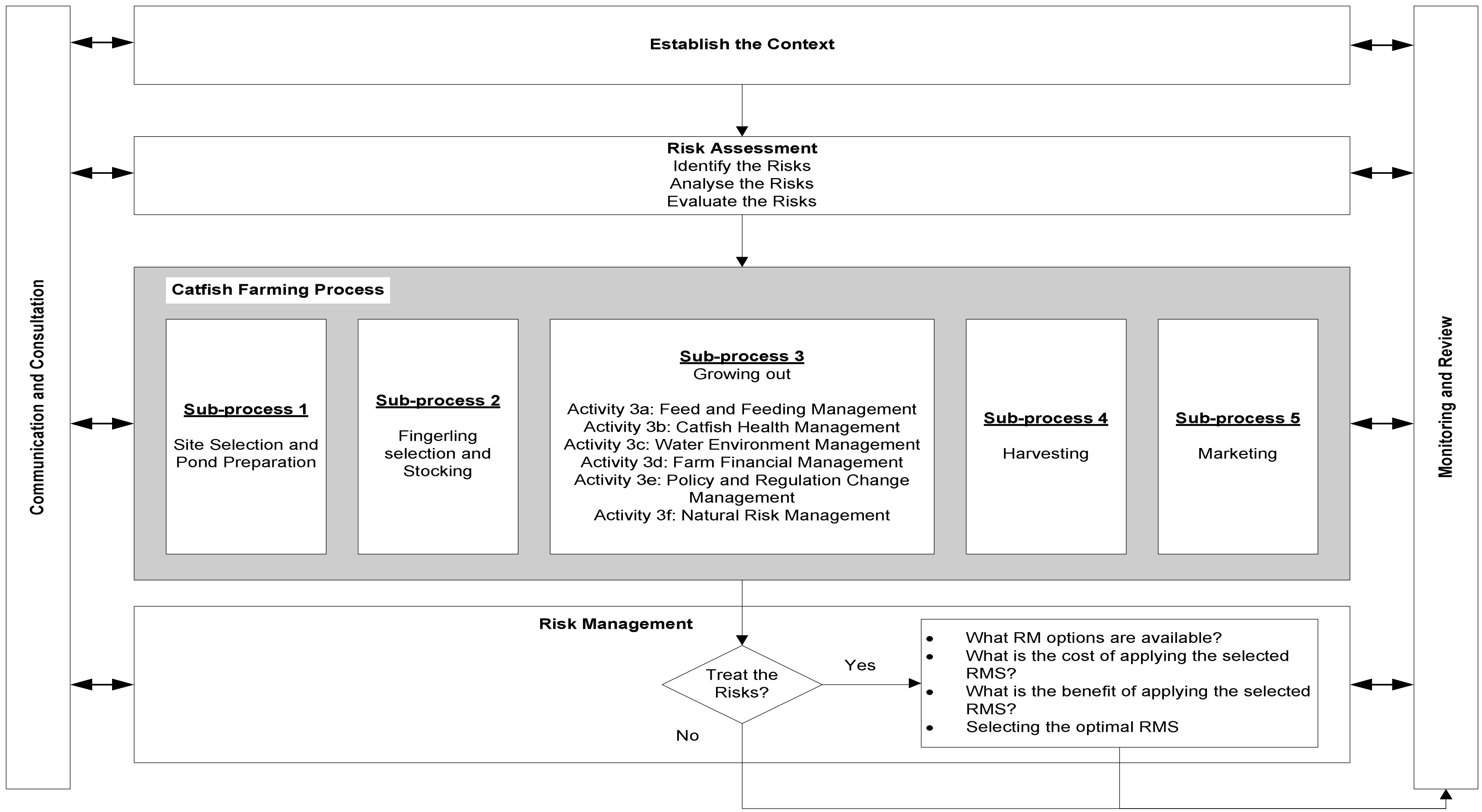


Figure 5-2 Conceptual Framework for Risk Management

Subsections from 5.3.1 to 5.3.7 in this chapter describe in detail the contents of each step of the risk management process suggested by AS/NZS 4360:2004, which are applied to Vietnamese catfish farming.

5.3.1 Communicate and Consult

At the early stage of this research, communication and consultancy work was done through the means of personal interviews and a focus group workshop. Personal interviews were mostly conducted with local aquacultural staff and academics to obtain general ideas about risks and problems in Vietnamese catfish farming. Following this, the opinions of interviewees were taken into account in designing the focus group workshop.

5.3.2 Establish the Context

A focus group workshop at the early stage of the research was organized to establish the context for the development of a risk management framework for Vietnamese catfish farming. The focus group consisted of 20 people who were stakeholders in catfish farming, including catfish farmers, aquacultural staff and managers, academics, and researchers. In this workshop, brainstorming and group discussion methods were used to achieve the goal of establishing the context. Through the workshop, the context of the risk management framework was established as follows:

- The organizational objective was to maximize profit or income.
- The environment in which this objective was pursued was Vietnamese catfish farming in the Mekong Delta.
- The main scope of risk management was the food-fish (growing-out) stage of the catfish farming industry, which includes seed and fingerlings production, growing out production, and fish processing and exporting.
- Economic and environmental criteria were used to measure the risks.
- Business process modelling combined with brainstorming and group discussion were used

to identify the risk. The “level of risk” criterion was used to assess the risks.

5.3.3 Risk Identification

Business process modelling was used to identify the risks involved in Vietnamese catfish farming. As described in section 5.2, the catfish farming business process can be broken into five sub-processes, including: pond section and preparation, selecting and stocking fingerlings, growing out, harvesting, and marketing and cost management. Subsections 5.3.3.1 to 5.3.3.5 explain the sub-processes and risks and risk management strategies associated with each sub-process. A summary of the risks and risk management strategies associated with each sub-process is provided at the end of this section.

5.3.3.1 Sub-process 1: Pond Location Selection and Pond Preparation

The first step in the whole catfish farming process is selecting the site to locate the pond and preparing the pond (if it already exists) before real rearing. This is an important step in the whole process of catfish farming. An appropriate pond location will provide advantages in production and hence reduce the operational cost substantially. Careful preparing of the pond before stocking is also an important activity that farmers have to do, in order to provide a good and healthy environment for the rearing of fish and to reduce the chances of disease infection or toxic substances seriously affecting catfish health and growth. This step of catfish production is presented in Figure 5-3.

This sub-process can be clearly divided into two activities: (1a) pond location selection and (1b) pond preparation. Pond location selection only applies if a pond is being built, usually from the rice field, while pond preparation is an activity conducted every time the new crop is about to start.

A good pond location for catfish farming is a site near a river or large channel, which can provide a large volume of fresh and healthy water for catfish farming. Because most catfish farming in Vietnam is under highly intensive farming systems, the need for water replacement is very high. Therefore, the availability of water supply, especially in the dry season, is the decisive factor the success of catfish farming. Locating the pond near a good water supply source can also reduce the cost of pumping water for replacement, especially with gravity flow.

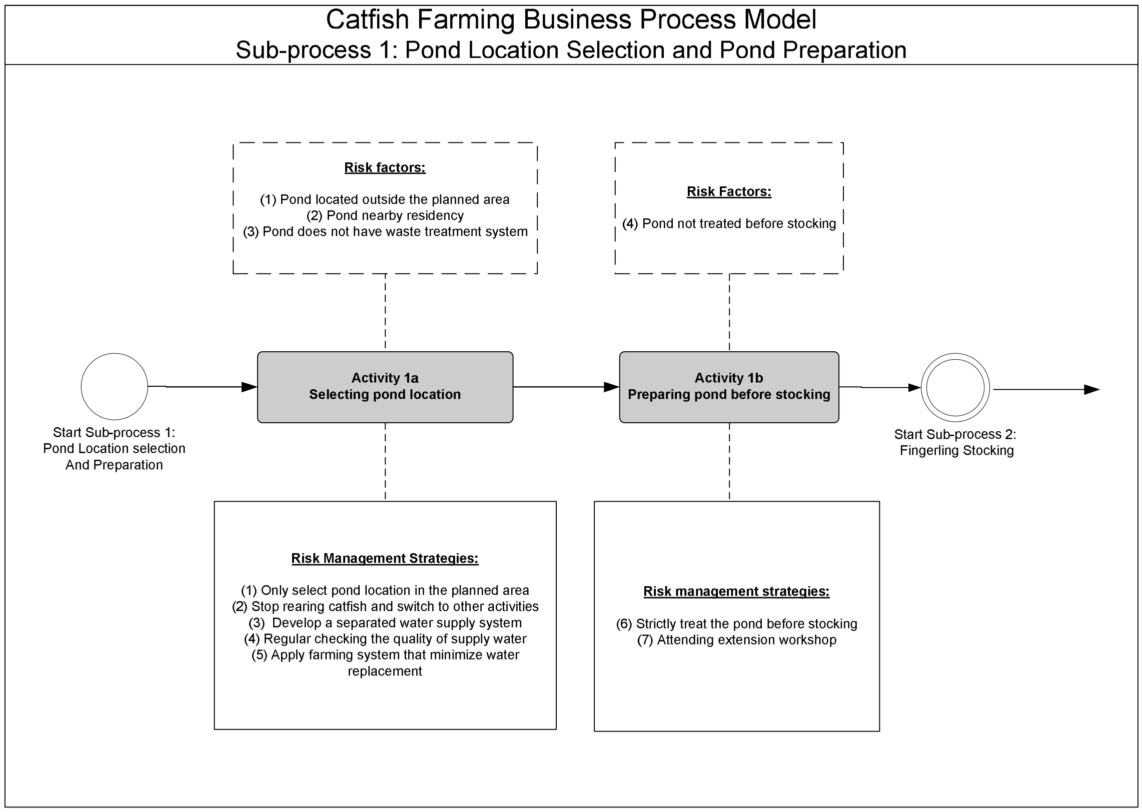


Figure 5-3 Sub-process 1: Pond Location Selection and Pond Preparation

Unfortunately, not every land area meets this condition. At certain times, when catfish farming is considered a super profit business and land for developing catfish ponds is limited, many unsuitable areas have been used for catfish pond development, even located outside government-planned areas. In addition, most of land used for catfish farming in recent years was transformed from rice field areas. The irrigation system has been developed for rice production can be inappropriate for catfish production, in particular, and for aquaculture in general. There is a need for renovation of this irrigation system to make it suitable for aquaculture. However, this requires a large amount of capital investment and time. The selection of inappropriate locations for pond building incurs higher costs of operation and increases the chance of disease infection from water supply sources.

In Figure 5-3 (and other following figures in this section), each activity is presented in a solid box and sources of risk and risk management strategies associated with each activity are presented in dashed boxes located above and below the activity box, respectively. From practical perspectives, the following are risk factors[2] involved with pond location: (1) pond located outside the government planned area, (2) pond located near residences, and (3) pond does not have a supply and waste water treatment system. Risk management strategies available for mitigating these risk factors are: (1) only selecting in the planned area, (2) stopping the rearing of catfish and switching to other activities, (3) developing a separated water supply system, (4) regular checking of the quality of supply water, and (5) applying farming systems that minimize water replacement.

The second activity in this step of production is preparing or treating the pond before stocking. The purpose of this activity is to ensure the pond environment, in terms of physical, chemical, and biological conditions, is suitable for the development of fish in the later stages. Specifically, the in-pond water temperature should be maintained between 26 and 30 degrees Celsius, the pH should be between 7 and 8, and dissolved oxygen content greater than 3 mg/litter. In addition, the water supply to the pond before stocking must be clean and meet the water standards for aquaculture. Specifically, the level of unionized ammonia (NH_3) must be less than 1 mg/litter, coliform below 10,000 MPN/100 ml, and lead content vary between 0.002-0.007 mg/litter (Ficen 2002).

A good pond preparation must follow the following activities. First, completely drain the pond, clear predator fish in pond, remove all weed and algae from pond, and enforce the pond dyke. Second, take out the liquid mud from the pond, leaving a layer of mud of 0.2-0.3m depth at the pond bottom. Fix all the leaking from the pond to prevent water leaking and predators from entering the pond. Third, apply agricultural lime ($Ca(OH)_2$) on the pond bottom and the dyke to adjust the pH level and destroy all the disease sources that could remain in pond from the previous crop. Forth, dry the pond for about two to three days before supplying water into the pond. Finally, in supplying water to the pond, be sure to use a filter to prevent predator fish entering the pond (Ficen 2002). The reasons for not treating the pond

[2] The numbers in parentheses in front of risk factors and risk management strategies are used as identification (ID) numbers for all risk factors and risk management strategies, respectively, in this study.

before stocking might be the cost involved and limited knowledge about the importance and technique of pond treating

Therefore, the risk involved in this activity is: (4) pond not treated before stocking. The risk management strategies to mitigate the risk in this activity are (6) strictly treat the pond before stocking and attending extension workshop.

5.3.3.2 Sub-process 2: Selecting and Stocking Fingerlings

The second sub-process in the catfish farming process is selecting and stocking fingerlings. This step can be divided into two activities: (2a) selecting fingerlings and (2b) stocking fingerlings. Each of these activities has its risk factors involved and corresponding risk management strategies to mitigate those risks. Figure 5-4 presents the activities in this step and its associated risks and risk management strategies.

Currently, catfish fingerlings are produced through artificial reproduction at hatcheries. For good growth of catfish in the growing out stage, fingerlings must be careful selected to ensure that the fingerlings are of good quality. Specifically, the fingerlings must be healthy, not infected by any disease, and the fingerling production process must be documented. However, in practice, in certain times, catfish fingerling supply dose not meet the demand due to the fast growing in catfish farming. As a result, low quality fingerlings have been used for the growing out production. The risks that the farmers face in these activities are: (5) low quality fingerlings, (6) fingerlings with unknown origin, (7) fingerlings infected by diseases, (8) fingerlings treated by antibiotic, and (9) fingerlings epidemic checking not conducted. These risks can reduce the growth rate of growing out fish, resulting in a high death rate due to diseases, and increase the difficulty of fish health management due to medicines and antibiotic resistance. In order to minimize the impact of these risks to the catfish production, the following risk management strategies can be applied: (8) only good select fingerlings for the growing out, buy fingerlings from reliable places, buy fingerlings from certified producers, and carefully check fingerlings when buying.

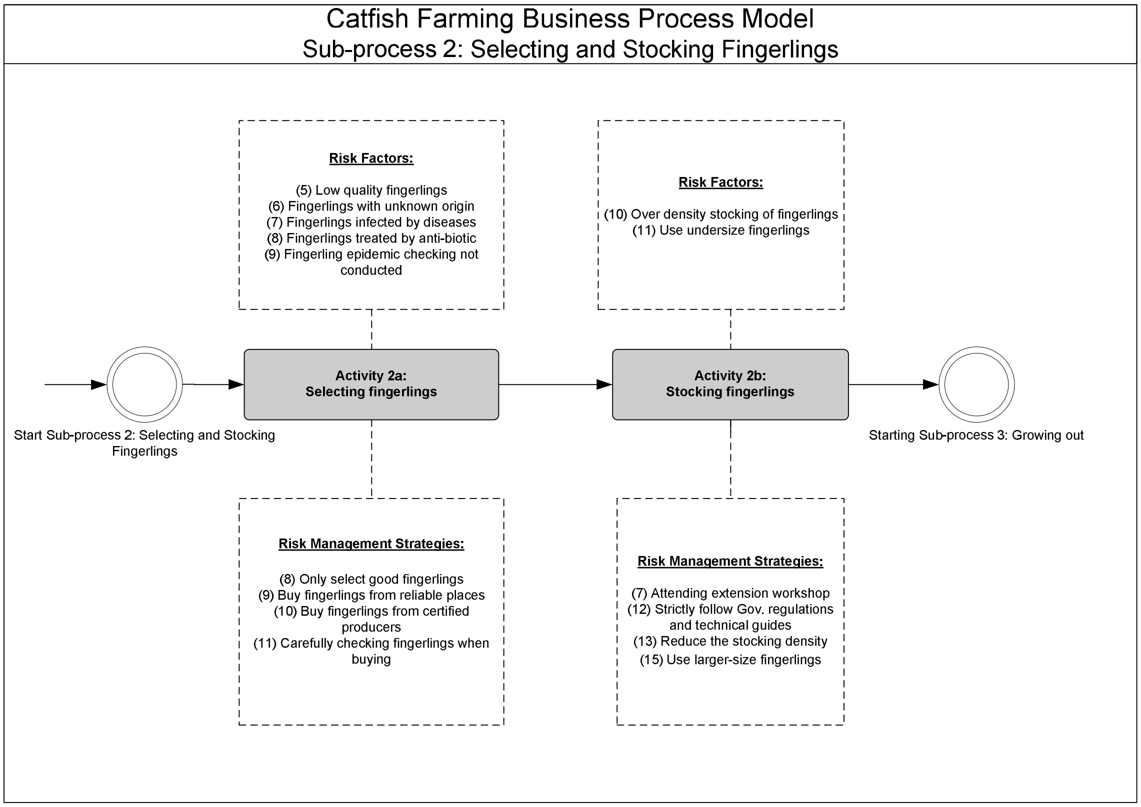


Figure 5-4 Sub-process 2: Selecting and Stocking the Fingerlings

After selecting the fingerlings, the next sub-activity in this step is stocking fingerlings into the pond. The key issues that need careful consideration are the density of fingerling stocking and the size of fingerlings for stocking. According to technical guide for catfish farming (Ficen 2002), the density of fingerlings varies from 15-40 fingerlings/m^2 across the farming systems. For the small pond farming system, the density of fingerlings stocking is between 15-20 fingerlings/m^2. For the intensive farming system with water replacement, the density can reach to 20-30 fingerlings/m^2. The density of fingerling stocking is between 25-30 fingerlings/m^2, if the pond is equipped with aeration system. The risks involved in this activity are: (10) over density stocking of fingerlings, and use under (small) size fingerlings. The following risk management strategies can be applied to mitigate risks related to fingerling stocking activity: (7) attending extension workshops to improve the knowledge about the technique of catfish farming, (12) strictly following technical guides, (13) reducing the stocking density, and (15) using larger size fingerlings.

5.3.3.3 Sub-process 3: Growing out

After stocking fingerlings into the pond, the growing out stage is the most important stage of the catfish farming process. This is also the longest step in terms of time required to complete; it usually takes from six to seven months to complete. There are many activities that take place in this stage of production. Successful managing of these activities will play a decisive role in the final outcome of the crop. The third sub-process in catfish farming can be broken down into six activities and presented as a group of activities, named growing out sub-process in Figure 5-1. There are six activities in the growing out sub-process and they happen simultaneously throughout the whole crop duration, namely: (3a) managing feed and feeding, (3b) managing catfish health, (3c) managing in-pond water environment, (3d) managing farm finance, (3e) managing policy changes, and (3f) managing natural and other risks. The following sections will elaborate on these activities and identify associated risks and risk management strategies one-by-one.

a. Activity 3a: Managing Feed and Feeding

Figure 5-5 below presents a complete description what is involved in the activity of managing feed and feeding for catfish farming. This activity can be broken down into three sub-activities: (3a1) buying feed from the market, (3a2) producing homemade feed and (3a3) feeding.

Catfish farmers can use either factory made (pelleted) feed or homemade feed, or a combination of both types of feed. These types of feed have both advantages and disadvantages. Factory made or pelleted feed is standardized industrial feed, which is nutritionally formulated to optimize the growth of fish at different stages of growth. The nutrition content is well controlled and easy to store. Pelleted feed is usually in dry and floatable form so it is easy for fish to eat and digest, which can reduce the pollution to the pond water environment due to waste feed and faeces. In addition, the cost of transport, storage, and labour for feeding is low. However, the price of factory made feed is often high, and in some instances it is too costly.

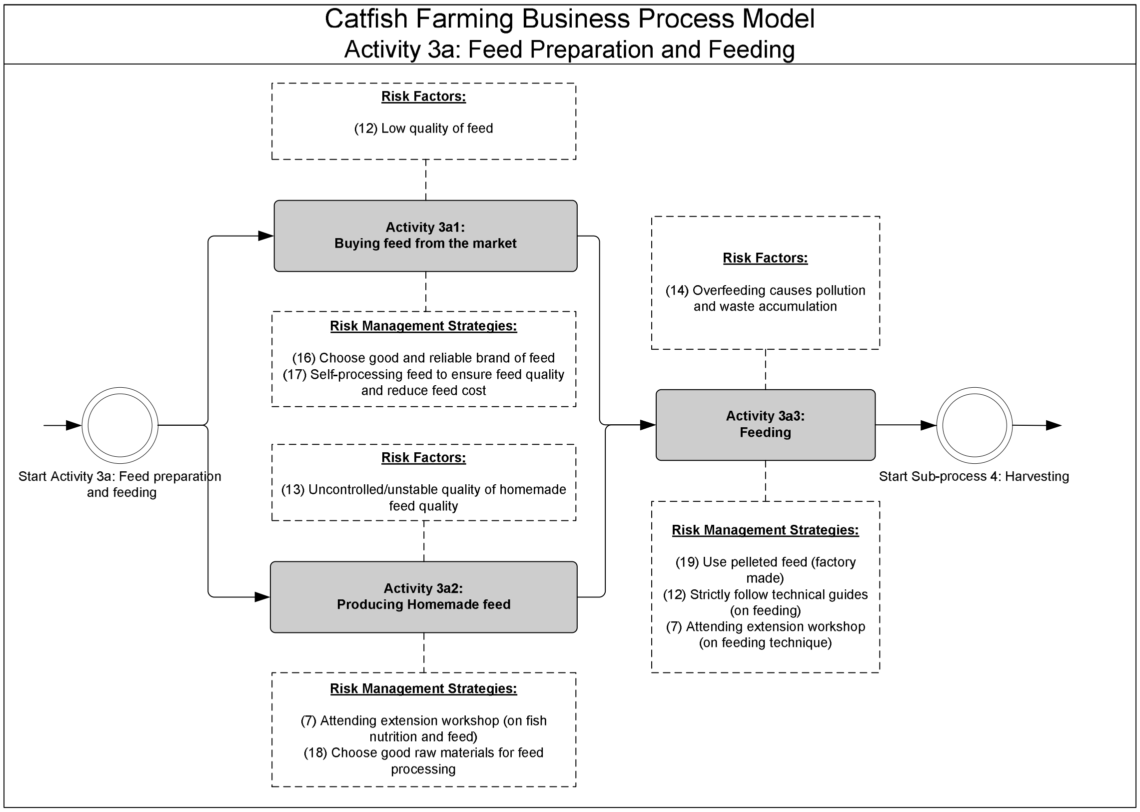


Figure 5-5 Activity 3a: Managing Feed and Feeding

Instead of using pelleted feed, catfish farmers can produce feed themselves using indigenous materials to reduce the cost of feed in catfish farming. This is the most important advantage of homemade feed over factory made feed. However, there are many disadvantages of using homemade feed to replace for factory made feed. First, the quality of homemade feed is difficult to control and unstable due to farmers' lack of knowledge about nutrition. The quality of raw materials is not easy to evaluate, which causes low or unstable quality of homemade feed, and this seriously affects the growth of growing out fish. Homemade feed is often produced right at the catfish farm and in wet form, which makes storage difficult. Home feed producing incurs costs of labour for feed processing and feeding. Using homemade feed in the wet form also increases the volume of feed used, which causes more pollution in the pond environment.

Both factory made and homemade feed need to meet the nutritional requirements, especially the protein content in feed, to ensure the normal growth of fish. The requirement on protein content in catfish feed varies from 20-28% according the stage of fish growth. There are risks involved in using either factory made or homemade feed. In the case of using factory made feed, a risk can be (12) buying low quality feed, of which the protein content is far below the announced rate. The farmers are not able to check or evaluate this by themselves. To mitigate this risk, catfish farmers can apply risk management strategies as follows: (16) choose good and reliable brands for feed, and (17) self-processing feed. For the homemade feed, the most important risk factor is uncontrolled and unstable quality of feed. In order to reduce the chance of this risk, catfish farmers can apply the following risk management strategies: (7) attending extension workshops to improve knowledge about nutrition and feed processing techniques, and (18) choosing good raw materials for feed producing.

Feeding practice is also an important aspect that catfish farmers need to do correctly. One of the biggest problems catfish producers encounter is to know how much to feed each day. Overfeeding wastes feed and money, and causes water-quality problem (Jensen 2009). This practice not only increases the cost of feed for the crop but also pollutes the water environment in pond, which in turn affects the development of catfish and reducing economic results. Therefore, it is considered as a risk; namely, (14) overfeeding. Catfish farmers can reduce this risk by applying the following risk management strategies: (19) use pelleted feed, and (12) strictly follow technical guides for feeding. Usually, the diet for fish is from 5-7% or from 2-2.5% of fish body weight, for the homemade feed or pelleted feed, respectively (Ficen 2002).

b. Activity 3b: Managing Catfish Health

Managing catfish health is one of the most important activities in the growing out stage of catfish farming. Disease infection reduces fish health and growth and hence reduces both output and quality of harvest fish. In managing catfish health, there are two aspects or sub-activities that catfish farmers have to be concerned about: (3b1) disease management and (3b2) medicines and chemical use management. While the former is more on the disease prevention, the latter is more on treatment of diseases that actually happened to the farm. The risks and risk management strategies related to these two sub-activities in catfish health management activity are presented in Figure 5-6.

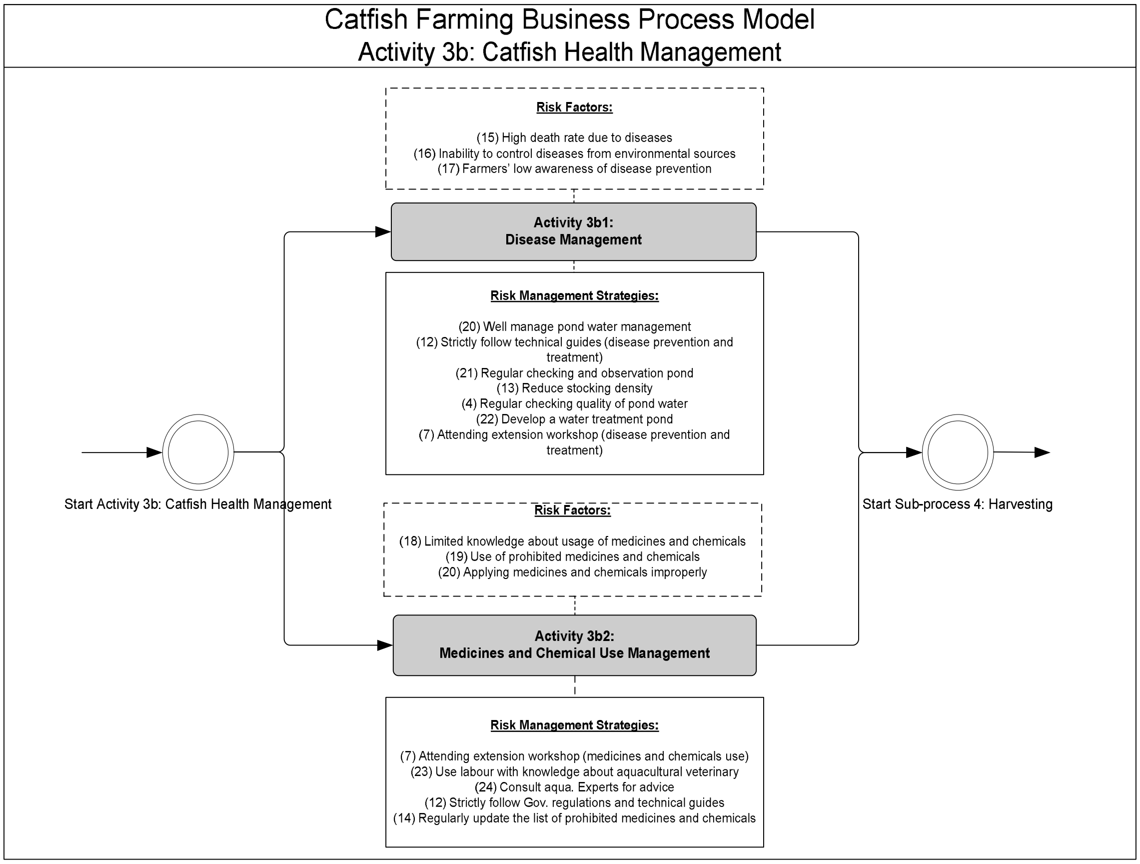


Figure 5-6 Activity 3b: Managing Catfish Health

For the disease management activity, disease risks can come from both inside and outside sources. Inside sources of diseases often originate from water and fingerling quality problems. The risks associated with the water quality problems will be discussed in the next section and the fingerling quality problems have been discussed previously (Sub-process 2: Selecting fingerling and stocking). Outside sources of disease come from environmental sources and are often difficult to be aware of and control. Hence, in the disease management activity, catfish farmers may face the risks as follows: (15) high dead rate due to diseases, (16) inability to control diseases from environment, and (17) low awareness of disease prevention. To manage these risk factors, catfish farmers can conduct risk management strategies as follows: (20) good management of the pond water environment, (12) strictly following technical guides (on disease prevention and treatment), (21) regular and careful checking and monitoring of fish in pond, (13) reducing the stocking rate, (4) regular checking of the quality of water in pond, (22) developing a water treatment pond that can treat the water to meet the required standard before supplying into the pond, and (7) attending extension workshops to improve knowledge about disease prevention and treatment.

In using medicines and chemicals to prevent and treat diseases in catfish farming, there are risks involved in this activity, mostly because of limited knowledge about the usage of medicines and chemicals and lack of awareness of the impacts of medicines and chemicals on food safety and hygiene standards. This practice can cause ineffective treatment for diseases and reduce the quality of food fish or even cause the complete abandonment from processing for export or domestic consumption. The common risks catfish farmers face are: (18) limited knowledge about usage of medicines and chemicals, (19) use of prohibited medicines and chemicals for disease treatment, and (20) applying medicines and chemicals improperly. To minimize these risk, the following strategies can by apply: (7) attending extension workshops (to improve knowledge about medicines and chemicals using), (23) use labour who have knowledge about aquacultural veterinary, (24) consulting aquacultural experts for advice, (12) strictly following government regulations and technical guides in using medicines and chemicals in aquaculture, and (14) regularly updating the list of prohibited medicines and chemicals to prevent the misuse of them.

c. Activity 3c: Water and Environment Management

Water and environment management activity in catfish farming aims to ensure the in-pond water is in good quality to support healthy growth for the rearing of catfish and, at the same time, to protect the environment from the pollution due to water and effluents released from the pond into the environment. This is an import factor to ensure the sustainability of the catfish farming industry. Most of the disease outbreaks in the industry in recent times originated from environmental sources. Disease infecting the water supply brings disease problems into ponds and releasing disease-infected waste water from the pond into the environment in turn becomes the water supply to other ponds, causing disease outbreaks to happen in a widespread area. Therefore, this activity can be divided into two sub-activities: (3c1) managing the in-pond water environment, and (3c2) managing the aquacultural and community environment.

The sub-activities and associated risks and risk management strategies in water and environment management activity are presented in Figure 5-7.

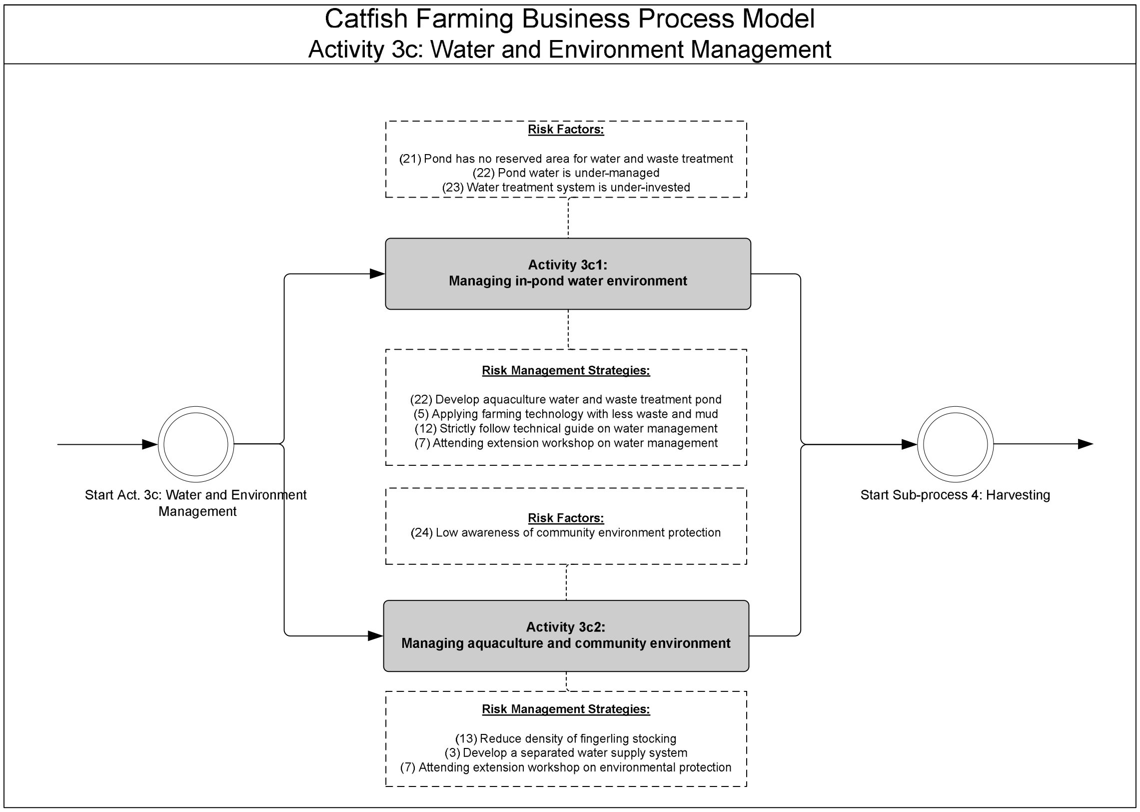


Figure 5-7 Activity 3c: Water and Environment Management

Managing the in-pond water environment is an important activity in catfish farming. This aims to maintain a good water environment for the catfish to grow healthily. It consists of maintaining the physical, chemical, and biological characteristics of in-pond water such as temperature, dissolved oxygen content (COD), pH, and coliform in proper status to support the normal growth of fish. In addition, keeping the in-pond water out of disease infection is also an important task. The risks related to this activity of preventing the pond from developing unfavourable environmental conditions are: (21) pond has no reserved area for water and waste treatment, (22) in-pond water is under-managed, and (23) water treatment system is under-invested. To overcome these risks, the possible associated risk management strategies are: (22) developing a water treatment pond so the water can be treated to meet requirements before being supplied into pond or released into the environment. The other risk management strategies for pond water environment management are (5) applying farming technology that produces less waste water and effluents (recirculation system), (12) strictly following the technical guidelines on water management, and (7) attending extension workshops to enhance knowledge in pond water management.

Besides managing the pond water environment, catfish farmers also need to take care about the aquaculture and community environment because this will in turn affect back to the pond environment. Catfish farming strongly impacts the quality of natural environment because of a large volume of waste water and effluent released into the environment. If this problem is not managed properly, it will deteriorate the environment rapidly and hence threaten the sustainability of the industry. Catfish farmers' low awareness of aquaculture and the community environment (24) is a risk to the sustainability of the catfish farming industry. To reduce the impact of this risk, the following risk management strategies can be applied: (13) reducing the density of fingerling stocking, (3) developing a separated water supply system, and (7) attending extension workshops to improve knowledge about environment protection.

d. Activity 3d: Farm Financial Management

Catfish farming requires a large amount of capital for initial investment and operation. A normal crop duration can last up to seven months to complete, during which operating expenses for feed, medicines, fuel, and labour take place throughout the crop. Therefore catfish farmers need to take special care about financial arrangements for both initial investment and operation. Lacking capital for feed and medicines, for example, can cause serious problems for the growth and health of fish, which can affect the yield and quality of harvested fish. Some financial risks catfish growers can face are: (32) underfinancing by own capital for the whole crop, (33) underfinancing by credits from banks or financial institutions, and (34) high interest rates for loans. Most Vietnamese catfish farmers finance their crop by both their own capital and credits. Limited access to credits from banks or other financial institutions is a major risk to catfish farmers in financial arrangement for their production. In most cases, catfish farmers cannot get enough credits for their production due to limited fund available from banks, lack of collateral assets for borrowing, and bad credit history (loans from previous bad crops). In order to minimize the risk of lacking capital for the crop, the following financial risk management strategies are possible solutions: (36) reducing the farm size to an appropriate scale, (37) increasing solvency ratio, (38) partnership with others to share the production financing, (39) making sufficient credit arrangements before the cropping starts, (40) good solvency-debt management, (41) using economic/financial consultant services, and (42) keeping enough cash in hand for all operating activities. Figure 5-8 summarizes the risks and the risk management strategies related to catfish farm financial management.

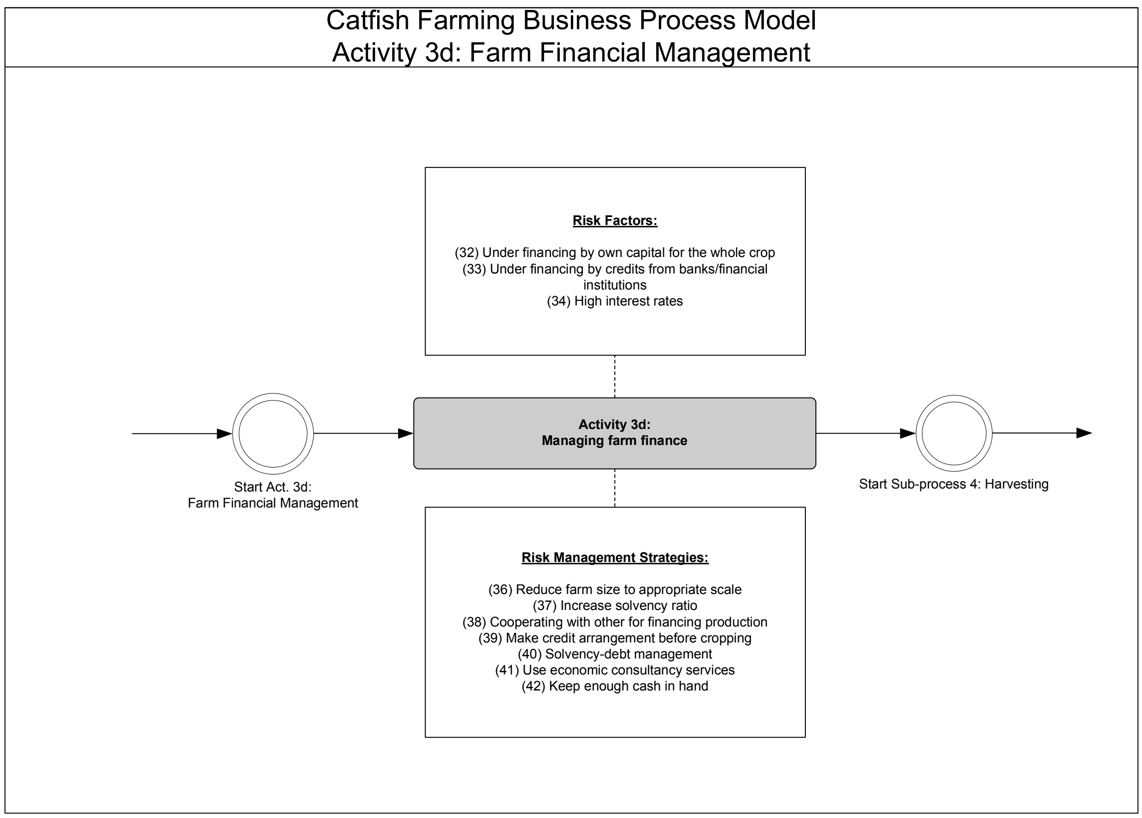


Figure 5-8 Activity 3d: Farm Financial Management

e. Activity 3e: Policy Change Management

Besides dealing with business and technical risks, catfish farmers are also faced with policy-related risks in a continuously changing business environment. Stricter environment protection regulations and higher standards for food hygiene and safety, for both domestic and export markets, are most obvious changes in government policies related to aquacultural production. Figure 5-9 presents the policy risks in catfish farming and possible risk management strategies used to mitigate those risks.

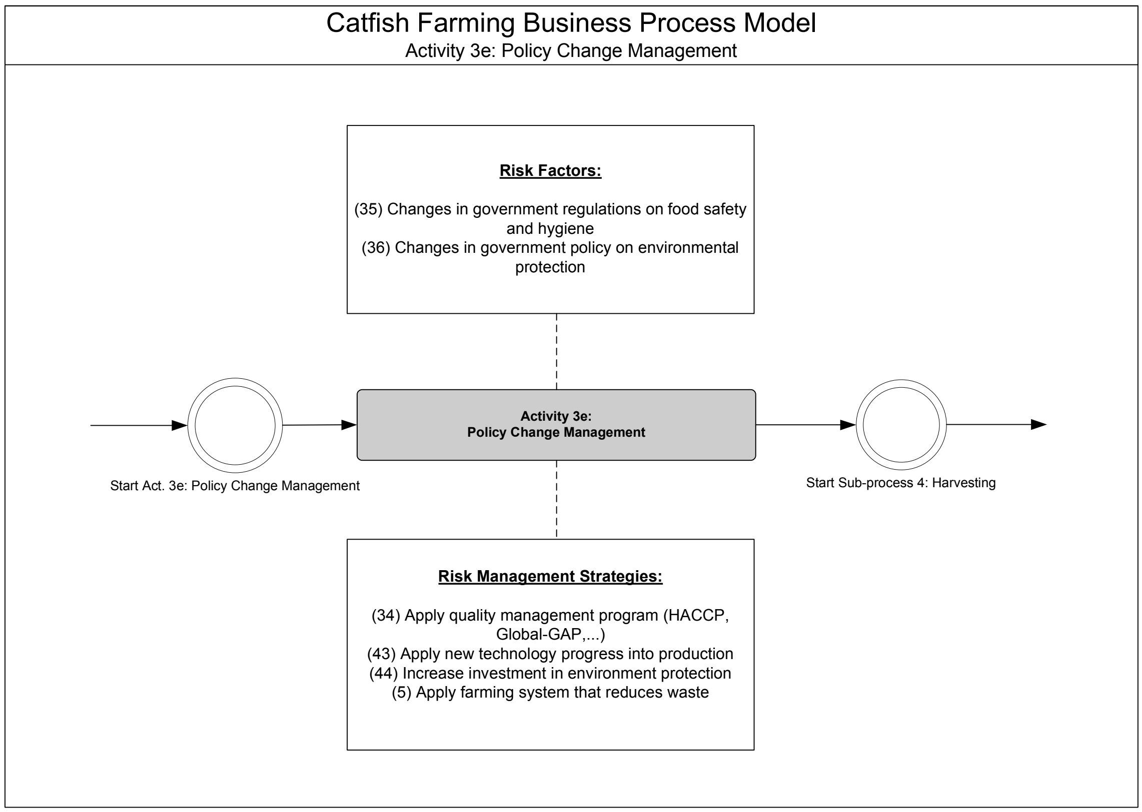


Figure 5-9 Activity 3e: Policy Change Management

From the survey, the following sources of risk in policy changes are most important to catfish farmers: (35) changes in government regulations on food safety and hygiene, and (36) changes in government policy on environmental protection. The former is a result of higher and stricter requirements from customers, especially importers from developed countries. Developed countries often have high standards for food safety and hygiene for imported products. In countries where the imported catfish might be a substitute for domestic products, this regulation can be used as a technical barrier to protect domestic production.

Regulations on environmental protection are getting stricter and stricter in many countries. Aquaculture, especially intensive aquaculture, releases a large amount of waste water and effluents from pond into natural water bodies. This can substantially deteriorate the environmental quality due to infected diseases and effluents. Polluted water can affect many other users, such as agriculture, industrial, and domestic uses. Therefore, governments tend to set a higher standard for aquacultural environmental management for the sustainability of the industry.

When faced with risks related to government policy change as mentioned above, the following risk management strategies can be used: (34) applying quality management programs (HACCP or Global-Gap), (43) applying new technology progress into production, (44) increasing investment in environment protection, and applying farming systems that reduce waste. Specifically, new technology requires less water replacement and reduces waste emission.

f. Activity 3f: Natural and Other Risk Management

Figure 5-10 summarises the risks and the risk management strategies related to natural and other risks in catfish farming. Agriculture in general, and aquaculture in particular, is a biological process and heavily influenced by natural conditions. Natural conditions can significantly change the pond environment and hence strongly affect the normal growth process of fish raised. Natural damages are often serious and can cause severe loss of business. Therefore, it is important to care about natural risks that can affect the catfish farming process. Risks related to natural conditions that can seriously affect catfish farming in the Mekong Delta are: (37) drought or lack of water supply, and (38) flood/storm problems.

Water is the main input for aquaculture, especially for intensive catfish farming. Serious drought often leads to a decrease in surface water levels and waterflow through rivers, which are the main sources of water supply for Vietnamese catfish farming in the Mekong Delta. Lack of water supply increases the costs of production, due to higher fuel costs for water pumping instead of water supply by gravity. Lack of water supply will also lead to a reduction in water replacement, which can affect the normal growth and reduce the quality of catfish, i.e. off flavour and dark colour problems. Besides, storm or flood problems can completely damage crops due to water overflow or pond dyke breaks. In such cases, the fish will freely escape into the environment, causing a loss of income for the catfish farmers.

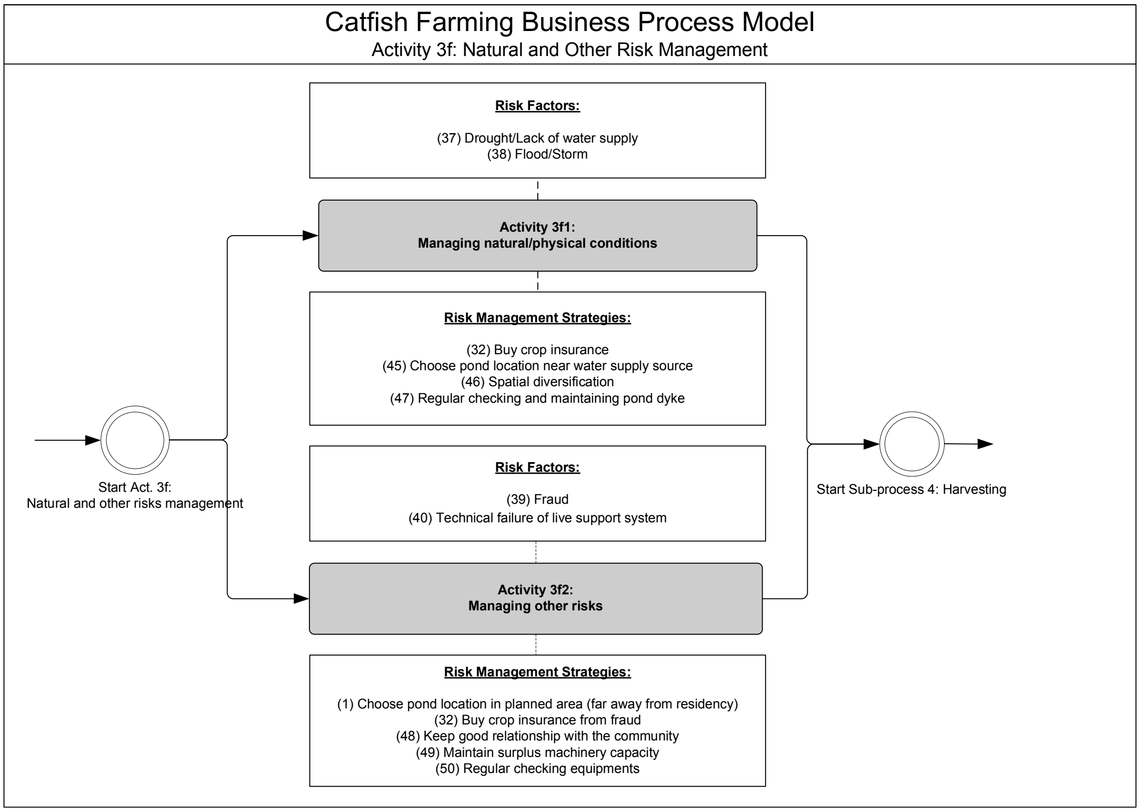


Figure 5-10 Activity 3f: Natural and Other Risk Management

To protect the crop against these natural risks, the following strategies can be applied: (32) buying crop insurance, (45) choosing pond locations near the water supply source, (46) spatial diversification, and (47) regular checking and maintenance of pond dykes.

Other possible risks in catfish farming are: (39) fraud, and (40) technical failure of live supportive system. Fraud is an infrequent risk; however, it is a very severe risk. When it happens, the loss often is 100%. In practice, introducing agricultural pesticides into the catfish pond is the most common fraud action in the Mekong Delta. Similarly, live supportive systems such as aeration system and water pumps are important equipment for maintaining pond environment conditions suitable for the survival of fish. Breaking out of these systems can seriously damage catfish health or even kill the fish. To reduce the impact of these risk factors, the following risk management strategies can be applied: (1) choosing pond location in planned area (far from residency), (32) buying insurance crop for fraud, (48) keeping good relationships with the community, (49) maintaining a surplus machinery capacity, and (50) regular checking of equipment.

5.3.3.4 Sub-process 4: Harvesting

Catfish can reach market size after six to seven months of rearing in a pond. However, harvesting time and the size of harvested fish are mainly dependent on the marketing contract with processors or traders. There are two types of harvesting methods: complete harvest, when all the fish are taken out of the pond; and partial harvest, when only a portion of the fish are taken out of the pond at one time (Jensen 2009). The methods used for harvesting depend on the marketing contract with buyers. Complete harvest is mostly used when the fish are sold to processors, who often buy a large volume of fish. Partial harvest is often used when the fish are sold to small traders, who usually buy a small volume of fish and transport the fish to domestic markets for home consumption. In either method, the fish need to be transported to the destinations (processing factories or retail markets) as quickly as possible to avoid reductions in quality and death.

Figure 5-11 depicts the risks and respective risk management strategies in the harvesting sub-process of catfish farming. The risks involved in the harvesting activity of catfish farming are: (25) harvesting fish with inappropriate size, and (26) harvesting with inappropriate methods. The risk of harvesting with inappropriate size often happens when the catfish farmers do not have a sale contract with buyers, or the buyers break the contract due to some other reasons. Most of catfish processors require a specific size for catfish purchasing, which is suitable to their market requirements. However, when the market is oversupplied, catfish farmers cannot sell their fish at a desired time and size, so they must continue to feed the fish in their pond. As a result, the fish become oversize and this reduces the price and quality of the fish, and increases the cost of production. Partial harvesting causes stress to the fish remaining in pond, which makes the fish stop eating and growing. This can reduce the yield of the crop.

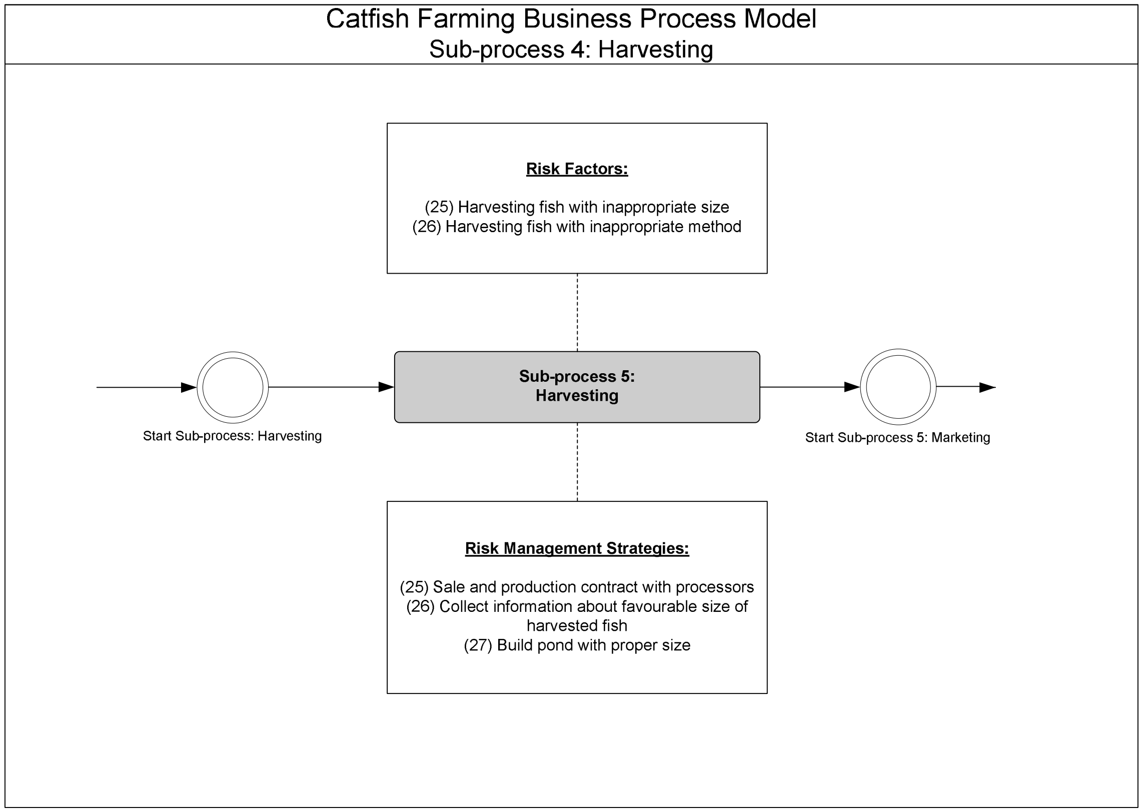


Figure 5-11 Sub-process 4: Harvesting

To reduce the impact of these risks, catfish farmers can apply the following strategies: (25) secure a sale and/or production contract with processors, (26) collect information about favourable size of harvested fish from processors or the market, and (27) build a pond with proper size so the fish can be harvested completely at one time.

5.3.3.5 Sub-process 5: Marketing and Cost Management

Marketing is the last sub-process in the entire catfish farming business process. However, it is a very important step in the process. All of the activities in the previous steps of catfish farming result in this stage of the production: selling the fish to the market. The outcome (income/profit) of the whole crop is realized in this step of production.

The risks that catfish farmers can face in this activity are: (27) fish price variability, (28) yield variability, (29) weak enforcement in conducting sale contract with processors, (30) strict technical barriers from importing countries, and (31) high costs of operating inputs. These are summarized in Figure 5-12.

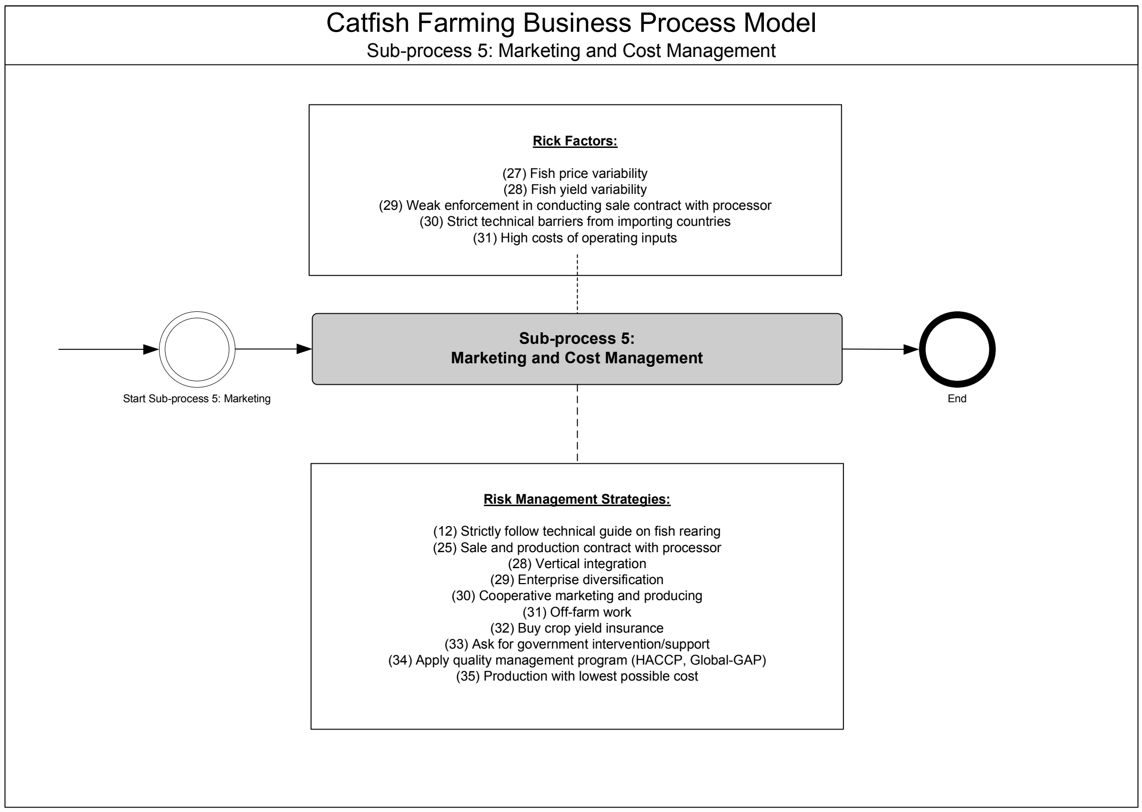


Figure 5-12 Sub-process 5: Marketing and Cost Management

Fish price variability is the most important risk in Vietnamese catfish farming. Catfish farmers never know what prices they can receive for their product at the end of the crop, even when they have a sale or production contract with processor. Buyers usually set the price at the time of harvest. Catfish farmers almost have no bargaining power in setting the price. Currently, futures and options market for commodity exchange where agricultural/aquacultural producers can achieve a predetermined price for their products does not exist in Vietnam. As a result, farm producers can only take the spot price at the moment they harvest their products, which often merely depends on the buyers.

Even catfish producers have a sale contract with a predetermined price; there is no guarantee for the catfish farmers to get the price set in the contract. Breaking the sale contract is a common practice in the Vietnamese catfish farming industry when the market conditions are not favourable. Weak law enforcement is a common practice in many fields of business practice in Vietnam. In this situation, catfish farmers are in disadvantaged position to fight against processors or traders in respecting the sale contract.

To mitigate or minimize the impacts of marketing-related risks, catfish farmers can apply the following strategies: (12) strictly follow the technical guide on fish rearing, (25) secure a sale and production contract with processor, (28) vertical integration, (29) enterprise diversification, (30) cooperative production and marketing, (31) off-farm work, (32) buying crop insurance, (33) asking for government intervention or support in conducting the sale contract with buyers, (34) applying a quality management program (HACCP, Global-GAP) to meet the standard required by importers, and (35) producing with lowest possible cost strategy.

5.3.3.6 Summary of Risks Associated with Each Sub-process

Risks associated with each sub-process in Vietnamese catfish farming are summarized and presented in Table 5-1. As shown in the table, most of the risks are concentrated in the growing out stage of the production process. The duration of the growing out stage is from four to six months. During this time, the fishes are exposed to all types of thread that can affect their normal growth. Among a total of 40 sources of risk identified, the growing out stage accounted for 22 sources of risk. Next, the fingerling selection and stocking sub-process had the second largest number of risks, at seven. The marketing and cost management sub-process takes the third place in terms of the number of risks. There were five sources of risk involved in this sub-process. The number of risks in pond location selection and preparation were four and the harvesting sub-process had the least number of risks, at two.

Table 5-1 Summary and Classification of Identified Risks

Sub-process 1: **Pond Location and Preparation**	**Sub-process 2:** **Fingerling Stocking**	**Sub-process 3:** **Growing out**	**Sub-process 4:** **Harvesting**	**Sub-process 5:** **Marketing**
• R#1: Pond outside planning area	• R#5: Low quality fingerlings	**Activity 3a: Feed and Feeding Management**	• R#25: Inappropriate size of harvested fish	• R#27: Fish price variability
• R#2: Pond near residence	• R#6: Fingerlings from unknown origin	• R#12: Low quality of feed	• R#26: Inappropriate method of harvesting	• R#28: Inaccessibility to the market
• R#3: Pond does not have waste treatment system	• R#7: Fingerlings infected by diseases	• R#13: Uncontrolled/unstable homemade feed quality		• R#29: Weak legislation on sale contracts between farmers and processors
• R#4: Pond not treated before stocking	• R#8: Fingerlings treated by antibiotics during fingerling production process	• R#14: Overfeeding causing pollution and waste accumulation		• R#30: Consequence of high level of technical barriers imposed by importing countries
	• R#9: Epidemic checking for the fingerlings not conducted	**Activity 3b: Catfish Health Management**		• R#31: High costs of operating inputs
	• R#10: Over (density) stocking fingerlings	• R#15: High death rate due to disease		
	• R#11: Use of undersized/oversized fingerlings	• R#16: Inability to control diseases caused by environmental sources		

Sub-process 1: **Pond Location and Preparation**	**Sub-process 2:** **Fingerling Stocking**	**Sub-process 3:** **Growing out**	**Sub-process 4:** **Harvesting**	**Sub-process 5:** **Marketing**
		• R#17: Low level of awareness of disease prevention among farmers		
		• R#18: Limited knowledge about use of chemicals and medicines		
		• R#19: Use of prohibited chemicals and medicines		
		• R#20: Applying chemicals and medicines improperly		
		Activity 3c: Water and Environment Management		
		• R#21: Farm has no reserved area for waste water and mud treatment		
		• R#22: Pond water is under-managed		
		• R#23: Waste water treatment system is under-invested		
		• R#24: Lack of awareness about community environmental protection		
		Activity 3d: Farm Financial Management		
		• R#32: Under-financing by own capital for the whole crop cycle		
		• R#33: Under-financing by credits from banks/credit institutions		
		• R#34: High interest rate for loans		
		Activity 3e: Policy Change Management		
		• R#35: Changes in government policy on product development strategy		
		• R#36: Changes in environmental policy		
		Activity 3f: Natural and other risks management		
		• R#37: Drought or lack of water supply		
		• R#38: Flood		
		• R#39: Fraud		
		• R#40: Technical failure		

5.3.4 Risk Measurement

This study used the concept of level of risk to measure the potential impact of a source risk on the income/profit of catfish farmers. According to the Australian Standard on Risk Management (ANZ 4360:2004), the level of risk is defined as the product of the consequence (severity) and the likelihood (probability) of risk, i.e. *Level of Risk = Consequence***Likelihood*. The next three sections will consecutively present the consequence, likelihood, and level of risk of all sources of risk included in the survey questionnaire.

5.3.4.1 Measuring the Consequence (Severity) of Risk

In total, 40 sources of risk were presented to the respondents. To measure the catfish farmers' perception about the potential impacts of the sources of risk, catfish farmers were asked to rate (on a 5-point Likert scale) the potential of the risk to affect their income/profit on each of the 40 risk factors. The consequence of risk was rated on a scale of 1 to 5, with, 1 representing very low or minor impact, and 5 representing very significant or severe impact.

Table 5-2 shows the mean scores, standard deviations, and rank of all 40 sources of risks. The risks are ranked in descending order in terms of risk consequences. Sources of risk such as *variability in prices, usage of prohibited medicines and chemicals, and inaccessibility to the market* were ranked as the top three most important sources of risk, reflecting catfish farmers' greatest concerns about risk factors, with average scores of 4.49, 4.06, and 4.04 respectively. The second cluster consists of the next 24 sources of risk (ranked from 4 to 27), with average scores varying from 3 to 4. The third cluster consists of the next ten risk factors rated from 2.5 to 3 (ranked from 28 to 37). Finally, three sources of risk were rated between 2.0 and 2.5 belonging to the fourth cluster, which included *technical failure, flood, and drought*.

Table 5-2 Mean Scores of Risk Consequences and Ranks of Risks

Risk ID	Sources of risk	N	Mean	Std. Deviation	Rank by mean
27	Fish price variability	261	4.49	0.807	1
19	Use of prohibited chemicals and medicines	233	4.06	1.26	2
28	Inaccessibility to the market	255	4.04	1.237	3
15	High death rate due to disease	257	3.96	0.926	4
31	High costs of operating inputs	255	3.95	0.886	5
7	Fingerlings infected by diseases	244	3.9	1.023	6
5	Low quality fingerlings	260	3.85	0.943	7
4	Pond not treated before stocking	248	3.83	1.034	8
32	Under-financing by own capital for the whole crop cycle	256	3.75	0.991	9
22	Pond water is under-managed	258	3.74	0.978	10
14	Overfeeding cause pollution and waste accumulation	246	3.7	1.065	11
12	Low quality of feed	242	3.62	1.005	12
33	Under-financing by credits from banks/credit institutions	245	3.62	1.063	13
34	High interest rate for loans	247	3.57	1.041	14
16	Inability to control diseases from environmental sources	259	3.54	1.054	15
10	Over (density) stocking fingerlings	251	3.49	0.948	16
29	Weak enforcement in conducting sale contract with processors	251	3.47	1.063	17
13	Uncontrolled/unstable homemade feed quality	250	3.45	1.13	18
18	Limited knowledge about usage of chemical and medicines	258	3.34	1.134	19
8	Fingerlings treated by antibiotic during fingerling production process	201	3.32	1.054	20
6	Fingerlings with unknown origin	237	3.27	1.147	21
26	Inappropriate method of harvesting causing reduction of fish quality and weight	257	3.19	1.302	22
17	Low awareness of disease prevention by farmers	242	3.18	1.167	23
36	Changes in environmental policy	236	3.1	1.089	24
20	Applying chemical and medicines improperly	230	3.07	1.218	25
21	Farm have no reserved area for waste water and mud treatment	255	3.06	1.145	26
3	Pond doesn't have waste treatment system	252	3	1.154	27
24	Lack of awareness about community environmental protection	222	2.94	1.242	28
30	High technical barriers from importing countries	234	2.91	1.061	29
25	Inappropriate size of harvested fish	261	2.88	1.298	30
1	Pond outside planning area	247	2.87	1.466	31
2	Pond nearby residency	241	2.86	1.318	32
35	Changes in government policy on product development strategy	236	2.83	1.148	33
9	Epidemic checking for fingerlings not conducted	209	2.8	1.116	34
11	Use undersize/oversize fingerlings	247	2.8	1.139	35

Risk ID	Sources of risk	N	Mean	Std. Deviation	Rank by mean
23	Waste water treatment system is under-invested	219	2.74	1.085	36
39	Lack of water supply	234	2.62	1.46	37
40	Technical failure	236	2.28	1.178	38
38	Flood	221	2.17	1.343	39
37	Drought	219	2.11	1.257	40

For the top three most important sources of risk, concern about the *variability of price* reflects the fact that catfish farmers are producing their product without any guarantee of sale price and are always facing a high price risk. Variations in catfish sale prices in the last few years have caused big losses for farmers, especially in 2008. Most of the farmers had to sell their catfish at a 10% to 15% lower price than production cost. It is important to understand the underlying reasons for this phenomenon as well as the perceptions of farmers about risk management strategies they use to mitigate the price risk.

Usage of prohibited medicines and chemicals was ranked second in the list. This shows that this risk factor can have a severe impact on the income and profits of farms. One possible reason for this finding is that the bulk of the Vietnamese catfish are produced for export markets, where standards and regulations for food hygiene and safety are very strict. In these markets, there is almost zero tolerance for residues of prohibited medicines and chemicals in the imported food. As a result, if the fish are infected by prohibited medicines and chemicals, catfish processors will refuse to buy these fish for processing. This has a serious impact on catfish farmers' income, causing big losses, or even bankruptcies.

The third important risk factor affecting catfish farmers' income is inaccessibility to the market. This source of risk causes a problem to the catfish farmer similar to the use of prohibited medicines and chemicals. However, the reason comes from the imbalance in market supply and demand, i.e. the oversupply problem. In recent years, the total catfish output has increased rapidly, far exceeding the growth in demand and processing capacities, and as a result, catfish processors could not buy all the catfish produced in that period of time. This created a cost to catfish producers because they could not stop feeding the fish, and it also caused a reduction in selling price of the fish due to oversize of fish and reduction in quality.

5.3.4.2 Measuring Likelihood of Risk

Similarly to the consequences of risk factors, the likelihood of risk factors' occurrences were measured on a 5-point Likert scale, 1 representing very rare occurrence to 5 representing almost certain occurrence within a catfish crop. The mean scores, standard deviations, and rank of the likelihoods of 40 sources of risk are presented in Table 5-3 and sorted in descending order of the likelihood of occurrence.

Table 5-3 Mean Scores of Risk Likelihoods and Ranks of Risk by Likelihood

Risk ID	Sources of risk	N	Mean	Std. Deviation	Rank by mean
27	Fish price variability	239	3.35	1.135	1
31	High costs of operating inputs	231	3.19	1.084	2
9	Epidemic checking for fingerlings not conducted	188	3.08	1.336	3
21	Farm has no reserved area for waste water and mud treatment	224	2.97	1.387	4
32	Under financing by own capital for the whole crop cycle	234	2.76	1.214	5
1	Pond outside planning area	206	2.67	1.504	6
3	Pond doesn't have waste treatment system	227	2.63	1.268	7
29	Weak enforcement in conducting sale contract with processors	228	2.53	1	8
34	High interest rate for loans	223	2.45	1.165	9
6	Fingerlings with unknown origin	214	2.41	1.17	10
8	Fingerlings treated by antibiotic during fingerling production process	179	2.4	1.163	11
33	Under financing by credits from banks/credit institutions	221	2.37	1.103	12
5	Low quality fingerlings	236	2.27	1.028	13
13	Uncontrolled/unstable homemade feed quality	224	2.27	1.088	14
15	High death rate due to disease	233	2.18	1.103	15
7	Fingerlings infected by diseases	221	2.16	1.112	16
10	Over (density) stocking fingerlings	226	2.14	0.992	17
23	Waste water treatment system is under-invested	195	2.14	1.089	18
14	Overfeeding causes pollution and waste accumulation	219	2.11	1.152	19
28	Inaccessibility to the market	224	2.11	1.113	20
16	Inability to control diseases from environmental sources	234	2.09	1.067	21
4	Do not treat the pond before stocking	228	2.05	1.377	22
30	High technical barriers from importing countries	206	2.05	0.925	23
2	Pond nearby residency	215	1.99	1.172	24
12	Low quality of feed	217	1.98	0.935	25
22	Pond water is under-managed	232	1.98	0.953	26
11	Use undersize/oversize fingerlings	221	1.93	0.826	27
17	Low awareness of disease prevention by farmers	217	1.88	1.025	28
18	Limited knowledge about usage of chemical and medicines	233	1.87	0.915	29

Risk ID	Sources of risk	N	Mean	Std. Deviation	Rank by mean
24	Lack of awareness about community environmental protection	197	1.79	0.972	30
25	Inappropriate size of harvested fish	235	1.78	0.868	31
35	Changes in government policy on product development strategy	212	1.75	0.885	32
36	Changes in environmental policy	212	1.75	0.842	33
39	Lack of water supply	210	1.7	0.938	34
26	Inappropriate method of harvesting causes reduction of fish quality and weight	233	1.68	0.762	35
20	Applying chemical and medicines improperly	208	1.67	0.839	36
40	Technical failure	211	1.63	0.722	37
38	Flood	195	1.51	0.846	38
19	Use of prohibited chemical and medicines	203	1.46	1.035	39
37	Drought	195	1.35	0.619	40

The first cluster of the sources of risk that have average scores of likelihood above 4 (out of 5) consists of three risk factors, namely: (1) *fish price variability,* (2) *high costs of operating inputs, and* (3) *epidemic checking for fingerlings not conducted*, with average scores of 3.35, 3.19, and 3.08, respectively.

The second cluster of risk factors that had the probability of occurrence in the range of 2.5 to 3.0 were: (1) farm has no reserved area for water and mud treatment, (2) under-financing by own capital for the whole crop cycle, (3) pond located outside of planned area, (4) pond dose not have the waste treatment system, and (5) weak enforcement in conducting sale contract with processor. Their average scores of probability were 2.97, 2.76, 2.67, 2.63, and 2.53, respectively. These factors are considered as having the potential to occur with relatively high probability, and hence need careful monitoring.

The third cluster includes 15 risk factors that have an average score between 2.0 to 2.5 on the 5-point scale. The next 15 risk factors belong to the fourth cluster, which has average scores from 1.5 to 2.0, and were considered as having relatively low likelihood of occurrence. The fifth cluster, in which the sources of risk have the lowest likelihood, with average scores of probability of occurrence between 1.0 and 1.5, consists of two risk factors, namely: (1) *use of prohibited medicines and chemicals, and* (2) *drought problem*, with the scores of 1.46 and 1.35 respectively.

Among the top three risk factors that have the highest likelihoods of occurrences, two of them relate to marketing risks, more specifically: (1) *price of catfish variability and* (2) high costs *of operating inputs.* These two risks are beyond the control of catfish farmers and are set by catfish processors and feed producers. The markets for catfish output and feed are obviously imperfect markets in terms of pricing mechanism. As a result, catfish farmers often have to face variations in output and input prices that go beyond the control of catfish farmers.

5.3.4.3 Measuring Level of Risk

According to the AS/NZS 4360:2004, the level of risk is defined as the product of the consequence and the likelihood of risk. Using this formula, the levels of risk of the 40 sources of risk in Vietnamese catfish farming were calculated and presented in Table 5-4.

The level of risk of all 40 sources of risk is presented in the fifth column of Table 5-4. The consequence and likelihood of risk factors are reproduced and presented in the third and fourth columns, respectively, for convenience of reference. Values presenting the levels of risk are simply used for ranking purposes only and do not represent the loss value due to risk.

Table 5-4 Consequence, Likelihood, and Level of Risk of the Identified Risks

Risk ID	Sources of risk	Consequence	Likelihood	Level of Risk	Rank
27	Fish price variability	4.49	3.35	15.04	1
31	High costs of operating inputs	3.95	3.19	12.60	2
32	Under-financing by own capital for the whole crop cycle	3.75	2.76	10.35	3
21	Farm have no reserved area for waste water and mud treatment	3.06	2.97	9.08	4
29	Weak enforcement in conducting sale contract with processors	3.47	2.53	8.77	5
34	High interest rate for loans	3.57	2.45	8.74	6
5	Low quality fingerlings	3.85	2.27	8.73	7
15	High death rate due to disease	3.96	2.18	8.63	8
9	Epidemic checking for fingerlings not conducted	2.8	3.08	8.62	9
33	Under-financing by credits from banks/credit institutions	3.62	2.37	8.57	10
28	Inaccessibility to the market	4.04	2.11	8.52	11
7	Fingerlings infected by diseases	3.9	2.16	8.42	12
8	Fingerlings treated by antibiotic during fingerling production process	3.32	2.4	7.96	13

Risk ID	Sources of risk	Consequence	Likelihood	Level of Risk	Rank
3	Pond doesn't have waste treatment system	3	2.63	7.89	14
6	Fingerlings with unknown origin	3.27	2.41	7.88	15
4	Do not treat the pond before stocking	3.83	2.05	7.85	16
13	Uncontrolled/unstable homemade feed quality	3.45	2.27	7.83	17
14	Overfeeding cause pollution and waste accumulation	3.7	2.11	7.80	18
1	Pond outside planning area	2.87	2.67	7.66	19
10	Over (density) stocking fingerlings	3.49	2.14	7.46	20
22	Pond water is under-managed	3.74	1.98	7.40	21
16	Inability to control diseases from environmental sources	3.54	2.09	7.39	22
12	Low quality of feed	3.62	1.98	7.16	23
18	Limited knowledge about usage of chemical and medicines	3.34	1.87	6.24	24
17	Low awareness of disease prevention by farmers	3.18	1.88	5.97	25
30	High technical barriers from importing countries	2.91	2.05	5.96	26
19	Use of prohibited chemical and medicines	4.06	1.46	5.92	27
23	Waste water treatment system is under-invested	2.74	2.14	5.866	28
2	Pond nearby residency	2.86	1.99	5.69	29
36	Changes in environmental policy	3.1	1.75	5.42	30
11	Use undersize/oversize fingerlings	2.8	1.93	5.40	31
26	Inappropriate method of harvesting causes reduction of fish quality and weight	3.19	1.68	5.35	32
24	Unawareness about community environmental protection	2.94	1.79	5.26	33
20	Applying chemicals and medicines improperly	3.07	1.67	5.12	34
25	Inappropriate size of harvested fish	2.88	1.78	5.12	35
35	Changes in government policy on product development strategy	2.83	1.75	4.95	36
39	Lack of water supply	2.62	1.7	4.45	37
40	Technical failure	2.28	1.63	3.71	38
38	Flood	2.17	1.51	3.27	39
37	Drought	2.11	1.35	2.84	40

5.3.4.4 Probability Distribution Functions for Risk Consequences and Likelihoods

While the mean score based on 5-point Likert scale can present the severity, the likelihood, and the resulting level of risk of a specific source of risk collected from a sample of observations, this measure may cause problems in measuring and ranking the risks in case of a specific farmer. For example, a catfish farmer, using the 5-point Likert scale, can rate the consequence and likelihood (denoted as (C, L)) of a source of risk, say R#1 as 5 and 1 (denoted as (5, 1)), respectively. Similarly, he rates the consequence and the likelihood for the second source of risk (R#2) as (1, 5). Both these two sources of risk will have the same level of risk of 15 (5*1=15 and 1*5=15). In that case, the levels of the two sources of risk are binding and we cannot rank the risks according to their levels of risk. In addition, solely using the individual rating without consideration of the underlining distribution of the variable might lead to a bias in evaluating the actual level of risk consequence and likelihood. To overcome these problems, in our research, we use the cumulative density functions (CDF) to quantify the magnitudes of the risk consequences and likelihoods. Data collected from a fresh survey on the perceptions of risk and risk management using 5-point Likert rating were used to estimate the underlining probability distribution functions (PDF) of all the sources of risk consequences and likelihoods. The @RISK V.5.0 software was used to fit the data. Because the input data for PDF fitting were discrete data, only discrete probability distribution functions were fitted and the best-fit PDFs were selected based on the Chi squares (χ^2) criteria. The probability distribution functions for all the risk consequences and likelihoods are presented in Table 5-5 and Table 5-6, respectively. Appendix C and Appendix D in the Appendices present complete details of the properties of these CDFs.

Table 5-5 Probability Distribution Functions for Risk Consequences

ID	Name	Function	Min	Mean	Max
1	Pond outside planning area	Binomial(9,0.31849)	0	2.86641	9
2	Pond near residence	Binomial(7,0.40842)	0	2.85894	7
3	Pond has no waste treatment system	Binomial(5,0.6)	0	3	5
4	Pond not treated before stocking	Binomial(5,0.76694)	0	3.8347	5
5	Low quality fingerlings	Binomial(5,0.77077)	0	3.85385	5
6	Fingerlings with unknown origin	Binomial(5,0.65401)	0	3.27005	5
7	Fingerlings infected by diseases	Binomial(5,0.77951)	0	3.89755	5
8	Fingerlings treated by antibiotics during fingerling production process	Binomial(5,0.66468)	0	3.3234	5
9	Epidemic checking for fingerlings not conducted	Binomial(5,0.56077)	0	2.80385	5
10	Over (density) stocking fingerlings	Binomial(5,0.69801)	0	3.49005	5
11	Use of undersized/oversized fingerlings	Binomial(5,0.56032)	0	2.8016	5
12	Low quality of feed	Binomial(5,0.72314)	0	3.6157	5
13	Uncontrolled/unstable homemade feed quality	Binomial(5,0.6896)	0	3.448	5
14	Overfeeding which causes pollution and waste accumulation	Binomial(5,0.73902)	0	3.6951	5
15	High death rate due to disease	Binomial(5,0.79222)	0	3.9611	5
16	Inability to control diseases caused by environmental sources	Binomial(5,0.70734)	0	3.5367	5

ID	Name	Function	Min	Mean	Max
17	Low level of awareness of disease prevention among farmers	Binomial(5,0.63636)	0	3.1818	5
18	Limited knowledge about use of chemicals and medicines	Binomial(5,0.66899)	0	3.34495	5
19	Use of prohibited chemicals and medicines	Binomial(5,0.81116)	0	4.0558	5
20	Applying chemicals and medicines improperly	Binomial(5,0.61478)	0	3.0739	5
21	Farm has no reserved area for waste water and mud treatment	Binomial(5,0.61255)	0	3.06275	5
22	Pond water is under-managed	Binomial(5,0.74806)	0	3.7403	5
23	Waste water treatment system is under-invested	Binomial(5,0.54703)	0	2.73515	5
24	Lack of awareness about community environmental protection	Binomial(6,0.48949)	0	2.93694	6
25	Inappropriate size of harvested fish	Binomial(6,0.47957)	0	2.87742	6
26	Inappropriate method of harvesting causing reduction of fish quality and weight	Binomial(6,0.53243)	0	3.19458	6
27	Fish price variability	Binomial(5,0.89808)	0	4.4904	5
28	Inaccessibility to the market	Binomial(5,0.80863)	0	4.04315	5
29	Weak legislation on sale contracts between farmers and processors	Binomial(5,0.69323)	0	3.46615	5
30	High level of technical barriers imposed by importing countries	Binomial(5,0.58291)	0	2.91455	5
31	High costs of operating inputs	Binomial(5,0.78902)	0	3.9451	5
32	Under-financing by own capital for the whole crop cycle	Binomial(5,0.74922)	0	3.7461	5
33	Under-financing by credits from banks/credit institutions	Binomial(5,0.72408)	0	3.6204	5
34	High interest rate for loans	Binomial(5,0.71417)	0	3.57085	5
35	Changes in government policy on product development strategy	Binomial(5,0.56525)	0	2.82625	5
36	Changes in environmental policy	Binomial(5,0.61949)	0	3.09745	5
37	Drought	Poisson(2.105)	0	2.105	+∞
38	Flood	Poisson(2.1674	0	2.1674	+∞
39	Fraud	IntUniform(1,5)	1	3	5
40	Technical failure	Poisson(2.2839)	0	2.2839	+∞

Table 5-6 Probability Distribution Functions for Risk Likelihoods

ID	Name	Function	Min	Mean	Max
1	Pond outside planning area	Binomial(16,0.16687)	0	2.66992	16
2	Pond near residence	Poisson(1.9907)	0	1.9907	+∞
3	Pond has no waste treatment system	Binomial(7,0.37508)	0	2.62556	7
4	Pond not treated before stocking	Poisson(2.0482)	0	2.0482	+∞
5	Low quality fingerlings	Binomial(5,0.45339)	0	2.26695	5
6	Fingerlings with unknown origin	Poisson(2.4112)	0	2.4112	+∞
7	Fingerlings infected by diseases	Binomial(6,0.36048)	0	2.16288	6
8	Fingerlings treated by antibiotics during fingerling production process	Binomial(6,0.39944)	0	2.39664	6
9	Epidemic checking for fingerlings not conducted	RiskIntUniform(1,5)	1	3	5

ID	Name	Function	Min	Mean	Max
10	Over (density) stocking fingerlings	Binomial(5,0.42832)	0	2.1416	5
11	Use of undersized/oversized fingerlings	Binomial(5,0.38643)	0	1.93215	5
12	Low quality of feed	Binomial(5,0.39539)	0	1.97695	5
13	Uncontrolled/unstable homemade feed quality	Binomial(6,0.37798)	0	2.26788	6
14	Overfeeding which causes pollution and waste accumulation	Poisson(2.1096)	0	2.1096	+∞
15	High death rate due to disease	Binomial(6,0.36338)	0	2.18028	6
16	Inability to control diseases caused by environmental sources	Binomial(6,0.34829)	0	2.08974	6
17	Low level of awareness of disease prevention among farmers	Poisson(1.8802)	0	1.8802	+∞
18	Limited knowledge about use of chemicals and medicines	Binomial(5,0.37425)	0	1.87125	5
19	Use of prohibited chemicals and medicines	Binomial(10,0.14631)	0	1.4631	10
20	Applying chemicals and medicines improperly	Poisson(1.6731)	0	1.6731	+∞
21	Farm has no reserved area for waste water and mud treatment	RiskIntUniform(1,5)	1	3	5
22	Pond water is under-managed	Binomial(5,0.39655)	0	1.98275	5
23	Waste water treatment system is under-invested	Binomial(6,0.35726)	0	2.14356	6
24	Lack of awareness about community environmental protection	Binomial(5,0.35736)	0	1.7868	5
25	Inappropriate size of harvested fish	Binomial(5,0.35574)	0	1.7787	5
26	Inappropriate method of harvesting causing reduction of fish quality and weight	Binomial(5,0.33562)	0	1.6781	5
27	Fish price variability	Binomial(5,0.67029)	0	3.35145	5
28	Inaccessibility to the market	Binomial(6,0.35193)	0	2.11158	6
29	Weak legislation on sale contracts between farmers and processors	Binomial(5,0.50614)	0	2.5307	5
30	High level of technical barriers imposed by importing countries	Binomial(5,0.40971)	0	2.04855	5
31	High costs of operating inputs	Binomial(5,0.63896)	0	3.1948	5
32	Under-financing by own capital for the whole crop cycle	Binomial(6,0.4594)	0	2.7564	6
33	Under-financing by credits from banks/credit institutions	Binomial(5,0.47421)	0	2.37105	5
34	High interest rate for loans	Binomial(6,0.40807)	0	2.44842	6
35	Changes in government policy on product development strategy	Binomial(5,0.35094)	0	1.7547	5
36	Changes in environmental policy	Binomial(5,0.35)	0	1.75	5
37	Drought	Binomial(5,0.26974)	0	1.3487	5
38	Flood	Binomial(5,0.30256)	0	1.5128	5
39	Fraud	Binomial(5,0.34095)	0	1.70475	5
40	Technical failure	Binomial(4,0.4064)	0	1.6256	4

5.3.5 Risk Evaluation: Risk Ranking and Prioritizing

A two-dimensional matrix, with consequence on one dimension (horizontal) and likelihood on the other (vertical), is used to describe the level of risk of all sources of risk in study. On each dimension, a scale was assigned to measure the magnitude of the consequence and the likelihood of all sources of risk. Specifically, the scale for the consequence consists of I, II, III, IV, and V, representing the following degrees or levels of severity respectively: negligible, minor, moderate, major, and severe. Similarly, the scale for the likelihood of sources of risk includes A, B, C, D, and E, representing the following likelihoods of occurrence: almost certain, likely, possible, unlikely, and rare. Table 5-7 locates each source of risk in this two-dimensional matrix, based on a 5-point scale for both risk consequence and probability. The interpretation of the levels of risk of the factors is as follows: (1) factors with very high risk levels are listed in cells AIV, AV, BV, (2) factors with high risk levels are listed in cells AII, AIII, BIII, BIV, CIII, CIV, CV, and DV, (3) factors with moderate levels are listed in cells AI, BI, BII, CII, DIII, and DIV, and (4) factors with low levels are listed in cells CI, DI, and DII.

Only the risk factor of *fish price variability* is classified as very high-risk level with the potential of having the most severe impact on catfish farmers' income and profit. Therefore, it definitely needs serious attention for risk mitigating strategies. A large number of risk factors (23 factors) are classified as very high risk level according to AS/NZS 4360:2004 and they also need special attention from management. The remaining 16 risk factors are classified as moderate risks. None of the risks identified is classified as low-level risks with negligible impact.

Table 5-7 Locating Risks in a Two-Dimensional Matrix

Likelihood Label	Consequence Label				
	Negligible (I)	**Minor (II)**	**Moderate (III)**	**Major (IV)**	**Severe (V)**
Almost Certain (A)					
Likely(B)			• R#9: Epidemic checking for fingerlings not conducted (8.6)	• R#31: High cost of operating inputs (12.60)	• R#27: Fish price variability (15.04)
Possible (C)			• R#30: High technical barriers from importing countries (5.96) • R#1: Pond located outside planned area (7.66) • R#23: Waste water treatment is under-invested (5.86)	• R#15: High death rate due to diseases (8.63) • R#7: Fingerlings infected by diseases (8.42) • R#5: Low quality of fingerlings (8.73) • R#4: Do not treating the pond before stocking (7.85) • R#32: Under-financing by own capital (10.35) • R#14: Overfeeding cause pollution problem (7.80) • R#33: Under-financing by credits (8.57) • R#34: High interest rate for loans (8.7) • R#16: Inability to control disease sources from environment (7.39) • R#10: Overstocking fingerlings (7.46) • R#29: Weak enforcement of sale contract with processor (8.77) • R#13: Uncontrolled homemade feed (7.83) • R#8: Fingerlings treated by antibiotics (7.96) • R#6: Fingerlings with unknown origin (7.88) • R#21: Farm has no reserved area for water/mud treatment (9.08) • R#3: Farm has no waste treatment system (7.89)	• R#28: Inaccessibility to the market (8.52)
Unlikely (D)			• R#24: Unawareness about community environment protection (5.26) • R#25: Harvest fish at inappropriate size (5.12)	• R#22: Pond water is under-managed (7.40) • R#12: Low quality of feed (7.16) • R#18: Limited knowledge about usage of chemicals and medicines (6.24)	• R#19: Use of prohibited chemicals and medicines (5.92)

Likelihood Label	Consequence Label				
	Negligible (I)	**Minor (II)**	**Moderate (III)**	**Major (IV)**	**Severe (V)**
			• R#2: Pond located nearby residency (5.69) • R#45: Change in Gov. policy on product development strategy (4.95) • R#11: Use undersize or oversize fingerlings (5.4) • R#39: Fraud (4.45) • R#40: Technical failure of the live supporting system (3.71) • R#38: Flood (3.27) • R#37: Drought or lack of water supply (2.84)	• R#26: Inappropriate method of harvesting (5.35) • R#17: Low awareness of disease prevention (5.97) • R#36: Change in Gov. environmental policy (5.42) • R#20: Applying chemicals and medicines improperly (5.12)	
Rare (E)					

Note: Numbers in parentheses are Level of Risk, defined as the product of consequence and likelihood (in 5-point Likert scale).

5.3.6 Risk Management

Risk management is a set of actions undertaken to reduce the impacts of risks on the organizational objectives. The selection of a specific risk management strategy for risk management can be based on the efficiency or/and the net benefit of applying it. This section will first present catfish farmers' perceptions of risk management strategies and their efficacy in mitigating risks. The second section will present the selection of risk management for mitigating specific risk, called "treat the risks", and based on risk management efficacy or net benefit.

5.3.6.1 Risk Management Strategies

In this section, the perceptions of risk management strategies are presented both in terms of their efficacy and classification. First of all, the risk management strategies were rated in a 5-point Likert scale to measure their efficacy in mitigating the risks. Risks management strategies were then ranked by their efficiency. Next, the risk management strategies were then classified into six categories for the ease of reference.

a. Measuring Efficacy of Risk Management Strategies

In this study, catfish farmers rated 50 risk management strategies (RMS) in regards to their efficacy for mitigating each risk factor. The efficacy of the risk management strategies was rated on a 5-point Likert scale, with 1 as negligible effect, and 5 as very significant effect.

Average scores, standard deviations, and rank of the efficacy of the strategies are presented in Table 5-8 in decreasing order of mean scores. Six strategies were rated as very highly significant in mitigating catfish farming risks. These are: (1) strictly treat the pond before stocking, with a score of 4.34; (2) well manage water environment in pond, with a score of 4.29; (3) select good fingerlings, with a score of 4.14; (4) choose pond location nearby good water supply source, with a score of 4.10; (5) choose good brand feed, with a score of 4.06; and (6) buy the fingerlings from reliable sources, with a score of 4.04.

Table 5-8 Mean Scores and Ranks of Risk Management Strategies

RMS ID	Risk Management Strategies	N	Score	Std. Deviation	Rank
6	Strictly treat the pond before stocking	261	4.34	0.70	**1**
20	Well manage water environment in pond	259	4.29	0.72	**2**
8	Select good fingerlings	251	4.14	0.77	**3**
45	Choose location nearby good water supply sources	213	4.10	0.89	**4**
16	Choose good brand for feed	238	4.06	0.90	**5**
9	Buy fingerlings from reliable places	249	4.04	0.75	**6**
21	Prevent disease infection by regular checking and observation of pond	244	3.94	0.92	**7**
48	Keep a good relationship with the community	232	3.94	0.78	**8**
33	Ask for government support	250	3.78	1.18	**9**
34	Apply quality management program (HACCP, Global-GAP)	239	3.72	0.56	**10**
12	Strictly follow government regulations and technical guides	248	3.72	0.75	**11**
11	Careful checking of fingerlings when buying	252	3.71	0.77	**12**
4	Regular checking of quality of supply water	246	3.70	0.88	**13**
19	Use only factory-made (pallet) feed	231	3.68	1.14	**14**
18	Choosing good raw materials	242	3.65	1.11	**15**
13	Reduce density of fingerling stocking	244	3.63	0.72	**16**
35	Production at lowest possible cost/keep fixed cost low	236	3.62	0.93	**17**
14	Regularly update list of prohibited chemical and medicines	218	3.50	1.23	**18**
22	Develop aquacultural water treatment pond	231	3.48	1.21	**19**
28	Vertical integration	253	3.48	1.20	**20**
3	Develop a separated water supply system	238	3.46	0.82	**21**
42	Keep cash on hand for farming	214	3.46	1.15	**22**
15	Use large size fingerlings	252	3.45	0.90	**23**
47	Regular checking and maintaining of dyke	184	3.44	1.13	**24**
39	Make credit arrangement before cropping	224	3.43	0.79	**25**
10	Buy fingerlings only from certified producers	219	3.42	1.04	**26**
24	Consult people who have knowledge about aquacultural veterinary	227	3.41	0.97	**27**
43	Apply new technology in production	233	3.41	0.78	**28**
17	Self-processing to ensure feed quality and reduce cost	239	3.39	0.86	**29**
1	Locate pond in designated (planning) area	241	3.38	1.23	**30**
25	Sale and production contract with processor	255	3.37	1.07	**31**
23	Use labour with knowledge about aquacultural veterinary/advice	216	3.37	1.02	**32**
37	Increase solvency ratio	223	3.35	0.94	**33**
7	Attend extension workshop	233	3.31	0.66	**34**
44	Increase investment in environmental protection	225	3.25	0.96	**35**
50	Regular checking of equipment	239	3.22	1.06	**36**
36	Reduce farm size to appropriate scale	247	3.15	1.18	**37**
27	Choose proper size of pond	226	3.13	1.03	**38**
49	Surplus machinery capacity	239	3.13	1.17	**39**
5	Apply farming system that minimize water replacement	229	3.03	0.79	**40**
30	Cooperative marketing	234	3.02	1.03	**41**

RMS ID	Risk Management Strategies	N	Score	Std. Deviation	Rank
40	Solvency-debt management	214	2.80	0.93	**42**
32	Buying insurance for crop	224	2.75	1.27	**43**
26	Collect information about favourable size from processors	246	2.72	0.92	**44**
38	Co-operate with others for financing production	210	2.70	1.30	**45**
41	Use economic consultancy services	186	2.54	0.99	**46**
46	Spatial diversification	186	2.17	0.94	**47**
29	Enterprise diversification	232	2.04	1.05	**48**
2	Change to other activity	232	2.00	0.99	**49**
31	Off-farm work	209	1.97	1.07	**50**

The second cluster consisted of a large number (35 out of 50) of suggested strategies with average scores between 3.0 and 4.0 and considered as relatively good effective strategies. Next, there were eight strategies rated as having moderate effects on risk mitigation, scoring from 2.0 to 3.0. Finally, off-farm work was rated as the least efficient strategy in the list, with a score of 1.97.

Although price risks were perceived as the most important sources of risk on average (refer to Table 5-2), risk management strategies to deal with price risks (sale and production contract, vertical integration, enterprise diversification, cooperative marketing, and off-farm work) were not perceived as important strategies (refer to Table 5-8). This finding is similar to the case of Dutch livestock farmers' perception of risk and risk management (Meuwissen, Huirne & Hardaker 2001). The highest-rated risk management strategies were the ones related to cultivation techniques, pond location selection, disease control, and water management.

b. Classification of Risk Management Strategies

Based on the nature and the impacts of the risk management strategies, the 50 identified risks management strategies can be classified into the six following categories: farming techniques, economic and financial measures, knowledge improvement, input control, diversification, and pond selection and investment, as shown in Table 5-9.

Table 5-9 Classification of Risk Management Strategies

Farming Techniques (M)	**Economic and Financial Measures (N)**	**Education / Extension and Knowledge Improvement (O)**	**Input Control (P)**	**Risk Diversification Measures (Q)**	**Pond Selection and Investment (R)**
RM#4: Regular checking of quality of supply water RM#5: Apply farming system that minimizes water replacement RM#6: Strictly treat the pond before stocking RM#12: Strictly follow government regulations and technical guides RM#13: Reduce density of fingerling stocking RM#15: Use large size fingerlings RM#20: Well manage water environment in pond RM#21: Prevent disease infection by regular checking and observation of pond RM#34: Apply quality management program	RM#25: Sale and production contract with processor RM#26: Collect information about favourable size from processors RM#27: Choose proper size of pond RM#28: Vertical integration RM#30: Cooperative marketing RM#33: Ask for government support RM#36: Reduce farm size to appropriate scale RM#37: Increase solvency ratio RM#38: Co-operate with others for financing	RM#7: Attend extension workshop RM#14: Regularly update list of prohibited chemical and medicines RM#23: Use labour with knowledge about aquacultural veterinary/advice RM#24: Consult people who have knowledge about aquacultural veterinary	RM#8: Select good fingerlings RM#9: Buy fingerlings from reliable places RM#10: Buy fingerlings only from certified producers RM#11: Careful checking fingerlings when buying RM#16: Choose good brand for feed RM#17: Self-processing to ensure feed quality and reduce cost RM#18: Choosing good raw materials RM#19: Use only factory made (pallet) feed	RM#2: Change to other activity RM#29: Enterprise diversification RM#31: Off-farm work RM#32: Buying insurance for crop RM#46: Spatial diversification	RM#1: Locate pond in designated (planning) area RM#3: Develop a separated water supply system RM#22: Develop aquacultural water treatment pond RM#44: Increase investment in environmental protection RM#45: Choose location nearby good water supply sources RM#47: Regular checking and maintaining of dyke RM#49: Surplus machinery capacity RM#50: Regular checking of equipment

Farming Techniques (M)	Economic and Financial Measures (N)	Education / Extension and Knowledge Improvement (O)	Input Control (P)	Risk Diversification Measures (Q)	Pond Selection and Investment (R)
(HACCP, Global-GAP) RM#35: Production at lowest possible cost/keep fixed cost low RM#43: Apply new technology in production	production RM#39: Make credit arrangement before cropping RM#40: Solvency-debt management RM#41: Use economic consultancy services RM#42: Keep cash on hand for farming RM#48: Keep a good relationship with the community				

5.3.6.2 Treat the Risks

In treating the risks, a risk management strategy for mitigating a risk can be selected upon different criteria. In our research, we provide two criteria for selecting a risk management strategy: risk management efficacy and net benefit. The sections below will present the procedure of selecting risk management strategies according to these two criteria.

a. Selecting Risk Management Strategies based on Risk Management Efficacy

Given the risks and the risk management strategies identified and analysed in the previous sections, this section will match the risks and their corresponding risk management strategies together for the ease of reference and evaluation. The complete list of risks and their corresponding management strategies is presented in Table 5-10 below.

Table 5-10 Risks and Corresponding Risk Management Strategies

CODE	Risk management strategies for identified risks	Mean scores
R#1	**Risk management strategies for risk #A1: Pond outside planning area**	2.87
RM#1	Locate pond in designated (planning) area	3.38
RM#2	Change to other activity	2
R#2	**Risk management strategies for risk #A2: Pond nearby residency**	2.86
RM#3	Develop a separated water supply system	3.46
RM#4	Regular checking of quality of supply water	3.7
R#3	**Risk management strategies for risk #A3: Pond doesn't have waste treatment system**	3
RM#3	Develop a separated water supply system	3.46
RM#5	Apply farming system that minimize water replacement	3.03
R#4	**Risk management strategies for risk #A4: Pond not treated before stocking**	3.83
RM#6	Strictly treat the pond before stocking	4.34
RM#7	Attend extension workshop	3.31
R#5	**Risk management strategies for risk #B1: Low quality fingerlings**	3.85
RM#8	Select good fingerlings	4.14
RM#9	Buy fingerlings from reliable places	4.04

CODE	Risk management strategies for identified risks	Mean scores
R#6	**Risk management strategies for risk #B2: Fingerlings with unknown origin**	3.27
RM#10	Buy fingerlings only from certified producers	3.42
RM#7	**Risk management strategies for risk #B3: Fingerlings infected by diseases**	3.9
RM#10	Buy fingerlings only from certified producers	3.42
RM#11	Careful checking fingerlings when buying	3.71
R#8	**RMS for risk #B4: Fingerlings treated by antibiotic during fingerling production process**	3.32
RM#10	Buy fingerlings only from certified producers	3.42
RM#11	Careful checking fingerlings when buying	3.71
R#9	**Risk management strategies for risk #B5: Epidemic checking for fingerlings not conducted**	2.8
RM#7	Attend extension workshop	3.31
RM#12	Strictly follow government regulations and technical guides	3.72
RM#13	Reduce density of fingerling stocking	3.63
R#10	**Risk management strategies for risk #B6: Over (density) stocking fingerlings**	3.49
RM#7	Attend extension workshop	3.31
RM#15	Use large size fingerlings	3.45
R#11	Use undersize/oversize fingerlings (deleted)	2.8
R#12	**RMS for risk #C1: Low quality of feed**	3.62
RM#16	Choose good brand for feed	4.06
RM#17	Self-processing to ensure feed quality and reduce cost	3.39
R#13	**RMS for risk # C2: Uncontrolled/unstable homemade feed quality**	3.45
RM#7	Attend extension workshop	3.31
RM#18	Choosing good raw materials	3.65
R#14	**RMS for risk #C3: Overfeeding cause pollution and waste accumulation**	3.7
RM#19	Use only factory made (pallet) feed	3.68
RM#12	Strictly follow government regulations and technical guides	3.72
RM#7	Attend extension workshop	3.31
R#15	**RMS for risk #D1: High death rate due to disease**	3.96
RM#20	Well manage water environment in pond	4.29

CODE	Risk management strategies for identified risks	Mean scores
RM#12	Strictly follow government regulations and technical guides	3.72
RM#21	Prevent disease infection by regular checking and observation pond	3.94
RM#13	Reduce density of fingerling stocking	3.63
R#16	**RMS for risk #D2: Inability to control diseases from environmental sources**	3.54
RM#4	Regular checking of quality of supply water	3.7
RM#22	Develop aquacultural water treatment pond	3.48
R#17	**RMS for risk #D3: Low awareness of disease prevention by farmers**	3.18
RM#7	Attend extension workshop	3.31
R#18	**RMS for risk #D4: Limited knowledge about usage of chemical and medicines**	3.34
RM#7	Attend extension workshop	3.31
RM#23	Use labour with knowledge about aquacultural veterinary/advice	3.37
RM#24	Consult people who have knowledge about aquacultural veterinary	3.41
R#19	**RMS for risk #D5: Use of prohibited chemicals and medicines**	4.06
RM#12	Strictly follow government regulations and technical guides	3.72
RM#14	Regularly update list of prohibited chemical and medicines	3.5
RM#7	Attend extension workshop	3.31
R#20	**RMS for risk #D6: Applying chemical and medicines improperly**	3.07
RM#23	Use labour with knowledge about aquacultural veterinary/advice	3.37
RM#24	Consult people who have knowledge about aquacultural veterinary	3.41
R#21	**RMS for risk #E1: Farm has no reserved area for waste water and mud treatment**	3.06
RM#22	Develop aquacultural water treatment pond	3.48
RM#5	Apply farming system that minimizes water replacement	3.03
R#22	**RMS for risk #E2: Pond water is under-managed**	3.74
RM#12	Strictly follow government regulations and technical guides	3.72
RM#7	Attend extension workshop	3.31
R#23	Waste water treatment system is under-invested (deleted)	2.74
R#24	**RMS for risk #E3: Unawareness about community environmental protection**	2.94
RM#13	Reduce density of fingerling stocking	3.63
RM#3	Develop a separated water supply system	3.46
RM#7	Attend extension workshop	3.31

CODE	Risk management strategies for identified risks	Mean scores
R#32	**RMS for risk #F1: Under financing by own capital for the whole crop cycle**	3.75
RM#36	Reduce farm size to appropriate scale	3.15
RM#37	Increase solvency ratio	3.35
RM#38	Co-operate with others for financing production	2.7
R#33	**RMS for risk #F2: Under financing by credits from banks/credit institutions**	3.62
RM#39	Make credit arrangement before cropping	3.43
RM#40	Solvency-debt management	2.8
RM#41	Use economic consultancy services	2.54
RM#42	Keep cash on hand for farming	3.46
RM#38	Co-operate with others for financing production	2.7
R#34	**High interest rate for loans**	3.57
R#35	**RMS for risk #G1: Changes in government policy and food safety and hygiene regulations**	2.83
RM#43	Apply new technology in production	3.41
RM#34	Apply quality management program (HACCP, Global-GAP…)	3.72
R#36	**RMS for risk #G2: Changes in environmental policy**	3.1
RM#44	Increase investment in environmental protection	3.25
RM#5	Apply farming system that minimizes water replacement	3.03
R#37	**RMS for risk # H1: Drought/Lack of water supply**	2.11
RM#32	Buying insurance for crop	2.75
RM#45	Choose location nearby good water supply sources	4.1
RM#46	Spatial diversification	2.17
R#38	**RMS for risk #H2: Flood**	2.17
RM#47	Regular checking and maintaining of dyke	3.44
RM#32	Buying insurance for crop	2.75
RM#46	Spatial diversification	2.17
R#39	**RMS for risk #H3: Fraud**	2.62
RM#32	Buying insurance for crop	2.75
RM#48	Keep a good relationship with the community	3.94
RM#1	Locate pond in designated (planning) area	3.38
R#40	**RMS for risk #H4: Technical failure**	2.28
RM#49	Surplus machinery capacity	3.13

CODE	Risk management strategies for identified risks	Mean scores
RM#50	Regular checking of equipment	3.22
R#25	**RMS for risk #I1: Inappropriate size of harvested fish**	2.88
RM#25	Sale and production contract with processor	3.37
RM#26	Collect information about favourable size from processors	2.72
R#26	**RMS for risk #I2: Inappropriate method of harvesting causing reduction of fish quality and weight**	3.19
RM#25	Sale and production contract with processor	3.37
RM#27	Choose proper size of pond	3.13
R#27	**RMS for risk #J1: Fish price variability**	4.49
RM#25	Sale and production contract with processor	3.37
RM#28	Vertical integration	3.48
RM#29	Enterprise diversification	2.04
RM#30	Cooperative marketing	3.02
RM#31	Off-farm work	1.97
R#28	**RMS for risk #J2: Inaccessibility to the market**	4.04
RM#25	Sale and production contract with processor	3.37
RM#32	Buying insurance for crop	2.75
RM#12	Strictly follow government regulations and technical guides	3.72
R#29	**RMS for risk #J3: Weak enforcement in conducting sale contract with processors**	3.47
RM#33	Ask for government support	3.78
RM#30	Cooperative marketing	3.02
R#30	**RMS for risk #J4: High technical barriers from importing countries**	2.91
RM#34	Apply quality management program (HACCP, Global-GAP…)	3.72
RM#7	Attend extension workshop	3.31
R#31	**RMS for risk #J5: High costs of operating inputs**	3.95
RM#35	Production at lowest possible cost/keep fixed cost low	3.62

The identified risks and corresponding mitigating measures are further matched into a two-dimensional table, with the risks listed vertically and risk management strategies listed horizontally. Table 5-11 presents a complete view of the matching.

Table 5-11 Matching Risks and Risk Management Strategies in a Two-Dimensional Matrix

R/RMS CODE	Farming techniques (M)	Economic and financial measures (N)	Knowledge improvement (O)	Input control (P)	Diversification (Q)	Pond selection and investment (R)
Pond risks (A)	A2-M1 A3-M2 A4-M3		A4-O1		A1-Q1	A1-R1 A2-R2 A3-R2
Fingerlings risks (B)	B5-M4 B5-M5 B6-M6		B5-O1 B6-O1	B1-P1 B1-P2 B2-P3 B3-P3 B3-P4 B4-P3 B4-P4		
Feed risks (C)	C3-M4		C2-O1 C3-O1	C1-P5 C1-P6 C2-P7 C3-P8		
Disease risks (D)	D1-M7 D1-M4 D1-M8 D1-M5 D2-M1 D5-M4		D3-O1 D4-O1 D4-O3 D4-O4 D5-O2 D5-O1 D6-O3 D6-O4			D2-R3
Water and environment risks (E)	E1-M2 E2-M4 E4-M5		E2-O1 E4-O1			E1-R3 E4-R2
Financial risks (F)		F1-N7 F1-N8 F1-N9 F2-N10 F2-N11 F2-N12 F2-N13 F2-N9				
Policy risks (G)	G1-M1 G1-M9 G2-M2					G2-R4
Natural and other risks (H)		H3-N14			H1-Q4 H1-Q5 H2-Q5 H3-Q4	H1-R5 H2-R7 H3-R1 H4-R7 H4-R8
Harvesting risks (I)		I1-N1 I1-N2 I2-N1 I2-N3				
Marketing and cost of operation risks	J2-M4 J4-M9 J5-M10	J1-N1 J1N4 J1-N5 J2-N1	J4-O1		J1-Q2 J1-Q3 J2-Q4	

R/RMS CODE	Farming techniques (M)	Economic and financial measures (N)	Knowledge improvement (O)	Input control (P)	Diversification (Q)	Pond selection and investment (R)
(J)		J3-N6 J3-N5				

In Table 5-12 below, the risks and the risk mitigation measures are furthered rearranged by the level of risk, vertically, and by the efficacy of risk management strategies, horizontally. Given that arrangement, the risks listed at the top of the table received higher priority in treating the risks due to their higher risk exposure. When an identified risk was selected for treatment, risk mitigation measures specific to this risk might be implemented, but the risk mitigation measures with higher effectiveness as shown in Table 5-13 received higher priority.

In Table 5-13, the risks were first sorted by the rank of risk. Risk with higher level of risk received more priority on treating the risk. For each risk, corresponding risk management strategies were then sorted in a descending order in terms of efficacy of the risk management strategies. The order of implementing risk management strategies is from left to right as shown in the last five columns of Table 5-13.

Table 5-12 Risks and Corresponding Risk Management Strategies with Their Efficacy

Risk ID	Sources of risk	Level of Risk	Rank	RMS applied to SOR*				
				RM1	RM2	RM3	RM4	RM5
1	Pond outside planning area	**7.66**	**19**	3.28	2			
2	Pond nearby residency	**5.69**	**29**	3.46	3.7			
3	Pond doesn't have waste treatment system	**7.89**	**14**	3.46	3.03			
4	Do not treat the pond before stocking	**7.85**	**16**	4.34	3.31			
5	Low quality fingerlings	**8.73**	**7**	4.14	4.04			
6	Fingerlings with unknown origin	**7.88**	**15**	3.42				
7	Fingerlings infected by diseases	**8.42**	**12**	3.42	3.71			
8	Fingerlings treated by antibiotic during fingerling production process	**7.96**	**13**	3.42	3.71			
9	Epidemic checking for fingerlings not conducted	**8.62**	**9**	3.31	3.72	3.63		
10	Over (density) stocking fingerlings	**7.46**	**20**	3.31	3.45			
11	Use undersize/oversize fingerlings	**5.4**	**31**					
12	Low quality of feed	**7.16**	**23**	4.06	3.39			
13	Uncontrolled/unstable homemade feed quality	**7.83**	**17**	3.31	3.65			
14	Overfeeding cause pollution and waste accumulation	**7.8**	**18**	3.68	3.72	3.31		
15	High death rate due to disease	**8.63**	**8**	4.29	3.72	3.94	3.63	
16	Inability to control diseases from environmental sources	**7.39**	**22**	3.7	3.48			
17	Low awareness of disease prevention by farmers	**5.97**	**25**	3.31				
18	Limited knowledge about usage of chemical and medicines	**6.24**	**24**	3.31	3.37	3.41		
19	Use of prohibited chemical and medicines	**5.92**	**27**	3.72	3.5	3.31		
20	Applying chemical and medicines improperly	**5.12**	**34**	3.37	3.41			
21	Farm has no reserved area for waste water and mud treatment	**9.08**	**4**	3.48	3.03			
22	Pond water is under-managed	**7.4**	**21**	3.72	3.31			
23	Waste water treatment system is under-invested	**5.866**	**28**					
24	Lack of awareness about community environmental protection	**5.26**	**33**	3.63	3.46	3.31		
25	Inappropriate size of harvested fish	**5.12**	**35**	3.37	2.72			
26	Inappropriate method of harvesting causes reduction of fish quality and weight	**5.35**	**32**	3.37	3.13			

Risk ID	Sources of risk	Level of Risk	Rank	RMS applied to SOR*				
				RM1	RM2	RM3	RM4	RM5
27	Fish price variability	**15.04**	**1**	3.37	3.48	2.04	3.02	1.97
28	Inaccessibility to the market	**8.52**	**11**	3.37	2.75	3.72		
29	Weak enforcement in conducting sale contract with processors	**8.77**	**5**	3.78	3.02			
30	High technical barriers from importing countries	**5.96**	**26**	3.72	3.31			
31	High costs of operating inputs	**12.6**	**2**	3.62				
32	Under-financing by own capital for the whole crop cycle	**10.35**	**3**	3.15	3.35	2.7		
33	Under-financing by credits from banks/credit institutions	**8.57**	**10**	3.43	2.8	2.54	3.46	2.7
34	High interest rate for loans	**8.74**	**6**					
35	Changes in government policy on product development strategy	**4.95**	**36**	3.41	3.72			
36	Changes in environmental policy	**5.42**	**30**	3.25	3.03			
37	Drought/Lack of water supply	**2.84**	**40**	2.75	4.1	2.17		
38	Flood	**3.27**	**39**	3.44	2.75	2.17		
39	Fraud	**4.45**	**37**	2.75	3.94	3.38		
40	Technical failure	**3.71**	**38**	3.13	3.22			

** Numbers in the last five columns are the mean scores of the risk management strategy efficacy.*

Table 5-13 Prioritizing Mitigation Measures for Identified Risks

Risk ID	Sources of risk	Level of Risk	Rank	RMS applied to SOR Implementing sequence (I, II, III...)				
				I	II	III	IV	V
27	Fish price variability	**15.04**	**1**	RM#28 (3.48)	RM#25 (3.37)	RM#30 (3.02)	RM#29 (2.04)	RM#31 (1.97)
31	High costs of operating inputs	**12.6**	**2**	RM#35 (3.62)				
32	Under-financing by own capital for the whole crop cycle	**10.35**	**3**	RM#37 (3.35)	RM#36 (3.15)	RM#38 (2.7)		
21	Farm has no reserved area for waste water and mud treatment	**9.08**	**4**	RM#22 (3.48)	RM#5 (3.03)			
29	Weak enforcement in conducting sale contract with processors	**8.77**	**5**	RM#33 (3.78)	RM#30 (3.02)			
34	High interest rate for loans	**8.74**	**6**					
5	Low quality fingerlings	**8.73**	**7**	RM#8 (4.14)	RM#9 (4.04)			
15	High death rate due to disease	**8.63**	**8**	RM#20 (4.29)	RM#21 (3.94)	RM#12 (3.72)	RM#13 (3.63)	
9	Epidemic checking for fingerlings not conducted	**8.62**	**9**	RM#12 (3.72)	RM#13 (3.63)	RM#7 (3.31)		
33	Under-financing by credits from banks/credit institutions	**8.57**	**10**	RM#42 (3.46)	RM#39 (3.43)	RM#40 (2.8)	RM#38 (2.7)	RM#41 (2.54)
28	Inaccessibility to the market	**8.52**	**11**	RM#12 (3.72)	RM#25 (3.37)	RM#32 (2.75)		
7	Fingerlings infected by diseases	**8.42**	**12**	RM#11 (3.71)	RM#10 (3.42)			
8	Fingerlings treated by antibiotic during fingerling production process	**7.96**	**13**	RM#11 (3.71)	RM#10 (3.42)			
3	Pond doesn't have waste treatment system	**7.89**	**14**	RM#3 (3.46)	RM#5 (3.0)			
6	Fingerlings with unknown origin	**7.88**	**15**	RM#10 (3.42)				
4	Not treating the pond before stocking	**7.85**	**16**	RM#6 (4.34)	RM#7 (3.31)			
13	Uncontrolled/unstable homemade feed quality	**7.83**	**17**	RM#18 (3.65)	RM#7 (3.31)			
14	Overfeeding cause pollution and waste accumulation	**7.8**	**18**	RM#12 (3.72)	RM#19 (3.68)	RM#7 (3.31)		
1	Pond outside planning area	**7.66**	**19**	RM#1 (3.28)	RM#2 (2.0)			
10	Over (density) stocking fingerlings	**7.46**	**20**	RM#15 (3.45)	RM#7 (3.31)			
22	Pond water is under-managed	**7.4**	**21**	RM#12 (3.72)	RM#7 (3.31)			
16	Inability to control diseases from environmental	**7.39**	**22**	RM#4 (3.7)	RM#22 (3.48)			

Risk ID	Sources of risk	Level of Risk	Rank	RMS applied to SOR Implementing sequence (I, II, III...)				
				I	II	III	IV	V
	sources							
12	Low quality of feed	**7.16**	**23**	RM#16 (4.06)	RM#17 (3.39)			
18	Limited knowledge about usage of chemical and medicines	**6.24**	**24**	RM#24 (3.37)	RM#23 (3.41)	RM#7 (3.31)		
17	Low awareness of disease prevention by farmers	**5.97**	**25**	RM#7 (3.31)				
30	High technical barriers from importing countries	**5.96**	**26**	RM#34 (3.72)	RM#7 (3.31)			
19	Use of prohibited chemicals and medicines	**5.92**	**27**	RM#12 (3.72)	RM#14 (3.5)	RM#7 (3.31)		
23	Waste water treatment system is under-invested	**5.866**	**28**	DELETED				
2	Pond nearby residency	**5.69**	**29**	RM#4 (3.7)	RM#3 (3.46)			
36	Changes in environmental policy	**5.42**	**30**	RM#44 (3.25)	RM#5 (3.03)			
11	Use undersize/oversize fingerlings	**5.4**	**31**					
26	Inappropriate method of harvesting causes reduction of fish quality and weight	**5.35**	**32**	RM#25 (3.37)	RM#27 (3.31)			
24	Lack of awareness about community environmental protection	**5.26**	**33**	RM#13 (3.63)	RM#3 (3.46)	RM#7 (3.31)		
20	Applying chemical and medicines improperly	**5.12**	**34**	RM#24 (3.41)	RM#23 (3.37)			
25	Inappropriate size of harvested fish	**5.12**	**35**	RM#25 (3.37)	RM#26 (2.72)			
35	Changes in government policy on product development strategy	**4.95**	**36**	RM#34 (3.72)	RM#43 (3.41)			
39	Fraud	**4.45**	**37**	RM#48 (3.94)	RM#1 (3.38)	RM#32 (2.72)		
40	Technical failure	**3.71**	**38**	RM#50 (3.22)	RM#49 (3.13)			
38	Flood	**3.27**	**39**	RM#47 (3.44)	RM#32 (2.75)	RM#46 (2.17)		
37	Drought/Lack of water supply	**2.84**	**40**	RM#45 (4.1)	RM#32 (2.75)	RM#46 (2.17)		

Note: numbers in parentheses are rating on risk management strategy efficacy.

b. Selecting Risk Management based on Cost-Benefit Analysis

The data for costs and benefits of applying a risk management strategy in catfish farming are diverse and not universal. For the same risk, different catfish farmers can apply strategies to mitigate risk. The approach might be different across different farms or farmers. As a result the costs and benefits are also difficult to record and calculate. To provide a brief picture about this, this section will describe catfish farmers' opinions, obtained from eight in-depth, face-to-face interviews in An Giang province. Each paragraph will describe the cost and the benefit of applying a specific risk management strategy for a specific source of risk done by each farmer. A short summary will follow to provide a common cost and benefit justification for that strategy. A template table of the costs and benefits of applying risk management strategies is provided at the end of this subsection, for the purposes of synthesis and developing the DSS in the next chapter.

- **Summary of the Cost and Benefit of Applying Risk Management Strategies Collected from the Eight in Depth Interviews**

R1 (Pond outside planning area) - RMS1 (Locate pond in designated (planning) area)

- Farmer 1: The difference between cost of land in a designated area vs. not in designated area is 100,000,000.00 VND/ha. If the farm is not in the designated area, the fish are not certified as clean catfish and so the farmer cannot sell them to processors or borrow money from banks. As a result, producers can only sell them to domestic users, usually at a lower price (-1,000 VND/kg)

- Farmer 2: The benefit of locating a farm in the designated area is to reduce the cost of infrastructure investment, such as road, water supply and waste draining systems, good environment, and security

- Farmer 4: Locating the pond in the planned area will reduce the cost of infrastructure investment, and will be easy for water supply and draining. This will also reduce conflict with rice farmers due to waste water release, especially in the rice seeding and harvesting period.

- Farmer 5: Yes, the pond is in the planned area but the infrastructure is not developed yet. The cost of land in a planned area is 50% higher than the cost of land located outside the planned area. If the land is located in planned area, the farmers can borrow money from the banks.

- Farmer 6: The pond is not in the planned area but has been converted to an aquaculture purpose. Still continues to rear fish; located in the remote area, so the pollution is not important.

- Farmer 7: Yes, the pond is in the planned area but the infrastructure has not been developed. The land price is higher than that in an unplanned area by 30-50 mill (million) VND /1,000m^2.

- Farmer 8: The pond is located in the planned area for catfish culture. However, the infrastructure has not been developed yet. The land price difference is 100%, varying from 50 to 100 mill VND/ha.

R2 (Pond near residence) - RMS3 (Develop a separate water supply system)

- Farmer 1: The investment cost of the water supply system is 100 mill VND/5 ha of ponds. This increases the income by 10-15%.

- Farmer 2: The cost of investment for a water supply system is about 74 mill VND per ha, but it can give a good quality of fish that can improve the profit of farming. If the system is not invested in, the profit can be reduced by 50%.

- Farmer 3: Invest 200 mill VND for the water supply system, serving for 8000 m2 of pond.

- Farmer 4: The investment for water supply system cost 150 mill VND for 12,000 m2. The waste water system is 5 mill. VND That can be used in 10 years of farming.

- Farmer 5: The total investment cost for the water supply system is 500 mill VND for 10,000m2, including 300 mill VND for electricity, pipe, and pumps. 200 mill VND for other equipment.

- Farmer 6: Invest 200 mill VND for the water supply system.
- Farmer 7: Investment cost for the water supply system is 150 mill VND/9000 m2. If not invested, cannot rear fish.
- Farmer 8: The investment cost for water supply system is 250 mill-1 billion VND/25,000 m2. Due to low water level, pumping is the only way to get water into pond.

R3 (Pond has no waste treatment system) - RMS3 (Develop a separate water supply system)

- Farmer 3: Investment per ha is 20 mill VND.

R3 (Pond has no waste treatment system) - RMS5 (Apply farming systems that minimises water replacement)

- Farmer 1: Applying farming system that reduces water replacement by 40-50%, saving about 60 litres of diesel per day, within 180 days of crop.
- Farmer 2: Applying the farming system, reducing the water replacement by 50%, the cost of water replacement is cut by 50%, equivalent to 300VND/kg of fish
- Farmer 3: Replacing the water every day to keep the water fresh.
- Farmer 4: replacing about 25% of the water in pond to keep the water in fresh condition.
- Farmer 5: Replace water by 25% when the fish are less than 500 grams in weight. When the fish are bigger, running water replacement continuously. The cost of water replacement increases by 200%. However, the catfish selling price is the same as the price for catfish produced in farms not doing water replacement.
- Farmer 6: When the fish are less than 500gr, water replacing is conducted once a day, with the cost of 200,000 VND/day/30,000 m2. The quality is good, with the price increase by 1,000-1,500 d/kg fish.

- Farmer 7: When the fish are small, replacing water by 25%; when the fish are larger than 800 grams, replacing 100%, the cost of water replacing is 3-3.5 mill/month. The price increases by 700-1000 VND/kg with the output of 250 tons/year.

- Farmer 8: Replacing the water by half when the fish are small and every day when they are big. The benefit of this is that the quality of fish is good and the selling price is 1000 VND/kg more.

R4 (Pond not treated before stocking) -RMS6 (Strictly treat the pond before stocking)

- Farmer 1: Treating the pond before stocking. This costs about 20 mill VND/ha. However, the efficiency of this treatment is unclear.

- Farmer 2: Strictly treating the pond before stocking can cost 200 VND/kg of fish, but it can reduce the cost of disease control by 50%.

- Farmer 3: Treat the pond strictly, costing 10 mill VND/8000 m2. If not, can lose up to 50% of the total production.

- Case 4: Treating the pond before stocking will reduce the loss of fingerlings by 10%, from 20% to 10%. At the same time, if not treating the pond, the cost of medicine and chemicals will increase by 10-20%.

- Farmer 5: Cost 5 mill VND/5000 m2, but reduced the cost of medicines by 50%.

- Farmer 6: Removing the bottom mud will cost about 5-6 mill VND/0.6 ha of pond surface. If not the loss could be 100%.

- Farmer 7: Treating the pond before stocking costs 10 VND mill /6,400 m2. If not treated, the loss can be 100%.

- Farmer 8: Applying pond treatment costs 1 mill/4,000m2, reducing the mortality of fish

R5 (Low quality fingerlings) - RMS8 (Select good fingerlings)

- Farmer 1: Choosing good quality of fingerlings will increase cost of fingerlings by

10-20% (about 200 VND/fingerlings). However, it will reduce the mortality rate of stocking fingerlings. As a result, the actual cost of fingerlings will reduce by 30, and increase the profit by 20%

- Farmer 2: Always choose to use good fingerlings for stocking.
- Farmer 3: Using large size fingerlings that can reduce disease, loss of fingerlings up to 20-30%. It costs an extra10-20% of fingerling cost.
- Farmer 4: Using self-produce fingerlings. Selecting the good fingerlings for growing out leads to less disease in the crop. The cost is the same as buying fingerlings from the market.
- Farmer 5: With a small extra cost for choosing good fingerlings, farmers can reduce the cost of medicines by 30%. Most of fingerlings selection based on intuition, not the certificate.
- Farmer 6: Using homemade fingerlings. If buying good quality that can cost 100-200d/fingerling more. The yield is no different.
- Farmer 7: Using homemade fingerlings. If buying from reliable source, the cost of fingerings is about 20% higher. Equivalent to 100-150 d/fingerling – using small fingerlings can give higher profit if controlling the mortality rate well. Using larger fingerlings will increase the cost of fingerlings by 100-150 d/fg, but reduces the medicine cost by 30-40%.
- Farmer 8: Using home fingerlings; if not enough, buy out. Choosing good fingerlings will reduce cost and mortality

R8 (Fingerlings treated by antibiotics during fingerling production process) - RMS10 (Buy fingerlings only from certified producers)

- Farmer 2: Buying fingerlings from certified producers cost 100 VND/fingerling more than the normal price

R9 (Epidemic checking for fingerlings not conducted) - RMS7 (Attend extension workshop)

- Farmer 5: When the fish are still small (<500 grs), have to replace the water weekly, apply lime, and lime water. When the fish > 500 grs, replace the water more regularly. This can improve the quality of fish and the sell price can be 1,000 VND higher then low quality fish price. Also reduces 30% of medicine cost

R9 (Epidemic checking for fingerlings not conducted) - RMS13 (Reduce density of fingerling stocking)

- Farmer 2: Reducing the stocking density by 50% (to 20 fingerlings/m2) cut the cost of fingerlings by 50% (500 VND/kg of fish)
- Farmer 6: Reducing the stocking density by 25% can cut the total cost by 30%.

R10 (Use of undersized/oversized fingerlings) - RMS15 (Use large-sized fingerlings)

- Farmer 1: Using large size fingerlings will increase the cost up by 0% but reduce the production cost by 10%
- Farmer 2: Using large fingerlings will cost 500 VND/fingerling more, but can reduce the mortality rate.
- Farmer 4: Using large size fingerlings will cost 300 VND/fingerling more but can reduce the cost of water replacing by one month. The cost is unchanged but the fish are healthier, less disease infections.
- Farmer 5: Reducing stocking density by using large size fingerlings will cost 500 VND/fingerling. But the cost of medicines is reduced by 60%.

R12 (Low quality of feed) - RMS16 (Choose good brand of feed)

- Farmer 1: Using good brand of feed will increase the cost of feed by 3-5% but improve the FCR and increase the profit by 5%.

- Farmer 2: Choosing good brand of feed will cost 1,300d/kg more
- Farmer 6: Using homemade feed when the fish are small, pellet feed for the larger fish. The cost of good brand feed is 500-700 VND/kg higher than the price of other brands, but the FCR is 1.6 vs. 1.7-2.0 of other brands.

R12 (Low qualities of feed) - RMS17 (Self-processing to ensure feed quality and reduce cost)

- Farmer 4: Making homemade feed can reduce the cost of feed by 30%. If using good raw materials, the cost increases by 500-700 VND/kg of trash fish; FCR improves from 2.5 to 2.2.
- Farmer 6: Using good materials for making homemade feed, cost is 4,000d/kg of trash fish

R12 (Low quality of feed) - RMS19 (Use only factory-made (pellet) feed)

- Farmer 3: Using pellet feed for small fish costs 400 d/kg more, with the FCR 1.47-1.55 vs. 1.7 of other brands. Using homemade feed with good sources of materials costs more, with the price 3,000-4,000 VND/kg, FCR 2.4-2.5 vs. 3.0-3.5.

R13 (Uncontrolled/unstable homemade feed quality) – RMS19 (Use only factory-made (pellet) feed)

- Farmer 3: Use pellet feed will cost 3,000 VND/kg feed more than homemade feed, but the quality of feed is better and can sell the fish with 1000 VND/kg more.
- Farmer 5: Small fish: using pellet feed, FCR 2.2-2.5 kg/kg fish. Larger fish, using homemade feed, cut back 30% of the feed cost, by 1000 d/kg fish. In comparison with pellet feed, FCR: 16-1.7 kg feed/1 kg fish.
- Farmer 7: Using homemade feed reduces disease infection. However water must be replaced more frequently by 20-30%.

R13 (Uncontrolled/unstable homemade feed quality) - RMS18 (Choose good quality raw materials)

- Case 3: Choosing good quality material for preparing feed that costs 500 VND/kg more but can reduce the FCR from 2.5-2.6 to 2.2-2.3.
- Case 4: Buying feed materials from good sources, with the cost increase by 400 d/kg, but can reduce the FCR by 0.3kg1kg of fish.
- Case 8: Using homemade feed with the price of rice brown cover 5,400 d/kg. The cost of bottom mud removal is higher, removing the mud every month in comparison with once in two month if using pellet feed. FCR 2.4-2.5 vs. 2.7-2.8

R14 (Overfeeding which causes pollution and waste accumulation) - RMS12 (Strictly follow government regulations and technical guidelines)

- Farmer 3: Feeding just enough for the feed, no waste

R14 (Overfeeding which causes pollution and waste accumulation) - RMS7 (Attend extension workshop)

- Farmer 3: Attending the workshop can improve the efficiency of using feed up to 50%.

R15 (High death rate due to disease) - RMS20 (Manage water environment in pond well)

- Farmer 3: Manage the pond effectively, applying treating water and mud removal.
- Farmer 6: Carefully observe the water in pond.
- Farmer 7: Check the PH and water colour frequently.

R16 (Inability to control diseases caused by environmental sources) - RMS22 (Develop aquacultural water treatment pond)

- Farmer 5: Developing a water treatment pond can reduce 50% of medicine cost.

- Farmer 6: Not developing the water treatment pond. Replacing the water in pond continuously.
- Farmer 7: Invest in 3,000 m2 waste water treatment pond. Reducing the water emissions to the environment, cut the cost of water replacement.

R18 (Limited knowledge about use of chemicals and medicines) – RMS7 (Attend extension workshop)

- Farmer 4: Self study, learning by doing, learn through friends, self decision.

R18 (Limited knowledge about use of chemicals and medicines) - RMS23 (Use labour that has knowledge of aquacultural and veterinary matters)

- Farmer 1: Cost of hiring technical labour is about 3,000,000.00 VND/month * 6 months. But reduces 10% of total management costs.
- Farmer 5: Do not hire technical labour, learning and doing by own self. Learning from friend. No cost occurs.
- Farmer 6: Obtain knowledge from staff, medicine seller.
- Farmer 7: Learning, take advice from aquacultural staff, medicine sellers, providers.
- Farmer 8: Learning from friend, ask staff for advice, medicine providers.

R19 (Use of prohibited chemicals and medicines) - RMS14 (Regularly update list of prohibited chemicals and medicines)

- Farmer 4: Learning, updating the list of prohibited chemicals and medicines by attending workshop.
- Farmer 5: Never use prohibited medicines and chemicals. If used, processors will not buy the fish.
- Farmer 7: In case of using antibiotics, must apply two months before harvest time.

Absolutely not applying prohibited medicines (for instance, Macelit).

R19 (Use of prohibited chemicals and medicines) - RMS24 (Consult with people who have knowledge of aquacultural and veterinary matters)

- Farmer 6: Using consultancy from medicine shops, extension workshops update lists of medicines used from public sources.

R21 (Farm has no reserved area for waste water and mud treatment) - RMS22 (Develop aquacultural water treatment pond)

- Farmer 1: The water treatment pond takes up 10% of the total area of the farm. This will reduce the impact of the water environment to the fish and increase profits by 5-10%.
- Farmer3: Develop a 6,000 m2 waste water treatment pond. Reducing waste water emissions from pond will reduce conflicts with neighbours, cost of water replacement; can cut down 30% of total cost.

R25 Inappropriate size of harvested fish - RMS25 Sale and production contract with processor

- Farmer 3: Sign sale contract with catfish processors that guarantees sale to processors.
- Farmer 4: Sign sale contract with processors, cut down the intermediate cost, increase profit.
- Farmer 5: Signing the sale contract with processors before harvesting, but the legacy of the contract is weak and easy to be broken if the market conditions are not favourable.
- Farmer 6: Not commitment with the buyer. Can be sold to any buyer who pays the highest price.

R27 (Fish price variability) - RMS25 (Sale and production contract with processor)

- Farmer 4: Not yet having any organisation or association to present for the farmers. No bargain power to sign a contract with processors.

- Farmer 7: Sign production contract with processor.
- Farmer 8: The sale contract is not effective, dominant conditions set by processor.

R27 Fish price variability - RMS28 (Vertical integration)

- Farmer 7: Integrated with processor to receive 60% of the feed cost, without price determination. The selling price will be determined at the time to harvest. However, the fish producer must pay the interest for the cost of borrowing from processor.

R31 (High costs of operating inputs) - RMS35 (Production at lowest possible cost/keep fixed costs low)

- Farmer 1: Applying the strategy of minimizing the production cost can take place by: reducing the density of stocking by 20-50%; this basically converts to extensive or ecological farming. This can reduce the FCR by 50%, from 2:1 to 1-1.1:1.
- Farmer 3: Reducing the density of the stock, which reduces all other production cost items: feed, water, medicines.
- Farmer 6: Applying the cost minimization strategy. Especially for feed (which accounts for 80% of the production cost).
- Farmer 7: Reduce the stocking density by 25%, which can reduce the cost of water replacement, feed, medicines, and FCR reduced from 1.6 to 1.5 – cuts down the rearing time by one month.

R32 (Under-financing by own capital for the whole crop cycle) - RMS36 (Reduce farm size to appropriate scale)

- Farmer 8: No, borrow when needed, usually for pumping water; in three months, sometimes two months, before harvesting.

R32 (Under-financing by own capital for the whole crop cycle) - RMS37 (Increase solvency ratio)

- Farmer 1: Reduce debt ratio. The cost of borrowing is about 19% of the profit.
- Farmer 2: Make a loan arrangement for 50% of the total capital required with the interest rate of 1.1-1.7%/month. The remaining required capital is borrowed from relative, friend with the same interest rate. Reduce the farm size to appropriate scale.

R33 (Under-financing by credits from banks/credit institutions) - RMS39 (Ensure credit arrangement before cropping)

- Farmer 1: Advanced credit arrangement can reduce the cost of borrowing by 50% in comparison with unarranged loan.
- Farmer 2: No, borrowing from unofficial lender with interest rate of 5%/month. Also cooperate with relatives to share the capital required.
- Farmer 3: Arrange the loan before the crop. Take a loan of 300 mill VND/8,000m2.
- Farmer 5: Make arrangement for credit of 50% of required capital, with the interest rate of 10-15% annually.
- Farmer 6: Make credit arrangement for 30-50% of total required capital with the interest rate of 10-15% annually. If not, borrowing from unofficial lending with the interest rate up to 3%/month. Usually borrow only one month before harvesting.
- Farmer 7: Make credit arrangement in advance for 40% of the total capital required. With the interest rate of 1.0-1.5% a month, in comparison with unofficial lender of 3% interest rate. Due to the small farm area, instead of reducing the farm size, farmer reduces the stocking density instead. The output reduced from 300tons to 120-180tons.

R33 (Under-financing by credits from banks/credit institutions) - RMS40 (Solvency-debt management)

- Farmer 3: The unofficial credit interest rate is 3-4% vs. 0.85-1.1% of official credit.
- Farmer 8: Keep 10% of the total capita for other activities.

R35 (Changes in government policy on product development strategy) - RMS34 (Apply quality management program (e.g. HACCP, Global-GAP))

- Farmer 3: Applying the SQF 1000 standard with no cost (supported by the program) can improve the quality of fish. However, there is no difference in selling prices in comparison with normal fish.
- Farmer 5: Not applying the standard because the processor buys fish based on the location, region. Not based on farm.
- Farmer 6: Not applying, because the processors do not distinguish the fish. The price is the same with other fish.
- Farmer 7: Applying for 20-30% of the farm area but not for the whole farm, due to no difference in the selling price.
- Farmer 8: Not applying the standard because there is no difference in selling price.

R33 (Under-financing by credits from banks/credit institutions) - RMS42 (Keep cash on hand for farming)

- Farmer 6: Borrowing from friends, relatives; not borrowing from the banks

R39 (Fraud) – RMS48 (Maintain a good relationship with the community)

- Farmer 2: Keep good relationship with neighbour and community.

R40 Technical failures - RMS49 (Surplus machinery capacity)

- Farmer 1: Preserving a surplus machines capacity. It takes up 20% of total investment for the farm (200 mill VND/5 ha). If not, when technical failure happens, the loss is huge due to the fish dying.
- Farmer 5: Preserving 50% of surplus capacity. If not, when the equipment has failed, the damage could be huge, 100%.
- Farmer 6: Preserving about 50% of surplus capacity. If not the loss could be 100%.
- Farmer 7: Preserving 30% capacity for the case of technical failure.
- Farmer 8: Preserving 30% of surplus capacity.

- **Template Table for Cost and Benefit of Applying Risk Management**

Due to the limitations of the information, we can not provide a complete synthesis of cost and benefit of risk management strategies which are applied by catfish farmers to mitigate risks. In addition, as the purpose of this study is to develop a framework for risk management, we provide here a template table for accounting the cost and benefit of applying risk management strategies and facilitating the DSS development in the next chapter.

Table 5-14 provides a template for catfish farmers to account for the cost and the benefit of applying risk management strategies for catfish farming. Once the costs and the benefits have been accounted completely into the table, the net benefit values will be calculated. The table is sorted by risk ranks and then by the net benefits of RMSs so that catfish farmers can easily see and select the best risk management strategies in terms of net benefit. All the calculations and sorting will be conducted automatically by the DSS that is developed in the next chapter.

Table 5-14 Template Table for RMSs' Cost and Benefit Analysis

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#27	Fish price variability (R#27)	1				
R#27		1	Sale and production contract with processor (RMS#25)			

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#27		1	Vertical integration (be a member in fish association that process the fish itself) (RMS#28)			
R#27		1	Enterprise diversification (RMS#29)			
R#27		1	Cooperative marketing (RMS#30)			
R#27		1	Off-farm work (RMS#31)			
R#17	Low awareness of disease prevention by farmers (R#17)	2				
R#17		2	Attend extension workshop (RMS#7)			
R#01	Pond outside planning area (R#1)	3				
R#01		3	Locate pond in designated (planning) area (RMS#1)			
R#01		3	Change to other activity (RMS#2)			
R#23	Waste water treatment system is under-invested (R#23)	4				
R#23		4				
R#09	Epidemic checking for the fingerlings not conducted (R#9)	5				
R#09		5	Strictly follow government regulations and technical guides (RMS#12)			
R#09		5	Reduce density of fingerling stocking (RMS#13)			
R#09		5	Attend extension workshop (RMS#7)			
R#10	Over (density) stocking fingerlings (R#10)	6				
R#10		6	Use large size fingerlings (RMS#15)			
R#10		6	Attend extension workshop (RMS#7)			
R#22	Pond water is under-managed (R#22)	7				
R#22		7	Strictly follow government regulations and technical guides (RMS#12)			
R#22		7	Attend extension workshop (RMS#7)			
R#24	Unawareness about community environmental protection (R#24)	8				
R#24		8	Reduce density of fingerling stocking (RMS#13)			
R#24		8	Develop a separate water supply system (RMS#3)			

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#24		8	Attend extension workshop (RMS#7)			
R#18	Limited knowledge about usage of chemical and medicines (R#18)	9				
R#18		9	Use labour with knowledge about aquacultural veterinary/advice (RMS#23)			
R#18		9	Consult people who have knowledge about aquacultural veterinary (RMS#24)			
R#18		9	Attend extension workshop (RMS#7)			
R#30	Consequence of high technical barriers from importing countries (R#30)	10				
R#30		10	Apply quality management program (HACCP, Global-GAP…) (RMS#34)			
R#30		10	Attend extension workshop (RMS#7)			
R#36	Changes in environmental policy (R#36)	11				
R#36		11	Increase investment in environmental protection (RMS#44)			
R#36		11	Apply farming system that minimize water replacement (RMS#5)			
R#15	High death rate due to disease (R#15)	12				
R#15		12	Strictly follow government regulations and technical guides (RMS#12)			
R#15		12	Reduce density of fingerling stocking (RMS#13)			
R#15		12	Well manage water environment in pond (RMS#20)			
R#15		12	Prevent disease infection by regular checking and observation of pond (RMS#21)			
R#31	Costs of operating inputs (R#31)	13				
R#31		13	Production at lowest possible cost/keep fixed cost low (RMS#35)			
R#40	Technical failure (R#40)	14				
R#40		14	Surplus machinery capacity (RMS#49)			
R#40		14	Regular checking equipments (RMS#50)			
R#38		15	Regular checking and maintaining the dyke (RMS#47)			

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#38		15	Buying insurance for crop (RMS#32)			
R#38		15	Spatial diversification (RMS#46)			
R#38		15	Regular checking and maintaining the dyke (RMS#47)			
R#25	Inappropriate size of harvested fish (R#25)	16				
R#25		16	Sale and production contract with processor (RMS#25)			
R#25		16	Collect information about favourable size from processors (RMS#26)			
R#33	Under-financing by credits from banks/credit institutions (R#33)	17				
R#33		17	Co-operate with others for financing production (RMS#38)			
R#33		17	Make credit arrangement before cropping (RMS#39)			
R#33		17	Solvency-debt management (RMS#40)			
R#33		17	Use economic consultancy services (RMS#41)			
R#33		17	Keep cash on hand for farming (RMS#42)			
R#29	Weak enforcement in conducting sale contract with processors (R#29)	18				
R#29		18				
R#04	Pond not treated before stocking (R#4)	19				
R#04		19	Strictly treat the pond before stocking (RMS#6)			
R#04		19	Attend extension workshop (RMS#7)			
R#35	Changes in government policy on product development strategy (R#35)	20				
R#35		20	Apply quality management program (HACCP, Global-GAP…) (RMS#34)			
R#35		20	Apply new technology in production (RMS#43)			
R#37	Drought (R#37)	21				
R#37		21	Buying insurance for crop (RMS#32)			
R#37		21	Choose location nearby good water supply sources (RMS#45)			
R#37		21	Spatial diversification			

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
			(RMS#46)			
R#07	Fingerlings infected by diseases (R#7)	22				
R#07		22	Only buy fingerlings from certified producers (RMS#10)			
R#07		22	Careful checking of fingerlings when buying (RMS#11)			
R#13	Uncontrolled/unstable home-made feed quality (R#13)	23				
R#13		23	Choose good raw materials (RMS#18)			
R#13		23	Attend extension workshop (RMS#7)			
R#05	Low quality fingerlings (R#5)	24				
R#05		24	Select good fingerlings (RMS#8)			
R#05		24	Buy fingerlings from reliable places (RMS#9)			
R#11	Use undersize/oversize fingerlings (R#11)	25				
R#11		25				
R#39	Fraud (R#39)	26				
R#39		26	Locate pond in designated (planning) area (RMS#1)			
R#39		26	Buying insurance for crop (RMS#32)			
R#39		26	Keep a good relationship with the community (RMS#48)			
R#06	Fingerlings from unknown origin (R#6)	27				
R#06		27	Only buy fingerlings from certified producers (RMS#10)			
R#08	Fingerlings treated by anti-biotic during fingerling production process (R#8)	28				
R#08		28	Only buy fingerlings from certified producers (RMS#10)			
R#08		28	Careful checking of fingerlings when buying (RMS#11)			
R#21	Farm have no reserved area for waste water and mud treatment (R#21)	29				
R#21		29	Develop aquacultural water treatment pond (RMS#22)			
R#21		29	Apply farming system that minimize water replacement (RMS#5)			
R#28	Inaccessibility to the market (R#28)	30				

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#28		30	Strictly follow government regulations and technical guides (RMS#12)			
R#28		30	Sale and production contract with processor (RMS#25)			
R#28		30	Buying insurance for crop (RMS#32)			
R#16	Inability to control diseases from environmental sources (R#16)	31				
R#16		31	Develop aquacultural water treatment pond (RMS#22)			
R#16		31	Regular checking of quality of supply water (RMS#4)			
R#26	Inappropriate method of harvesting (R#26)	32				
R#26		32	Sale and production contract with processor (RMS#25)			
R#26		32	Choose proper size of pond (RMS#27)			
R#02	Pond nearby residence (R#2)	33				
R#02		33	Develop a separate water supply system (RMS#3)			
R#02		33	Regular checking of quality of supply water (RMS#4)			
R#34	High interest rate for loans (R#34)	34				
R#34		34				
R#14	Overfeeding causing pollution and waste accumulation (R#14)	35				
R#14		35	Strictly follow government regulations and technical guides (RMS#12)			
R#14		35	Use only factory made (pallet) feed (RMS#19)			
R#14		35	Attend extension workshop (RMS#7)			
R#32	Under-financing by own capital for the whole crop cycle (R#32)	36				
R#32		36	Reduce farm size to appropriate scale (RMS#36)			
R#32		36	Increase solvency ratio (RMS#37)			
R#32		36	Co-operate with others for financing production (RMS#38)			
R#12	Low quality of feed (R#12)	37				
R#12		37	Choose good brand of feed (RMS#16)			

Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#12		37	Self-processing to ensure feed quality and reduce cost (RMS#17)			
R#03	Pond does not have waste treatment system (R#3)	38				
R#03		38	Develop a separate water supply system (RMS#3)			
R#03		38	Apply farming system that minimize water replacement (RMS#5)			
R#19	Use of prohibited chemical and medicines (R#19)	39				
R#19		39	Strictly follow government regulations and technical guides (RMS#12)			
R#19		39	Regularly update list of prohibited chemical and medicines (RMS#14)			
R#19		39	Attend extension workshop (RMS#7)			
R#20	Applying chemical and medicines improperly (R#20)	40				
R#20		40	Use labour with knowledge about aquacultural veterinary/advice (RMS#23)			
R#20		40	Consult people who have knowledge about aquacultural veterinary (RMS#24)			

5.3.7 Risk Monitoring and Review

Risk monitoring and consulting is an ongoing review of the risk management plan to ensure the plan is still relevant with respect to internal and external changes. In this step, we regularly examine the targets set and risk management strategies employed. If any deviation has occurred, corrective actions will be devised and evaluated. Risk consequence and likelihood may change due to other factors. The suitability or the cost of treatment options may also change over time. Therefore, it is necessary to review the risk management process regularly.

5.4 Discussion

The data on costs and benefits of applying risk management strategies collected in this research were not completed due to the data availability and strategy application. However, the lack of this data has not affected the framework development. The framework is open for including the data once it becomes available. Future research on the costs and benefits of applying risk management strategies in Vietnamese catfish farming would be necessary for the completion of the framework.

The risk management framework developed in this chapter is aimed at managing the risks involved in Vietnamese catfish farming. However, due to similarities, the framework can be generalised and adapted to other products in aquaculture such as shrimp, snake head fish, tilapia, etc., or other types of activities in the industry such as brooding and fingerling production.

5.5 Summary

This chapter developed a risk management framework for Vietnamese catfish farming following the risk management process suggested by AS/NZS 4360:2004 (Australia Standard: Risk Management). Forty sources of risk and 50 risk management strategies were identified throughout the catfish production process.

BPM was used to break the catfish process into five (5) sub-processes: (1) selecting pond location and pond preparation, (2) stocking fingerlings, (3) growing, (4) harvesting, and (5) marketing. In each of the above sub-processes, all business activities involved were identified. At the activity level, sources of risk and related risk management strategies were the identified. As a result, the number of sources of risk and risk management strategies in the five subsequent sub-processes were four (4) and seven (7); six (6) and eight (8); 21 and 48; two (2) and three (3); and five (5) and 10, respectively.

For each source of risk, risk consequence (severity) and risk likelihood were first rated on a 5-point Likert scale. Next, the level of risk was calculated as the product of the risk consequence and risk likelihood. All sources of risk were then sorted by level of risk in descending order. The risks with highest level of risk were then ranked as the most important source of risk. In addition, 80 probability distribution functions were estimated using @Risk Version 5.0 to measure the risk consequences and risk likelihoods of the 40 identified sources of risk. This measure helps to overcome the problem of binding conditions in risk ranking.

Using the data collected from the fresh survey of 261 catfish farmers in the Mekong Delta, based on a 5-point Likert scale, the most important sources of risk in terms of the level of risk were *'fish price variability', 'high costs of operating input',* and *'under financing by own capital for the whole crop'* with an average score of 4.49, 4.06, and 4.04, respectively.

Similarly, 50 risk management strategies were rated in terms of their efficacy using 5-point Likert scale. The most efficient risk management strategies in mitigating risk in Vietnamese catfish farming were *'strictly treat the pond before stocking', 'well manage water in pond',* and *'select good fingerlings'*, with average scores of 4.39, 4.29, and 4.14, respectively.

Risks and risk management strategies were matched together to provide a complete list of risks and risk management strategies available to mitigate that risks For each source of risk, risk management strategies were sorted and prioritized in terms of efficacy or cost-benefit efficiency. Based on these two ways of prioritization, catfish farmers can make their own decision on choosing the risk management strategies that best meet their risk mitigation objectives.

In summary, this chapter described all the steps necessary in developing a risk management framework in the case of Vietnamese catfish farming. Based on this a DSS will then be developed as an implementing tool for risk management in Vietnamese catfish farming. Chapter 6, which follows, will present the development process for the DSS.

Chapter 6

DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR RISK MANAGEMENT

6.1 Introduction

This chapter will describe in detail the development process of the decision support system (DSS), named Fish@Risk, for risk management in Vietnamese catfish farming. The chapter starts with a description of the DSS development approach, providing an overview of how and what of the DSS will be developed. Then, the following sections will describe in more detail each step in the DSS development process.

6.2 DSS development approach

The DSS development process consists of the following 6 steps, i.e. (1) DSS conceptualization, (2) data collection and analysis, (3) DSS design, (4) implementation, and (5) testing and evaluation. In addition, stakeholder consultation is important and necessary work at all steps of the development process. This ensures the DSS is suitable for the end user in terms of the functionalities of the DSS and the ease of use of the system. The process of the DSS development is presented in Figure 6-1.

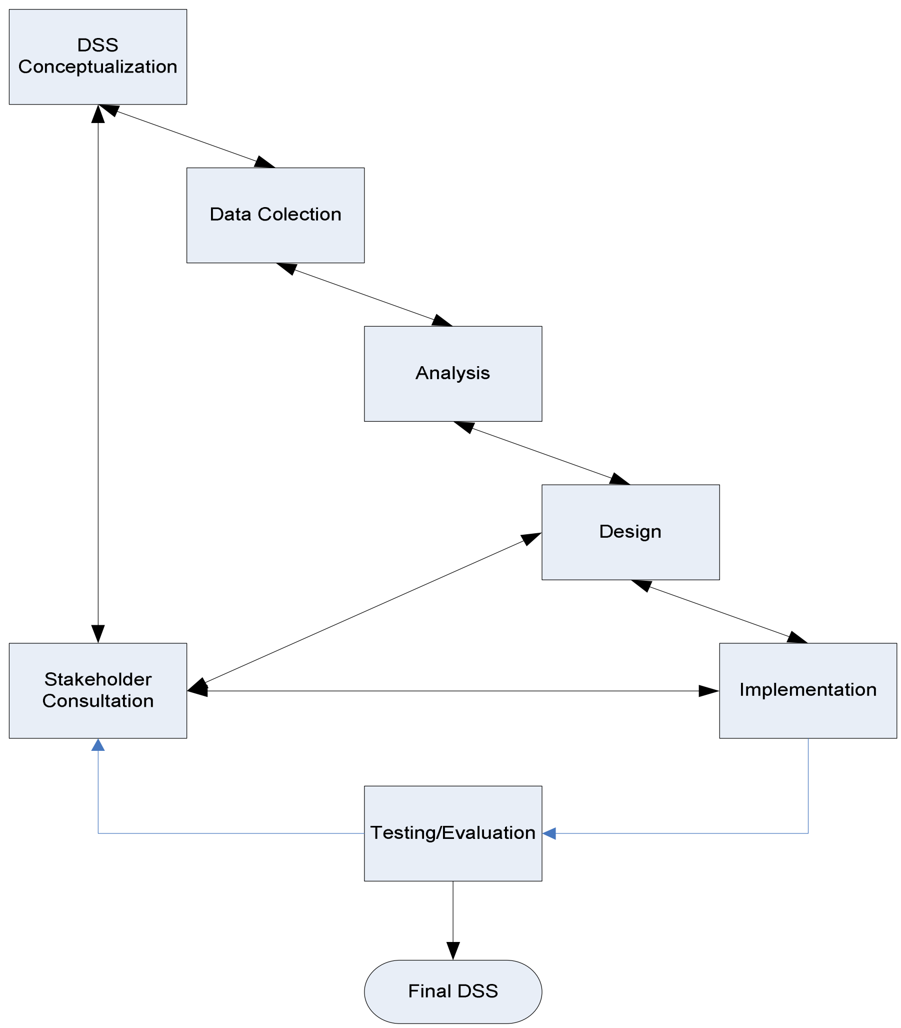


Figure 6-1 DSS Development Process

6.3 DSS Conceptualization

At the start of the development process, in the conceptualization stage, the potential uses of the DSS by stakeholders are assessed based on the risk management framework developed in the previous chapter. From the consultation process and literature review, several concepts are developed. The purpose of this step is clearly to identify: (i) what the system can do, (ii) who the end users of the system are, and (iii) how can it be developed.

From the consultation stage, the development team is able to identify which activities the system can allow the users to do with the system. Specifically, the system must be able to allow the end user to conduct all steps of a risk management process, consisting of: risk identifying, risk measuring, risk evaluating, risk treating, and risk monitoring and reviewing.

Also from the consultation stage, the type of the DSS is obtained. The development team decides to build a prototype DSS using Visual Basic Application for Excel over the period of two months, which can then be used to get more feedback from different stakeholders. This prototype DSS allows users to conduct a complete risk management process, including: (1) to enter input data on risks and risk management strategies, (2) to conduct a risk analysis section, and (3) to choose the best risk management strategies. After a prototype DSS is developed, it is introduced to potential users for trying and evaluating. Comments and feedbacks from them are then used for DSS improvement, both in terms of functionality and the user interface.

6.4 Data Collection and Analysis

There are two types of data used for the operation of the DSS. The first type of data is data on the perceptions of risk and risk management directly entered into the system by the user. This type of data includes data on risk consequence, risk likelihood, risk management strategy efficacy, and costs and benefits of risk management strategies. The second type of data is predetermined probability distribution function for risk consequences and likelihoods. Primary data collected from a fresh survey on risk perceptions in Vietnamese catfish farming was used to estimate these functions using @Risk V5.0 software developed by Palisade. Predetermined probability distribution functions were then incorporated into the DSS for risk analysis functionality.

Input data on risk and risk management were taken and processed by the DSS to calculate the levels of risk and risk management efficacy. Based on the calculated levels, the DSS will then go on to rank and prioritize, and evaluate the risks. Combining with the risk management input data, the system will suggest the optimal risk management strategies available for treating the risk, according to the efficacy or net benefit of relevant risk management strategies.

6.5 Design of the DSS

Based on the information from the consultation in the conceptualization stage, basic requirements for the design of the system were obtained and developed. The system should be able to achieve the following three essential tasks: (1) managing input and output data on risks and risk management in Vietnamese catfish farming, (2) carrying a risk analysis process, and (3) providing options for decision in risk management. This section starts with an overview of how the DSS works, using a flowchart diagram. Then the architecture and the functionalities of the DSS will be described in detail, using use case presentations.

6.5.1 DSS flow chart

Figure 2-12 presents the process of how the DSS works through a complete risk management process. The process consists of a series of actions: managing input data, conducting risk analysis, and selecting optimal risk management strategies. This section will explain how the DSS works, step-by-step, via the flow chart diagram.

When the DSS first starts, the system is ready to take input data from users including data on risks, risk management, and costs and benefits of risk management strategies (box 1). Input data will then be saved in relevant databases (Excel spreadsheets). The lists of risks and risk management strategies were identified in the previous chapter. Users can add or remove risk and risk management items at this step of the process.

Once input data on risks and risk management strategies have been taken into the system, users are ready to conduct a risk analysis (box 2). At this step, the system will automatically calculate the levels of risk of all sources of risk entering into the system using predetermined probability distribution functions (PDFs) and predetermined formulas. The result of this step is a table containing all the sources of risk and their calculated levels of risk. The system will next allow the user to rank the risks according to the importance of risk; risks with higher levels of risk will be assigned as higher rank (smaller rank number) (box 3). In this step, the system also lets the user prioritize the risks that need to be treated by their corresponding ranks.

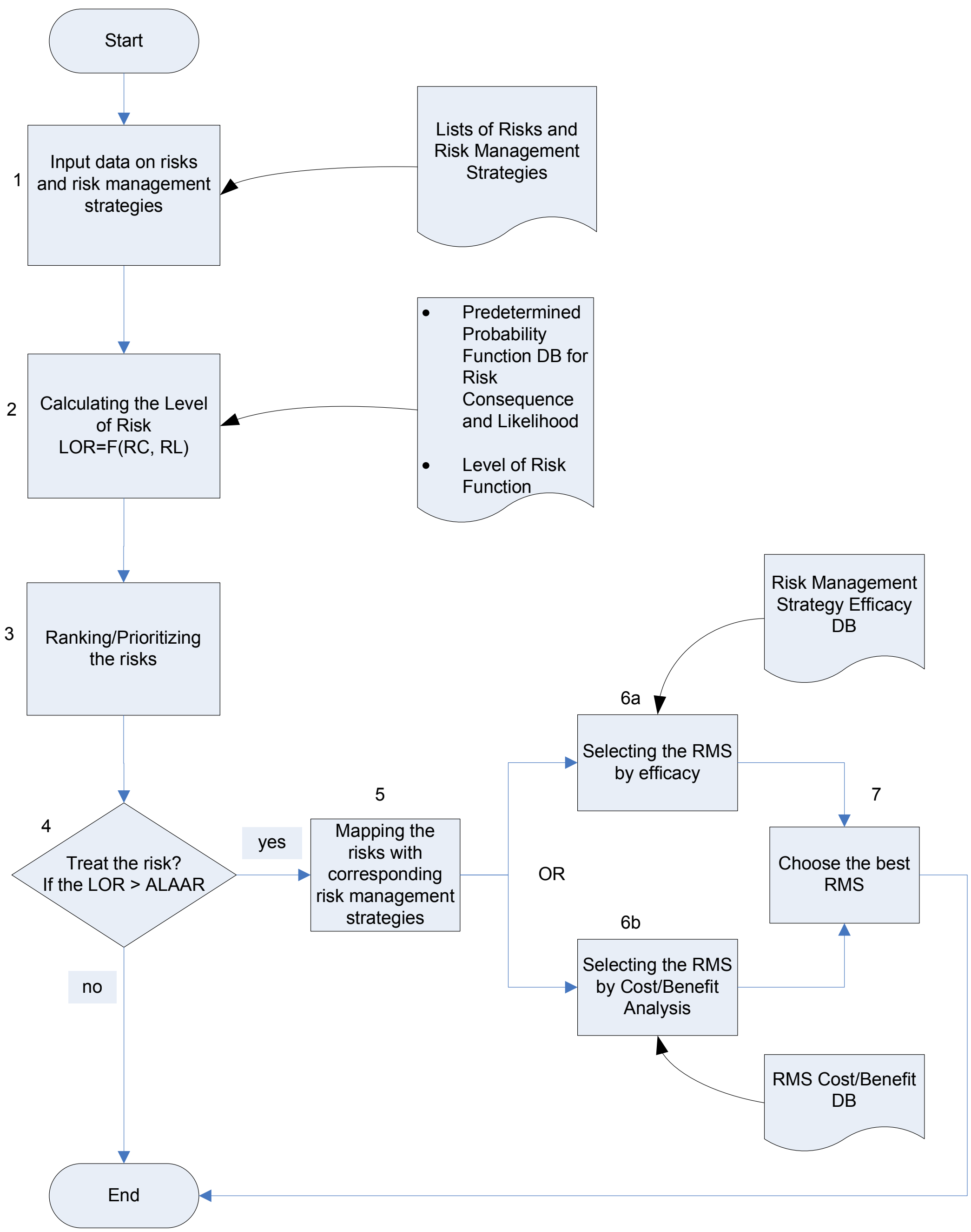


Figure 6-2 Fish@Risk Flow Chart

At this point (box 4), the user is able to decide which risks need to treated and which risks need no further attention, based on the comparison between the levels of risk and threshold values of ALAAR. Once the user decides on which risks need to be treated, the system will take him/her to the risk management step (box 5).

At this stage, the system will conduct risk management strategy selection according to different criteria. The user can have a choice of selecting risk management strategies by efficacy (box 6a) or by net benefit (benefit minus cost) of applying a risk management strategy (box 6b). After reviewing the output results, the user can then make his/her decision on choosing specific risk management strategies for his/her catfish farming business (box 7). After conducting this step the system will come to an end.

6.5.2 DSS Architecture

Like most of the typical DSS, the Fish@Risk system has three main components: a model sub system, a data sub system, and a user interface. The Fish@Risk main components are described in Figure 6-3, which presents the general architecture and the relationships between subsystems of the Fish@Risk system.

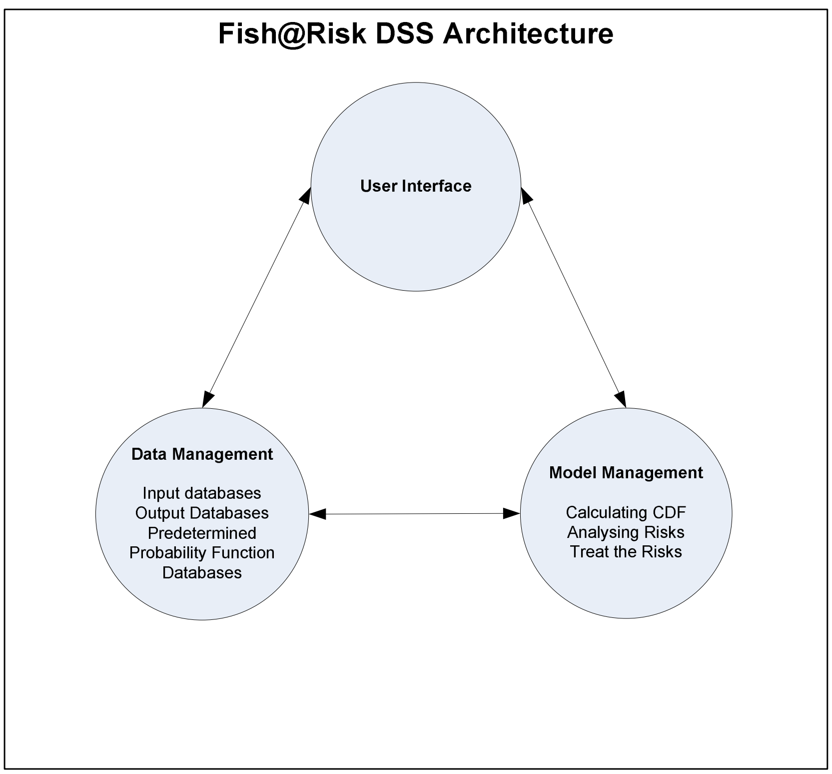


Figure 6-3 Fish@Risk DSS Architecture

6.5.2.1 Data Sub System

The DSS data system allows the user to manage both input data and result outputs from the system. Specifically, the data system will contain an input database and an output database.

The input database contains the following four spreadsheets: (1) a spreadsheet for risk input data; (2) a spreadsheet for risk management strategy input data; (3) a spreadsheet for predetermined probability functions of all risk factors' consequences and likelihoods; and (4) a spreadsheet for costs and benefits of all risk management strategies used to mitigate risks in catfish farming.

The risk input data spreadsheet contains variables holding information on risks consisting of the risk ID, risk names (descriptions), risk consequences, and risk likelihoods. The variables are organized in a tabular form for ease of handling. A similar table is also built to contain information on risk management strategy variables: specifically, RMS ID names (descriptions) and efficacy of risk management strategies in catfish farming.

The third spreadsheet contains all the predetermined probability distribution functions of risk consequences and likelihoods. For each source of risk, there are two probability functions for it: one for risk consequence and one for risk likelihood. For each PDF, the spreadsheet contains the important statistical properties of the functions including probability function name, main distributional parameters, and the mean. These probability functions were estimated outside the system and incorporated into the system for calculation. Finally, the fourth spreadsheet contains the data on cost and benefit of each risk management strategy that can be applied for risk mitigation.

The resulting outputs from the system, including risk analysis results, risk and corresponding risk management strategies, can be organized in a tabular form or a two-dimensional matrix. The user can view the analysis results in tabular or graph forms. Therefore, the output database consists of the following three spreadsheets and one graph: (1) a spreadsheet presenting the levels of risk; (2) a spreadsheet showing the matrix of matching between risks and corresponding risk management strategies sorted by RMS efficacy; a spreadsheet showing the matrix of matching between risk and risk management strategies by RMS net benefit; and a graph presenting risks in a two-dimensional matrix.

6.5.2.2 Model Sub System

The Fish@Risk contains a framework for risk assessment and risk management decisions. Input data on risk consequences and likelihoods (in Likert scale) are first converted into continuous values using cumulative probability functions (CDF) of the respective variables. Then the levels of risk are calculated using the formula of risk exposure as AS/NZS 4360:2004 defined: *Level of Risk (LOR) = Risk Consequence (RC)* * *Risk Likelihood (RL)*. The system will then go on to rank and prioritize the risks according to the level of risk in a descending order. Risks with LOR considered as low acceptable risk (ALAAR) will no longer be considered for further treatment.

The model system also conducts cost and benefit analysis for selected risk management strategies that correspond to selected sources of risk. The results of cost and benefit analysis will then be displayed onto the screen or printed out for a decision. Fish@Risk will be written by Visual Basic for Application on the Excel platform to take advantage of Excel table and graph power and numerous build-in statistical functions. In addition, Excel is commonly available software and requires only the most basic computer skills to use.

6.5.2.3 User Interface

In the Fish@Risk system, the user interacts with the DSS via a user-friendly graphical interface (GUI) written in Visual Basics for Application on the Microsoft Excel platform. Due to the low literacy in computer of farmers, the graphical user interface will be designed with ease of use in mind. All calculations and analysis procedures will be suppressed from the screen and only necessary inputs and outputs will be displayed for entering data or evaluating the results. Details on the GUI of the Fish@Risk will be discussed in more details below, in the DSS Graphical User Interface section.

6.5.3 DSS Functionalities

Fish@Risk has two main functionalities: the data management and the risk analysis functionalities. The first functionality is related to the management of input and output data of the system. The second functionality focuses on the risk analysis procedures. Each function of the system can be considered as a use case, consisting of all activities that users need to interact with the system. This section will describe in detail the two main functionalities of the Fish@Risk, using use case presentations.

6.5.3.1 Data Management Use Case

The data management use case content presents all the activities that a system user can adapt to Fish@Risk in managing and manipulating input and output data of the system. The first four activities in the data management use case are related to input data management. Specifically, in this use case, the user can conduct manipulation on the risk input data, the RMS input data, the probability functions for risk consequences and likelihoods, and the cost and benefit of all RMSs. In this stage, the user can enter, edit, view, save or print all the input data. These data will, in turn, be the inputs for the subsequent risk analysis and risk management stages.

In addition, besides manipulation of the input data, the use case also allows the user to handle the output results from the system. For the output results, the user can view the analysis output both in tabular and chart forms, including the results of risk analysis (in the forms of table or chart); the results of risk management by RMSs efficacy or by RMSs cost-benefit analysis. Figure 6-4 is a graphical presentation of the data management use case.

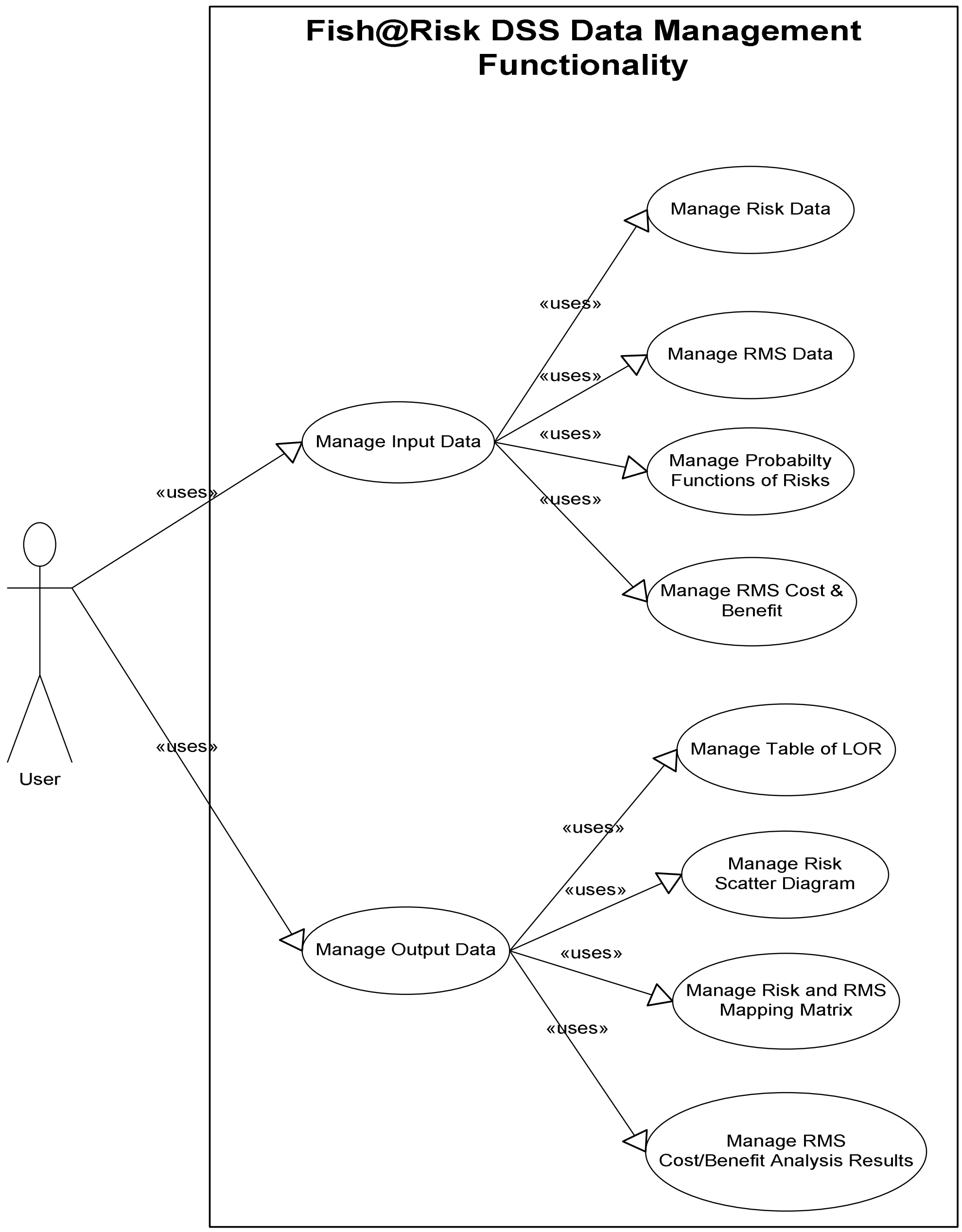


Figure 6-4 Data Management Use Case Diagram

6.5.3.2 Risk Analysis and Management Use Case

The risk analysis use case presents the activities that user can adapt to the system in conducting risk analysis. There are five activities that a user can adapt to and request the system to execute, namely: (1) to calculate the levels of risk, (2) to draw a risk scatter diagram, (3) to allow the user to select the risk factors they want to treat, (4) to build a matrix matching risks and corresponding risk management strategies, and (5) to conduct cost and benefit analysis for suggested risk management strategies. Figure 6-5 presents the graphical presentation of the risk analysis use case.

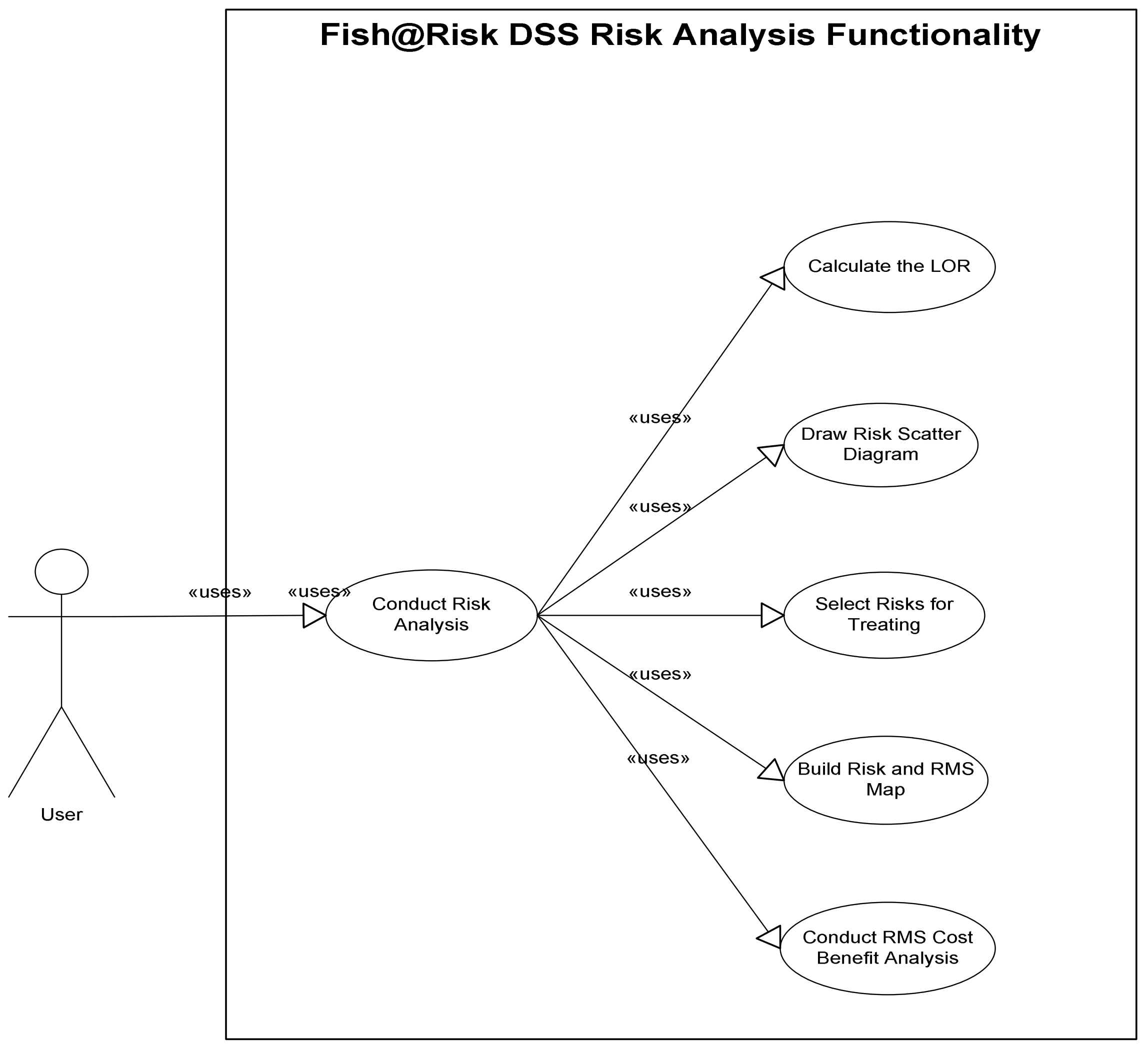


Figure 6-5 Risk Analysis and Management Use Case Diagram

6.5.4 DSS Graphical User Interface (GUI)

The targeted end users of the Fish@Risk DSS are Vietnamese catfish farmers, who generally have limited knowledge and skills of using computers. Therefore, the Fish@Risk user interface is developed with ease of use in mind. The user interface is designed in such a way that can guide the farmer through the process of risk analysis in a straightforward and easy way to understand and use. To meet the requirements, Fish@Risk user interface is designed as a graphical user interface with tabs, buttons, and pop-up windows allowing the user to achieve their goals with ease. Fish@Risk contains four main screens: the main screen, the input database management screen, the risk analysis screen, and the risk management screen. From these main screens, the user can go to more specific screen to interact with the system for specific goals. This section will briefly outline the appearance of the system's interface system.

6.5.4.1 Main Screen

When first starting Fish@Risk, a welcome screen will appear. It is also the main screen of the system. From this screen, the catfish farmer (user) can choose to go to database management or go to risk analysis functionalities by clicking on the appropriate buttons. Figure 6-6 presents a screen shoot of the main screen of the Fish@Risk V 1.0 DSS.

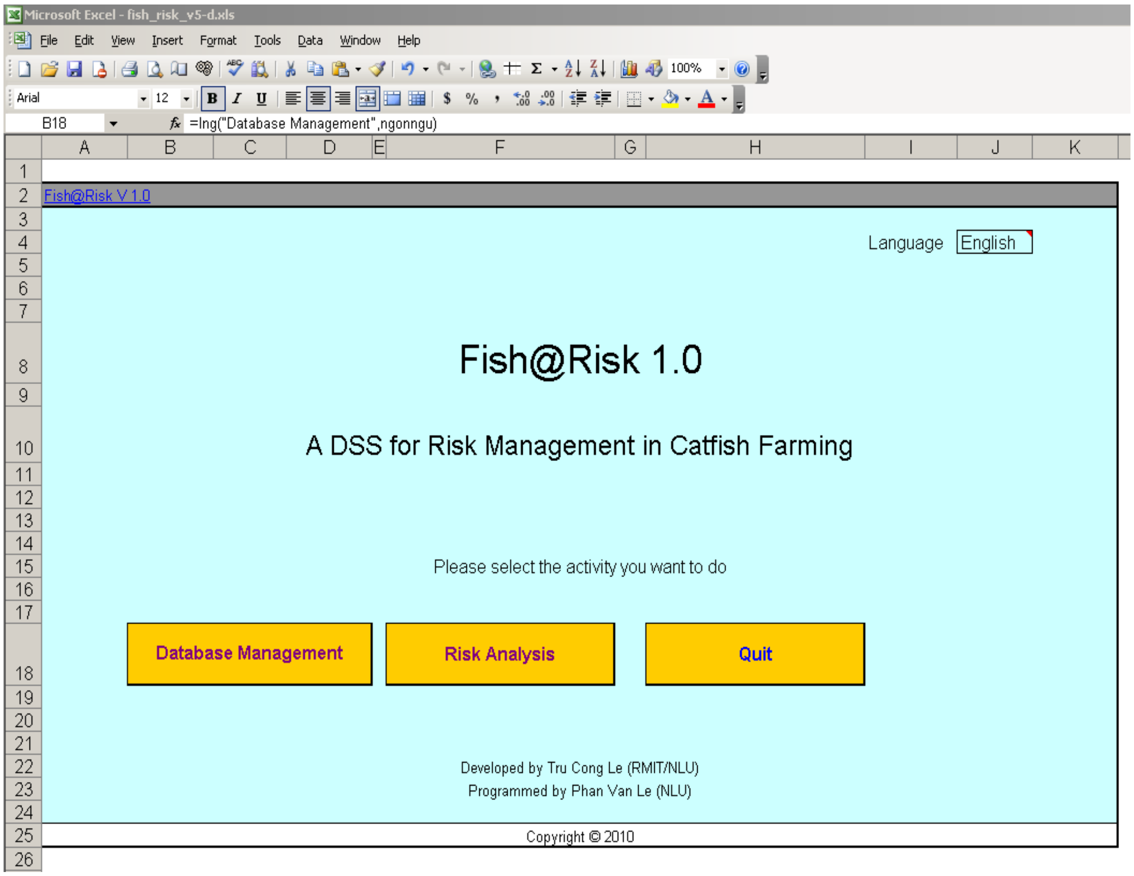
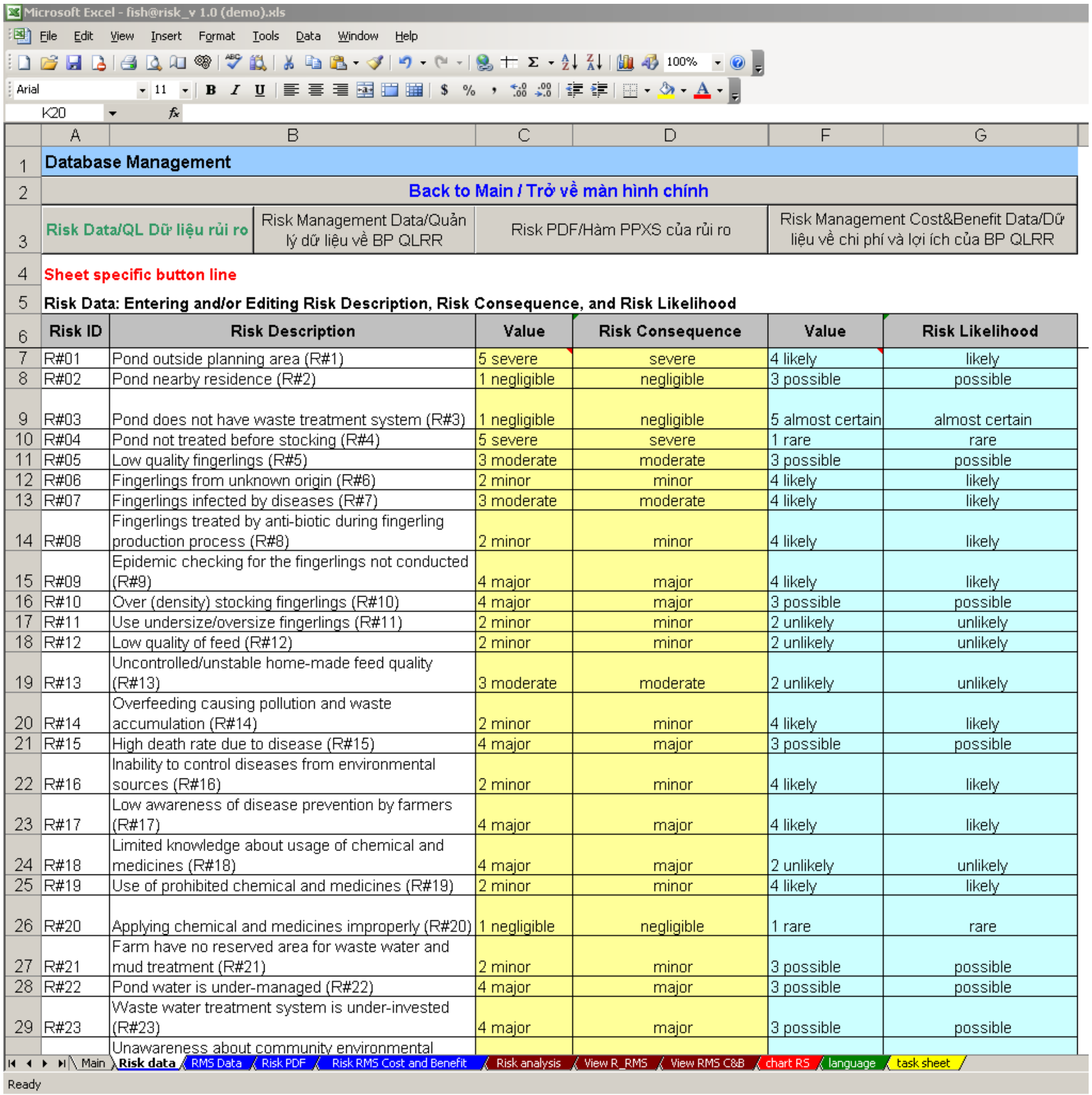


Figure 6-6 Main Screen

6.5.4.2 Database Management Screens

After the user has selected the database management button in the welcome/main screen, the system will take the user to the database management screen. In this screen, there are four tabs that allow the user to manipulate four different input databases: the risk input database, the risk management database, the risk probability function database, and the risk management strategy cost and benefit database. By selecting one of the four tabs, the user can go directly to the database he/she wants to manage. By default, the risk input data screen will be displayed when the user clicks the data base management button in the system main screen. Figure 6-7 below depicts the appearance of the database management user interface, with the risk data input screen set as the default active screen.



Microsoft Excel - fish@risk_v 1.0 (demo).xls

	A	B	C	D	F	G
1	Database Management					
2	Back to Main / Trở về màn hình chính					
3	Risk Data/QL Dữ liệu rủi ro	Risk Management Data/Quản lý dữ liệu về BP QLRR	Risk PDF/Hàm PPXS của rủi ro		Risk Management Cost&Benefit Data/Dữ liệu về chi phí và lợi ích của BP QLRR	
4	Sheet specific button line					
5	Risk Data: Entering and/or Editing Risk Description, Risk Consequence, and Risk Likelihood					
6	Risk ID	Risk Description	Value	Risk Consequence	Value	Risk Likelihood
7	R#01	Pond outside planning area (R#1)	5 severe	severe	4 likely	likely
8	R#02	Pond nearby residence (R#2)	1 negligible	negligible	3 possible	possible
9	R#03	Pond does not have waste treatment system (R#3)	1 negligible	negligible	5 almost certain	almost certain
10	R#04	Pond not treated before stocking (R#4)	5 severe	severe	1 rare	rare
11	R#05	Low quality fingerlings (R#5)	3 moderate	moderate	3 possible	possible
12	R#06	Fingerlings from unknown origin (R#6)	2 minor	minor	4 likely	likely
13	R#07	Fingerlings infected by diseases (R#7)	3 moderate	moderate	4 likely	likely
14	R#08	Fingerlings treated by anti-biotic during fingerling production process (R#8)	2 minor	minor	4 likely	likely
15	R#09	Epidemic checking for the fingerlings not conducted (R#9)	4 major	major	4 likely	likely
16	R#10	Over (density) stocking fingerlings (R#10)	4 major	major	3 possible	possible
17	R#11	Use undersize/oversize fingerlings (R#11)	2 minor	minor	2 unlikely	unlikely
18	R#12	Low quality of feed (R#12)	2 minor	minor	2 unlikely	unlikely
19	R#13	Uncontrolled/unstable home-made feed quality (R#13)	3 moderate	moderate	2 unlikely	unlikely
20	R#14	Overfeeding causing pollution and waste accumulation (R#14)	2 minor	minor	4 likely	likely
21	R#15	High death rate due to disease (R#15)	4 major	major	3 possible	possible
22	R#16	Inability to control diseases from environmental sources (R#16)	2 minor	minor	4 likely	likely
23	R#17	Low awareness of disease prevention by farmers (R#17)	4 major	major	4 likely	likely
24	R#18	Limited knowledge about usage of chemical and medicines (R#18)	4 major	major	2 unlikely	unlikely
25	R#19	Use of prohibited chemical and medicines (R#19)	2 minor	minor	4 likely	likely
26	R#20	Applying chemical and medicines improperly (R#20)	1 negligible	negligible	1 rare	rare
27	R#21	Farm have no reserved area for waste water and mud treatment (R#21)	2 minor	minor	3 possible	possible
28	R#22	Pond water is under-managed (R#22)	4 major	major	3 possible	possible
29	R#23	Waste water treatment system is under-invested (R#23)	4 major	major	3 possible	possible
		Unawareness about community environmental				

Main / Risk data / RMS Data / Risk PDF / Risk RMS Cost and Benefit / Risk analysis / View R_RMS / View RMS C&B / chart RS / language / task sheet

Ready

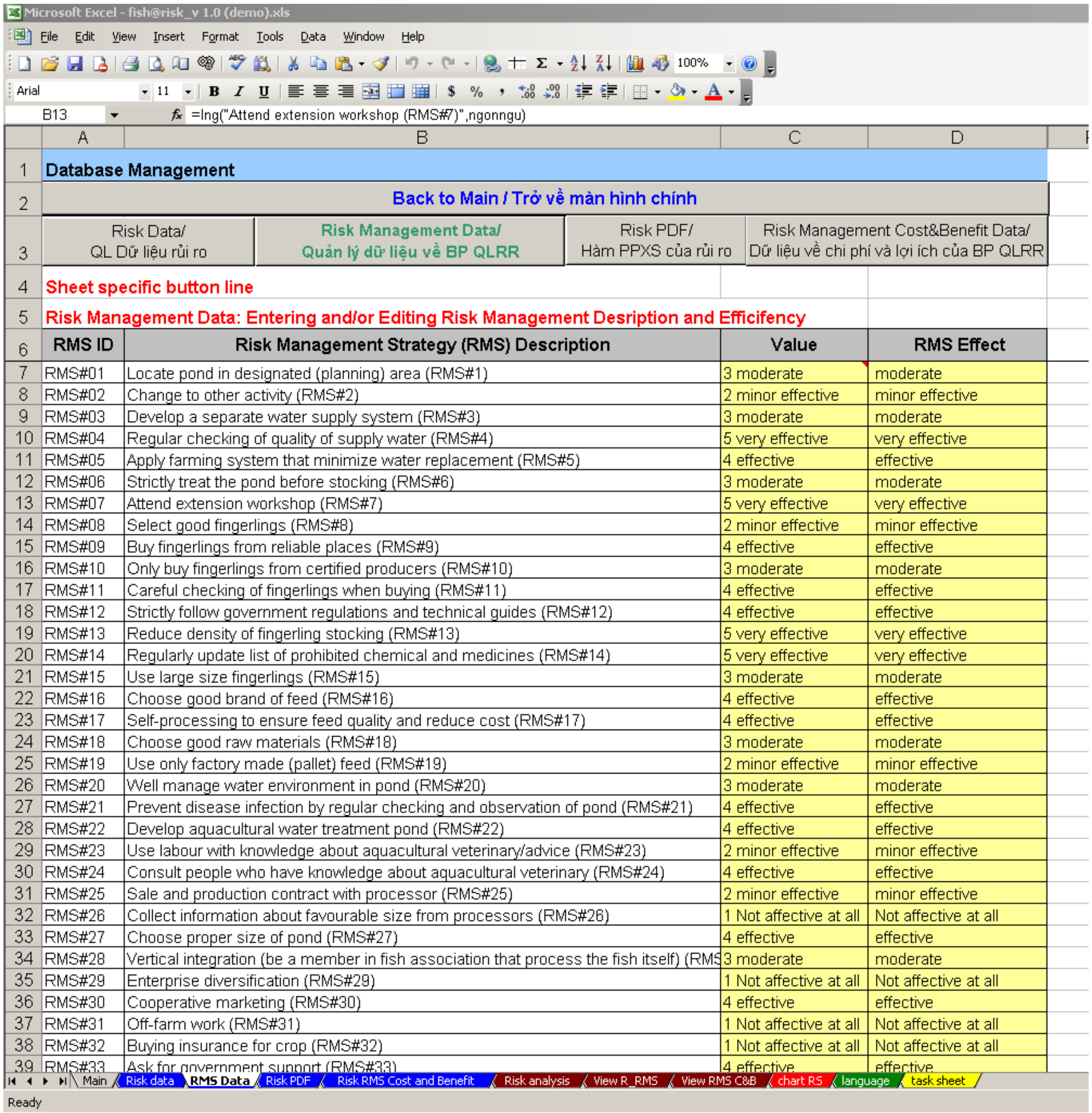
Figure 6-7 Risk Data Input Screen

a. Risk Data Input Screen

In the risk input data screen, the user can manipulate four characteristics of a risk factor, namely: Risk ID, Risk Description, Risk Consequence, and Risk Likelihood. For each of the risk consequence and likelihood values, a combo box is designed to allow the user to easily select the relevant value from the list as the input value for the system. After completing the input data entering, the user can save, view, or print the risk input data for reviewing and checking.

b. Risk Management Strategy Input Screen

The second database in the database management system of the Fish@Risk DSS is the risk management strategy database. This database allows the user to manipulate the input data of the risk management strategies available for risk management in Vietnamese catfish farming. Figure 6-8 provides a screenshot of the user interface of the DSS for this action. In this screen, the user can manage the input data on the 50 risk management strategies applicable for risk management activity, including add or change the risk management strategies, or enter the level of RMS efficacy by selecting appropriate values from the combo box as the input data. After finishing the editing RMS characteristics, the user can save, print, and review the RMS input data.



Microsoft Excel - fish@risk_v 1.0 (demo).xls

B13 =lng("Attend extension workshop (RMS#7)",ngonngu)

Database Management

Back to Main / Trở về màn hình chính

Risk Data/ QL Dữ liệu rủi ro | Risk Management Data/ Quản lý dữ liệu về BP QLRR | Risk PDF/ Hàm PPXS của rủi ro | Risk Management Cost&Benefit Data/ Dữ liệu về chi phí và lợi ích của BP QLRR

Sheet specific button line

Risk Management Data: Entering and/or Editing Risk Management Desription and Efficifency

RMS ID	Risk Management Strategy (RMS) Description	Value	RMS Effect
RMS#01	Locate pond in designated (planning) area (RMS#1)	3 moderate	moderate
RMS#02	Change to other activity (RMS#2)	2 minor effective	minor effective
RMS#03	Develop a separate water supply system (RMS#3)	3 moderate	moderate
RMS#04	Regular checking of quality of supply water (RMS#4)	5 very effective	very effective
RMS#05	Apply farming system that minimize water replacement (RMS#5)	4 effective	effective
RMS#06	Strictly treat the pond before stocking (RMS#6)	3 moderate	moderate
RMS#07	Attend extension workshop (RMS#7)	5 very effective	very effective
RMS#08	Select good fingerlings (RMS#8)	2 minor effective	minor effective
RMS#09	Buy fingerlings from reliable places (RMS#9)	4 effective	effective
RMS#10	Only buy fingerlings from certified producers (RMS#10)	3 moderate	moderate
RMS#11	Careful checking of fingerlings when buying (RMS#11)	4 effective	effective
RMS#12	Strictly follow government regulations and technical guides (RMS#12)	4 effective	effective
RMS#13	Reduce density of fingerling stocking (RMS#13)	5 very effective	very effective
RMS#14	Regularly update list of prohibited chemical and medicines (RMS#14)	5 very effective	very effective
RMS#15	Use large size fingerlings (RMS#15)	3 moderate	moderate
RMS#16	Choose good brand of feed (RMS#16)	4 effective	effective
RMS#17	Self-processing to ensure feed quality and reduce cost (RMS#17)	4 effective	effective
RMS#18	Choose good raw materials (RMS#18)	3 moderate	moderate
RMS#19	Use only factory made (pallet) feed (RMS#19)	2 minor effective	minor effective
RMS#20	Well manage water environment in pond (RMS#20)	3 moderate	moderate
RMS#21	Prevent disease infection by regular checking and observation of pond (RMS#21)	4 effective	effective
RMS#22	Develop aquacultural water treatment pond (RMS#22)	4 effective	effective
RMS#23	Use labour with knowledge about aquacultural veterinary/advice (RMS#23)	2 minor effective	minor effective
RMS#24	Consult people who have knowledge about aquacultural veterinary (RMS#24)	4 effective	effective
RMS#25	Sale and production contract with processor (RMS#25)	2 minor effective	minor effective
RMS#26	Collect information about favourable size from processors (RMS#26)	1 Not affective at all	Not affective at all
RMS#27	Choose proper size of pond (RMS#27)	4 effective	effective
RMS#28	Vertical integration (be a member in fish association that process the fish itself) (RMS	3 moderate	moderate
RMS#29	Enterprise diversification (RMS#29)	1 Not affective at all	Not affective at all
RMS#30	Cooperative marketing (RMS#30)	4 effective	effective
RMS#31	Off-farm work (RMS#31)	1 Not affective at all	Not affective at all
RMS#32	Buying insurance for crop (RMS#32)	1 Not affective at all	Not affective at all
RMS#33	Ask for government support (RMS#33)	4 effective	effective

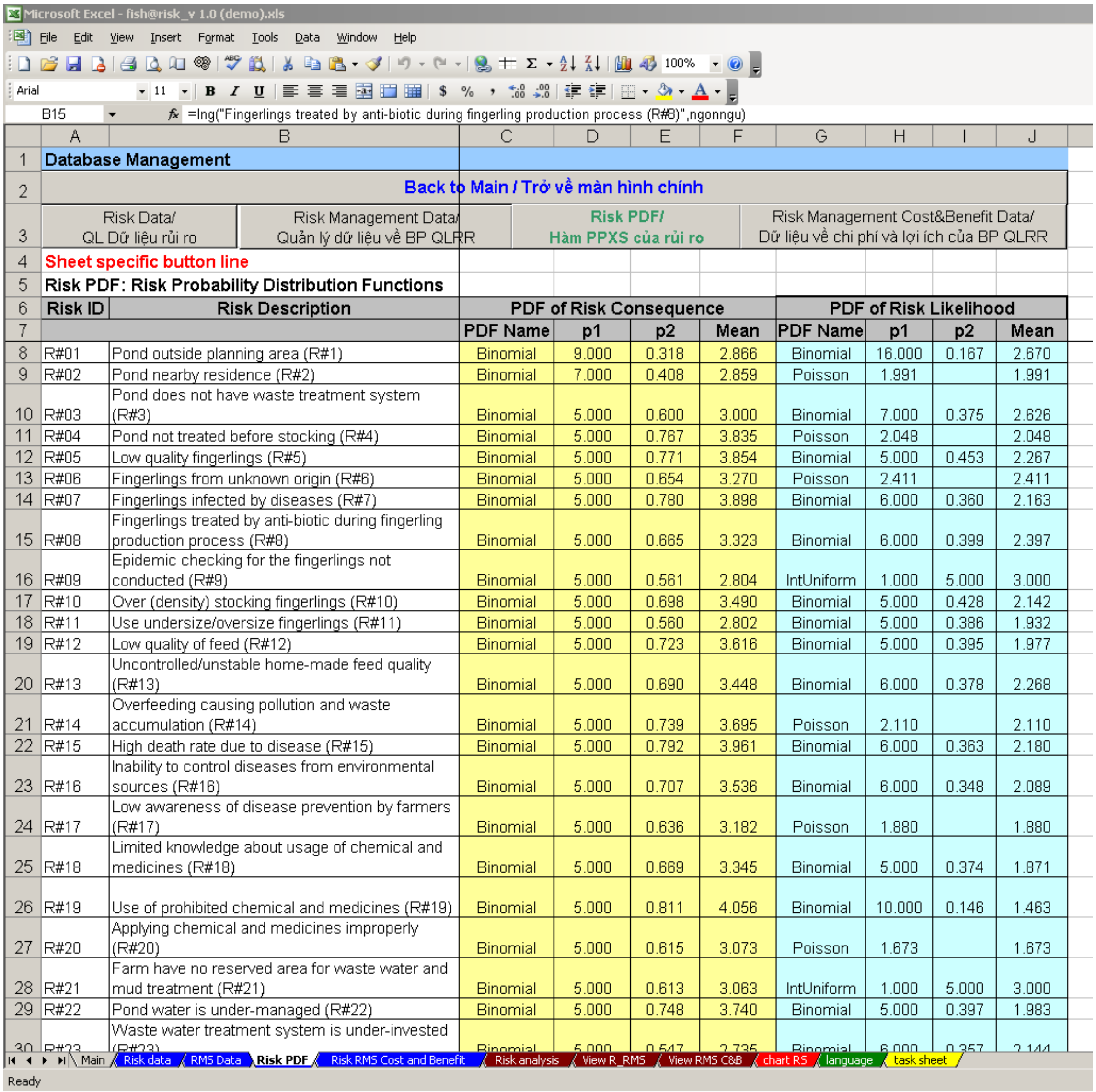
Main / Risk data / RMS Data / Risk PDF / Risk RMS Cost and Benefit / Risk analysis / View R_RMS / View RMS C&B / chart RS / language / task sheet

Ready

Figure 6-8 Risk Management Strategy Data Input Screen

c. Probability Distribution Function Management Screen

The third database in the database system of the DSS is the risk probability distribution function database. This database includes 40 probability distribution functions (PDF) of risk consequences and 40 probability distribution functions of risk likelihoods. These 80 PDFs were predetermined functions achieved from estimations outside of the DSS system and were presented in Table 5-5 and Table 5-6 of chapter 5. Figure 6-9 shows a screenshot of the PDF database of the Fish@Risk DSS.



Risk ID	Risk Description	PDF of Risk Consequence				PDF of Risk Likelihood			
		PDF Name	p1	p2	Mean	PDF Name	p1	p2	Mean
R#01	Pond outside planning area (R#1)	Binomial	9.000	0.318	2.866	Binomial	16.000	0.167	2.670
R#02	Pond nearby residence (R#2)	Binomial	7.000	0.408	2.859	Poisson	1.991		1.991
R#03	Pond does not have waste treatment system (R#3)	Binomial	5.000	0.600	3.000	Binomial	7.000	0.375	2.626
R#04	Pond not treated before stocking (R#4)	Binomial	5.000	0.767	3.835	Poisson	2.048		2.048
R#05	Low quality fingerlings (R#5)	Binomial	5.000	0.771	3.854	Binomial	5.000	0.453	2.267
R#06	Fingerlings from unknown origin (R#6)	Binomial	5.000	0.654	3.270	Poisson	2.411		2.411
R#07	Fingerlings infected by diseases (R#7)	Binomial	5.000	0.780	3.898	Binomial	6.000	0.360	2.163
R#08	Fingerlings treated by anti-biotic during fingerling production process (R#8)	Binomial	5.000	0.665	3.323	Binomial	6.000	0.399	2.397
R#09	Epidemic checking for the fingerlings not conducted (R#9)	Binomial	5.000	0.561	2.804	IntUniform	1.000	5.000	3.000
R#10	Over (density) stocking fingerlings (R#10)	Binomial	5.000	0.698	3.490	Binomial	5.000	0.428	2.142
R#11	Use undersize/oversize fingerlings (R#11)	Binomial	5.000	0.560	2.802	Binomial	5.000	0.386	1.932
R#12	Low quality of feed (R#12)	Binomial	5.000	0.723	3.616	Binomial	5.000	0.395	1.977
R#13	Uncontrolled/unstable home-made feed quality (R#13)	Binomial	5.000	0.690	3.448	Binomial	6.000	0.378	2.268
R#14	Overfeeding causing pollution and waste accumulation (R#14)	Binomial	5.000	0.739	3.695	Poisson	2.110		2.110
R#15	High death rate due to disease (R#15)	Binomial	5.000	0.792	3.961	Binomial	6.000	0.363	2.180
R#16	Inability to control diseases from environmental sources (R#16)	Binomial	5.000	0.707	3.536	Binomial	6.000	0.348	2.089
R#17	Low awareness of disease prevention by farmers (R#17)	Binomial	5.000	0.636	3.182	Poisson	1.880		1.880
R#18	Limited knowledge about usage of chemical and medicines (R#18)	Binomial	5.000	0.669	3.345	Binomial	5.000	0.374	1.871
R#19	Use of prohibited chemical and medicines (R#19)	Binomial	5.000	0.811	4.056	Binomial	10.000	0.146	1.463
R#20	Applying chemical and medicines improperly (R#20)	Binomial	5.000	0.615	3.073	Poisson	1.673		1.673
R#21	Farm have no reserved area for waste water and mud treatment (R#21)	Binomial	5.000	0.613	3.063	IntUniform	1.000	5.000	3.000
R#22	Pond water is under-managed (R#22)	Binomial	5.000	0.748	3.740	Binomial	5.000	0.397	1.983
R#23	Waste water treatment system is under-invested (R#23)	Binomial	5.000	0.547	2.735	Binomial	6.000	0.357	2.144

Figure 6-9 Risk Probability Distribution Function Screen

These PDFs were estimated using data from a primary survey on risks and risk management perceptions of catfish farmers and the @Risk v 5.0 simulation software. The PDF database is not open for the DSS user to manipulate. It is locked against the end user to prevent accidental changes. For each risk factor, the PDF database contains the information on risk ID, risk name (description), properties (PDF name and parameters) of risk consequence PDF, and properties of risk likelihood PDF. These PDFs can be changed only if there are new data and the PDFs need to be re-estimated.

d. Cost and Benefit Input Screen

The last database in the input database is the database of risk management strategy cost and benefit. This database allows the user to manage the data on cost and benefit of all the risk management strategies available for Vietnamese catfish farming.

In this screen, the user can manipulate data on the cost and benefit of each risk management strategy by clicking on appropriate cells in the spreadsheet. After selecting the relevant cell for data input, the end user then needs to click the “Edit Cost” or “Edit Benefit” to start editing cost or benefit data. Figure 6-10 below provides a screenshot for the RMS cost and benefit database with “Edit Cost” case as an example. A pop-up box will appear after the user clicks on the “Edit Cost” or “Edit Benefit” button located at the top of the corresponding columns. In this pop-up box (take the “Edit Cost” pop-up box for example), the user can add to or change the cost item names and cost values for the selected management strategy. Input values for cost or benefit will be automatically summed up and added to the relevant cell in the database for restoring. A similar pop-up window for “Edit Benefit” allows user to manipulate the input data for the benefit of risk management strategies.

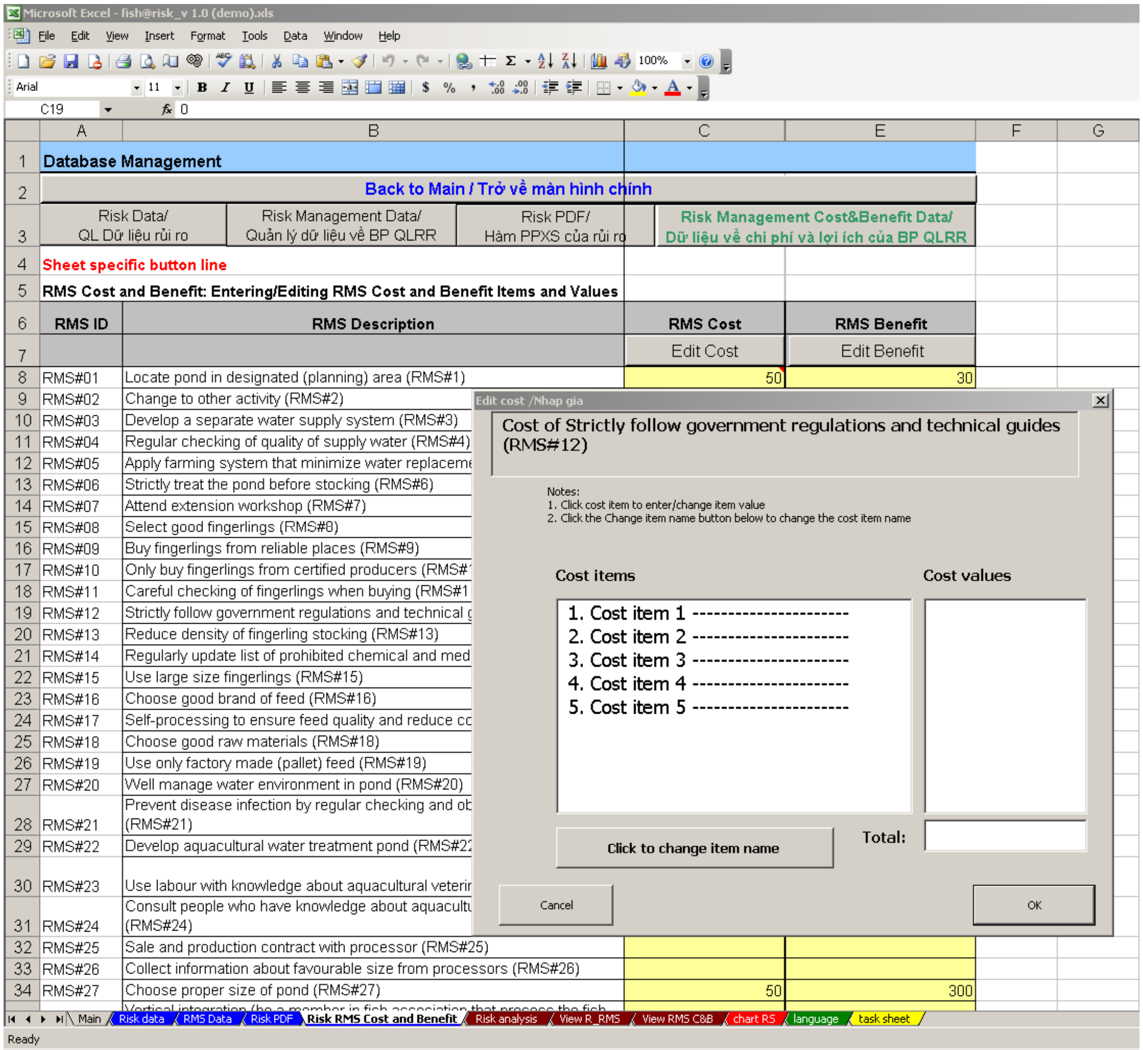
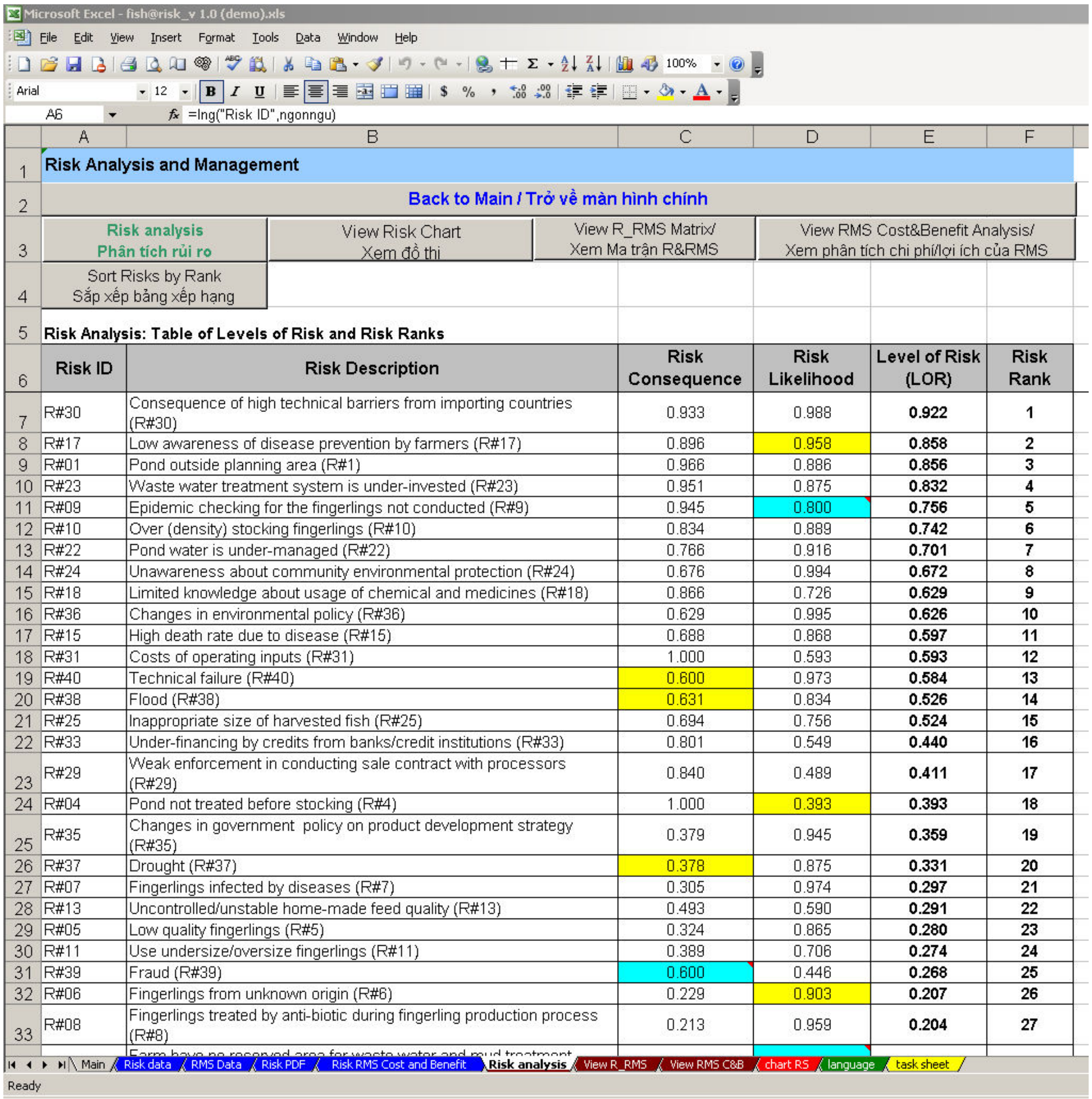


Figure 6-10 RMS Cost-Benefit Input Screen

6.5.4.3 Risk Analysis and Management Screens

From the main screen, by clicking the Risk Analysis button, the system will take the user to the Risk Analysis and Management screen. The underlining calculation processes will be suppressed from display to reduce complications and confusion for the user. Results of the risk analysis and risk management are displayed in either a tabular or a graphical form. There are four tabs in the screen, including a tab for Table of Levels of Risk and Risk Ranks, a tab for the Risk Scatter Diagram, a tab for the Risk and Risk Management Matrix (by RMS

Efficacy), and a tab for the Risk and Risk Management Matrix (by Cost-Benefit Analysis). Figure 6-11 presents a screen shot for risk analysis and the management user interface.


Risk Analysis and Management

Back to Main / Trở về màn hình chính

Risk analysis / Phân tích rủi ro | View Risk Chart / Xem đồ thị | View R_RMS Matrix/ Xem Ma trận R&RMS | View RMS Cost&Benefit Analysis/ Xem phân tích chi phí/lợi ích của RMS

Sort Risks by Rank / Sắp xếp bảng xếp hạng

Risk Analysis: Table of Levels of Risk and Risk Ranks

Risk ID	Risk Description	Risk Consequence	Risk Likelihood	Level of Risk (LOR)	Risk Rank
R#30	Consequence of high technical barriers from importing countries (R#30)	0.933	0.988	0.922	1
R#17	Low awareness of disease prevention by farmers (R#17)	0.896	0.958	0.858	2
R#01	Pond outside planning area (R#1)	0.966	0.886	0.856	3
R#23	Waste water treatment system is under-invested (R#23)	0.951	0.875	0.832	4
R#09	Epidemic checking for the fingerlings not conducted (R#9)	0.945	0.800	0.756	5
R#10	Over (density) stocking fingerlings (R#10)	0.834	0.889	0.742	6
R#22	Pond water is under-managed (R#22)	0.766	0.916	0.701	7
R#24	Unawareness about community environmental protection (R#24)	0.676	0.994	0.672	8
R#18	Limited knowledge about usage of chemical and medicines (R#18)	0.866	0.726	0.629	9
R#36	Changes in environmental policy (R#36)	0.629	0.995	0.626	10
R#15	High death rate due to disease (R#15)	0.688	0.868	0.597	11
R#31	Costs of operating inputs (R#31)	1.000	0.593	0.593	12
R#40	Technical failure (R#40)	0.600	0.973	0.584	13
R#38	Flood (R#38)	0.631	0.834	0.526	14
R#25	Inappropriate size of harvested fish (R#25)	0.694	0.756	0.524	15
R#33	Under-financing by credits from banks/credit institutions (R#33)	0.801	0.549	0.440	16
R#29	Weak enforcement in conducting sale contract with processors (R#29)	0.840	0.489	0.411	17
R#04	Pond not treated before stocking (R#4)	1.000	0.393	0.393	18
R#35	Changes in government policy on product development strategy (R#35)	0.379	0.945	0.359	19
R#37	Drought (R#37)	0.378	0.875	0.331	20
R#07	Fingerlings infected by diseases (R#7)	0.305	0.974	0.297	21
R#13	Uncontrolled/unstable home-made feed quality (R#13)	0.493	0.590	0.291	22
R#05	Low quality fingerlings (R#5)	0.324	0.865	0.280	23
R#11	Use undersize/oversize fingerlings (R#11)	0.389	0.706	0.274	24
R#39	Fraud (R#39)	0.600	0.446	0.268	25
R#06	Fingerlings from unknown origin (R#6)	0.229	0.903	0.207	26
R#08	Fingerlings treated by anti-biotic during fingerling production process (R#8)	0.213	0.959	0.204	27

Figure 6-11 Table of Levels of Risk (LOR) and Risk Ranks Screen

a. The Table of Levels of Risk and Risk Rank Screen

By default, the Table of Levels of Risk and Risk Ranks will be displayed as a result of clicking the Risk Analysis button in the main screen. The table will display the list of risk factors with their risk characteristics such as Risk ID, Risk Description, Risk Consequence, Risk Likelihood, Level of Risk and Rank. The risks factors are sorted and displayed in descending order by rank (importance) of risk. The smaller the rank number, the more important the risk factor is (see Figure 6-11). From this screen, the user can view the scatter diagram of the risk factors by clicking the View Risk Chart button. Figure 6-12 below presents a screen shot of the Risk Scatter Diagram view.

b. Risk Scatter Diagram Screen

The importance of sources of risk can be viewed in graphical form. The 40 identified sources of risk were plotted in a two-dimensional scatter diagram, with the risk consequence on the horizontal axis and risk likelihood on the vertical axis. Risk factors located in the North-eastern direction are the most important risks. Those risks located in the South-western direction are the least important risks.

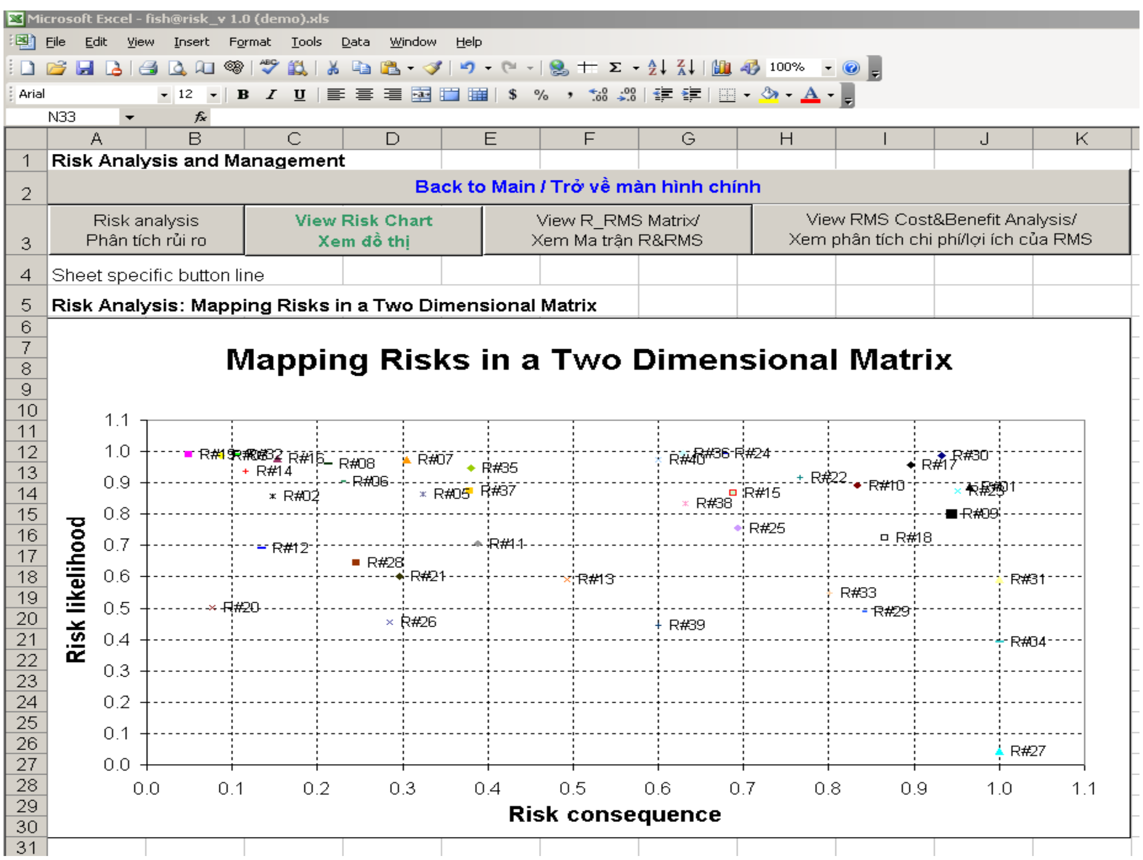
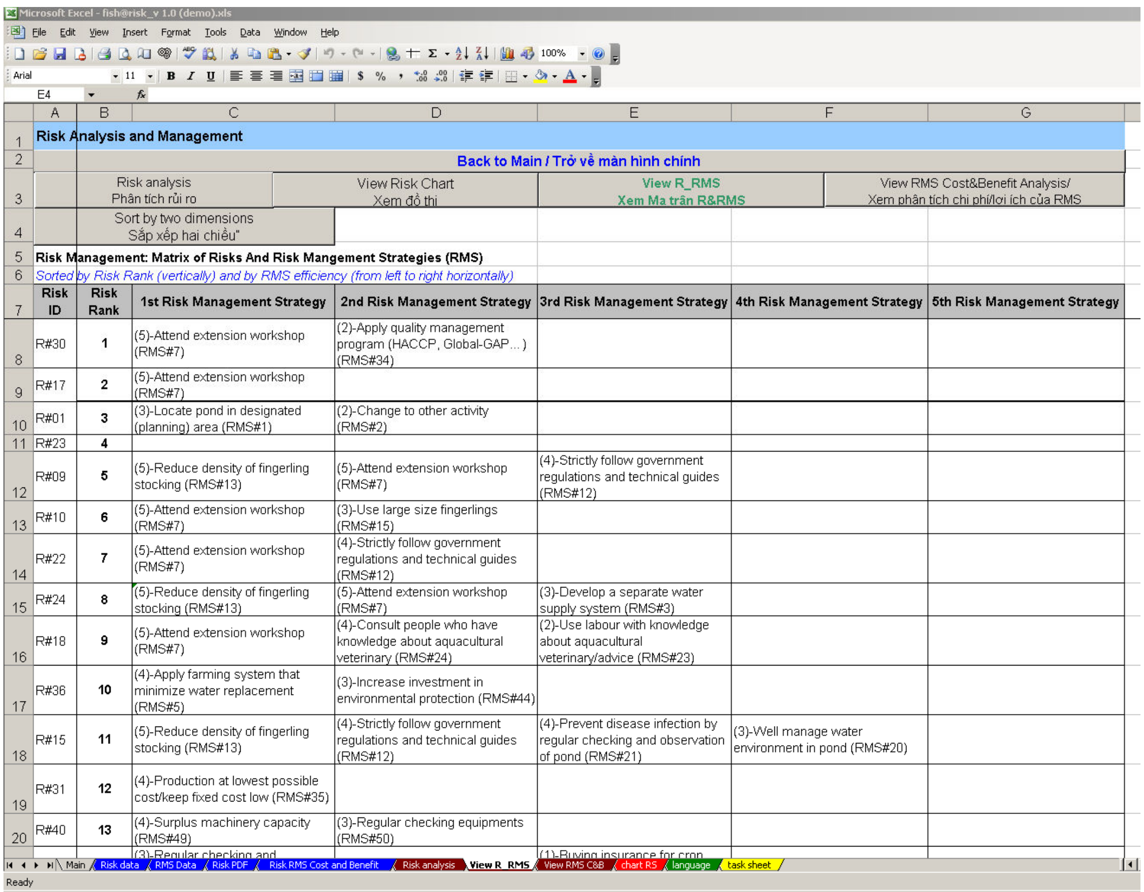


Figure 6-12 Mapping Risks in a Two-Dimensional Matrix

c. Risk and RMS Matrix Display Screen (by Efficacy)

When selecting the third tab in the Risk Analysis and Management screen, the system will display the Risk and RMS Matrix. In this screen, the user can find the corresponding risk management strategies that can be used for a given risk factor. For a given risk factor, the corresponding risk management strategies applicable to the risk are listed in descending order (from left to right) in terms of their efficiency for reducing the risk, as shown in Figure 6-13. The RMS listed in the left is more efficient than those in the right.



Risk Analysis and Management

Back to Main / Trở về màn hình chính

Risk analysis / Phân tích rủi ro | View Risk Chart / Xem đồ thị | View R_RMS / Xem Ma trận R&RMS | View RMS Cost&Benefit Analysis/ Xem phân tích chi phí/lợi ích của RMS

Sort by two dimensions / Sắp xếp hai chiều"

Risk Management: Matrix of Risks And Risk Mangement Strategies (RMS)

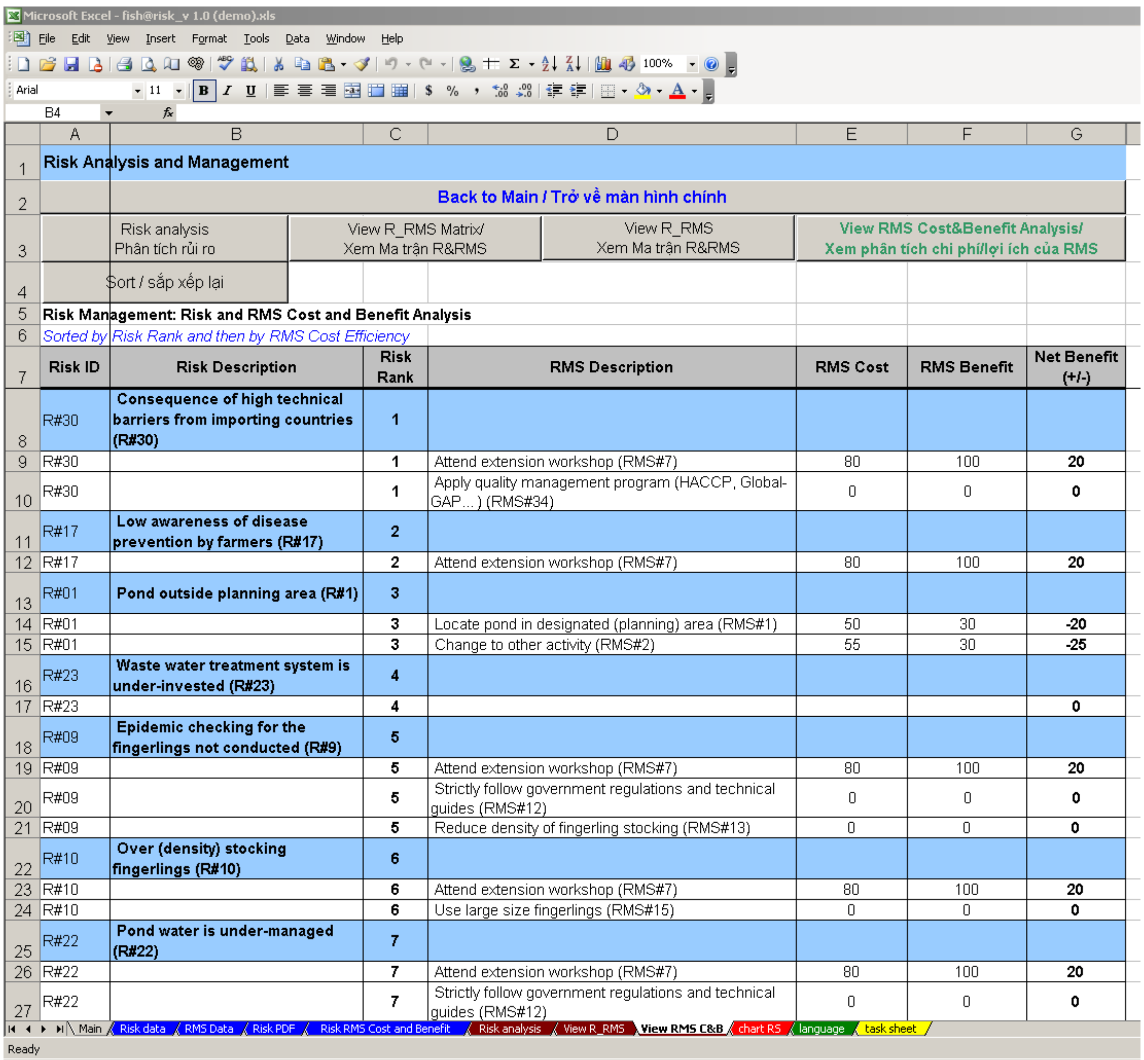
Sorted by Risk Rank (vertically) and by RMS efficiency (from left to right horizontally)

Risk ID	Risk Rank	1st Risk Management Strategy	2nd Risk Management Strategy	3rd Risk Management Strategy	4th Risk Management Strategy	5th Risk Management Strategy
R#30	1	(5)-Attend extension workshop (RMS#7)	(2)-Apply quality management program (HACCP, Global-GAP...) (RMS#34)			
R#17	2	(5)-Attend extension workshop (RMS#7)				
R#01	3	(3)-Locate pond in designated (planning) area (RMS#1)	(2)-Change to other activity (RMS#2)			
R#23	4					
R#09	5	(5)-Reduce density of fingerling stocking (RMS#13)	(5)-Attend extension workshop (RMS#7)	(4)-Strictly follow government regulations and technical guides (RMS#12)		
R#10	6	(5)-Attend extension workshop (RMS#7)	(3)-Use large size fingerlings (RMS#15)			
R#22	7	(5)-Attend extension workshop (RMS#7)	(4)-Strictly follow government regulations and technical guides (RMS#12)			
R#24	8	(5)-Reduce density of fingerling stocking (RMS#13)	(5)-Attend extension workshop (RMS#7)	(3)-Develop a separate water supply system (RMS#3)		
R#18	9	(5)-Attend extension workshop (RMS#7)	(4)-Consult people who have knowledge about aquacultural veterinary (RMS#24)	(2)-Use labour with knowledge about aquacultural veterinary/advice (RMS#23)		
R#36	10	(4)-Apply farming system that minimize water replacement (RMS#5)	(3)-Increase investment in environmental protection (RMS#44)			
R#15	11	(5)-Reduce density of fingerling stocking (RMS#13)	(4)-Strictly follow government regulations and technical guides (RMS#12)	(4)-Prevent disease infection by regular checking and observation of pond (RMS#21)	(3)-Well manage water environment in pond (RMS#20)	
R#31	12	(4)-Production at lowest possible cost/keep fixed cost low (RMS#35)				
R#40	13	(4)-Surplus machinery capacity (RMS#49)	(3)-Regular checking equipments (RMS#50)			
		(3)-Regular checking and		(1)-Buying insurance for crop		

Figure 6-13 Matrix of Risks and RMSs

d. Risk and RMS Matrix Display Screen (by Cost-Benefit Analysis)

In this screen, the RMS cost benefit analysis results will be displayed in a tabular form by a descending order of a risk's rank in terms of risk importance (a larger risk rank value will mean a less important risk). Within each risk factor, the RMS for that risk will be sorted and displayed in descending order in terms of net benefit values. To view the RMS's cost and benefit analysis results, the user can select the last tab in this screen. The matrix of risk and risk management strategies sorted by cost and benefit analysis is shown in Figure 6-14.



Risk ID	Risk Description	Risk Rank	RMS Description	RMS Cost	RMS Benefit	Net Benefit (+/-)
R#30	Consequence of high technical barriers from importing countries (R#30)	1				
R#30		1	Attend extension workshop (RMS#7)	80	100	20
R#30		1	Apply quality management program (HACCP, Global-GAP…) (RMS#34)	0	0	0
R#17	Low awareness of disease prevention by farmers (R#17)	2				
R#17		2	Attend extension workshop (RMS#7)	80	100	20
R#01	Pond outside planning area (R#1)	3				
R#01		3	Locate pond in designated (planning) area (RMS#1)	50	30	-20
R#01		3	Change to other activity (RMS#2)	55	30	-25
R#23	Waste water treatment system is under-invested (R#23)	4				
R#23		4				0
R#09	Epidemic checking for the fingerlings not conducted (R#9)	5				
R#09		5	Attend extension workshop (RMS#7)	80	100	20
R#09		5	Strictly follow government regulations and technical guides (RMS#12)	0	0	0
R#09		5	Reduce density of fingerling stocking (RMS#13)	0	0	0
R#10	Over (density) stocking fingerlings (R#10)	6				
R#10		6	Attend extension workshop (RMS#7)	80	100	20
R#10		6	Use large size fingerlings (RMS#15)	0	0	0
R#22	Pond water is under-managed (R#22)	7				
R#22		7	Attend extension workshop (RMS#7)	80	100	20
R#22		7	Strictly follow government regulations and technical guides (RMS#12)	0	0	0

Figure 6-14 RMS Cost-Benefit Analysis Screen

6.6 Implementation

In the implementing step, the design is coded by a software programmer using Visual Basic for Application (VBA) on the Microsoft Excel platform. The first prototype is an Excel file that includes separated sheets for the DSS main screen, risk data, risk management strategy data, risk probability distribution functions, risk management strategy cost and benefit, risk analysis, view matrix of risk and risk management strategies (by efficacy), view matrix of R&RMS (by net benefit), chart of risks, and a language sheet acting as system dictionary for translating between English and Vietnamese. Several versions of this prototype DSS were developed during the development process to reach the most satisfying prototype. The last version of the prototype will then be introduced to the stakeholders for testing, trying, and evaluating.

6.7 Testing

The prototype DSS was tested for its working logic and correctness of calculations. For the working logic, a hypothetical risk management process was used to test the responses of the system to the specific requirements of the user. The testing results confirmed that the DSS responded correctly to the command requested by the user.

In regard to testing the correctness of calculations, three test cases were developed to test the system. Three randomly selected observations from the survey on perceptions of risks and risk management in Vietnamese catfish farming were used as test cases. The calculations for risk analysis were conducted separately using Microsoft Excel and the DSS. The calculation results from these two platforms were then compared to check the correctness of the DSS calculations. Comparison results confirmed the calculation results conducted by the DSS were completely consistent with those conducted by Microsoft Excel. This suggested the DSS achieved the correctness of the computations we wanted. Details on the comparison of the calculations conducted by DSS and Excel are presented in Appendix E.

6.8 Evaluation

This section used simple descriptive statistics to examine how potential Fish@Risk DSS users evaluate the system. The means and frequencies were used to describe the perceptions of the DSS users about the usefulness, ease of use, and intension to use of the DSS. Table 6-1 depicted the means and the frequencies of user rating on all the items related to performance expectancy, effort expectancy, and behavioural intention.

In regards to the DSS performance expectancy (usefulness), on a 5-point Likert scale, all the items were rated relatively high and well above the medium scale of 3, with means ranging from 3.95 to 4.0. This suggested that the system was considered to be useful to the users. More specifically, the cumulative percentage of rating above 3, which is the medium scale (fair), in items PE1, PE2, PE3, and PE4 were 85.5%, 85.5%, 85.5%, and 89.1% respectively. Only small percentages of the rating were below 3, which were considered as low rating on the usefulness of the system. The percentages of rating below 3 (including 1 and 2) for PE1, PE2, PE3, and PE4 were 3.6%, 1.8%, 5.5%, and 1.8% respectively.

Evaluation of the ease of use of the system was measured by the rating on the items related to effort expectancy variable. All four items in the effort expectancy were also rated well above the medium scale of 3. Specifically, the means of rating on the items of EE1, EE2, EE3, and EE4 were 3.58, 3.69, 3.58, and 3.8, respectively. This can be interpreted as showing that the system is relatively easy to use. Cumulative percentages explained further the positive perceptions of the user to the system's ease of use. The cumulative percentages of the ratings greater than 3 for items EE1, EE2, EE3, and EE4 were 63.6%, 73.7%, 66.3%, and 72.7%. This suggested that the majority of the surveyed users perceived the system as easy to use for risk management. Finally, ratings on the items related to behavioural intention reflected the willingness of the catfish farmers to adopt the Fish@Risk DSS for risk management in their catfish farming.

Table 6-1 Descriptive Statistics of Rating on DSS Usefulness, Ease of Use, and Intention to Use

Items	**Mean**	**Frequency / (Percentage%)**				
		1	2	3	4	5
Performance expectancy						
PE1: I would find the software useful in managing risk in my catfish farming	3.95	0 (0)	2 (3.6)	6 (10.9)	40 (72.7)	7 (12.7)
PE2: Using the software enables me to accomplish risk analysis and risk management	4.00	0	1	7	38	9

Items	Mean	Frequency / (Percentage%)				
		1	2	3	4	5
more quickly		(0)	(1.8)	(12.7)	(69.1)	(16.4)
PE3: Using the software would increase my profit/income by reducing risk	3.96	0 (0)	3 (5.5)	5 (9.1)	38 69.1)	9 (16.4)
PE4: If I use the software, I will increase my chance to get a better income/profit	3.98	0 (0)	1 (1.8)	5 (9.1)	43 (78.2)	6 (10.9)
Effort Expectancy						
EE1: My interaction with the software would be clear and understandable	3.58	0 (0)	8 (14.5)	12 (21.8)	30 (54.5)	5 (9.1)
EE2: It would be easy for me to become skilful at using the software	3.69	4 (7.3)	6 (10.9)	5 (9.1)	28 (50.9)	12 (21.8)
EE3: I would find the software easy to use	3.58	2 (3.6)	7 (12.7)	9 (16.4)	31 (56.4)	6 (10.9)
EE4: Learning to operate the software is easy for me	3.80	0 (0)	5 (9.1)	10 (18.2)	31 (56.4)	9 (10.9)
Behavioural intention						
BI1: When the software is available, then I intend to use the it in the next 2 months	3.58	1 (1.8)	6 10.9)	13 23.6)	30 (54.5)	5 (9.1)
BI2: When the software is available, I predict I would use the it in the next 2 months	3.75	2 (3.6)	2 3.6)	16 (29.1)	23 (41.8)	12 (21.8)
BI3: When the software is available, then I plan to use the it in the next 2 months	3.87	1 (1.8)	4 (7.3)	9 (16.4)	28 (50.9)	13 23.6)

The means of the items reflecting the intention to use the system were relatively high and well above the medium scale of 3, ranging from 3.58 to 3.87. In all items, only less 15% of the rating was below the medium. The cumulative percentages of the rating below 3 for items BI1, BI2, and BI3 were 14.5%, 10.9%, and 10.9%. In contrast, the cumulative percentages for rating above 3 for the items BI1, BI2, and BI3 were 63.6%, 63.6%, and 74.5%, suggesting a relative high chance for adopting the system in the near future. Chapter 8 follows, using a modified UTAUT model, and will present a more rigorous assessment of the influences of factors on the acceptance of the DSS system.

6.9 Summary

The purpose of this chapter was to develop a systematic and quantitative tool that supports the Vietnamese catfish farmers to make decisions on risk management in catfish farming in Vietnam. The proposed system can be used to quantify the levels of risk of all risks that could be involved in catfish farming. Based upon quantifying the levels of risk, a list of risks that need to be treated was suggested as the basis for further treatment or mitigation. With a given risk that needs to be treated, the system will suggest to the system user a set of available risk management strategies to choose from. The user can choose a risk management strategy according to the risk management strategy efficacy or net benefit.

To achieve that goal, the proposed DSS has three main components: a data system, a model system, and a graphical user interface. The data system consists of two main databases: input database and output database. The input database contains four (4) databases of risk input data, risk management strategy data, probability distribution functions for risk consequences and likelihoods, and risk management strategy costs and benefits. The output database also contains four (4) databases to present output results: table of levels of risk, risk scatter diagram, matrix of risk and RMS by RMS efficacy, and matrix of risk and RMS sorted by RMS cost-benefit analysis.

The model system includes all the calculating principles used to conduct a risk management process including risk measuring, risk evaluating, and risk treating. The model system makes use of the input data from the input database together with analysis principles to conduct a risk analysis section and to suggest the best risk management strategies under different selecting criteria.

A simple GUI guides the user through a risk management process by entering necessary inputs, then running the risk analysis, and presenting the risk analysis results, suggesting the best risk management strategies for the user to choose from. To facilitate the interaction between the user and the system, the system has been developed with an ease of use in mind. Visual Basic for Application for Excel has been used to maximize the user's accessibility to computer platform, ease, and familiarity of the user with computers.

The prototype DSS has been developed through several versions before it reached the most satisfied version. The last version of the DSS was then introduced to potential users for trying and testing to get feedback and comments for improvement.

Chapter 7

MODELLING THE ACCEPTANCE OF THE DECISION SUPPORT SYSTEM

7.1 Introduction

The success of an IT innovation is the acceptance and use of that innovation by end users in their real life or work. The Fisk@Risk DSS developed in the previous chapter is not an exception. Validating the acceptance of an IT project ensures project developers focus on users' needs and requirements, both in the development stage and post-introduction stage. This chapter aims to evaluate the acceptance of the DSS developed in Chapter 6 using a modified UTAUT model.

Several theoretical models have been developed to explain the influences that affect the acceptance and use of information technology, as discussed in Chapter 2. The aim of this chapter is to adapt the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. (2003) to explain the impacts of factors on the acceptance of the Fish@Risk DSS by Vietnamese catfish farmers. The model is validated using data collected by means of questionnaire. The survey is administered using a focus group workshop and face-to-face surveys. The reliability of the instrument is validated using item analysis, reliability estimates, content validity, and construct validity. Partial Least Squares technique is used to determine the structural relationship among factors.

7.2 Proposed Model and Hypotheses

To achieve our goal, we adapted the UTAUT model, which is popular in the IS literature, to explain the impacts of influences on the acceptance of our DSS by users in Vietnamese catfish farming industry. Because the Fish@Risk DSS is still at a beta version stage and is introduced to potential users to obtain evaluations for improvement, the model will only aim to evaluate the relationships of the influences and the behavioural intention (intention to use), not the use behaviour (actual use). So the use behaviour variable, which plays as one of the dependent variables in the original UTAUT model, will be left out of the research model.

The original UTAUT model considered performance expectance, effort expectancy, and social influence as direct influences on the behaviour intention (intention to use), whereas gender, age, experience, and voluntariness were assumed to have moderating effects on performance expectancy, effort expectancy, and social influence. In our model, however, besides traditional direct-effect variables such as performance expectancy, effort expectancy, and social influence, we included computer anxiety, self efficacy, and some demographic variables as factors influencing the behaviour intention of the DSS.

We developed a modified UTAUT model as shown in Figure 7-1 to test the hypotheses. The definitions and hypotheses of included factors are described as below.

Performance expectancy (or perceived usefulness) is defined as the degree to which an individual believes that using the system will help him or her to obtain gains in job performance (Davis 1989; Venkatesh et al. 2003). In the UTAUT model, performance expectancy is expected to have a positive direct influence on behaviour intention.

Effort expectancy (or perceived ease of use) is defined as the degree of ease associated with the use of the system (Davis 1989; Venkatesh et al. 2003). Given that definition, effort expectance is expected to have a positive direct effect on behaviour intention. The easier the system is to use the better chance for users to accept the system for use.

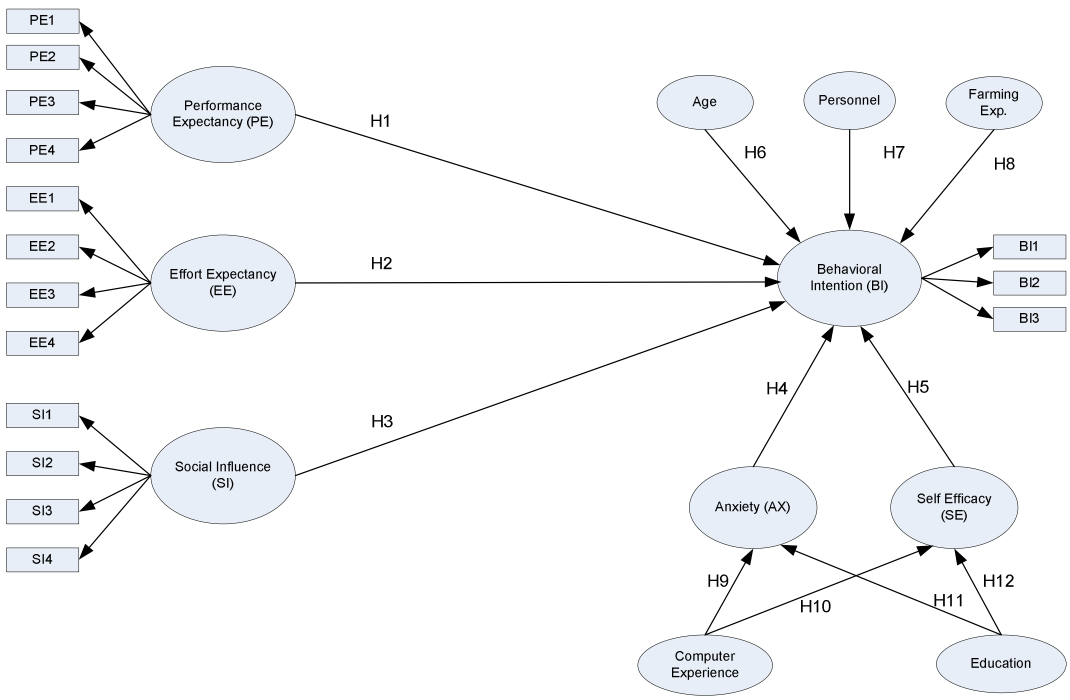


Figure 7-1 Proposed Research Model

Social influence, as defined by Venkatesh et al. (2003), is the degree to which an individual perceives that important others believe he or she should use the system. Therefore it is expected that social influence will have a positive direct impact on behaviour intention to use an IT system

Self efficacy is defined as people's beliefs in their ability to influence events that affect their lives and is considered the foundation of human motivation, performance accomplishments, and emotional well-being (Bandura 2010). In the context of computer utilisation, self efficacy was hypothesised to have impacts on computer anxiety, affect, and use (Compeau, Higgins & Huff 1999). In our study, computer self efficacy is modelled as both an independent and a dependent variable. We hypothesised that computer self efficacy will have a positive impact on behaviour intension. At the same time, computer self efficacy is influenced by some demographic variables such as a user's computer experience and education level. Both users' computer experience and education level are expected to have a positive impact on computer self efficacy.

Computer anxiety is commonly defined as emotional fear, apprehension and phobia felt by individuals towards interactions with computers or towards the thought of using computers (Herdman 1983; Howard & Smith 1986). Although computer anxiety is assumed to be correlated to many other factors, the most three common correlates are age, gender, and computer experience (Chua, Chen & Wong 1999). In our study, computer anxiety is modelled as both an independent and a dependent variable. Thus, computer anxiety is hypothesised to have a direct negative effect on the intention to use the DSS system and to be negatively influenced by the computer experience of the user.

Based on the proposed model, the research hypotheses are stated in Table 7-1.

Table 7-1 Research Hypotheses for the DSS Acceptance Model

Hypotheses	Description
H1	Performance expectation will have a positive impact on user intention to use the IT system
H2	Effort expectancy will have a positive impact on the user intention to use the IT system
H3	Social influence will have a positive impact on the user intention to use the IT system
H4	Anxiety will have a negative impact on the user intention to use the IT system
H5	Self efficacy will have a positive impact on the user behaviour intention to use the IT system
H6	Age will have a negative impact on user intention to use information technology, e.g. the impact is stronger for the younger and weaker for the older
H7	Personality will have a positive impact on the user behaviour intention to use the IT system. One who has higher professional degree tends to use computers more and thus more willing to adopt a new IT innovation
H8	Farming experience is expected to have a positive impact on intention to use the IT system
H9	Computer experience will have a negative impact on computer anxiety
H10	Computer experience will have a positive impact on the computer self efficacy
H11	Education will have a negative impact on computer anxiety
H12	Education will have a positive impact on computer self efficacy

7.3 Development of Survey Instrument

The survey instrument used in this chapter is mainly adapted from Venkatesh et al. (2003) and modified to suit the specific characteristics of Vietnamese catfish farmers in the DSS acceptance. The scales used in the UTAUT models are widely used, validated, and published in many technology acceptance studies. All the scales are described in the following sections.

7.3.1 Measuring Performance Expectancy

A commonly accepted definition of performance expectancy or perceived usefulness, drawn from the literature, is the degree to which an individual believes that using the system will help him or her to attain gains in job performance (Davis 1989). Performance expectancy is recognized differently in different IS theories, i.e., perceived usefulness (TAM, C-TAM-TPB), extrinsic motivation (MM), Job-fit (MPCU), relative advantage (IDT), and outcome expectations (SCT) (Venkatesh et al. 2003). Given the similarity of these five constructs, and in light of this definition, four survey items were written to present the construct of performance expectancy. The four items included:

- (PE1) I would find the software useful in managing risk in my catfish farming
- (PE2) Using the software enables me to accomplish risk analysis and risk management more quickly
- (PE3) Using the software would increase my profit/income by reducing risk
- (PE4) If I use the software, I will increase my chance to get a better income/profit

7.3.2 Measuring Effort Expectancy

Effort expectancy, as commonly accepted in the literature, is the degree of ease associated with the use of the system. This construct is recognized as similar to constructs in previous studies, such as perceived ease of use (TAM/TAM2), complexity (MPCU), and ease of use (IDT). As noted by (Venkatesh et al. 2003), there is substantial similarity among these constructs and measurement scales. In light of this definition and the context of this study, four survey items are developed to represent the construct of effort expectancy:

- (EE1) My interaction with the software would be clear and understandable
- (EE2) It would be easy for me to become skilful at using the software
- (EE3) I would find the software easy to use
- (EE4) Learning to operate the software is easy for me

7.3.3 Measuring Social Influence

Social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh et al. 2003). From the literature, social influence is considered as similar to subjective norms in TAM/TAM2, TPB/DTPB and C-TAM-TPB, social factors in MPCU, and image in IDT. Although these constructs might have different labels and measuring items, each of these constructs represents the influence of how other people think or believe on how he or she should use the new system. Adapted from (Venkatesh et al. 2003), the following four items are developed to represent the construct social influence:

- (SI1) If people who are influencing my behaviour think that I should use the software, then I should use the software
- (SI2) If people who are important to me think that I should use the software, then I should use the software
- (SI3) If the aquacultural extension staff are helpful in the use of the software, then I should use the software
- (SI4) In general, if I have the support for using the software from friends, extension staff, and aquacultural monitoring institutions, then I should use the software

7.3.4 Measuring Computer Anxiety

Computer anxiety is commonly defined as the emotional fear, apprehension, and phobia felt by individuals towards interactions with computers or towards the thought of using computers. Because the construct is well validated in the literature, we adapted the four following items for measuring computer anxiety in our research:

- (AX1) I feel apprehensive (scared) about using the software
- (AX2) It scares me to think that I could lose a lot of information used the software by hitting the wrong key
- (AX3) I hesitate to use the software for fear of making mistakes I cannot correct
- (AX4) The software is somewhat intimidating me

7.3.5 Measuring Computer Self Efficacy

In our study, self efficacy is defined as the user's belief that he/she has the ability and the confidence to conduct a risk analysis and management section using the introduced DSS. Adapted from (Venkatesh et al. 2003), the self efficacy construct was developed and included the following four items:

- (SE1) I could complete a risk analysis and risk management decision using the software, if there was no one around to tell me what to do as I go
- (SE2) I could complete a risk analysis and risk management decision using the software, if I could call someone for help if I got stuck
- (SE3) I could complete a risk analysis and risk management decision using the software, if I have a lot of time to complete the job for which the software was provided
- (SE4) I could complete a risk analysis and risk management decision using the software, if I had just the built-in help facility for assistance

7.3.6 Measuring Demographic Factors Influencing Behavioural Intention

Besides traditional constructs adopted from the UTAUT and SCT models, some demographic variables were also incorporated into our model to account for the influences of demographic factors on behaviour intention. In the context of our study, our model included five demographic variables: age, computer experience, education, personnel, and farming experience. Due to the dominant group of male respondents (90%) and the fact that the use of the DSS is total voluntary (100%), the gender and voluntariness variables were dropped out of the model.

7.3.6.1 Age

Ages of the farm decision makers are classified into five groups, ranging from one (1) to five (5), with 1, 2, 3, 4, and 5 for the group of age of (20-30), (31-35), (36-40), (41-50), and >50, respectively. The estimated coefficients presenting the moderating effects of age are expecting to be negative. This implies that the moderating effects of age on intention to use the DSS will be stronger for the younger users.

7.3.6.2 Computer Experience

In our model, experience is defined as catfish farmer's experience in using a basic personal computer, measured by the time using the computer before being introduced to the system. To measure the user's computer experience, a 5-response Likert scale was employed, with 1: never use before, 2: experience less than 3 months, 3: experience 3-6 months, 4: experience 6-12 months, and 5: experience greater than 1 year. Experience is expected to have a positive effect on behavioural intention, so estimated coefficients of moderating effects by experience are expected to be positive.

7.3.6.3 Education

Education reflects the highest education attained by catfish farm owner. Education was classified into 5 levels corresponding to a 5-point Likert scale, e.g. 1: secondary school or below, 2: high school graduates, 3: professional training, 4: university graduate, and 5: post graduate degree. In our model, education is hypothesised to have a positive impact on self efficacy and a negative impact on computer anxiety.

7.3.6.4 Personnel

The personnel variable captures the type of work that the respondent is doing related to the catfish farming business. There are four work categories is our research, which are measured by a 4-point Likert scale, specifically, 1: catfish farmer, 2: aquaculture extension staff, 3: aquaculture management officer, and 4: aquaculture academic. It is expected that personnel will have a positive impact on behaviour intention to use the DSS because one who is in the higher scored categories tends to have more computer use in their everyday work and thus tends to be more willing to accept a new software system.

7.3.6.5 Farming Experience

Farming experience was included in the research model to measure the impact of the time spent in the catfish farming business on the intention to use or acceptance of the DSS for risk management in their catfish farming. It is expected that an experienced catfish farmer is more likely to recognise the importance of a DSS tool for his/her risk management. Therefore, we expected that farming experience would have a positive impact on intention to use the DSS for risk management. A 4-point Likert scale was also used to measure the experience in catfish farming, e.g. 1: less than 1 year, 2: 2-5 years, 3: 5-10 years, and 4: more than 10 years.

7.3.7 Measuring Behaviour Intention (Intention to Use)

Behaviour intention or intention to use is the degree to which an individual intends to use a system. In our model, behavioural intention is the dependent variable. To represent this construct, the current study used the following three items adapted from Venkatesh et al., (2003):

- (BI1) When the software is available, then I intend to use it in the next 2 months
- (BI2) When the software is available, I predict I would use it in the next 2 months
- (BI3) When the software is available, then I plan to use it in the next 2 months

In total, the survey instrument contained 10 dimensions and 34 items. Most of items used a 5-response Likert scale, ranging from strongly disagree (1) to strongly agree (5). The complete survey questionnaire is included in Appendix B.

7.4 Data Collection

To validate the hypotheses and the conceptual model using a quantitative approach, a questionnaire survey is undertaken. The following subsections present the sampling and the process of conducting the questionnaire survey.

7.4.1 Sampling

As the DSS is developed for risk management in Vietnamese catfish farming, this chapter is focused on catfish farmers and aquacultural staff in the Mekong Delta where all the catfish are produced in Vietnam. Two criteria for sample selection are: (a) the selected sample must represent the research population; and (b) the sample size must be appropriate.

In modelling the acceptance of the DSS, SEM is used to create an acceptance model. The justification for using SEM was presented in chapter 3. When using SEM as a research method, the sample size is an important issue in estimating and interpreting the results (Hair et al. 2006). A sample size of less than 50 would render the chi-square estimator inaccurate (Boomsma 1983). Boomsma suggested that a sample size of 100 or more is suitable to ensure accuracy. In addition, according to Hair et al. (2006), an essential requirement of the sample size is a minimum ratio of at least 5 respondents for each estimated parameter, with a ratio of 10 respondents per parameter being most appropriate.

Owing to the length of time required for an interview and the difficulty in accessing a catfish farmer, a sample of 55 participants is randomly selected in which 45 are catfish farmers and 10 are local aquacultural extension staff or managers. The sample is evenly distributed across three surveying provinces consisting of 15 farmers and 3-4 aquacultural staff for each province.

7.4.2 Questionnaire Survey

A questionnaire survey, which is included in Appendix B, is administrated as a face-to-face survey to obtain a sufficient number of respondents for the study. The survey was conducted in three provinces of An Giang, Dong Thap, and Can Tho in the Mekong Delta, where most of the catfish production in Vietnam takes place.

Prior to the survey, a training section on the Fish@Risk DSS was conducted to 10 local aquacultural staff by the research investigator. In this training section, the research investigator introduced the system, demonstrated the operation of the system, explained all the questions in the survey questionnaire, and made clear all the questions that surveyors may have regarding conducting the survey laterally. After the training session, these local staff were asked to conduct an actual risk analysis and management section using the introduced Fish@Risk DSS as a trial. After the trial finished, these staff were asked to complete the survey questionnaire. The same procedure was applied when the local aquacultural staff conducted the interview sections with catfish farmers. At each province, the study contact collected all the surveys and returned them to the researchers. After data cleaning, all questionnaires were usable and the final number of responses was 55.

7.5 Data Analysis

The research model was assessed by using Partial Least Squares (PLS) technique. SmartPLS 2.0 software (Ringle, Wende & Will 2005) was used to assess the research model. PLS is a least squares regression based technique that can analyse structural models with multiple-item construct with direct and indirect paths. PLS provides all the necessary outputs to assess the measurement and structural models, including loadings between items and constructs, standardized regression coefficients between constructs (path coefficients), R^2 values for dependent constructs. Bootstrapping procedure with the resample of 200 was applied to provide the standard error and the t-statistics of the path coefficients. Given the relatively small sample size for this study, PLS is an appropriate technique to assess the research model since the aim of this study was to assess the impact of performance expectancy, effort expectancy, social influence, and other demographic characteristics on the intention to use the Fish@Risk DSS in catfish farming rather than the overall model appropriateness. In addition, PLS is considered as a robust estimation method with respect to the distributional assumptions regarding the underlying data and tests of normality (Cassel, Hackl & Westlund 1999; Wold 1982).

The measurement model in PLS is assessed in terms of item loadings, internal consistency, and discriminant validity. For construct validity, item loadings and internal consistencies greater than 0.7 (in some cases 0.5 for item loadings) are considered as adequate (Fornell & Larcker 1981; Hair et al. 2006). For discriminant validity, item loadings on their own construct should be higher than on other constructs, and the average variance shared between each construct and its measures should be greater than the average variance shared between the construct and other construct (the squared root of AVE of each construct is greater than all the correlation coefficients with other constructs).

The structural model and hypotheses are tested by examining the standardized path coefficients. The explained variance in the dependent constructs (R^2 values) is assessed as an indication of the overall predictive power of the model.

7.6 Results

The research model was estimated and tested using partial least squares (PLS), a structural equation modelling technique. SmartPLS Version 2.0 (Ringle, Wende & Will 2005) was used for the analysis, and bootstrapping resampling method (200 resamples) was used to obtain the T-statistics for path coefficient hypothesis testing.

7.6.1 Demographics

The 55 catfish farmers were selected to introduce the DSS and collect the data on their ratings about the DSS. The demographic data is shown in Table 7-2. The male respondents made up 89.1%, while the female were 10.9%. This reflected the fact that males were dominant in making decision in Vietnamese catfish farming. More than 50% of the farmers were older than40. More than 70% of the respondents had a high school degree or higher. Only 25.5% of the respondent had a secondary school or lower education level. This indicated that most catfish farmers were well educated. In the survey, 83.6% of the respondents were catfish farmers. The remaining 16% were aquacultural extension staff and officers. More than 70% of the respondents had been in the catfish farming industry for two to 10 years. Experienced catfish farmers who had been in the industry for more than 10 years made up 12.7%. The distribution of the farmers by farm size was quite even, with the percentage of each farm size being 36.4%, 45.5%, and 18.2% for small, medium, and large farm size, respectively.

Table 7-2 Demographics of the Surveyed Farmers

Variables	**Categories**	**Frequency**	**Percentage (%)**
Gender	Male	49	89.1
	Female	6	10.9
Age	< 30	13	23.6
	31-35	4	7.3
	36-40	10	18.2
	41-50	14	25.5
	> 50	14	25.5

Variables	Categories	Frequency	Percentage (%)
Education background	Secondary school or below	14	25.5
	High school	17	30.9
	Professional training	6	10.9
	University graduates	16	29.1
	Post graduate degree	2	3.6
Personnel	Catfish farmer	46	83.6
	Aquacultural extension staff	5	9.1
	Aquacultural management officer	4	7.3
	Aquacultural academic	0	0.0
Farming experience	< 1 year	2	3.6
	2-5 years	19	34.5
	5-10 years	19	34.5
	> 10 years	7	12.7
Farm size	Small (< 5000 m^2)	20	36.4
	Medium (5000-20,000 m^2)	25	45.5
	Large (> 20,000 m^2)	10	18.2

7.6.2 Measurement Model (Reliability and Validity)

Before the structural model is estimated, the measurement model is checked for reliability and validity. The test of the measurement model includes the estimation of internal consistency and the convergent and discriminant validity of the instrument items. Cronbach's alpha coefficient is used to examine the reliability of the survey instrument. The values of alphas range from zero (unreliable) to one (perfect reliable). A value of greater than 0.7 is optimum. However, a value of greater than 0.5 is acceptable, but lower than 0.35 must be rejected (Hair et al. 2006). Table 7-3 lists the survey scales and their internal consistency reliabilities. Most of the Cronbach's Alphas are above 0.7 except effort expectancy (0.690), performance expectancy (0.652), and self efficacy (0.581). These indicate adequate reliabilities of all the constructs used in the model.

Table 7-3 Survey Items and Measurement Properties

Constructs and Items	Cronbach's Alpha	Mean	Std. Deviation
Anxiety (AX)	0.860		
• AX1: I feel apprehensive (scared) about using the software		2.62	1.37
• AX2: It scares me to think that I could lose a lot of information used the software by hitting the wrong key		2.69	1.35
• AX3: I hesitate to use the software for fear of making mistakes I cannot correct		2.76	1.28
• AX4: The software is somewhat intimidating me		2.49	1.36
Age (DE4)	1.000	3.22	1.51
Education background (DE5)	1.000	2.55	1.26
Personnel (DE6)	1.000	1.24	0.58
Framing years (DE7)	1.000	2.27	1.19
Effort Expectancy (EE)	0.690		
• EE1: My interaction with the software would be clear and understandable		3.58	0.85
• EE2: It would be easy for me to become skilful at using the software		3.69	1.15
• EE3: I would find the software easy to use		3.58	0.98
• EE4: Learning to operate the software is easy for me		3.80	0.83
Computer experience (EX)		3.18	1.82
Behaviour Intention (BI)	0.722		
• BI1: When the software is available, then I intend to use it in the next 2 months		3.58	0.88
• BI2: When the software is available, I predict I would use it in the next 2 months		3.75	0.97
• BI3: When the software is available, then I plan to use it in the next 2 months		3.87	0.92
Performance Expectancy (PE)	0.652		
• PE1: I would find the software useful in managing risk in my catfish farming		3.95	0.62
• PE2: Using the software enables me to accomplish risk analysis and risk management more quickly		4.00	0.61
• PE3: Using the software would increase my profit/income by reducing risk		3.96	0.69
• PE4: If I use the software, I will increase my chance to get a better income/profit		3.98	0.53
Self Efficacy (SE)	0.581		
• SE1: I could complete a risk analysis and risk		3.02	1.21

Constructs and Items	Cronbach's Alpha	Mean	Std. Deviation
management decision using the software, if there was no one around to tell me what to do as I go			
• SE2: I could complete a risk analysis and risk management decision using the software, if I could call someone for help if I got stuck		3.65	0.95
• SE3: I could complete a risk analysis and risk management decision using the software, if I have a lot of time to complete the job for which the software was provided		3.64	0.93
• SE4: I could complete a risk analysis and risk management decision using the software, if I had just the built-in help facility for assistance		3.36	0.95
Social Influence (SI)	0.751		
• SI1: If people who are influencing my behaviour think that I should use the software, then I should use the software		3.73	0.85
• SI2: If people who are important to me think that I should use the software, then I should use the software		3.75	0.97
• SI3: If the aquacultural extension staff are helpful in the use of the software, then I should use the software		4.00	0.90
• SI4: In general, if I have the support for using the software from friends, extension staff, and aquacultural monitoring institutions, then I should use the software		4.05	0.85

Convergent validity is adequate when constructs have an average variance extracted (AVE) of at least 0.5 (Fornell & Larcker 1981; Joreskog & Sorbom 1989). For discriminant validity, the square root of AVE for each construct should be greater than the correlation coefficients between the particular constructs and any other constructs (Chin 1998b). Table 7-4 lists the correlations of the latent variables and the square root of AVE on the diagonal. In all cases, the square root of AVE for each construct is greater than 0.5, indicating sufficient convergent validity of the constructs. And in all cases, the square root of AVE is larger than correlation of that construct with all other constructs in the model, indicating adequate discriminant validity for all constructs.

Table 7-4 Correlations of Latent Variables

	AX	DE4	DE5	DE6	DE7	EE	EX	BI	PE	SE	SI
Anxiety (AX)	**0.92**										
Age (DE4)	0.31	**1.00**									
Education (DE5)	-0.38	-0.40	**1.00**								
Personnel (DE6)	-0.28	-0.46	0.51	**1.00**							
Farming years (DE7)	0.12	0.49	-0.41	-0.74	**1.00**						
Effort Expectancy (EE)	-0.28	-0.22	0.42	0.33	-0.31	**0.83**					
Computer Experience (Com. EX)	-0.45	-0.33	0.55	0.35	-0.33	0.42	**1.00**				
Behavioural intention (BI)	-0.35	-0.15	0.08	0.15	0.01	0.44	0.05	**0.85**			
Performance expectancy (PE)	-0.17	-0.09	-0.03	0.03	0.00	0.33	0.03	0.45	**0.81**		
Self Efficacy (SE)	-0.33	-0.31	0.31	0.45	-0.42	0.48	0.43	0.39	0.25	**0.70**	
Social Influence (SI)	-0.16	0.01	0.05	0.01	-0.20	0.41	0.23	0.33	0.13	0.27	**0.86**

Construct validity was further examined by using factor loading analysis. First, items with factor loadings below 0.5 among all factors are to be deleted. Second items with factor loadings of greater than 0.5 and which appear for more than one factor are also deleted. From the testing results, four items were deleted from the following analysis. These items are PE2, EE1, SI1, and SE4. The matrix of loadings and cross loadings of the remaining items is presented in Table 7-5.

Table 7-5 Matrix of Loadings and Cross Loadings

	AX	Age	Education	Personnel	Farming Experience	EE	Com. EX	IN	PE	SE	SI
AX1	**0.930**	0.274	-0.425	-0.283	0.054	-0.237	-0.486	-0.266	-0.085	-0.307	-0.084
AX2	**0.943**	0.271	-0.347	-0.191	0.077	-0.261	-0.424	-0.330	-0.173	-0.332	-0.178
AX3	**0.954**	0.210	-0.345	-0.250	0.104	-0.302	-0.437	-0.346	-0.184	-0.358	-0.275
AX4	**0.882**	0.407	-0.300	-0.316	0.213	-0.222	-0.307	-0.353	-0.200	-0.216	-0.060
Age	0.308	**1.000**	-0.404	-0.464	0.490	-0.222	-0.332	-0.154	-0.088	-0.312	0.008
Education	-0.384	-0.404	**1.000**	0.508	-0.409	0.422	0.547	0.085	-0.030	0.313	0.053
Personnel	-0.278	-0.464	0.508	**1.000**	-0.742	0.331	0.347	0.154	0.030	0.451	0.013
Farming Experience	0.116	0.490	-0.409	-0.742	**1.000**	-0.314	-0.331	0.008	-0.001	-0.421	-0.196
EE2	-0.207	-0.258	0.259	0.224	-0.247	**0.790**	0.275	0.361	0.319	0.523	0.328
EE3	-0.238	-0.037	0.400	0.278	-0.218	**0.844**	0.378	0.416	0.285	0.322	0.371
EE4	-0.243	-0.306	0.392	0.335	-0.338	**0.857**	0.383	0.284	0.200	0.360	0.313
Com. EX (EX)	-0.450	-0.332	0.547	0.347	-0.331	0.415	**1.000**	0.053	0.027	0.427	0.233
IN1	-0.270	-0.280	0.211	0.273	-0.172	0.551	0.072	**0.840**	0.351	0.355	0.227
IN2	-0.359	-0.063	0.177	0.110	0.061	0.354	0.101	**0.867**	0.312	0.330	0.259
IN3	-0.259	-0.059	-0.146	0.023	0.116	0.227	-0.030	**0.842**	0.480	0.302	0.349
PE1	-0.116	-0.066	0.110	0.088	-0.030	0.382	0.091	0.378	**0.788**	0.270	0.064
PE3	-0.190	-0.081	-0.062	-0.024	0.079	0.241	0.020	0.440	**0.882**	0.150	0.070
PE4	-0.080	-0.065	-0.180	0.014	-0.110	0.140	-0.093	0.220	**0.747**	0.222	0.252
SE1	-0.264	-0.367	0.237	0.446	-0.376	0.324	0.327	0.179	0.022	**0.739**	-0.048
SE2	-0.126	-0.218	0.347	0.356	-0.292	0.536	0.317	0.236	0.204	**0.739**	0.102
SE3	-0.347	-0.166	0.157	0.267	-0.309	0.269	0.336	0.427	0.311	**0.808**	0.463
SI2	-0.192	0.013	-0.021	-0.023	-0.131	0.276	0.196	0.246	0.068	0.244	**0.798**
SI3	-0.111	0.014	0.049	0.036	-0.206	0.410	0.169	0.347	0.195	0.255	**0.926**
SI4	-0.139	-0.009	0.110	0.011	-0.161	0.369	0.258	0.249	0.044	0.189	**0.873**

7.6.3 Structural Model (Hypothesis Testing)

The estimation of the structural model includes the estimation of the path coefficients and the R^2 values. Path coefficients indicate the impacts of the independent variables on the dependent variable, while R^2 values represent the amount of variance explained by the independent variables or the overall explanatory power of the model. Together, the R^2 and the path coefficients (loadings and significance) indicate how well the data support the hypothesised model. The path coefficients from the PLS analysis are shown in Figure 7-2. Bootstrapping resampling method (with the resamples of 200) was used to generate the standard errors and the t-statistics.

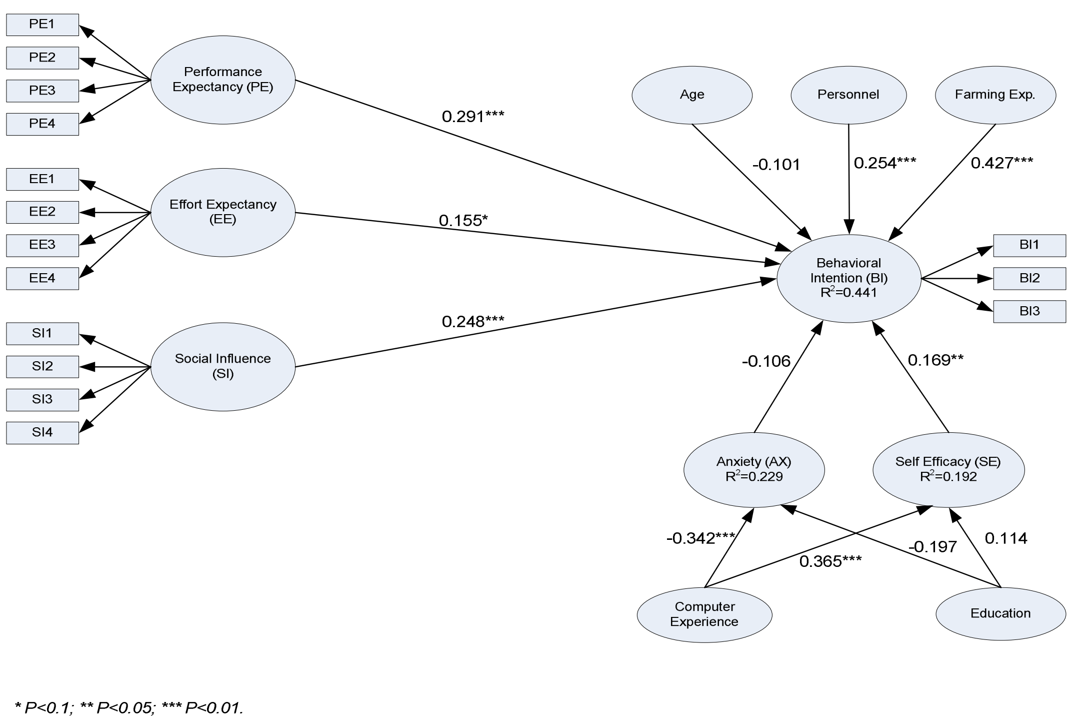


Figure 7-2 Structural Model Result

Overall, the research model explained about 44.1% of the variance in intention to use. In addition, computer experience and education explained about 22.9% of the variance of anxiety and 19.2% of the variance of self efficacy.

As expected, the traditional UTAUT constructs significantly impact on the behavioural intention to use the system, with the path coefficients for performance expectancy, effort expectancy, and social influence being 0.291, 0.155, and 0.248, respectively. Among these three key influences on behaviour intention, performance expectation has the strongest effect. This is consistent with most of other studies in technology acceptance.

Not as expected, anxiety showed no significant impact on intention. However, computer self efficacy had significant impact on the behavioural intention, with the path coefficient of 0.169. In our model, we hypothesised that anxiety is influenced by computer experience and education level of the users. Estimation results showed that computer experience had a strong negative impact on anxiety as expected, with the path coefficient -0.342. However, education level did not have a statistically significant impact on intention to use. Similarly, self efficacy was hypothesised to be influenced by computer experience and education. Again, only computer experience had a positive impact on self efficacy while education showed no impact on self efficacy. Computer experience has a positive and significant indirect impact on behavioural intention via self efficacy (0.365*0.169 = 0.061) and positive but not significant indirect effect via anxiety (-0.342*-0.106 = 0.036). Similarly, education also has positive but not significant indirect effect on behavioural intention via self efficacy (-0.197*-0.106 = 0.020) and anxiety (0.114*0.169 = 0.019).

Other demographic variables such as age, personnel, and farming experience were also included in the research model to capture the impact of user demographic characteristics with respect to the acceptance of technology innovation. The PLS analysis results showed that personnel and farming experience are significantly influential on the intention to use the system, with the path coefficients of 0.245 and 0.427 for personnel and farming experience, respectively. Age of the user, however, has no significant impact on intention to use the system. Table 7-6 summarizes the hypothesis testing results for the research model.

Table 7-6 Results of Hypothesis Testing

Hypotheses	Description	Result
H1	Performance expectation will have a positive impact on user intention to use the IT system	Supported
H2	Effort expectancy will have a positive impact on the user intention to use the IT system	Supported
H3	Social influence will have a positive impact on the user intention to use the IT system	Supported
H4	Anxiety will have a negative impact on the user intention to use the IT system	**Not supported**
H5	Self efficacy will have a positive impact on the user behaviour intention to use the IT system	Supported
H6	Age will have a negative impact on user intention to use information technology	**Not supported**
H7	Personnel will have a positive impact on the user behaviour intention to use the IT system.	Supported
H8	Farming experience is expected to have a positive impact on intention to use the IT system	Supported
H9	Computer experience will have a negative impact on computer anxiety	Supported
H10	Computer experience will have a positive impact on the computer self efficacy	Supported
H11	Education will have a negative impact on computer anxiety	**Not supported**
H12	Education will have a positive impact on computer self efficacy	**Not supported**

7.7 Discussion

This section discusses the consistency and deviation of our main findings as well as the structural differences between this research models in comparison with the general findings of previous studies. The roles of demographic variables are also emphasised. Finally, we discuss some important implications for the practice of developing a DSS for catfish farmers.

7.7.1 Key findings

The findings of this study provide insights into the role of traditional UTAUT factors influencing the intention to use the Fish@Risk DSS for risk management in Vietnamese catfish farming. Performance expectancy, effort expectancy, and social influence are significant influences on behavioural intention. Among these three factors, performance expectancy showed the strongest effect on behavioural intention (0.291) in comparison with effort expectation (0.155) and social influence (0.248).

This implies that end users consider the usefulness (functions) of the system the most important factor affecting their decision in adopting the DSS for risk management. Besides the usefulness, social influence is also found to be an important influence on users' intention to use. Catfish farmers often rely on others, such as friends and aquacultural extension staff, for help on information and technical support. Thus, influence from these people is significant in catfish farmers' decisions regarding their farming management in general, and in using the DSS for risk management, in particular. In this study, we expected that ease of use would play an important role in determining users' intention to use the Fish@Risk system due to their low level of education and computer literacy. The study results showed that ease of use is found to be important in influencing the behavioural intention; the impact, however, is not so strong (0.155). This finding is also consistent with the conclusion from David (1989) that the presence of usefulness will make the effect of ease of use become less significant.

Among the five demographic variables introduced into to the model, only computer experience, personnel, and farming experience showed significant impacts on the behavioural intention. Age and education level of the user had no significant impact on intention to use. In our study, computer experience is hypothesised to have an indirect effect on intention to use, via anxiety and self efficacy. The results showed that computer experience had an important role in affecting the acceptance of the DSS. Higher computer experience significantly reduces the anxiety, which in turn increases the intention to use the DSS. At the same time, computer experience significantly increases user self efficacy (confidence and belief), which in turn, enhances the intention to use of the DSS. This gives us an important implication in practice that training potential users on how to use the system is a crucial factor affecting the success of the system adoption.

7.7.2 Including the Anxiety and Self efficacy

Although anxiety and self efficacy were not included in the original UTAUT model, our study hypothesised them as important influencing factors on intention and further explained them by end users' education and computer experience. We assume that catfish farmers often do not use computers on a regular basis, and consider this as computer illiteracy. It is sensible to hypothesise that they are afraid of using computers in concern about making a mistake. The analysis results, however, showed that anxiety is not an issue in accepting the DSS. Computer popularity nowadays may be the reason for that behaviour and they tend to accept using computers as a normal activity, not a "scared event" anymore. As expected, self efficacy showed a strong impact on intention to use the system. This result is different from Venkatesh et al. (2003), in which self efficacy is assumed to have no impact on both intention and use. The difference between user groups in their study and in this study might the reason for that. In Venkatesk et al. (2003), users are large corporate employees, who often at least have an undergraduate degree and computer proficiency is often a must, whereas in this study, end users are considered as computer illiterate. The level of confidence in using computers and the users' belief on their ability to achieve a job goal by using computer is largely depended on their computer experience. This is confirmed by the significant impact of computer experience on self efficacy, as the result of this study showed.

7.7.3 Eliminating the Mediators

In the UTAUT model, gender, experience, and voluntariness were assumed to have moderating effects on behaviour intention. These moderating effects, however, were not included in our model. In our sample, only six out of 55 respondents are female and account for about 10% of the sample. In developing countries, especially in rural areas, the decision maker in a household is often male and thus the proportion of males and females in our survey is quite unevenly distributed. So we decided to remove the gender variable from the model. The introduction of our Fish@Risk DSS to Vietnamese catfish farmers is totally on a voluntary basic, so voluntariness also dropped out of the model. In our study, catfish farmers were asked to complete the survey questionnaires within an hour after the system was introduced to them to let them explore the system on their own. Due to our time restriction, we cannot conduct the survey for the second time to capture the change in experience and its effect on intention to use the system. Thus, experience about the DSS was also left out of our research model.

7.7.4 Implications for Practice

Key findings of this study suggest some important implications in practice. Firstly, catfish farmers are concerned more about the usefulness of the DSS than the ease of use and other system characteristics. This pattern of effect is consistent with the finding from the research done by Davis (1989), in which he concluded the prominence of usefulness over ease of use in technology behaviour. This suggested that we should pay more attention to improving the usefulness of the DSS in later versions. Secondly, computer experience and self efficacy play important roles in affecting catfish farmers' intention to use the risk management DSS. Thus, training on the DSS will have a significant impact on the success of the DSS adoption. In the context of Vietnamese catfish farming, this activity can be achieved through the aquacultural extension network, which currently provides technical support on aquacultural farming issues to catfish farmers. In addition, user manuals and built-in help components will further enhance catfish farmers' self efficacy in using the DSS and thus increase intention to use the system.

7.8 Summary

This study used a modified UTAUT model to test the hypotheses on the influences of performance expectancy, effort expectancy, social influence, and some other demographic variables on intention to use the Fish@Risk DSS, which is still under a development process, for Vietnamese catfish farming. The study results confirm the role of the three key UTAUT model constructs in affecting behavioural intention. Among demographic variables, computer experience, personnel, and farming experience showed significant impacts on intention while age and education did not. Computer experience has a significant indirect impact on intention via self efficacy, which is shown to have a positive direct impact on behavioural intention to use the system.

The study results suggest some important implications for practice and future research. For practice, in developing the DSS, we need to pay significant attention to the usefulness of the system because this is the most important characteristic affecting catfish farmers' acceptance of the system. In addition, training on how to use the system, as well as system documentation and built-in help components, will enhance the chances of success for adopting the system in practice. For future research, alternative research models can be developed to explore all possible relationships of these factors to behavioural intention and use. Multiple time surveys should be conducted to capture the changes in users' perceptions about the DSS in studies. A web-based and GIS integrated version of the DSS may increase the accessibility and spatial analysis of the system.

Chapter 8

CONCLUSION

8.1 Introduction

In a risky business environment, a risk management framework that allows Vietnamese catfish farmers to manage risks in their catfish farming is an obvious need. This framework will enable Vietnamese catfish farmers to manage risks systematically and efficiently. There are many risks factors involved in the catfish farming process. Identifying sources of risks and appropriate risk management strategies is important in reducing losses to catfish farmers. The developed risk management framework will provide Vietnamese catfish farmers with a tool to mitigate risks in a systematic and efficient way.

The aim of this research is to develop a risk management framework for Vietnamese catfish farming. Three research objectives were proposed: (1) to examine the perceptions of risks and risk management in Vietnamese catfish farming and the relationships between these perceptions and farm socioeconomic characteristics; (2) to develop a risk management framework for Vietnamese catfish farming; and (3) to develop a decision support system (DSS) as an implementing tool for risk management in Vietnamese catfish farming.

To address the research objectives, different statistical techniques were used for different analysing purposes, including simple descriptive statistics, factor analysis, multivariate regression, business process modelling, and structural equation modelling. In analysing the development of the Vietnamese catfish industry in the past decade, simple descriptive statistics and graphs were used to describe the change and fluctuation of main indicators of the industry over time. Exploratory factor analysis and multivariate regression techniques were used to examine the influences of catfish farm socioeconomic characteristics on the perceptions of risks and risk management in Vietnamese catfish farming. To develop the risk management framework, a business process model for Vietnamese catfish farming was first developed. The general risk management framework (based on AS/NZS 4360:2004) was then applied to the Vietnamese catfish farming process to develop the risk management framework. Based on the developed risk management framework, a DSS was the built as an implementing tool for risk management in practice. A system approach was used in developing the DSS. The system consists of three main components: a data system, a model system, and a graphical user interface. With ease of use and accessibility in mind, Visual Basic for Application on Excel platform was used to develop the system. Last, we developed a modified UTAUT model to evaluate the acceptance of the DSS for risk management in Vietnamese catfish farming. The model was assessed using PLS technique. SmartPLS version 2.0 was used to assess both measurement and structural models.

8.2 Thesis Summary

To achieve the objectives of this research, the research was conducted in four separate phases. In phase 1, we examined the perceptions of risks and risk management in Vietnamese catfish farming. The results of this phase provided empirical insights about how Vietnamese catfish farmers perceived risks and risk management in their catfish farming, taking into account the differences in farm socioeconomic characteristics. Understanding risks and risk management is an important factor for the success of applying risk management strategies to mitigate risks. Exploratory factor analysis and multivariate regression techniques were used to achieve the research objective. Phase 2 aimed to develop a risk management framework for Vietnamese catfish farming. Seven steps of risk management process, based on the AS/NZS 4360: 2004 risk management standard, were applied on the catfish business process model to develop the risk management framework. Phase 3 of the research aimed at developing a DSS as a tool facilitating the implementing of the risk management in Vietnamese catfish farming. Last, the evaluation of the acceptance of the DSS for risk management was assessed in phase 4 of the study. The details of these four phases are described in the following sections.

As an introduction to the development of the Vietnamese catfish industry, some major indicators for the development of the industry were analysed to provide a general picture of the current state of the industry. When analysing the development of the Vietnamese catfish industry, secondary data from MARD and VASEP were used. Time series data on Vietnamese catfish production, prices, exports, and input markets were analysed to describe the trends and fluctuations of the industry in the past decade. Based on the industry analysis, the opportunities, challenges, and risk issues facing the industry were derived. The findings of this phase provided information on the industry vulnerability that leads to the need for developing a risk protection tool for the industry.

Analysis results showed that production and exports of Vietnamese catfish has grown rapidly in the period of 1997-2008. The annual growth rate of total catfish production during this period was 40.23%. Export volume and values of Vietnamese catfish also experienced a phenomenal increase in the period of 2000-2007, an increase of 561 times in export volume and 377 times in export values within a period of seven years. The farm-gate price of catfish, however, showed a difficulty for Vietnamese catfish farmers. While the current price continued to increase over time, the real farm-gate price decreased significantly over the period 1997-2008. This was a direct effect of high inflation in Vietnam during this period. In addition, the average export price of Vietnamese catfish decreased constantly over the period 2000-2007. It decreased by 33% from its highest price of USD 3.87 per kilogram in 2000 to USD 2.53 per kilogram in 2007. This decreasing trend of export prices were considered as a major reason for the decreasing profitability the of Vietnamese catfish industry.

Phase 1 of this research aimed to provide empirical insights about perceptions of risks and risk management in Vietnamese catfish farming. Descriptive statistics methods were used to evaluate Vietnamese catfish farmers' perceptions of risk and risk management. Exploratory factor analysis and multivariate regression techniques were used to assess the relationships between the perceptions of risks and risk management with farm socioeconomic characteristics. Data used for this analysis were collected by a face-to-face survey of 261 catfish farmers in the Mekong Delta. The results revealed that, in general, price and production risks were perceived as the most import sources of risk. However, price risk reduction strategies such as sale contracts, insurance and diversification were not perceived as relevant strategies for price risk management. Instead, catfish farmers perceived farm management, disease prevention and selecting good quality inputs (such as water source, feed and fingerlings) as the most relevant risk management strategies.

In terms of the relationships between perceptions of risk and farm and farmer socioeconomic characteristics, farmers from medium- and large-scale farms were more concerned about the potential impact of disease, environment and production risks than are those from small farms. Younger farmers also showed more concern about disease and environmental risks than did older farmers. However, education was found to have no significant impact on the perceptions of risk in catfish farming. Consultancy had an important impact on farmers' perceptions of pond location and natural risks. Experienced farmers perceived natural and legislation risks as significant.

Farm management and extension/education were perceived as more relevant and important risk management strategies among farmers from medium- and large-scale farms. Insurance and diversification were not considered to be relevant risk management tools among farmers from across the range of farm sizes, age, education levels, farming experience, and gender differences. The impact of extension/education on risk management was highly valued by farmers from large-scale farms, experienced farmers and female farm heads.

In regards to developing the risk management framework, a business process modelling technique was first used to identify all the sources of risks and associated risk management strategies available for risk mitigation. Forty sources of risk and 50 risk management strategies were defined in this step of phase 2. The general risk management framework adopted from AS/NZS 4360:2004 was then applied on the business process model to develop the risk management framework for Vietnamese catfish farming. The framework enables catfish farmers to manage sources of risks and risk management systematically and efficiently. Specifically, the framework allows users to measure, to rank, and to prioritise the risks for treatment. The framework also allows users to select the optimal risk management strategies based on the efficacy of risk management strategies or based on the cost-efficient criteria.

Phase 3 of this research aimed to develop a DSS as an implementing tool for risk management in Vietnamese catfish farming. The proposed DSS has three main components: a data system, a model system, and a graphical user interface. The data system consists of two main databases: input database and output database. The model system included all the calculating principles used to conduct a risk management process including risk measuring, risk evaluating, and risk treating. The model system makes use of the input data from the input database together with analysis principles to conduct a risk analysis section and suggest the best risk management strategies under different selecting criteria. The graphical user interface facilitates the interaction between the user and the system, allowing the user to conduct a risk management process including managing input data, running the risk analysis, presenting the risk analysis results, and suggesting the best risk management strategies for the user to choose from. Given the ease of use of the system in mind, Visual Basic for Application on Excel platform has been used to develop the system.

The last phase of this research (phase 4) was aimed to evaluate the acceptance of the DSS for risk management in Vietnamese catfish farming. A modified UTAUT model was used to assess the influences of conventional UTAUT variables and other demographic variables on the acceptance of the DSS for risk management. Data collected from a fresh face-to-face survey of 45 catfish farmers and 10 aquacultural staff was used to assess the model. PLS technique was used to estimate the measurement and structural model, using SmartPLS V2.0 software. Our results revealed that traditional UTAUT variables are important factors influencing the intention to use of the DSS. Performance expectancy, effort expectancy, and social influence showed significant influences on the behavioural intention. Among these three factors, performance expectancy showed the strongest effect on the behavioural intention (0.291). The path coefficients for effort expectation and social influence were (0.155) and (0.248), respectively.

Among the five demographic variables introduced into to the model, only computer experience, personnel, and farming experience showed significant impacts on the behavioural intention. The age and education level of the user had no significant impact on intention to use. In our study, computer experience is hypothesised to have an indirect effect on intention to use, via anxiety and self efficacy. The results showed that computer experience had an important role in affecting the acceptance of the DSS. Higher computer experience significantly reduced computer anxiety, which in turn increased the intention to use of the DSS. In addition, computer experience significantly increased user self efficacy (confidence and belief), which in turn, enhanced the intention to use of the DSS for risk management.

8.3 Research Contributions

The purpose of this research is to develop a risk management framework for risk management in Vietnamese catfish farming. This research provides a theoretical and practical basic for the development and implementation of a risk management framework that could enhance Vietnamese catfish farmers' ability in dealing with risks in their catfish farming. The research has three main research objectives: (1) analysing the development of the Vietnamese catfish industry in the past decade; (2) to develop a risk management framework for Vietnamese catfish farming; and (3) to develop a DSS as an implementing tool for risk management in Vietnamese catfish farming.

When analysing the development of the Vietnamese catfish industry, we provide a general picture about the current situation of the industry. This research contributes to the policy makers' information on industry opportunities and challenges, upon which policy makers can shape development policy that helps to achieve the sustainability of the industry.

Understanding how Vietnamese catfish farmers perceive risks and risk management plays an important role in ensuring the success of the development of a risk management framework for Vietnamese catfish farming. In this regard, by examining the perceptions of risks and risk management, this research contributes to providing empirical insights about how Vietnamese catfish farm perceive risks and risk management in their catfish farming.

In regard to developing the risk management framework, a combination of Business Process Modelling (BPM) and Risk Management Process (RPM) is used to identify all the possible risks and risk management strategies that can occur along all stages of the whole production process. Business process modelling and risk management process are well known in business and risk management fields, but have not yet been applied in a combined way to study risk management in agriculture or aquaculture in general, and in catfish farming in particular. This contribution is marked by an innovative approach by using BPM in combination with general risk management process to develop a risk management framework for Vietnamese catfish farming.

Based on the developed risk management framework, a decision support system (DSS) for risk management in Vietnamese catfish farming has been built. The DSS is developed as an implementing tool for actual risk management activity in catfish farming. This research can thus contribute to practical aspects of research activity. Specifically, the product (DSS) of this research can be introduced and transferred to catfish farmers for use in practice. This makes the research practically useful.

In addition, by using SEM to assess the acceptance of the DSS for risk management in Vietnamese catfish farming, some importance conclusions can be derived from the model. Besides traditional variables from the UTAUT model being important influences to behaviour intention, demographic factors also played an important role in accepting the DSS. Computer experience, for example, showed significant impacts in reducing computer anxiety and enhancing self efficacy, which in turn increases behaviour intention. The result of the research contributes to the practical aspects of developing the DSS. To be successful in developing and introducing the DSS for risk management in Vietnamese catfish farming, training on how to use the system plays an important role in increasing the acceptance of the product.

8.4 Limitations of the Research

Despite the contributions of the research, this research has limitations in relation to the scope of the data and methodology used to achieve the research objectives.

The data used to evaluate the perceptions of risk and risk management were limited in scope because they consisted only of data collected from the three provinces of Can Tho, An Giang, and Dong Thap in the Mekong Delta. This limit was acceptable in terms of representation of catfish farmer population as these three provinces represented more than 80% of the total catfish output in the country.

Owing to time and cost limitations, the data used for calculating the costs and benefits of applying risk management strategies was collected from only ten in-depth interviews with catfish farmers. This limit, however, was acceptable in terms of achieving the research objective, which was to illustrate how the risk management framework and the DSS can incorporate the information on the costs and benefits of applying a risk management strategy to the system. In addition, not all catfish farmers applied the same risk management strategies in the same way. Therefore there was no common outline for identifying cost and benefit items in applying a risk management strategy. Taking into account the diversity of this practice, the framework and the DSS have been optionally designed and leave the system open to the end users for data entering.

In conducting the modelling acceptance of the DSS for risk management, there were two limitations on the data. One limitation of this data was the relative small sample size, consisting of 55 observations used for the estimation. To reduce the negative impacts of the small sample size on the estimation results, PLS technique was used. The advantage of the PLS technique over other tradition SEM methods is assumed to be distributional insensitive.

The other limitation of the data relates to the distribution of the data by gender. Only three out of 55 observations were female farm decision makers. Therefore, the impact of the gender difference has not been considered in the model. In addition, again owing the cost and time limitations, the data used for this modelling was collected at only one time point. This limits the potential users of the DSS to get acquaintance with the system. The data should be collected repeatedly after a certain time intervals such as one or two months after introducing the system to the users. A longer time horizon will allow the potential DSS users to get to know the system better, which might increase positive attitudes about behaviour intention to use the system.

8.5 Suggestions for Future Research

Risk management frameworks have been developed and applied extensively in construction, manufacturing, transportation, banking, and health care, to name just a few, but to a far lesser extent in agriculture and aquaculture. This research could be considered as pioneer work in developing a framework that can systematically manage the risks and the risk management in a highly risky business such as catfish farming. Although the framework and the DSS were originally developed for Vietnamese catfish farming, it can be generalised and adapted to other aquacultural activities or products. For possible future research, it is first suggested that researchers can adapt and modify the framework created in this research to apply to other aquacultural products produced in Vietnam, such as shrimp, tilapia, and snakehead fish, as well as for use in other countries in the region such as Thailand, Indonesia, and Malaysia.

This research aimed to develop a risk management framework for intensive catfish farming in Vietnam. Another question raised by this research is: would the same risk management framework be applied to other types of catfish farming such as semi-intensive and extensive (ecological) catfish farming? Under other types of catfish farming, sources of risk and risk management strategies might have different impacts and importance. Thus these differences may need to be examined using the framework created in this research.

An interesting result of the findings related to the perceptions of risks and risk management. Although Vietnamese catfish farmers perceived market and price risks (such as price variability, market accessibility) as the most important sources of risk, they did not perceived market and price risk mitigation measures (for instance, sale contract and insurance) as important strategies. So we may ask: what are the reasons why Vietnamese catfish farmers do not rely on market and price risk mitigation measures for protecting their income and profit? Would the market for crop insurance be underdeveloped? Are the market conditions unfavourable for catfish farmers? Further research on the fresh catfish market structure is suggested.

Lastly, the DSS built in this research has been developed using Visual Basic for Application on an Excel platform. This approach aims at providing the catfish farmers with a tool that can easily used on a home personal computer with a minimum configuration and IT knowledge requirements. However, this limits the accessibility of the system. Thus, it is recommended that, in the future, researchers can upgrade the system on a web-based basic. This will increase the number of potential users to access the system and to input data updating. A GIS-integrated DSS will add spatial aspects to the system for a more useful application.

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APPENDIX A

SURVEY QUESTIONNAIRE 1
Project: Risk Management Framework for Vietnamese Catfish Farming
Component: Perceptions of Risk and Risk Management in Vietnamese Catfish Farming

PART I: General information of the farm

1. Name of interviewee: . . . .
2. Address: (ward) . . . .(village) . . . .
   (district). . . . . (province). . . . .
3. Age: . . . .
4. Sex: . . . 1. Male . . . . 2. Female . . . .
5. Education level. . . . .(years) . . . .
6. Number of years in catfish farming: . . . . (years)
7. Total area of catfish ponds. . .. .………..(m^2)
8. Number of ponds/cages currently operated: . . . .
9. Do you get any technical support or consultancy from outside?
   1: Yes 0: No
10. If yes, which ones of the following are the sources of supports
    a. Local extension service
    b. Local input suppliers
    c. Processors
    d. Friends/relatives
    e. Others (please specify) . . . .
11. How did you sell your catfish in the last crop (% of total output)?
    a. Directly to processors under contract with a predetermined price (. . . . . . .%)
    b. Directly to processors under contract without a predetermined price (. . . . . %)
    c. Directly to processors without a contract . . . . (. . . . . .%)
    d. To collectors/wholesalers . . .. (. . . . . . .%)
    e. Others (please specify) . . . . (. . . . . .%)

12. What was your actual yield per hectare and selling price for your catfish of the last five years?

Year	Actual yield (tons/ha)	Price (VND/kg)

2003		
2004		
2005		
2006		
2007		

13. For your catfish crop over the last five years, please indicate the largest fluctuation from your five year average.

	Item	***Check (X) only 1 percentage range for each item.***				
		< 10 %	10-24 %	25-49 %	50-74 %	75-100 %
a.	Annual yield per ha					
b.	Annual average price					
c.	Profit *(after deducting production and marketing expenses from revenue)*					

14. What was the main cause of your lowest profit from your catfish production over the last five years?

	Causes	***(Please check (X)only one box)***
a.	Poor yield per ha/cage	
b.	Poor quality	
c.	High input cost	
d.	Low market price	
e.	Inability to market the output	
f.	Other (specify)	

PART II: Information about sources of risks in catfish farming

15. How often do these factors occur in your fish farming activities(from 1: almost never to 5:very often)

	Factors	*(please circle only one degree for each factor)*				
a.	Farm site is appropriately selected	1	2	3	4	5
b.	Lack of Water supply	1	2	3	4	5
c.	Low quality of water supply	1	2	3	4	5
d.	Low quality of fingerlings	1	2	3	4	5
e.	Not enough fingerling supply	1	2	3	4	5
f.	Breakdown of the live support system	1	2	3	4	5
g.	Disease	1	2	3	4	5
h.	Input price fluctuation	1	2	3	4	5
i.	Output price fluctuation	1	2	3	4	5
j.	Adverse temperature (heat, frost, etc.)	1	2	3	4	5
k.	Flood	1	2	3	4	5
l.	Drought	1	2	3	4	5

In the following questions, please indicate the significance and the frequency of the following risk factors on your farm income

For consequences, (from 1 to 5) 1: indicates least significant to 5: most significant impacts on your farm income

For frequency, (from 1 to 5) 1: indicates rarely happen to 5: almost certain

16. R1: The consequence(significance) and frequency of risk factors related to pond location and pond preparation

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
R1.1	Pond located outside the planning area		
R1.2	Pond located nearby residency area		
R1.3	Pond doesn't have a separated water treating and drain system		
R1.4	Do not treat the pond before fingerling stocking		

17. R2: The consequence(significance) and frequency of risk factors related to fingerlings

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
R2.1	Low quality of fingerlings (not healthy)		
R2.2	Fingerlings with unknown origin		
	Fingerlings infected by diseases		
	Fingerlings treated by antibiotics during fingerling production process		
	Do not conduct epidemic checking for the fingerlings		
	Over (density) stocking fingerlings		
	Use undersize/oversize fingerlings		

18. R3: The consequence(significance) and frequency of risk factors related to feed and feeding

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Low quality of feed		
	Uncontrolled/unstable homemade feed quality		
	Overfeeding cause pollution and waste accumulation		

19. R4: The consequence(significance) and frequency of risk factors related to disease

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	High dead rate due to disease		
	Inability to control uncontrolled disease sources		
	Low awareness of disease prevention by farmers		

20. R5: The consequence(significance) and frequency of risk factors related to the use chemical, antibiotics, and medicines

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Limited knowledge about usage of chemical and medicines		
	Applying chemical and medicines improperly		
	Use of prohibited chemical and medicines		
	Using wrong source of consultancy in using chemical and medicines		

21. R6: The consequence(significance) and frequency of risk factors related to aquacultural and community environment

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Farm have no reserved area for waste water and mud treatment		
	Pond water is under-managed		
	Waste water treatment system is under-invested		
	Unawareness about community environmental protection		

22. R7: The consequence(significance) and frequency of risk factors related to harvesting activity

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Inappropriate size of harvested fish		
	Harvesting without checking for residuals of chemical, antibiotics, and medicines in fish body		
	Inappropriate method of harvesting causes reduction of		

	fish quality and weight		
	Fish yield variability		

23. R8: The consequence(significance) and frequency of risk factors related to Marketing

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Fish price variability		
	Inaccessibility to the market		
	Weak enforcement in conducting sale contract with processors		
	High technical barriers from importing countries		
	Low market price and demand due to anti-dumping trials		
	High costs of operating inputs		
	Costs of hired labour		
	Changes in consumer preferences		

24. R9: The consequence(significance) and frequency of risk factors related to financial issues

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Under financing by own capital for the whole crop cycle		
	Under financing by credits from banks/credit institutions		
	High interest rate for loans		
	High inflation rate		
	Credit availability		

25. R10: The consequence(significance) and frequency of risk factors related to policy issues

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Changes in government policy on product development strategy		

	Changes in regulations on food safety and product hygiene		
	Changes in environmental policy		
	Changes in tax policy		

26. R11: The consequence(significance) and frequency of risk factors related to natural risks

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Drought		
	Flood		
	Polluted water		
	Disease infected water supply		
	Lack of water supply		

27. R12: The consequence(significance) and frequency of other risk factors

Variable	Risk Factors	Consequences (1-5)	Frequency (1-5)
	Technical failure		
	Live support system break-down		
	Death/disability of farm operator		
	Family relation		

PART III: Information about risk management strategies in your catfish farming

In the following questions, please evaluate the effectiveness of applying risk management strategies in protecting your crop and income (from 1: not effective at all to 5: highly effective)

28. RM1: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to pond location and pond preparation

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Pond located outside the planning area	Locate pond in designated (planning) area		RM1.1.1
	Change to other activity		RM1.1.2
			RM1.1.3
Pond located nearby residency area	Develop a separated water supply system		
	Regular checking quality of supply water		
Pond doesn't have a separated water treating and drain system	Develop a separated water supply system		
	Apply farming system that minimize water replacement		
Do not treat the pond before fingerling stocking	Strictly treat the pond before stocking		
	Attending extension workshop		

29. RM2: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to fingerlings

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Low quality of fingerlings (not healthy)	Select good fingerlings		
	Buy fingerlings from reliable places		
Fingerlings with unknown origin	Only buy fingerlings from certified producers		

Fingerlings infected by diseases	Only buy fingerlings that have complete production documents		
	Careful checking the fingerlings when buying		
Fingerlings treated by antibiotics during fingerling production process	Only buy fingerlings that have complete production documents		
	Careful checking the fingerlings when buying		
Over (density) stocking fingerlings	Attending extension workshop		
	strictly follow farming technical guide		
	reduce density of fingerling stocking		
Use undersize fingerlings	Attending extension workshop		
	Use large size fingerlings		

30. RM3: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to feed and feeding

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Low quality of feed	Choose the good brand for feed		
	Buying feed from reliable place		
	Checking for prohibited substances (hormone, chemicals)		
Uncontrolled/unstable homemade feed quality	Attending extension workshop		
Overfeeding cause pollution and waste accumulation	Use only factory made (pallet) feed		
	Strictly follow technical guide		

	Attending extension workshop		

31. RM4: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to disease

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
High dead rate due to disease	Well manage water environment in pond		
	Apply medicines and chemicals to protect fingerlings as guided		
	preventing disease infection by regular checking and observation pond		
	Reduce density of fingerling stocking		
Inability to control uncontrolled disease sources	Regular checking and treating water in fish pond		
	Develop aquacultural water treatment pond		
Low awareness of disease prevention by farmers	Attending extension workshop		

32. RM5: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to the use of chemicals, antibiotics, and medicines

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Limited knowledge about usage of chemical and medicines	Attending extension workshop		
	Use labours with knowledge about aquacultural veterinary		
Applying chemical and medicines improperly	Attending extension workshop		
	Use labours with knowledge about aquacultural veterinary		

Use of prohibited chemical and medicines	Strictly follow government regulations on chemical and medicine use in aquaculture		
	Attending extension workshop		
Using wrong source of consultancy in using chemical and medicines	Use labours with knowledge about aquacultural veterinary		
	Consult people who have knowledge about aquacultural veterinary		
	Attending extension workshop		

33. RM6: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to aquacultural and community environment

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Farm have no reserved area for waste water and mud treatment	Spend a certain area for waste water and mud treatment		
Pond water is under-managed	Strictly follow technical guide on water management		
	Attending extension workshop		
Unawareness about community environmental protection	Attending extension workshop		
	Reduce fingerling stocking		
	Develop separated system for aquacultural water and domestic use water		

34. RM7: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to harvesting

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Inappropriate size of	Production contract with		

harvested fish	predetermined size of harvest fish		
	Collect information about favourable size from processors		
Harvesting without checking for residuals of chemical, antibiotics, and medicines in fish body	Careful checking for residuals of chemicals, antibiotics, and medicines		
Inappropriate method of harvesting causes reduction of fish quality and weight	Attending extension workshop		
	Sale contract with processor		

35. RM8: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to marketing activities

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Fish price variability	Sale contract with processors		
	Vertical integration (be a member in fish association that process the fish itself)		
	Enterprise diversification		
	Cooperative marketing		
	Off-farm work		
Yield variability	Production contract with processor		
	Buying insurance for crop		
	Strictly follow technical process in farming		
	Off-farm work		
Weak enforcement in conducting sale contract with processors			
High technical barriers from importing countries	Applying international recognized quality management standards (HACCP, SQF, BMP, Global GAP)		

	Attending extension workshop in food safety and hygiene regulations		
High production costs	Production at lowest possible cost		
	Keep fixed cost low		
High costs of hired labour	Sign long-term contract with labours		
	Use home labours		
Changes in consumer preferences	Collecting information on consumer preferences		
	Product Diversification		

36. RM9: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to Financial issues

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Under financing by own capital for the whole crop cycle	Reduce farm size to appropriate scale		
	Increase solvency ratio		
Under financing by credits from banks/credit institutions	Make credit arrangement before cropping		
	Solvency–debt management		
High interest rate for loans	Use economic consultant services		
High inflation rate			
Low credit availability	Keep enough cash in hand (liquidity)		
	Share ownership of equipment, partnership		

37. RM10: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to changes government policies

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Changes in government policy on product development strategy	Follow government development strategy		
Changes in regulations on food safety and product hygiene	Apply new technology in production		
	Apply quality management program (HACCP, Global-GAP…)		
Changes in environmental policy	Increase investment in environmental protection		

38. RM11: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to natural risks

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Drought/Lack of water supply	Buy crop insurance		
	Choose location nearby good water supply sources		
	Spatial diversification		
Flood	Regular checking and enforcing the dyke		
	Buy crop insurance		
	Spatial diversification		
Fire	Buy crop insurance		
Fraud	Buy crop insurance		
	Maintain good relationship with labours and community		

39. RM12: Please indicate the effectiveness of the following risk management strategies in controlling risk factors related to other risk factors

Risk Factors	Risk management strategies	Effectiveness (1-5)	Variable
Technical failure	Surplus machinery capacity		
	Regular checking production process		
Live support system break-down	Surplus machinery capacity		
	Regular checking live support system		
Death/disability of farm operator	By personal insurance		
Family relation			

APPENDIX B

SURVEY QUESTIONNAIRE 2
Project: Risk Management Framework for Vietnamese Catfish Farming
Component: Fish@Risk DSS User Acceptance Evaluation

Investigator: Cong Tru Le
School of Business IT and Logistics
RMIT University, Melbourne, Australia

PART A: Demography Variables

1. DE1: Your full name . . . .

2. DE2: Address: Village. . . . . , District . . . . , Province . . . .

3. DE3: Gender: Male . . . . , Female . . . .

4. DE4: Age: 20-30 . . . .
   31-35 . . . .
   36-40 . . . .
   41-50 . . . .
   > 50 . . . .

5. DE5: Educational background
   1. Secondary school or below
   2. High school graduates
   3. Professional training
   4. University graduates
   5. Post-graduate degree

6. DE6: Personnel:
   1. Catfish farmer
   2. Aquaculture Extension Staff
   3. Aquaculture Management Officer
   4. Aquaculture Academic

7. DE7: Years of catfish farming:
   1. Less than 1 years
   2. 2-5 years
   3. 5-10 years
   4. > 10 years

8. DE8: Farm size:
   1. Less than 5,000 m^2 (small farm size)
   2. 5000 m^2 – 20,000 m^2 (medium farm size)
   3. Greater than 20,000 m^2 (large farm size)

(Please continue on next page)

PART B: DSS Software Acceptance Validation

Please circle the number that best describes your agreement or disagreement with each statement bellow:

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

9. Performance Expectancy (PE)[a] : the degree to which an individual believes that using the software will help him or her to attain gains in job performance

Item	**Item Description**	**1**	**2**	**3**	**4**	**5**
PE1	I would find the software useful in managing risk in my catfish farming	1	2	3	4	5
PE2	Using the software enables me to accomplish risk analysis and risk management more quickly	1	2	3	4	5
PE3	Using the software would increase my profit/income by reducing risk	1	2	3	4	5
PE4	If I use the software, I will increase my chance to get a better income/profit	1	2	3	4	5

10. Effort Expectancy (EE)[a]: the degree of ease associate with use of the software

Item	**Item Description**	**1**	**2**	**3**	**4**	**5**
EE1	My interaction with the software would be clear and understandable	1	2	3	4	5
EE2	It would be easy for me to become skilful at using the software	1	2	3	4	5
EE3	I would find the software easy to use	1	2	3	4	5
EE4	Learning to operate the software is easy for me	1	2	3	4	5

11. Attitude toward using technology (AT): The degree to which an individual feels about the software in their work

Item	**Item Description**	**1**	**2**	**3**	**4**	**5**

AT1	Using the software is a good idea	1	2	3	4	5
AT2	The software makes work more interesting	1	2	3	4	5
AT3	Working with the software is fun	1	2	3	4	5
AT4	I like working with the software	1	2	3	4	5

12. Social influence (SI): the degree to which an individual perceives that important others believe he or she should use the software.

Item	Item Description	1	2	3	4	5
SI1	If people who are influencing my behaviour think that I should use the software, then I should use the software	1	2	3	4	5
SI2	If people who are important to me think that I should use the software, then I should use the software	1	2	3	4	5
SI3	If the aquacultural extension staff are helpful in the use of the software, then I should use the software	1	2	3	4	5
SI4	In general, if I have the support for using the software from friends, extension staff, and aquacultural monitoring institutions, then I should use the software	1	2	3	4	5

13. Facilitating conditions (FC): the degree to which an individual believes that an organization and technical infrastructure exists to support use of the software

Item	Item Description	1	2	3	4	5
FC1	I have the resources necessary to use the software	1	2	3	4	5
FC2	I have the knowledge necessary to use the software	1	2	3	4	5
FC3	The software is compatible with other software I use	1	2	3	4	5
FC4	I think that I will have someone (children, friends, extension staff, …) assisting me with the use of software when I have difficulties using the software	1	2	3	4	5

14. Voluntariness (VO): The degree to which use of IT is perceived as voluntary or free will.

Item	Item Description	1	2	3	4	5
VO1	For me, the use of the software is totally voluntary	1	2	3	4	5
VO2	Although it might be helpful, using the software is certainly not compulsory in my job	1	2	3	4	5

15. Experience (EX)[b] =IT experience. Please describe your experience level in using computer.

(5 points scale: 1: experience=never use before, 2: experience < 3 months, 3: experience 3-6 months, 4: experience 6 – 12 months, and 5: experience > 1 year).

Item	Item Description	1	2	3	4	5
EX1	How long ago did you start to use a computer	1	2	3	4	5
		1	2	3	4	5

16. Self Efficacy (SE)

Item	Item Description	1	2	3	4	5
SE1	I could complete a risk analysis and risk management decision using the software, if there was no one around to tell me what to do as I go	1	2	3	4	5
SE2	I could complete a risk analysis and risk management decision using the software, if I could call someone for help if I got stuck	1	2	3	4	5
SE3	I could complete a risk analysis and risk management decision using the software, if I have a lot of time to complete the job for which the software was provided	1	2	3	4	5
SE4	I could complete a risk analysis and risk management decision using the software, if I had just the built-in help facility for assistance	1	2	3	4	5

17. Anxiety (AX)

Item	Item Description	1	2	3	4	5
AX1	I feel apprehensive (scared) about using the software	1	2	3	4	5
AX2	It scares me to think that I could lose a lot of information used the software by hitting the wrong key	1	2	3	4	5
AX3	I hesitate to use the software for fear of making mistakes I cannot correct	1	2	3	4	5
AX4	The software is somewhat intimidating me	1	2	3	4	5

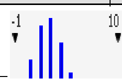
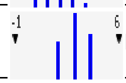
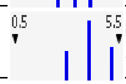
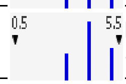
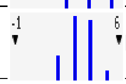
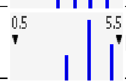
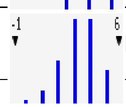
18. Intention to Use (IN) = the degree to which an individual intend to use the software

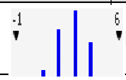
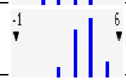
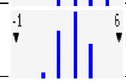
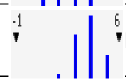
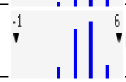
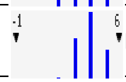
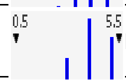
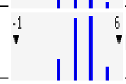
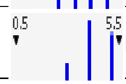
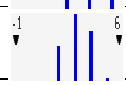
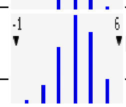
Item	Item Description	1	2	3	4	5
IN1	When the software is available, then I intend to use the it in the next 2 months	1	2	3	4	5
IN2	When the software is available, I predict I would use the it in the next 2 months	1	2	3	4	5
IN3	When the software is available, then I plan to use the it in the next 2 months	1	2	3	4	5

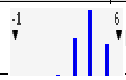
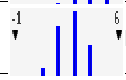
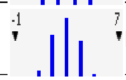
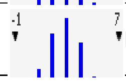
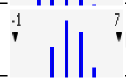
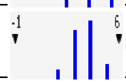
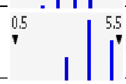
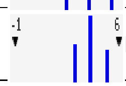
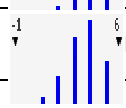
Thank you very much for your collaboration!

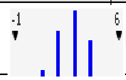
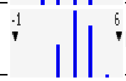
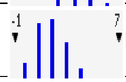
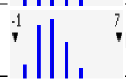
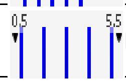
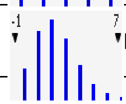
APPENDIX C

Discrete Probability Distribution Functions for Risk Consequences

ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#1	R1.1.c	AT267		RiskBinomial(9,0.31849,RiskName("R1.1.c"))	0	2.86641	9	3	1.397672	0.2597319
R#2	R1.2.c	AV267		RiskBinomial(7,0.40842,RiskName("R1.2.c"))	0	2.85894	7	3	1.300497	0.1408385
R#3	R1.3.c	AX267		RiskBinomial(5,0.6,RiskName("R1.3.c"))	0	3	5	3	1.095445	-0.1825742
R#4	R1.4.c	AZ267		RiskBinomial(5,0.76694,RiskName("Dataset #12"))	0	3.8347	5	4	0.9453651	-0.5647342
R#5	R2.1.c	BN267		RiskBinomial(5,0.77077,RiskName("R2.1.c-Dataset #28"))	0	3.85385	5	4	0.9399032	-0.5761657
R#6	R2.2.c	BP267		RiskBinomial(5,0.65401,RiskName("R2.2.c"))	0	3.27005	5	3	1.063675	-0.2895809
R#7	R2.3.c	BR267		RiskBinomial(5,0.77951,RiskName("R2.3.c"))	0	3.89755	5	4	0.9270225	-0.6030274
R#8	R2.4.c	BT267		RiskBinomial(5,0.66468,RiskName("R2.4.c"))	0	3.3234	5	3	1.055653	-0.3119966

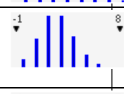
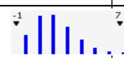
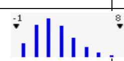
ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#9	R2.5.c	BV267		RiskBinomial(5,0.56077,RiskName("R2.5.c"))	0	2.80385	5	3	1.109746	-0.1095206
R#10	R2.6.c	BX267		RiskBinomial(5,0.69801,RiskName("R2.6.c"))	0	3.49005	5	4	1.026626	-0.3857492
R#11	R2.7.c	BZ267		RiskBinomial(5,0.56032,RiskName("R2.7.c"))	0	2.8016	5	3	1.109868	-0.1086976
R#12	R3.1.c	CB267		RiskBinomial(5,0.72314,RiskName("R3.1.c"))	0	3.6157	5	4	1.000521	-0.4460475
R#13	R3.2.c	CD267		RiskBinomial(5,0.6896,RiskName("R3.2.c"))	0	3.448	5	4	1.034533	-0.3665421
R#14	R3.3.c	CF267		RiskBinomial(5,0.73902,RiskName("R3.3.c"))	0	3.6951	5	4	0.9820118	-0.4867966
R#15	R4.1.c	CH267		RiskBinomial(5,0.79222,RiskName("R4.1.c"))	0	3.9611	5	4	0.907214	-0.644214
R#16	R4.2.c	CJ267		RiskBinomial(5,0.70734,RiskName("R4.2.c"))	0	3.5367	5	4	1.017374	-0.4075982
R#17	R4.3.c	CL267		RiskBinomial(5,0.63636,RiskName("R4.3.c"))	0	3.1818	5	3	1.075653	-0.253539
R#18	R5.1.c	CN267		RiskBinomial(5,0.66899,RiskName("R5.1.c"))	0	3.34495	5	4	1.052241	-0.3212001
R#19	R5.2.c	CP267		RiskBinomial(5,0.81116,RiskName("R5.2.c"))	0	4.0558	5	4	0.8751556	-0.7110964
R#20	R5.3.c	CR267		RiskBinomial(5,0.61478,RiskName("R5.3.c"))	0	3.0739	5	3	1.088176	-0.2109585
R#21	R6.1.c	CT267		RiskBinomial(5,0.61255,RiskName("R6.1.c"))	0	3.06275	5	3	1.08934	-0.2066388

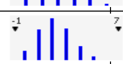
ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#22	R6.2.c	CV267		RiskBinomial(5,0.74806,RiskName("R6.2.c"))	0	3.7403	5	4	0.9707375	-0.5110754
R#23	R6.3.c	CX267		RiskBinomial(5,0.54703,RiskName("R6.3.c"))	0	2.73515	5	3	1.113077	-0.0845045
R#24	R6.4.c	CZ267		RiskBinomial(6,0.48949,RiskName("R6.4.c"))	0	2.93694	6	3	1.224474	0.0171666
R#25	R7.1.c	DB267		RiskBinomial(6,0.47957,RiskName("R7.1.c"))	0	2.87742	6	3	1.223722	0.0333899
R#26	R7.2.c	DD267		RiskBinomial(6,0.53243,RiskName("R7.2.c"))	0	3.19458	6	3	1.222166	-0.0530697
R#27	R8.1.c	DF267		RiskBinomial(5,0.89808,RiskName("R8.1.c"))	0	4.4904	5	5	0.6765069	-1.176869
R#28	R8.2.c	DH267		RiskBinomial(5,0.80863,RiskName("R8.2.c"))	0	4.04315	5	4	0.8796236	-0.701732
R#29	R8.3.c	DJ267		RiskBinomial(5,0.69323,RiskName("R8.3.c"))	0	3.46615	5	4	1.03117	-0.3747783
R#30	R8.4.c	DL267		RiskBinomial(5,0.58291,RiskName("R8.4.c"))	0	2.91455	5	3	1.102556	-0.150396
R#31	R8.5.c	DN267		RiskBinomial(5,0.78902,RiskName("R8.5.c"))	0	3.9451	5	4	0.9123251	-0.6335899
R#32	R9.1.c	DP267		RiskBinomial(5,0.74922,RiskName("R9.1.c"))	0	3.7461	5	4	0.9692507	-0.5142529
R#33	R9.2.c	DR267		RiskBinomial(5,0.72408,RiskName("R9.2.c"))	0	3.6204	5	4	0.9994702	-0.4483975
R#34	R9.3.c	DT267		RiskBinomial(5,0.71417,RiskName("R9.3.c"))	0	3.57085	5	4	1.010275	-0.4239835

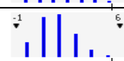
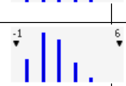
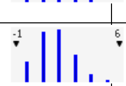
ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#35	R10.1.c	BB267		RiskBinomial(5,0.56525,RiskName("R10.1.c"))	0	2.82625	5	3	1.108473	-0.1177295
R#36	R10.2.c	BD267		RiskBinomial(5,0.61949,RiskName("R10.2.c"))	0	3.09745	5	3	1.085638	-0.2201286
R#37	R11.1.c	BF267		RiskPoisson(2.105,RiskName("Dataset #18"))	0	2.105	+∞	2	1.450862	0.6892455
R#38	R11.2.c	BH267		RiskPoisson(2.1674,RiskName("Dataset #20"))	0	2.1674	+∞	2	1.472209	0.6792513
R#39	R11.3.c	BJ267		RiskIntUniform(1,5,RiskName("Dataset #22"))	1	3	5	1	1.414214	0
R#40	R11.4.c	BL267		RiskPoisson(2.2839,RiskName("Dataset #24"))	0	2.2839	+∞	2	1.511258	0.6617005

APPENDIX D

Discrete Probability Distribution Functions for Risk Likelihoods

ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#1	R1.1.p	AU267		RiskBinomial(16,0.16687,RiskName("R1.1.p"))	0	2.66992	16	2	1.491439	0.4467229
R#2	R1.2.p	AW267		RiskPoisson(1.9907,RiskName("R1.2.p"))	0	1.9907	+∞	1	1.410922	0.7087566
R#3	R1.3.p	AY267		RiskBinomial(7,0.37508,RiskName("Dataset #11"))	0	2.62556	7	3	1.280923	0.1950468
R#4	R1.4.p	BA267		RiskPoisson(2.0482,RiskName("Dataset #13"))	0	2.0482	+∞	2	1.431153	0.6987371
R#5	R2.1.p	BO267		RiskBinomial(5,0.45339,RiskName("R2.1.p-Dataset #28"))	0	2.26695	5	2	1.113165	0.0837432
R#6	R2.2.p	BQ267		RiskPoisson(2.4112,RiskName("R2.2.p"))	0	2.4112	+∞	2	1.552804	0.6439963
R#7	R2.3.p	BS267		RiskBinomial(6,0.36048,RiskName("R2.3.p"))	0	2.16288	6	2	1.176097	0.2372593
R#8	R2.4.p	BU267		RiskBinomial(6,0.39944,RiskName("R2.4.p"))	0	2.39664	6	2	1.199719	0.1676392
R#9	R2.5.p	BW267		RiskIntUniform(1,5,RiskName("R2.5.p"))	1	3	5	1	1.414214	0
R#10	R2.6.p	BY267		RiskBinomial(5,0.42832,RiskName("R2.6.p"))	0	2.1416	5	2	1.106485	0.1295634

ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#11	R2.7.p	CA267		RiskBinomial(5,0.38643,RiskName("R2.7.p"))	0	1.93215	5	2	1.088811	0.2086129
R#12	R3.1.p	CC267		RiskBinomial(5,0.39539,RiskName("R3.1.p"))	0	1.97695	5	2	1.09329	0.1913673
R#13	R3.2.p	CE267		RiskBinomial(6,0.37798,RiskName("R3.2.p"))	0	2.26788	6	2	1.187715	0.2054702
R#14	R3.3.p	CG267		RiskPoisson(2.1096,RiskName("R3.3.p"))	0	2.1096	+∞	2	1.452446	0.6884937
R#15	R4.1.p	CI267		RiskBinomial(6,0.36338,RiskName("R4.1.p"))	0	2.18028	6	2	1.178138	0.2319252
R#16	R4.2.p	CK267		RiskBinomial(6,0.34829,RiskName("R4.2.p"))	0	2.08974	6	2	1.167007	0.2599985
R#17	R4.3.p	CM267		RiskPoisson(1.8802,RiskName("R4.3.p"))	0	1.8802	+∞	1	1.371204	0.7292862
R#18	R5.1.p	CO267		RiskBinomial(5,0.37425,RiskName("R5.1.p"))	0	1.87125	5	2	1.082097	0.232419
R#19	R5.2.p	CQ267		RiskBinomial(10,0.14631,RiskName("R5.2.p"))	0	1.4631	10	1	1.117602	0.6329446
R#20	R5.3.p	CS267		RiskPoisson(1.6731,RiskName("R5.3.p"))	0	1.6731	+∞	1	1.293484	0.773106
R#21	R6.1.p	CU267		RiskIntUniform(1,5,RiskName("R6.1.p"))	1	3	5	1	1.414214	0
R#22	R6.2.p	CW267		RiskBinomial(5,0.39655,RiskName("R6.2.p"))	0	1.98275	5	2	1.093842	0.1891498
R#23	R6.3.p	CY267		RiskBinomial(6,0.35726,RiskName("R6.3.p"))	0	2.14356	6	2	1.173777	0.2432149
R#24	R6.4.p	DA267		RiskBinomial(5,0.35736,RiskName("R6.4.p"))	0	1.7868	5	2	1.071573	0.2662254
R#25	R7.1.p	DC267		RiskBinomial(5,0.35574,RiskName("R7.1.p"))	0	1.7787	5	2	1.070488	0.2695219
R#26	R7.2.p	DE267		RiskBinomial(5,0.33562,RiskName("R7.2.p"))	0	1.6781	5	2	1.055886	0.3113593
R#27	R8.1.p	DG267		RiskBinomial(5,0.67029,RiskName("R8.1.p"))	0	3.35145	5	4	1.051193	-0.3239938
R#28	R8.2.p	DI267		RiskBinomial(6,0.35193,RiskName("R8.2.p"))	0	2.11158	6	2	1.169808	0.2531526

ID	Name	Cell	Graph	Function	Min	Mean	Max	Mode	Std Dev	Skewness
R#29	R8.3.p	DK267		RiskBinomial(5,0.50614,RiskName("R8.3.p"))	0	2.5307	5	3	1.11795	-0.0109844
R#30	R8.4.p	DM267		RiskBinomial(5,0.40971,RiskName("R8.4.p"))	0	2.04855	5	2	1.099654	0.1642153
R#31	R8.5.p	DO267		RiskBinomial(5,0.63896,RiskName("R8.5.p"))	0	3.1948	5	3	1.073988	-0.2587738
R#32	R9.1.p	DQ267		RiskBinomial(6,0.4594,RiskName("R9.1.p"))	0	2.7564	6	3	1.220701	0.0665192
R#33	R9.2.p	DS267		RiskBinomial(5,0.47421,RiskName("R9.2.p"))	0	2.37105	5	2	1.116546	0.0461961
R#34	R9.3.p	DU267		RiskBinomial(6,0.40807,RiskName("R9.3.p"))	0	2.44842	6	2	1.203866	0.1527246
R#35	R10.1.p	BC267		RiskBinomial(5,0.35094,RiskName("R10.1.p"))	0	1.7547	5	2	1.067195	0.2793491
R#36	R10.2.p	BE267		RiskBinomial(5,0.35,RiskName("Dataset #17"))	0	1.75	5	2	1.066536	0.2812843
R#37	R11.1.p	BG267		RiskBinomial(5,0.26974,RiskName("Dataset #19"))	0	1.3487	5	1	0.9924221	0.4640364
R#38	R11.2.p	BI267		RiskBinomial(5,0.30256,RiskName("Dataset #21"))	0	1.5128	5	1	1.027174	0.3844333
R#39	R11.3.p	BK267		RiskBinomial(5,0.34095,RiskName("Dataset #23"))	0	1.70475	5	2	1.05996	0.3001056
R#40	R11.4.p	BM267		RiskBinomial(4,0.4064,RiskName("Dataset #25"))	0	1.6256	4	2	0.9823218	0.1905689

APPENDIX E

DSS Testing Results

1. Input Data from three test cases

Risk ID	Risk Description	Case 1 (5000m2) Obs. 14		Case 2 (12000m2) Obs. 170		Case 3(72000m2) Obs. 223	
		Cons.	Likelihood	Cons.	Likelihood	Cons.	Likelihood
R#01	Pond outside planning area (R#1)	1	5	3	1	4	2
R#02	Pond nearby residence (R#2)	1	1	1	2	3	2
R#03	Pond does not have waste treatment system (R#3)	3	1	4	5	5	5
R#04	Pond not treated before stocking (R#4)	4	1	4	4	5	1
R#05	Low quality fingerlings (R#5)	4	1	5	3	3	3
R#06	Fingerlings from unknown origin (R#6)	4	1	2	2	3	3
R#07	Fingerlings infected by diseases (R#7)	4	1	5	2	4	2
R#08	Fingerlings treated by antibiotic during fingerling production process (R#8)	1	1	4	3	2	2
R#09	Epidemic checking for the fingerlings not conducted (R#9)	1	1	3	2	3	3
R#10	Over (density) stocking fingerlings (R#10)	4	1	4	3	4	1
R#11	Use undersize/oversize fingerlings (R#11)	4	1	3	2	2	1
R#12	Low quality of feed (R#12)	4	1	4	2	4	1
R#13	Uncontrolled/unstable homemade feed quality (R#13)	1	1	4	1	4	1
R#14	Overfeeding causing pollution and waste accumulation (R#14)	4	1	4	2	4	1
R#15	High death rate due to disease (R#15)	2	1	5	4	4	2
R#16	Inability to control diseases from environmental sources	4	1	4	4	5	2

Risk ID	Risk Description	Case 1 (5000m2) Obs. 14		Case 2 (12000m2) Obs. 170		Case 3(72000m2) Obs. 223	
		Cons.	Likelihood	Cons.	Likelihood	Cons.	Likelihood
	(R#16)						
R#17	Low awareness of disease prevention by farmers (R#17)	3	1	4	4	4	2
R#18	Limited knowledge about usage of chemical and medicines (R#18)	4	1	4	1	3	1
R#19	Use of prohibited chemical and medicines (R#19)	3	1	5	1	5	1
R#20	Applying chemical and medicines improperly (R#20)	1	1	4	2	4	2
R#21	Farm have no reserved area for waste water and mud treatment (R#21)	4	5	2	5	3	2
R#22	Pond water is under-managed (R#22)	3	1	4	3	4	1
R#23	Waste water treatment system is under-invested (R#23)	1	1	4	2	3	2
R#24	Unawareness about community environmental protection (R#24)	1	1	5	1	4	2
R#25	Inappropriate size of harvested fish (R#25)	1	2	3	3	3	1
R#26	Inappropriate method of harvesting (R#26)	4	2	2	2	3	1
R#27	Fish price variability (R#27)	5	4	5	4	5	3
R#28	Inaccessibility to the market (R#28)	3	2	5	2	5	1
R#29	Weak enforcement in conducting sale contract with processors (R#29)	3	1	4	4	4	3
R#30	Consequence of high technical barriers from importing countries (R#30)	2	2	4	5	3	3
R#31	High costs of operating inputs (R#31)	4	4	5	5	4	4
R#32	Under-financing by own capital for the whole crop cycle (R#32)	4	4	5	4	1	1
R#33	Under-financing by credits from banks/credit institutions (R#33)	3	2	4	4	1	1
R#34	High interest rate for loans (R#34)	4	3	4	2	1	1
R#35	Changes in government policy on product development strategy (R#35)	2	1	1	1	3	1
R#36	Changes in environmental policy (R#36)	2	1	2	1	3	1
R#37	Drought (R#37)	1	1	3	1	2	1
R#38	Flood (R#38)	1	1	3	1	2	1
R#39	Fraud (R#39)	4	1	4	3	1	1

Risk ID	Risk Description	Case 1 (5000m2) Obs. 14		Case 2 (12000m2) Obs. 170		Case 3(72000m2) Obs. 223	
		Cons.	Likelihood	Cons.	Likelihood	Cons.	Likelihood
R#40	Technical failure (R#40)	1	2	3	2	1	1

2. Levels of Risk (LOR) Calculation: Results from Microsoft Excel

Case 1 (sorted by rank)					Case 2 (sorted by rank)					Case 3 (sorted by rank)				
Risk ID	Cons.	Likelihood	Level of risk	Rank	Risk ID	Cons.	Likelihood	Level of risk	Rank	Risk ID	Cons.	Likelihood	Level of risk	Rank
R#21	0.914	1.000	0.914	1	R#31	1.000	1.000	1.000	1	R#03	1.000	0.987	0.987	1
R#27	1.000	0.865	0.865	2	R#15	1.000	0.974	0.974	2	R#20	0.912	0.764	0.697	2
R#32	0.764	0.924	0.706	3	R#30	0.933	1.000	0.933	3	R#24	0.900	0.754	0.679	3
R#26	0.857	0.787	0.674	4	R#32	1.000	0.924	0.924	4	R#29	0.840	0.805	0.676	4
R#34	0.814	0.810	0.659	5	R#03	0.922	0.987	0.910	5	R#16	1.000	0.651	0.651	5
R#31	0.694	0.894	0.620	6	R#05	1.000	0.865	0.865	6	R#17	0.896	0.709	0.635	6
R#39	0.800	0.446	0.357	7	R#27	1.000	0.865	0.865	7	R#30	0.692	0.905	0.626	7
R#11	0.945	0.361	0.341	8	R#17	0.896	0.958	0.858	8	R#31	0.694	0.894	0.620	8
R#18	0.866	0.383	0.332	9	R#29	0.840	0.967	0.812	9	R#19	1.000	0.558	0.558	9
R#14	0.780	0.377	0.294	10	R#16	0.823	0.978	0.805	10	R#27	1.000	0.532	0.532	10
R#04	0.735	0.393	0.289	11	R#33	0.801	0.976	0.782	11	R#23	0.748	0.632	0.473	11
R#12	0.802	0.345	0.277	12	R#39	0.800	0.951	0.761	12	R#02	0.694	0.679	0.471	12
R#40	0.335	0.813	0.272	13	R#10	0.834	0.889	0.742	13	R#07	0.712	0.626	0.446	13
R#06	0.880	0.306	0.269	14	R#08	0.870	0.822	0.716	14	R#06	0.564	0.776	0.438	14
R#16	0.823	0.323	0.266	15	R#22	0.766	0.916	0.701	15	R#09	0.727	0.600	0.436	15
R#17	0.598	0.439	0.263	16	R#20	0.912	0.764	0.697	16	R#15	0.688	0.621	0.427	16
R#10	0.834	0.290	0.242	17	R#04	0.735	0.943	0.693	17	R#01	0.878	0.486	0.427	17
R#33	0.422	0.549	0.231	18	R#25	0.694	0.943	0.654	18	R#04	1.000	0.393	0.393	18
R#30	0.347	0.666	0.231	19	R#40	0.803	0.813	0.653	19	R#37	0.648	0.591	0.383	19
R#37	0.378	0.591	0.224	20	R#28	1.000	0.643	0.643	20	R#38	0.631	0.523	0.330	20
R#07	0.712	0.300	0.214	21	R#07	1.000	0.626	0.626	21	R#28	1.000	0.316	0.316	21
R#38	0.363	0.523	0.190	22	R#23	0.951	0.632	0.602	22	R#35	0.721	0.427	0.308	22
R#05	0.728	0.251	0.183	23	R#19	1.000	0.558	0.558	23	R#14	0.780	0.377	0.294	23

Case 1 (sorted by rank)					Case 2 (sorted by rank)					Case 3 (sorted by rank)				
Risk ID	Cons.	Likelihood	Level of risk	Rank	Risk ID	Cons.	Likelihood	Level of risk	Rank	Risk ID	Cons.	Likelihood	Level of risk	Rank
R#35	0.379	0.427	0.162	24	R#12	0.802	0.691	0.554	24	R#25	0.694	0.418	0.290	24
R#01	0.166	0.962	0.160	25	R#11	0.729	0.706	0.514	25	R#05	0.324	0.865	0.280	25
R#28	0.245	0.643	0.158	26	R#14	0.780	0.647	0.504	26	R#12	0.802	0.345	0.277	26
R#19	0.240	0.558	0.134	27	R#37	0.838	0.591	0.495	27	R#26	0.594	0.456	0.271	27
R#03	0.663	0.194	0.128	28	R#38	0.826	0.523	0.432	28	R#36	0.629	0.428	0.270	28
R#22	0.371	0.343	0.127	29	R#34	0.814	0.528	0.430	29	R#22	0.766	0.343	0.263	29
R#36	0.285	0.428	0.122	30	R#24	0.986	0.415	0.409	30	R#21	0.641	0.400	0.256	30
R#25	0.130	0.756	0.098	31	R#18	0.866	0.383	0.332	31	R#10	0.834	0.290	0.242	31
R#29	0.486	0.180	0.087	32	R#21	0.296	1.000	0.296	32	R#13	0.844	0.269	0.227	32
R#02	0.148	0.409	0.060	33	R#09	0.727	0.400	0.291	33	R#18	0.535	0.383	0.205	33
R#24	0.120	0.415	0.050	34	R#13	0.844	0.269	0.227	34	R#40	0.335	0.464	0.155	34
R#23	0.134	0.306	0.041	35	R#26	0.285	0.787	0.224	35	R#11	0.389	0.361	0.140	35
R#20	0.076	0.502	0.038	36	R#01	0.688	0.227	0.156	36	R#08	0.213	0.546	0.116	36
R#09	0.121	0.200	0.024	37	R#06	0.229	0.567	0.130	37	R#39	0.200	0.446	0.089	37
R#15	0.064	0.295	0.019	38	R#36	0.285	0.428	0.122	38	R#34	0.026	0.221	0.006	38
R#08	0.046	0.235	0.011	39	R#02	0.148	0.679	0.100	39	R#33	0.023	0.222	0.005	39
R#13	0.035	0.269	0.009	40	R#35	0.117	0.427	0.050	40	R#32	0.016	0.152	0.002	40

3. Levels of Risk Calculation: Results from DSS

a. Test Case 1

Risk Analysis and Management

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Risk analysis / Phân tích rủi ro | View Risk Chart / Xem đồ thị | View R_RMS Matrix/ Xem Ma trận R&RMS | View RMS Cost&Benefit Analysis/ Xem phân tích chi phí/lợi ích của RMS

Sort Risks by Rank / Sắp xếp bảng xếp hạng

Risk Analysis: Table of Levels of Risk and Risk Ranks

Risk ID	Risk Description	Risk Consequence	Risk Likelihood	Level of Risk (LOR)	Risk Rank
R#21	Farm have no reserved area for waste water and mud treatment (R#21)	0.914	1.000	0.914	1
R#27	Fish price variability (R#27)	1.000	0.865	0.865	2
R#32	Under-financing by own capital for the whole crop cycle (R#32)	0.764	0.924	0.706	3
R#26	Inappropriate method of harvesting (R#26)	0.857	0.787	0.674	4
R#34	High interest rate for loans (R#34)	0.814	0.810	0.659	5
R#31	Costs of operating inputs (R#31)	0.694	0.894	0.620	6
R#39	Fraud (R#39)	0.800	0.446	0.357	7
R#11	Use undersize/oversize fingerlings (R#11)	0.945	0.361	0.341	8
R#18	Limited knowledge about usage of chemical and medicines (R#18)	0.866	0.383	0.332	9
R#14	Overfeeding causing pollution and waste accumulation (R#14)	0.780	0.377	0.294	10
R#04	Pond not treated before stocking (R#4)	0.735	0.393	0.289	11
R#12	Low quality of feed (R#12)	0.802	0.345	0.277	12
R#40	Technical failure (R#40)	0.335	0.813	0.272	13
R#06	Fingerlings from unknown origin (R#6)	0.880	0.306	0.269	14
R#16	Inability to control diseases from environmental sources (R#16)	0.823	0.323	0.266	15
R#17	Low awareness of disease prevention by farmers (R#17)	0.598	0.439	0.263	16
R#10	Over (density) stocking fingerlings (R#10)	0.834	0.290	0.242	17
R#33	Under-financing by credits from banks/credit institutions (R#33)	0.422	0.549	0.231	18
R#30	Consequence of high technical barriers from importing countries (R#30)	0.347	0.666	0.231	19
R#37	Drought (R#37)	0.378	0.591	0.224	20
R#07	Fingerlings infected by diseases (R#7)	0.712	0.300	0.214	21
R#38	Flood (R#38)	0.363	0.523	0.190	22
R#05	Low quality fingerlings (R#5)	0.728	0.251	0.183	23
R#35	Changes in government policy on product development strategy (R#35)	0.379	0.427	0.162	24
R#01	Pond outside planning area (R#1)	0.166	0.962	0.160	25
R#28	Inaccessibility to the market (R#28)	0.245	0.643	0.158	26
R#19	Use of prohibited chemical and medicines (R#19)	0.240	0.558	0.134	27
R#03	Pond does not have waste treatment system (R#3)	0.663	0.194	0.128	28

b. Test Case 2

Risk Analysis and Management

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Risk analysis Phân tích rủi ro	View Risk Chart Xem đồ thị	View R_RMS Matrix/ Xem Ma trận R&RMS	View RMS Cost&Benefit Analysis/ Xem phân tích chi phí/lợi ích của RMS
Sort Risks by Rank Sắp xếp bảng xếp hạng			

Risk Analysis: Table of Levels of Risk and Risk Ranks

Risk ID	Risk Description	Risk Consequence	Risk Likelihood	Level of Risk (LOR)	Risk Rank
R#31	Costs of operating inputs (R#31)	1.000	1.000	1.000	1
R#15	High death rate due to disease (R#15)	1.000	0.974	0.974	2
R#30	Consequence of high technical barriers from importing countries (R#30)	0.933	1.000	0.933	3
R#32	Under-financing by own capital for the whole crop cycle (R#32)	1.000	0.924	0.924	4
R#03	Pond does not have waste treatment system (R#3)	0.922	0.987	0.910	5
R#05	Low quality fingerlings (R#5)	1.000	0.865	0.865	6
R#27	Fish price variability (R#27)	1.000	0.865	0.865	7
R#17	Low awareness of disease prevention by farmers (R#17)	0.896	0.958	0.858	8
R#29	Weak enforcement in conducting sale contract with processors (R#29)	0.840	0.967	0.812	9
R#16	Inability to control diseases from environmental sources (R#16)	0.823	0.978	0.805	10
R#33	Under-financing by credits from banks/credit institutions (R#33)	0.801	0.976	0.782	11
R#39	Fraud (R#39)	0.800	0.951	0.761	12
R#10	Over (density) stocking fingerlings (R#10)	0.834	0.889	0.742	13
R#08	Fingerlings treated by anti-biotic during fingerling production process (R#8)	0.870	0.822	0.716	14
R#22	Pond water is under-managed (R#22)	0.766	0.916	0.701	15
R#20	Applying chemical and medicines improperly (R#20)	0.912	0.764	0.697	16
R#04	Pond not treated before stocking (R#4)	0.735	0.943	0.693	17
R#25	Inappropriate size of harvested fish (R#25)	0.694	0.943	0.654	18
R#40	Technical failure (R#40)	0.803	0.813	0.653	19
R#28	Inaccessibility to the market (R#28)	1.000	0.643	0.643	20
R#07	Fingerlings infected by diseases (R#7)	1.000	0.626	0.626	21
R#23	Waste water treatment system is under-invested (R#23)	0.951	0.632	0.602	22
R#19	Use of prohibited chemical and medicines (R#19)	1.000	0.558	0.558	23
R#12	Low quality of feed (R#12)	0.802	0.691	0.554	24
R#11	Use undersize/oversize fingerlings (R#11)	0.729	0.706	0.514	25
R#14	Overfeeding causing pollution and waste accumulation (R#14)	0.780	0.647	0.504	26
R#37	Drought (R#37)	0.838	0.591	0.495	27
R#38	Flood (R#38)	0.826	0.523	0.432	28

Main | Risk data | RMS Data | Risk PDF | Risk RMS Cost and Benefit | **Risk analysis** | View R_RMS | Test cases | View RMS C&B | chart RS | language | task sheet

c. Test Case 3

Risk Analysis and Management

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Risk analysis / Phân tích rủi ro	View Risk Chart / Xem đồ thị	View R_RMS Matrix/ Xem Ma trận R&RMS	View RMS Cost&Benefit Analysis/ Xem phân tích chi phí/lợi ích của RMS
Sort Risks by Rank / Sắp xếp bảng xếp hạng			

Risk Analysis: Table of Levels of Risk and Risk Ranks

Risk ID	Risk Description	Risk Consequence	Risk Likelihood	Level of Risk (LOR)	Risk Rank
R#03	Pond does not have waste treatment system (R#3)	1.000	0.987	**0.987**	**1**
R#20	Applying chemical and medicines improperly (R#20)	0.912	0.764	**0.697**	**2**
R#24	Unawareness about community environmental protection (R#24)	0.900	0.754	**0.679**	**3**
R#29	Weak enforcement in conducting sale contract with processors (R#29)	0.840	0.805	**0.676**	**4**
R#16	Inability to control diseases from environmental sources (R#16)	1.000	0.651	**0.651**	**5**
R#17	Low awareness of disease prevention by farmers (R#17)	0.896	0.709	**0.635**	**6**
R#30	Consequence of high technical barriers from importing countries (R#30)	0.692	0.905	**0.626**	**7**
R#31	Costs of operating inputs (R#31)	0.694	0.894	**0.620**	**8**
R#19	Use of prohibited chemical and medicines (R#19)	1.000	0.558	**0.558**	**9**
R#27	Fish price variability (R#27)	1.000	0.532	**0.532**	**10**
R#23	Waste water treatment system is under-invested (R#23)	0.748	0.632	**0.473**	**11**
R#02	Pond nearby residence (R#2)	0.694	0.679	**0.471**	**12**
R#07	Fingerlings infected by diseases (R#7)	0.712	0.626	**0.446**	**13**
R#06	Fingerlings from unknown origin (R#6)	0.564	0.776	**0.438**	**14**
R#09	Epidemic checking for the fingerlings not conducted (R#9)	0.727	0.600	**0.436**	**15**
R#15	High death rate due to disease (R#15)	0.688	0.621	**0.427**	**16**
R#01	Pond outside planning area (R#1)	0.878	0.486	**0.427**	**17**
R#04	Pond not treated before stocking (R#4)	1.000	0.393	**0.393**	**18**
R#37	Drought (R#37)	0.648	0.591	**0.383**	**19**
R#38	Flood (R#38)	0.631	0.523	**0.330**	**20**
R#28	Inaccessibility to the market (R#28)	1.000	0.316	**0.316**	**21**
R#35	Changes in government policy on product development strategy (R#35)	0.721	0.427	**0.308**	**22**
R#14	Overfeeding causing pollution and waste accumulation (R#14)	0.780	0.377	**0.294**	**23**
R#25	Inappropriate size of harvested fish (R#25)	0.694	0.418	**0.290**	**24**
R#05	Low quality fingerlings (R#5)	0.324	0.865	**0.280**	**25**
R#12	Low quality of feed (R#12)	0.802	0.345	**0.277**	**26**
R#26	Inappropriate method of harvesting (R#26)	0.594	0.456	**0.271**	**27**
R#36	Changes in environmental policy (R#36)	0.629	0.428	**0.270**	**28**

Main | Risk data | RMS Data | Risk PDF | Risk RMS Cost and Benefit | **Risk analysis** | View R_RMS | Test cases | View RMS C&B | chart RS | language | task sheet