

Van Dien VO

Gestion de la biodiversité et traçabilité dans la chaîne d'approvisionnement

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Sous la direction de: M. Pierre FENIES et M. Nicolas MAINETTI

Jury :

Rapporteur:	M. Gilles PACHE	Professeur des Universités, Aix Marseille Université
Rapporteur:	M. Frederic GAUTIER	Professeur des Universités, IAE, Université Paris 1 Pantheon-Sorbonne
Membre du jury:	Mme. Virginie NOIREAUX	Maître de conférences HDR, Université d'Auvergne
Membre du jury:	M. Eric PEZET	Professeur des Universités, Université Paris Nanterre
Membre du jury:	M. Thierry FOUQUE	Professeur des Universités, Université Paris Nanterre
Membre du jury:	M. Pierre FENIES	Professeur des Universités, Université Paris Nanterre
Membre du jury:	M. Nicolas MAINETTI	Professeur des Universités, Université d'Auvergne

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Presented by

Van Dien VO

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Advisory Committee

Director

Pierre FENIES

Professor | Université Paris Nanterre

Co-director

Nicolas MAINETTI

Professor | Université d'Auvergne

Reviewers

Frederic GAUTIER

Professor | IAE, Université Paris 1 Pantheon-Sorbonne

Gilles PACHE

Professor | Aix Marseille Université

Thierry FOUQUE

Professor | Université Paris Nanterre

Virginie NOIREAUX

Assistant Professor | Université d'Auvergne

Eric PEZET

Professor | Université Paris Nanterre

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To my family

VO Dong Loc, NGUYEN Thi Phu

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Abstract

This study observes corporate biodiversity management, the implementation of traceability systems and green supply chain management. In specific, this research attempts to develop a model for measuring the performance of corporate biodiversity management with linguistic variables under fuzzy logic theory (O_1), to investigate the relationships between biodiversity management, GSCM and the implementation of traceability systems (O_2), and to determine changes in the transaction attributes and costs of firms under the transaction cost economics framework (O_3). For these purposes, this study takes empirical examinations in the Vietnamese seafood supply chain using primary data from questionnaire surveys and field trips.

From the specialist survey, a set of five key performance indicators (KPIs) has been validated for measuring the performance of corporate biodiversity management. The empirical results show that the Vietnamese seafood companies perform better on the key indicators Biodiversity Stewardship Practice, Biodiversity Business Assessment, but lower scores on Biodiversity Conservation Commitment, Biodiversity Management Policy and Biodiversity Performance Reporting. Considering this fact, the green supply chain management practices are proposed to have positive effects on the performance of biodiversity management and traceability. As a result, the implementation of traceability systems leads to an increase in asset specificity (71%), a decrease in transaction uncertainty (60%) and low variation (7%) in the frequency of transactions.

Key words:

Corporate biodiversity management; Sustainability management; Traceability; Performance measurement; Fuzzy logic; Governance structure; Seafood supply chain.

List of relevance publications

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INTRODUCTION

Life began in oceans and continues to thrive in its particularly rich in biodiversity from the tiniest bacteria to the largest animal that ever lived on Earth - the blue whale. Historically, the oceans are considered as an inexhaustible source of fish, of which millions of people on the planet benefit for the centuries (UNEP, 2012). Nevertheless, human activities have been pushing the oceans to their limit just over the last few decades (WWF, 2016). Worm et al. (2006) alert that the fisheries worldwide are going to completely collapse by the year of 2048 unless the current situation improves. Consequently, marine biodiversity loss is increasingly weakening the ocean's capacity to provide food, maintain water quality, and recover from perturbations.

The life in the oceans is being severely threatened due to the several combined drivers such as unsustainable fishing, aquaculture, pollution, and climate change (WWF, 2015; Rogers and Laffoley, 2011; UNEP, 2012). Out of which, overfishing is the most significant immediate threat to marine biodiversity (TEEB, 2010b; MEA, 2005). Lack of traceability is another serious facing issue in the seafood sector (Warner et al., 2013). Across Europe and America, about 50 percent of seafood products could not be traced back to origin (Donnelly and Olsen, 2012). An article by Kirk Johnson (2013) entitled *"Fish are often not what the label says"* appears in The New York Times to apprise the mislabeling issue in the seafood supply chain. The World Wildlife Fund (2015) also make a precaution when we go to the market to select a piece of fish for dinner, there is no definitive assurance we are buying what we think we are buying. Lack of traceability to the origin of fish products through the seafood supply chain may allow illegal and unreported catches to be easily laundered (Pramod et al., 2014) that contribute to cause threats to the marine ecosystems (WWF, 2015).

From business point of view, the loss of biodiversity and the lack of origin information of fish products may pose significant risks to the seafood companies at least related to

the security of supply of raw material and satisfaction of customers' expectations on sustainable sourcing (ISIS and F&C, 2004; WEF, 2010; TEEB, 2010b; Hanson et al., 2012). By proactively managing potential risks, businesses can reduce the biodiversity loss and increase the traceability of products throughout the expansion of coordination with the partners in the supply chain (Abbott et al., 2002). Taking these elements into account, green supply chain management practices implementation is considered by academics and practitioners as an organizational philosophy able to maximize overall environmental performance and economic performance (Seuring and Muller, 2008, Guang Shi et al., 2012; Dashore and Sohani, 2013). As an environmental innovation, GSCM contributes to improve environmental performance by reducing pollution and economic benefits by using less energy and resources (Zhu et al., 2011).

1. Research objectives

This thesis aims to achieve three objectives. The first objective is to develop a model for measuring the performance of corporate biodiversity management. The second objective is to propose a model that is able to link green supply chain management, traceability and biodiversity management. The third objective aims to examine variation in the transaction attributes, transaction costs and transaction governance in the supply chain.

1.1. Measuring the performance of corporate biodiversity management (01)

Why does biodiversity – a term that seems purely from the biological domain – appear in the agenda of operations management? This interesting question is the motivation for this study. Biodiversity businesses interactions are perhaps small or large, negative or positive, direct or indirect, but they are inevitable. New business opportunities will open up to companies if they proactively develop strategies to cope with the risk of biodiversity loss, otherwise they will fail to seize these opportunities (van den Burg and Bogaardt, 2014; McKinsey, 2010). Companies may obtain many benefits from the

biodiversity management, e.g., strengthening the license to operate, gain competitive advantage, better stakeholder relations, new markets opportunities, long-term stability of operations (GRI, 2007; TEEB, 2010b). Hence, it becomes increasingly difficult to ignore the consequence of issues associated with the loss of biodiversity in business strategy.

The pioneer approaches in measuring the corporate biodiversity management (Globalbalance, 2014; EBBC, 2013; Schaltegger and Beständig, 2012; ECNC, 2012; Houdet, 2008) have contributed to establish a starting-point in assessing the interaction between business activities and biodiversity. Companies may apply some models to implement a biodiversity management process to help mitigate the potential risk and to take the advantage of the opportunity that biodiversity management offers. However, lack of sufficient data and subjectivity in the evaluator's preferences are the major limitations. Typically, reviewers make efforts to gather quantitative data where possible, but not all companies are able to provide sufficient data; and it is unavoidable that some degrees of subjectivity are inherent in the use of qualitative data (Globalbalance, 2014). Another crucial challenge is to find a set of performance indicators that allows a company to comprehensively measure its impact – dependence – risk – opportunity associated with biodiversity and ecosystems services (Bishop et al., 2008; ISIS and F&C, 2004).

To fill these gaps in terms of insufficient quantitative data and the subjectivity in evaluation process of corporate biodiversity management, the first objective (**01**) of this study is to develop a model for measuring the performance of corporate biodiversity management. In specific, the study attempts to follow the research questions:

- **RQ1.1:** What are the key performance indicators (KPIs) for measuring the corporate biodiversity management?
- **RQ1.2:** What is the procedure for the measurement of corporate biodiversity management?

1.2. Linkage biodiversity management, GSCM and traceability (02)

Measurement of corporate biodiversity management is a controversial challenge. Aside from the public goods attributes of biodiversity (non-excludability and non-rivalry), the interrelationships between businesses activities (procurement, manufacturing, transportation, sales, etc.) and biodiversity (genetic diversity, species, habitats, etc.) are very complex in nature (TEEB, 2010a; MEA, 2005). The publication of initial reports (Globalbalance, 2014; EBBC, 2013; Schaltegger and Beständig, 2012; ECNC, 2012; Houdet, 2008) suggest that major difficulty the businesses face in the measurement of biodiversity businesses interactions is to put the theory into practice. Moreover, the loss of the biological diversity is generally addressed at the local scale while local threats to species could be driven by activities from the upstream and downstream economic agents in the global supply chain (Lenzen et al., 2012; GRI, 2007). Even if a species is shown to decline at a site, this does not necessarily mean that it results from the company's activities (ISIS and F&C, 2004).

Biodiversity business interactions occur at all levels of a supply chain (Schaltegger and Beständig, 2012). Companies may have direct influences on biodiversity through their core operations and/or indirect effects through their supply chain partners' activities (GRI, 2007; Beständig, 2010). Thus, the businesses should address the management of biodiversity from a global perspective that takes into account not only the local producers who directly impact biodiversity, but also all other actors from the first-tier suppliers down to consumers who benefit from biodiversity along the global supply chain (Lenzen et al., 2012). Considering environmental elements, green supply chain management (GSCM) practices offer a framework to maximize overall environmental profit by adopting a life cycle approach through product design, material selection, manufacturing, and sales and recovery (Dashore and Sohani, 2013; Guang Shi et al., 2012; Zhu and Sakis, 2004).

The scope of GSCM has ranged from green purchasing to integrated supply chains flowing from supplier to manufactures to customer, and reverse logistics (Zhu and

Sarkis, 2004). Of which, traceability is as an integral part of logistics and supply chain management (Bosona and Gebresenbet, 2013). However, GSCM and traceability analyses rarely address some aspects of biodiversity management such as habitat change and/or invasive alien species. By integrating biodiversity components (species, population, ecosystems, genes) into the framework, investigation linkages between GSCM, biodiversity management and traceability implementation should be further studied.

The effects of implementation of the traceability on perspectives such as economic, society and environment make also a contribution to the performance of sustainable supply chain management (Kraisintu and Zhang, 2011). Indeed, traceability is a tool for companies to prove claims and attributes of sustainable products (UNGC, 2014). Therefore, the next interesting question is whether the implementation of traceability systems has a positive impact to reduce the loss of biodiversity in the supply chain. Thus, the second objective (**O2**) of this thesis is to investigate the relationships between GSCM, traceability implementation and biodiversity management. In specific, the corresponding research questions are:

- **RQ2.1:** How do GSCM practices improve the performance of biodiversity management?
- **RQ2.2:** How does the implementation of traceability system improve the performance of biodiversity management?
- **RQ2.3:** How do GSCM practices enhance product traceability in the supply chain?

1.3. Effect of traceability implementation on transaction governance (O3)

The implementation of traceability systems is considered a solution to reduce asymmetry information (Hobbs et al., 2005). Different aspects of traceability implementation have been investigated in the literature (Trautman et al., 2008). Most studies have focused on analyzing the drivers, on functions of traceability systems

(tracing and tracking) as well as on costs and benefits of traceability implementation (Karlsen et al., 2013). Usage of the traceability systems can improve supply chain management (Kraisintu and Zhang, 2011; Wang and Bravo, 2010), reduce transaction costs (Golan et al., 2004). In another aspect, the introduction of traceability systems may also lead to changes in the level of coordination in the supply chain (Banterle and Stranieri, 2008). This research presents attempts to examine the effects of the implementation of traceability systems on variations in the relationship between economic agents along the supply chain. Particularly, the third objective **(03)** of the thesis is to determine changes in the transaction attributes (i.e., asset specificity, uncertainty and frequency) and the transaction costs of firms. This study is designed to test the hypotheses by focusing on two questions:

- **RQ3.1:** How do the transaction features, transaction costs and transaction organization of firms change as they implement traceability systems?
- **RQ3.2:** Does the implementation of traceability systems increase the level of vertical integration among the economic agents in the supply chain?

The following diagram synthesizes the global linkage between research objectives of the thesis.

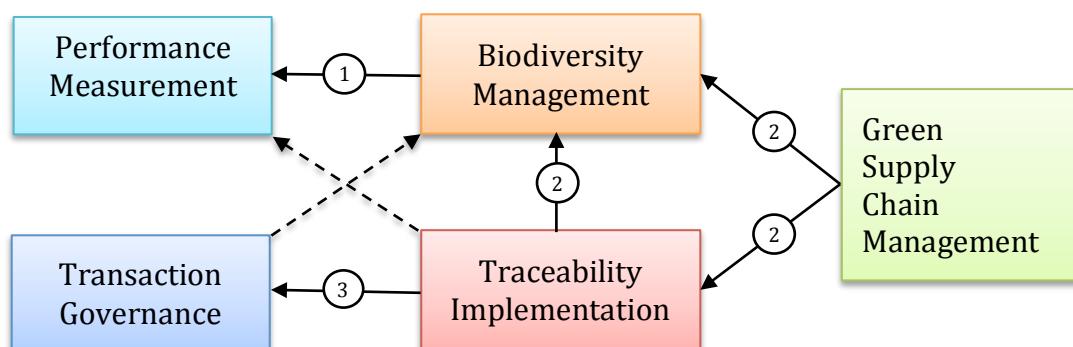


Figure 1.0.0 Linkages between research objectives

Businesses may affect biodiversity either directly by their core operations or indirectly through partners' activities in the supply chain. Therefore, the impact on biodiversity needs to be managed at all chain levels. Green supply chain management provides a fundamental framework for the analysis, of which traceability system plays a very important role in managing the information of a product including environmental impact assessment. The implementation of traceability systems can make changes in transaction characteristics between agents in the chain. Thus, this thesis analysis the impact of traceability implementation on variations in transaction governance structure in the supply chain.

2. Background and methodology

This thesis presents three models, of which each one addresses a particular objective and research questions. Specifically, the first model refers to the objective (O1) with respect to research questions *RQ1.1* and *RQ1.2*. The second model mentions to the objective (O2) with corresponds to research questions *RQ2.1*, *RQ2.2* and *RQ2.3*. The second model addresses to objective (O3) with research questions *RQ3.1* and *RQ3.2*.

For the objective (O1), a standard method for measuring the biodiversity management is to do a baseline survey of the flora and fauna within a given area and to undertake periodic monitoring of selected "indicator" species (ISIS and F&C, 2004). However, this approach may raise several difficulties for firms such as time-consuming, expensive, specialist expertise requirements. Lack of sufficient quantitative data and subjectivity of human thought in evaluation process are major limitations from the current measurement methods in the literature (Houdet, 2008; Globalbalance, 2014; EBBC, 2013). In order to overcome the mentioned limitations, the present study applies fuzzy logic that takes into account the incomplete quantitative data and to captures the subjective from the evaluators during preference process.

In several situations, crisp numbered data are insufficient to model real world systems due to vagueness, imprecision, and subjective nature of human thinking, judgment, and preferences. To deal with vagueness and allow qualitative expressions of human thought, Zadeh (1965) first introduced the fuzzy set theory, which addressed the rationality of uncertainty due to the ambiguity. By applying the fuzzy logic theory, the present model for measurement the performance of biodiversity management has two main tasks: the first one is to identify the key performance indicators (KPIs); the second one is to evaluate the firms' performance with respect to the KPIs. In the first task, a master list of biodiversity management performance indicators is submitted to experts (including academic experts and practitioners) in order to validate the relevance of each indicator. The second task consist in weighting the importance of each indicator and rating the performance of firms with respect to indicators, which have been determined from the company survey. Then, fuzzy operations are gradually implemented during measurement process.

The objective (O2) is addressed via a theoretical model, of which the relationships between variables are constructed. The fundamental concepts of biodiversity, traceability and green supply chain management have been reviewed from the literature. Customers and other stakeholders require the friendly environmental characteristics of the entire product life cycle from raw materials to processing to end-user consumption (Seuring and Muller, 2008). Thus, a complete traceability system should address the tracing and tracking of products and form the product history information throughout the supply chain (Bosona and Gebresenbet, 2013). The strong cooperation with partners in the supply chain is crucial required to get deeper and to share information through physical flows of a product including sustainable attributes. From this point of view, GSCM is considered as an appropriate process that may reduce environmental risks and is comprehensively addressed to the sustainability (Dashore and Sohani, 2013).

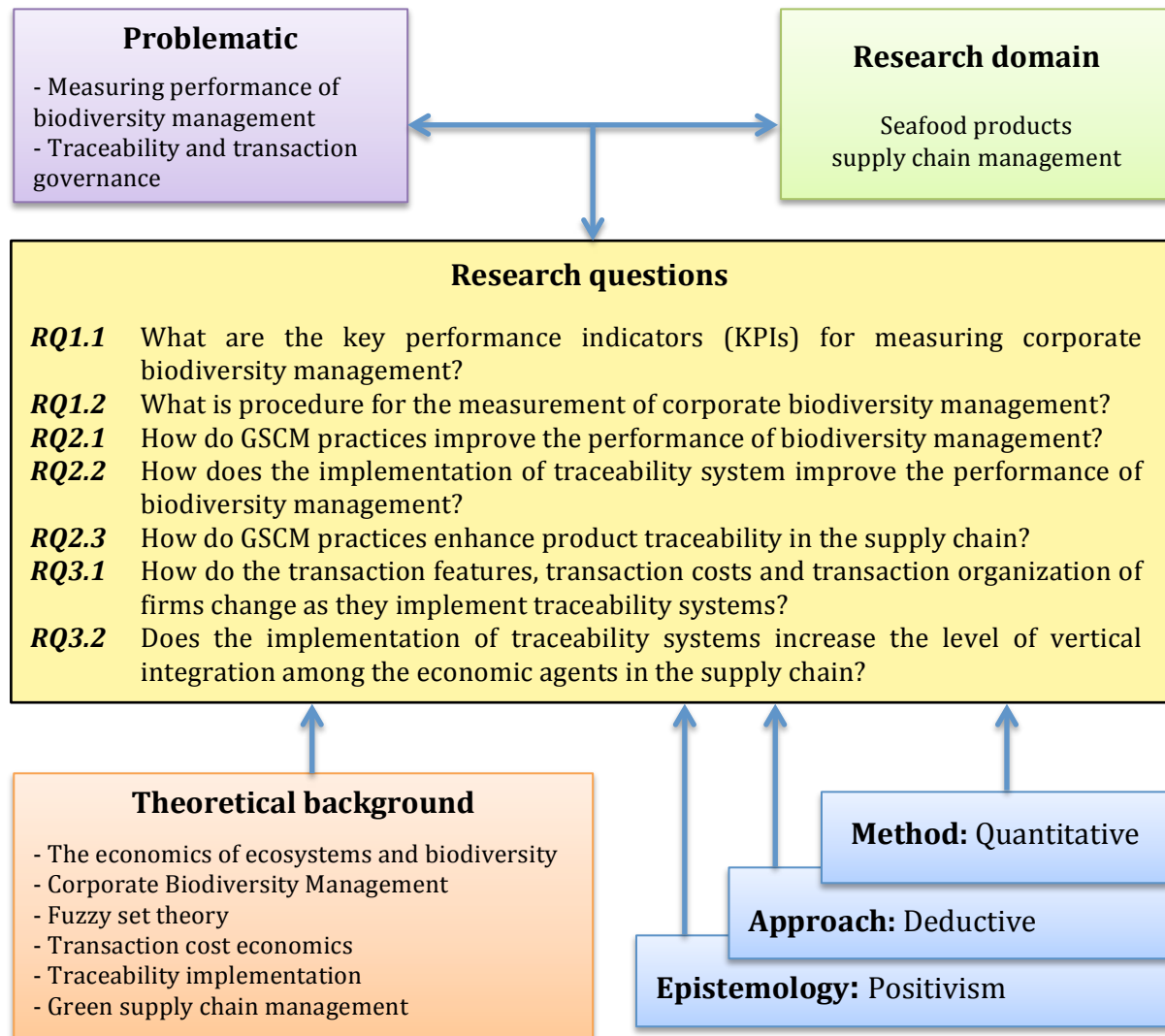


Figure 2.0.0 Research proposal

The theory of transaction cost economics (TCE) is often used to analyze organizational changes. A key concept of TCE program is to see the firm as a structure of governance (which is an organizational construction) that is beyond the neoclassical economics theory of the firm as a production function (which is the technological construction). Indeed, transaction cost economics proposes the problem of economic organization as a problem of contracting and that rests on two behavioral assumptions, i.e. bounded rationality and opportunism; and three main transaction attributes, i.e. asset specificity, uncertainty and frequency. Organizations attempt to minimize transaction costs by

developing new forms of transaction governance that allow for the reduction of transaction costs (Williamson, 1985; 1996).

To be able to reach the objective (O3), the transaction cost analysis framework has been applied. This study uses the transaction costs framework to analyze the effects of traceability on the coordination in the seafood supply chain. The implementation of traceability systems is hypothesized to lead to a reorganization of transaction governance between firms in the supply chain. The reorganizations are connected to (i) augmentation in transaction asset specificity among the agents that determine an increase in monitoring costs; (ii) a higher level of transaction transparency that decreases the level of transaction uncertainty and (iii) an increase in transaction frequency. A further reorganization of transactions is expected (iv) to shift from market to hybrid forms and transactions that are organized through hybrid forms should engender enforcement of these forms by introducing economic incentives through an increase in the price of raw materials and/or providing more contractual support.

3. Scope of study and data

This study particularly observes the seafood supply chain, of which management of biodiversity and traceability is considered the critical factors for the sustainability in the sector.

The biological diversity is the basis for whole economic sectors such as fishing and fish processing. Some consumers believe that there is still plenty of fish available in markets, although the types of seafood products have changed and the prices have become higher. So “*are we really running out of fish?*” or “*are coastal ecosystems nearing collapse?*” Nevertheless, the answer is absolutely yes. Indeed, the fisheries worldwide are facing a risk of total collapse by the year 2048 unless the current situation improves (Worm et al., 2006; Jaenike, 2007). The collapse of the population of Atlantic Cod¹ in the western North Atlantic is a classic example of the real situation (MEA, 2005). The sharp

¹ The Atlantic cod (*Gadus morhua*) is a benthopelagic fish of the family Gadidae, widely consumed by humans.

decline in stock of Atlantic Cod resulted in the reduction by 30% of the profit margins in the Cod-related products of Unilever – an international manufacturer of food. For businesses, the main reasons for seafood companies engaging with the issue of biodiversity include the securing supplies of target fish and reputation and accessibility to markets (Bishop et al., 2008).

Lack of traceability is another serious facing issue in the seafood sector (Pramod et al., 2014; Warner et al., 2013; Donnelly and Olsen, 2012). As the most globally traded food commodity (FAO, 2012), certain attributes of seafood product such as safety, legality and sustainability are very vital. Unfortunately, fish is among the most challenging food products to trace due to its complexity and globalized supply chain (Magera and Beaton, 2009). Across Europe and America, about 50 percent of seafood products could not be traced back to origin (Donnelly and Olsen, 2012). Investigation performed by OCEANA has released that one-third of seafood is mislabeled worldwide (Warner et al., 2013). The mislabeling can happen at any step of the supply chain – from fishermen, to middle trader, to processor, or even at the restaurant. Information about the product is often lost during the transfer between agents in the supply chain when mixing of individual batches of product at points (Hjort and Stern, 2004). As a result, the lack of transparency in seafood supply chain can allow illegal and unreported catches to be easily laundered (Pramod et al., 2014) and that can affect the marine ecosystem services.

As an example, this study empirically examines the Vietnamese seafood supply chain. Vietnam is one of the largest seafood exporters in the world. Vietnamese seafood products (shrimp, pangasius, tuna) have recently become available in major markets such as the EU, the US, Japan, Canada, South Korea, Russia, etc. Unfortunately, lack of traceability, lack of sustainability, low vertical integration and weak linkages between operators in the seafood chain are the most important bottlenecks for exports (CBI, 2012). Sometimes, Vietnamese seafood products are not able to align to the standards imposed by the importers due to the infection levels with antibiotics, microbiology, and other contaminants. Another bottleneck is represented by the small-scale and fragmentation of the Vietnamese seafood industry (Lai et al., 2009). Hence, it is

interesting to investigate how the small-scale attributes of the industry affect the way seafood firms collect materials and implement traceability systems as well as perform the environmental protection, especially in biodiversity management concerns.

To gather information, three questionnaires have been developed as instruments for getting the primary data. The first questionnaire is to survey specialists' opinion about the relevance of the indicators of measurement the performance of biodiversity management in the model. The second one is to collect data in terms of the importance of indicators and the performance of firms with respect to the selected indicators. The third questionnaire is to obtain information on the impact of the implementation of traceability on transaction governance structure for firms. The Vietnamese seafood companies are participants in the surveys. Two waves of field trips have been organized in 2014 and 2016 for visiting some companies in the sample.

4. Major results

Regarding the measuring the performance of corporate biodiversity management, the proposed model consists of two main components: *(i)* identifying key performance indicators (KPIs); *(ii)* constructing a mechanism for evaluating the performance in accordance with the identified indicators and ranking.

The KPIs include in total twenty indicators grouped into five categories:

- (1) Biodiversity Business Assessment
- (2) Biodiversity Management Policy
- (3) Biodiversity Conservation Commitment
- (4) Biodiversity Stewardship Practices
- (5) Biodiversity Performance Reporting

The measurement mechanism starts by submitting a master list of indicators and sub-indicators to the evaluator at each firm. The evaluators are demanded to express their

perception in terms of the importance of each indicator to the firm and self-assessment the performance of their firm with respect to each selected indicator in linguistic terms. The important weightings and performance ratings are inputs for the model. Fuzzy operators are applied for calculating aggregated fuzzy scores for each of the firms. These scores are then converted into crisp values to make rankings of the firms a straightforward accomplished task. The evaluating procedure consists of seven following steps:

Step 1: Assignment of the important indicators and corporate performance

Step 2: Fuzzification the importance weights and performance ratings

Step 3: Determining fuzzy important weights

Step 4: Calculating the aggregate fuzzy weights

Step 5: Setting up the fuzzy performance matrix

Step 6: Computing the aggregate fuzzy scores

Step 7: Defuzzification and ranking

To illustrate how the measurement model works, an empirical examination has been conducted with a case of five companies in the Vietnamese seafood supply chain. The results show that seafood companies have performed better on the indicators Biodiversity Stewardship Practices and Biodiversity Business Assessment. The performance scores of firms are lower on the indicators Biodiversity Conservation Commitment, Biodiversity Management Policy and Biodiversity Performance Reporting.

Biodiversity concerns and traceability have been integrated into green supply chain management framework, which currently is one of the significant interests for both practitioners of operation and supply chain management academia. Based on the theoretical framework, GSCM implementation is proposed to have positive effects on the performance of biodiversity management and traceability. In turn, the implementation of traceability system is proposed to enhance the performance of biodiversity management. Specifically:

Proposition 1: GSCM practices implementation increase the performance of biodiversity management of firms.

Proposition 2: The implementation of traceability has positive effect on the performance of biodiversity management.

Proposition 3: GSCM practices implementation improves traceability in the supply chain.

Analyzing the effect of the implementation of traceability on the transaction governance structure in the seafood supply chain, the empirical results indicate that almost all Vietnamese seafood companies use paper-based traceability systems. Small-scale characteristics of the fisheries industry have affected the way in which seafood firms manage transactions in their supply chains. The implementation of traceability systems leads to an increase in asset specificity, a decrease in transaction uncertainty and low variation in the frequency of transactions. The introduction of traceability has also increased transaction costs (information costs, negotiating costs, system management costs, and control supplier activity costs). Price incentives, purchasing and production rule enforcement and liability serve as proxies for the vertical relationship, which has shown an increase in variation.

5. Thesis structure

Along with an introduction and conclusions, the thesis consists of five chapters. The following diagram particularly presents the structure of this thesis. The chapter 1 presents the study of domain, which includes the introduction to fisheries industry and seafood supply chain. The issues of lack of traceability in the seafood supply chain and the concerns of biodiversity loss in the marine ecosystems that effects businesses in the sector are the major content in this chapter. The literatures on green supply chain management, traceability and biodiversity management are reviewed in the chapter 2. The conceptual framework of biodiversity business management, primarily of fuzzy logic application, transaction cost economics and green supply chain management practices implementation have been briefly introduced in this chapter. Based on the

literature review, research models have been developed in the chapter 3. Each of model addresses to particular objective and research questions.

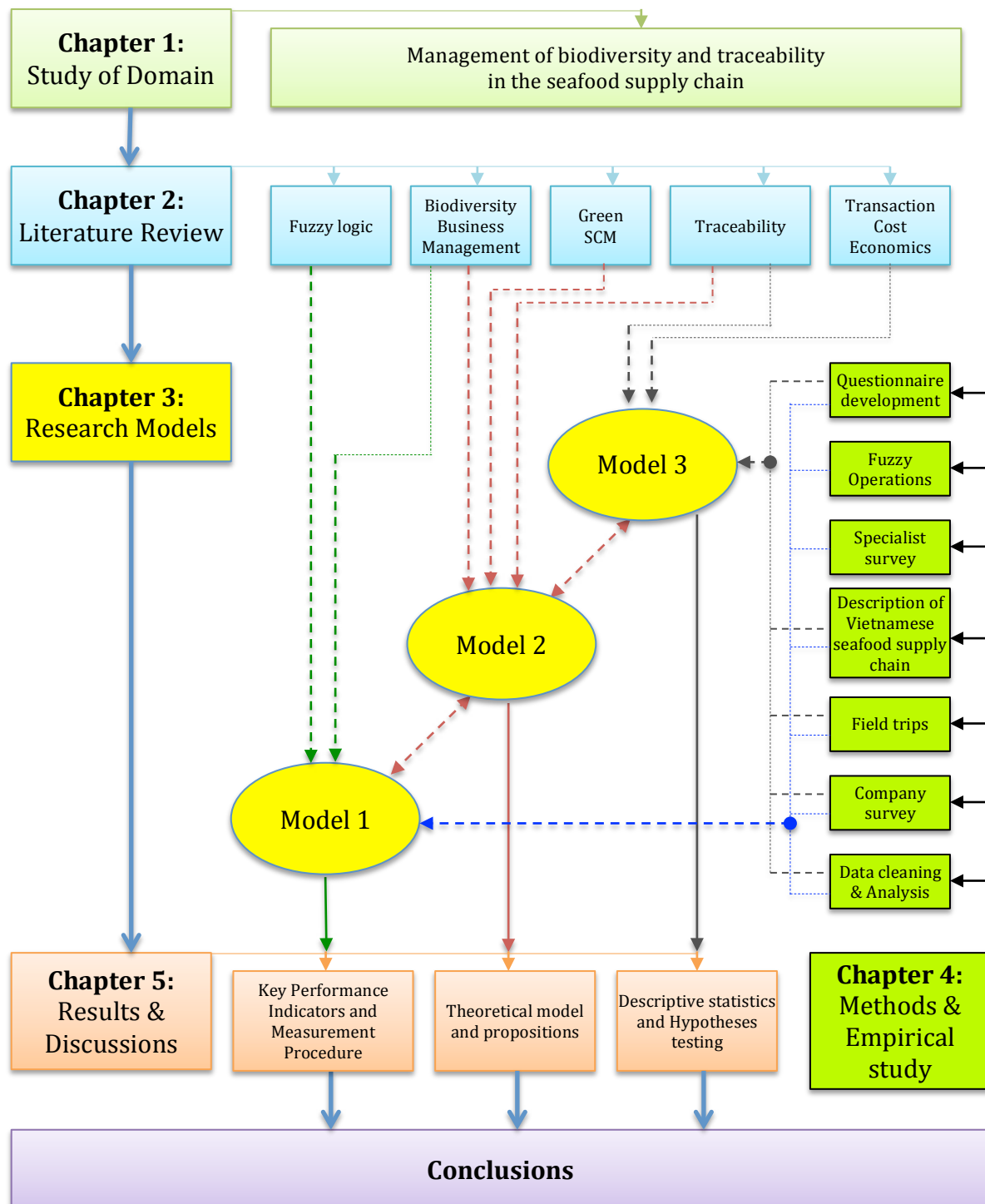


Figure 3.0.0 Thesis structure

Chapter 4 presents the methods and empirical study. General characteristics of the Vietnamese seafood supply chain, i.e., for pangasius, shrimp and tuna supply chain are introduced in this section. Methodology and research setting are also outlined in this chapter. The results of the study are the core content of the chapter 5. Some cases related to how Vietnamese seafood firms implement traceability systems and how they manage biodiversity are presented there. Discussion of the results, potential implications in terms of managerial, practical and theoretical aspects from the study are also included in this chapter. The thesis ends with remark findings, limitations and suggestions for further research and a general conclusion.

CHAPTER 1

STUDY OF DOMAIN

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Operations management is defined as the planning, organizing, coordinating and controlling of transformation of inputs to outputs (Singh, 2008). The definition of operations management covers all aspects of an organisation that is involved in the creation and delivery of products and services to customers. As such, operations management plays a critical role in the success of organisations. In the green business era, organizations cannot dissemble environmental issues in strategy business towards to sustainability concerns. Even so, what does sustainability mean for an organisation? Perhaps the biggest challenge is that there is no rulebook for sustainability. Although laws and regulations provide guidance on some issues, organizational sustainability is about identifying the optimum mix of strategies and practices to produce sustained, superior performance.

This study particularly observes the management of biodiversity and traceability that are considered as the critical factors for the sustainability in the seafood supply chain. Fish and fishery products represent a valuable source of nutrients of fundamental importance for diversified and healthy diets. Demand for seafood products is continuously increasing due to the growth of population in the world, technological innovation and globalization of food supply chains (FAO, 2014). Some consumers believe that there is still plenty of fish available in markets, although the types of fish may have changed and the prices may become higher. Unfortunately, the world's fisheries are facing the danger of completely collapsing in the next decades unless the current situation improves (Worm et al., 2006; Jaenike, 2007). From the business operation view, seafood companies should pay attention on biodiversity and traceability issues because of security of supply and access to market (ISIS and F&C, 2004; Bishop et al., 2008).

The sustainable development in fisheries sector has received more and more concerns not only from policy makers, non-government organizations, but also businesses and individual customer (Donnelly and Olsen, 2012). Integrating sustainability concerns into supply chain management has become increasingly significant performance in terms of a better customers and stakeholders service (Walton et al., 1998), and to maintain competitive advantage (Zhu et al., 2008a). The next subsections outline the background of inter-relationship between biodiversity and business activities and basic concepts of

traceability. The chapter ends with the introduction of the supply chain of seafood products as well as the current status of traceability and biodiversity issues in this sector.

1. Biodiversity business

Biodiversity is absolutely necessary to present and future operations of all types of businesses regardless of their size, sector, or location. No matter how complex a production process or a supply chain is, biodiversity always supports it (IUCN, 2014). Unfortunately, biodiversity is the next serious environmental issue for business (McKinsey, 2010). Indeed, companies themselves depend on biodiversity and ecosystem services as key inputs to production processes while they simultaneously impact biodiversity through output elements (EC, 2015). The biodiversity business interactions may be small or large, negative or positive, direct or indirect, but they are inevitable. It is hence becoming increasingly difficult to ignore the consequences of issues associated with the loss of biodiversity in business strategy.

1.1. Biodiversity, ecosystem services and drivers of changes

One should start by presenting key terms associated with biodiversity businesses interactions. Biodiversity or the biological diversity is defined in the Article 2 of the United Nations Convention on Biological Diversity as: *“The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”* (CBD, 1992). There are three core components of the biological diversity including (i) biomes, habitats and ecosystems; (ii) species and populations; and (iii) genetic diversity (MEA, 2005). Biodiversity and its links to ecosystem properties have cultural, intellectual, aesthetic and spiritual values that are important to society (Chapin et al., 2000). Ecosystem services – sometimes called “environmental services” or “ecological services” – are the benefits that people

obtain from ecosystems ² (Hanson et al., 2012). Examples of ecosystem services include freshwater, timber, climate regulation, and protection from natural hazards, erosion control, and recreation.

Sometimes biodiversity is confused with ecosystem services. In fact, biodiversity is not itself an ecosystem service but rather underpins the supply of ecosystem services (Hanson et al., 2012). The services provided by healthy ecosystems, in turn, are the foundation for human life. According to the Millennium Ecosystem Assessment (MEA, 2005), biodiversity particularly represents the foundation of ecosystems services that include provisioning services (food, water, timber, and fiber); regulating services (the regulation of climate, floods, disease, wastes, and water quality); cultural services (recreation, aesthetic enjoyment, and spiritual fulfillment); and supporting services (soil formation, photosynthesis, and nutrient cycling). These ecosystem services not only deliver the basic material needs for survival, but also underlie other aspects of a good life, including health, security, good social relations and freedom of choice (CBD, 2006). Thus, the loss of biodiversity disrupts ecosystem functions, making ecosystem more vulnerable to shocks and disturbances, less resilient, and less able to supply humans with needed services (CBD, 2006).

Cardinale et al. (2012) review two decades of research on biodiversity that has examined how biodiversity loss influences ecosystem functions, and the impacts that this can have on the goods and services ecosystems provide. Pimentel et al. (1997) analyze the vital services that are provided by biodiversity, including their genes and biomass, to humans and environment. For the world, the benefits of biodiversity are estimated to be \$ 2,928 billion per year, or approximately 11% of the total world economy of \$26 trillion per year. The rapidly growing world population and increased human activity threaten many of species. Changes in diversity can directly reduce sources of food, fuel, structural materials, medicinal or genetic resources. These changes also alter the abundance of other species that control ecosystem processes, leading to further changes in community composition and vulnerability to invasion (Chapin et al., 2000).

² An ecosystem is a dynamic complex of plant, animal, and micro-organism communities and their nonliving environment interacting as a functional unit. Examples of ecosystems include deserts, coral reefs, wetlands, rain forests, boreal forests, grasslands, urban parks, and cultivated farmlands (Hanson et al., 2012).

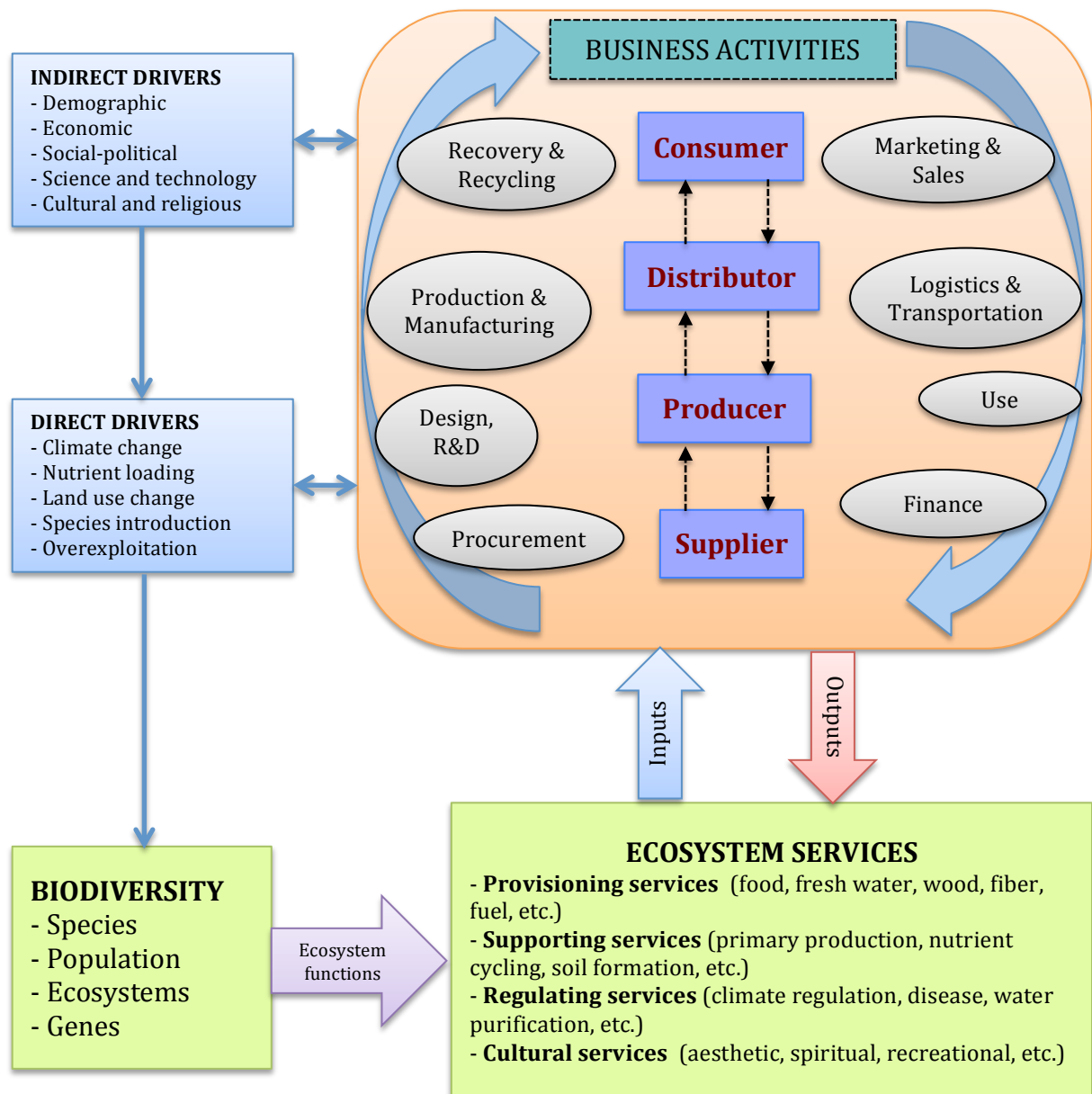


Figure 1.1.1 Interconnections between business activities, biodiversity, ecosystem services and drivers of changes

Generally, natural resources form the basis of a range of commercial products including food, paper, textiles, colorants, fabrics, etc., and services provided by ecosystems such as water and nutrient cycling that are essential to many production and processing operations (UNEP, 2010). While most attention is focused on the potential impacts of activities on biodiversity and ecosystem services, most businesses themselves are also

dependent on biodiversity at differing degrees. A company impacts an ecosystem service if the company affects the quantity or quality of the service meanwhile a company depends on an ecosystem service if that service functions as an input or if it enables, enhances, or influences environmental conditions required for successful corporate performance (Hanson et al., 2012). Impacts on biodiversity resulting from both of elements (business inputs and outputs) can be separated in time and space from where and when business activities (procurement, design, manufacturing, recovery and recycling, transportation, sales, etc.) take place, partly as a result of impacts being further up and down business supply chains (EC, 2015).

Drivers of change affect biodiversity and biodiversity itself is a factor that modifies ecosystem function. Drivers are factors – natural or man-made – that cause changes in an ecosystem and its ability to supply ecosystem services – biodiversity (Hanson et al., 2012). Changes in drivers that indirectly affect biodiversity, such as population, technology, and lifestyle, can lead to changes in drivers directly affecting biodiversity (MEA, 2005). These result in changes to biodiversity and to ecosystem services, thereby affecting human well-being and business activities.

A range of drivers including direct and indirect impacts causes biodiversity change. From an organizational point of view, the most common direct drivers that negatively affect biodiversity include habitat and climate changes, invasive species, overexploitation and pollution (GRI, 2007). Biodiversity change is most clearly a consequence of these direct factors. Moreover, these direct drivers also reflect changes in indirect drivers – the root causes of changes in ecosystem. These indirect factors can be classified into the following broad categories: change in economic activity, demographic change, sociopolitical factors, cultural and religious factors, and scientific and technological change (MEA, 2005). In fact, changes in biodiversity and ecosystems are almost caused by multiple, interacting drivers.

Table 1.1.1 Drivers of biodiversity loss

Driver	Impact
Climate change	Changes in climate have significant impacts on biodiversity and ecosystems, including causing changes in species distribution, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks (MEA, 2005).
Land-use change	Changes in landscape due to such activities as agriculture, urban sprawl and transportation infrastructure are generally recognized in the literature as major causes of biodiversity loss (Slingenberg et al., 2009). Vast stretches of land are necessary to meet the demands following from increasing consumption levels and global population growth. This conversion often comes with a cost for biodiversity (GRI, 2007).
Habitat degradation	Habitat loss occurs when natural environments are transformed or modified to serve human. It is the most significant cause of biodiversity loss globally (Noon-Mooney and Gibb, 2013). Under the Millennium Assessment scenarios, a further 10-20% of grassland and forestland is projected to be converted by 2050 (primarily to agriculture) (MEA, 2005). Reducing the size of habitats can result in isolated populations affecting their ability to reproduce and maintain a diverse gene pool (GRI, 2007).
Introduction of new species	Species have spread outside of their natural habitat and threaten biodiversity in their new area. These species are harmful to native biodiversity in a number of ways as predator or parasites (Noon-Mooney and Gibb, 2013). Organizations can intentionally and unintentionally (e.g., insects that have nested in cargo containers) introduce new species into habitats (GRI, 2007).
Overexploitation of resources	Unsustainable use happens when biodiversity is removed faster than it can be replenished and, over the long term, can result in the extinction of species (Noon-Mooney and Gibb, 2013). The use of natural resources cause of biodiversity loss in many extraction sectors such as fisheries, mining, forest (Slingenberg et al., 2009).
Pollution	Air pollution affects biodiversity on a great scale; most water pollution is the result of the introduction of various substances into water bodies that have negative effects on ecosystems, health and water-based activities (swimming, diving, fishing, etc.); Marine pollution from oil spills (Slingenberg et al., 2009).

Source: Adapted from MEA (2005); GRI (2007); Slingenberg et al. (2009); Noon-Mooney and Gibb (2013)

Chapin et al. (2000) argue that the most important causes of altered biodiversity are factors that can be regulated by changes in policy: emissions of greenhouse gases, land-use change and species introduction. In addition, international trade chains accelerate habitat degradation far removed from the place of consumption in the increasingly globalized economy (Lenzen et al., 2012). A significant number of species are threatened as a result of international trade along complex routes. In particular, consumers in developed countries cause threats to species through their demand of commodities that are ultimately produced in developing countries. The authors find that 30% of global species threats are due to international trade. These results emphasize the importance of examining biodiversity loss as a global systemic phenomenon, instead of looking at the degrading or polluting producers in isolation.

1.2. Biodiversity business interaction

As mentioned, businesses depend and affect biodiversity via ecosystem services for the inputs and outputs directly and/or indirectly. Biodiversity business is a term to indicate how firms integrate biodiversity concerns into their businesses activities in the green era. The term is defined as “*commercial enterprise that generates profits via activities which conserve biodiversity, use biological resources sustainably, and share benefits arising from this use equitably*” (Bishop et al., 2008). The loss of biodiversity and ecosystem decline are linked to various major trends affecting business including social, economic and environmental changes such as natural resources exhaustion, energy insecurity, climate change, increased environmental regulation or changing consumer preferences (TEEB, 2010a).

Indeed, consumer preferences, public awareness and increasing market share of the ecologically certified products significantly influence the linkages between business and biodiversity. The Economics of Ecosystems & Biodiversity (TEEB, 2010b) shows that consumers are more concerned about the environment today than just a few years ago: 82% of consumers in Latin American; 56% in Asia; 49% in USA and 48% in Europe. Reduced demand for traditional Chinese medicine due to perceived impacts on endangered species (e.g., tigers, bears, sea horses), or the decreased demand for fur

clothing in Europe and North America, with knock-on effects on both wild hunting and farming of animals for their fur (TEEB, 2010b) are only some examples of changes consumer preferences today.

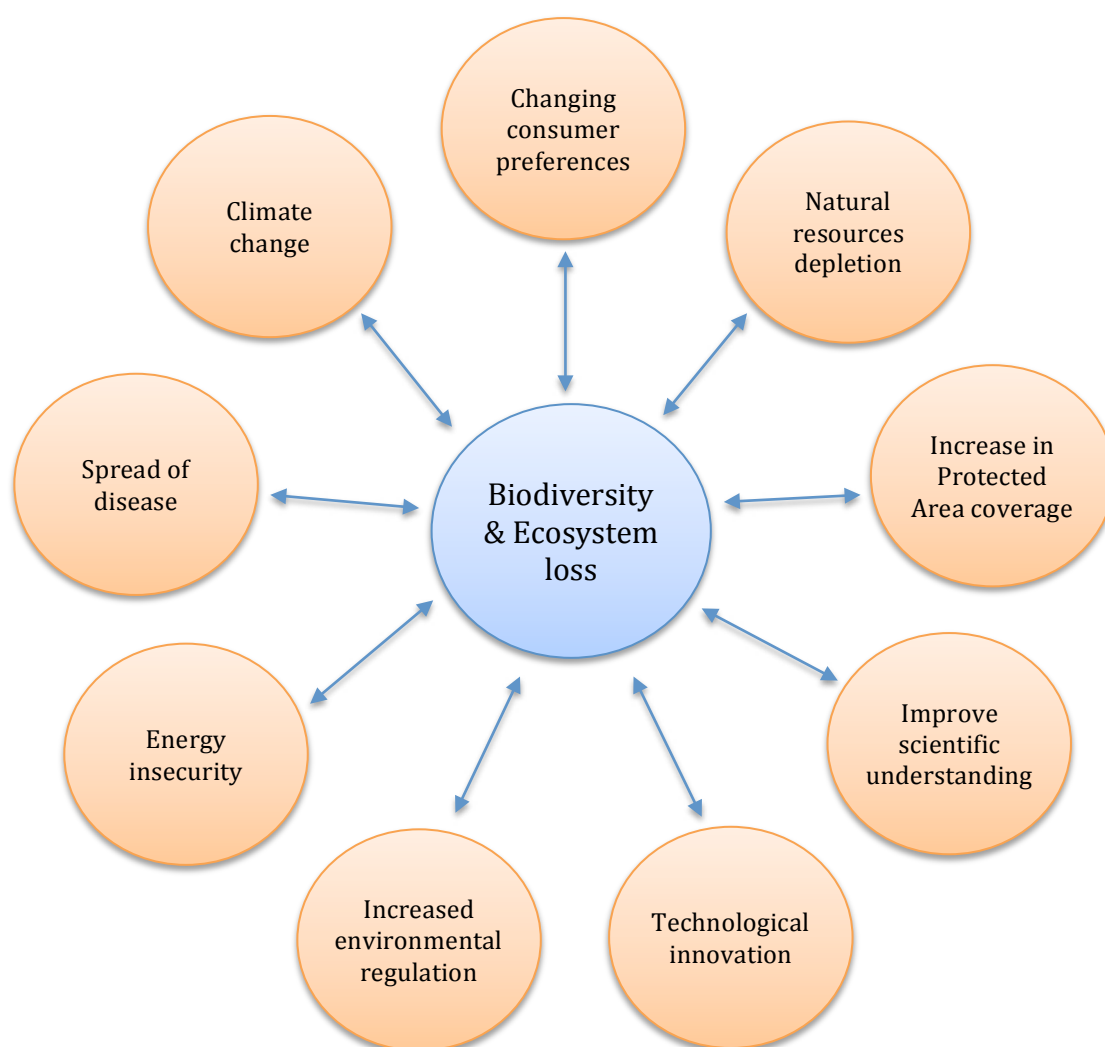


Figure 1.1.2 Links between biodiversity & ecosystem loss and other major trends

Source: The Economics of Ecosystems & Biodiversity - TEEB (2010b)

Another survey cited by the TEEB (2010b) indicates that almost 60 percent of consumers in Europe and the United States heard about biodiversity, representing an increased number as compared with the previous year. Increasing public awareness of biodiversity is likely to influence purchasing behavior. The survey also reveals that 81

percent of consumers interviewed declared that they would cease buying products from companies that disregard ethical sourcing practices. Another survey of UK consumers conducted in May 2010 demonstrated that around half of all respondents would be willing to pay by 10% to 25% more for their purchase in order to compensate their impacts on biodiversity and ecosystems (TEEB, 2010b). Between 2005 and 2007, sales of Forest Stewardship Council (FSC) labeled goods quadrupled while spending on ethical food and drink in general in 1999 jumped to over GB 6 million in 2008. Another example, between April 2008 and March 2009, the global market for Marine Stewardship Council (MSC) labeled seafood products grew by over 50% to reach a retail value of US\$ 1.5 billion (TEEB, 2010b).

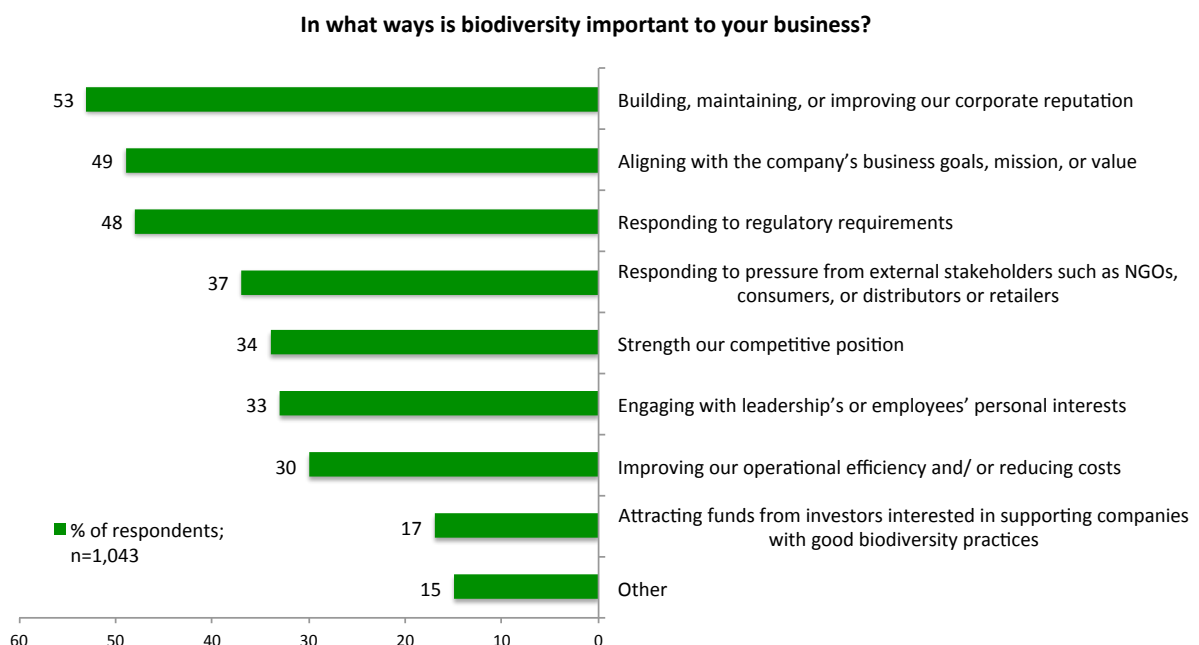


Figure 1.1.3 Where biodiversity and business interest meet

Source: McKinsey & Company (2010)

In 2010, McKinsey & Company took an online survey subject to how important is biodiversity to business. The survey received about thousand responses from

executives representing the full range of regions, industries, tenures, and functional specialties. Results show that almost 55 percent of respondents say that biodiversity issue should be somewhere among the top ten subjects in the corporate agenda. In addition, reputation (53% responses) and value (49% responses) are among the most important factors that a company shall consider within their biodiversity conservation actions. The conclusion is that biodiversity is the next crucial environmental issue for business (McKinsey, 2010).

2. Traceability

It could be understood in the simplest way that traceability refers to the ability to trace and follow a food product throughout all the stages of its production, processing and distribution (Moe, 1998). Thus, the implementation of traceability systems within a supply chain requires that all parties involved link the physical flow of products with the flow of information about them.

2.1. Definitions and common terms

Although there is an extensive literature on traceability (Trautman et al., 2008), there is no international agreement on the definition of traceability (Karlsen et al., 2013). Definition of traceability varies widely because of differences in geographic coverage, time period, business activities, industry structure, consumer perceptions and the legal framework regulating consumer and producer rights. Trautman et al. (2008) present a summary of 30 commonly definitions of traceability found in the literature. Some of organizations develop their own definition of traceability. For instance, the International Organization of Standardization (or Codex Alimentarius Commission), the Food and Agriculture Organization (FAO), European Community (Regulation 178/2002) offer different definitions of traceability. Of which the definition from Regulation 178/2002 is the most commonly used in the literature (Olsen and Borit, 2013).

International Organization of Standardization (ISO 8402: 1994) defines traceability as *“the ability to trace the history, application or location of an entity by means of recorded identifications”*.

The Food and Agriculture Organization (FAO) of the United Nations includes a dynamic aspect in the Codex Alimentarius (Latin for food code): *“traceability/product tracing is the ability to follow the movement of food through specified stage(s) of production, processing and distribution”*.

European Community Regulation 178/2002 offers a definition more pertinent to food and agribusiness in details: *“the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution”*.

It may be helpful to add a few of general terms prior to go deeper into traceability systems. As adapted from Moe (1998), these common terms describe different unit level along the supply chain.

- *Product*: a product can refer to any material at any stage of processing, whether it is a live fish or a processed seafood product.
- *Unit*: a unit is the level at which a product is packaged (e.g. an eight-pack of fish stick might constitute a retail unit, whereas a crate of fish sticks transported by pallet could be considered a logistic unit).
- *Batch*: a batch or lot is a quantity of product produced at a certain time, under similar circumstances (e.g. one run of fish sticks all produced on the same day at one plant).
- *Step*: a step is used to define a distinct operation or location where a process is performed on the product.
- *Chain*: a chain describes the sequence of steps.

- *Trace*: trace expresses the search for the history of a product origin.
- *Track*: track is used when investigating a product's history after it has been delivered.

2.2. Traceability categories and tools

Traceability can be categorized into two main levels, internal and external traceability. Internal traceability refers to the ability to keep track of what happened to a product, its ingredients and packaging within a company or production facility. External traceability refers to the ability to keep track of what happens to a product, its ingredients and packaging in the entire or part of a supply chain (Petersen and Green, 2004). "One up, one down" is the simplest model of external traceability in which each partner in the supply chain is responsible for linking input records to output records. This model of traceability provides more flexibility to individual businesses, but may be inefficient in the event of a trace-back due to the number of contact point throughout the supply chain. The integrity of the system depends on all partners in the supply chain and is only as good as the weakest link (Archipelago, 2005).

The simplest traceability system is what is traditionally known as a "paper trail" in which product's data is written on paper that follows the product through the supply chain (Magera and Beaton, 2009). In fact, most of traceability systems are a mixture of paper and electronic systems. Electronic traceability is divided into bar code systems and the more recent Radio Frequency Identification (RFID) systems. The size of the company is often a key factor in determining the type of traceability systems (Petersen and Green, 2004).

Paper-based traceability system: Paper traceability systems are widespread and are used for a long time throughout supply chains. If the company has a limited quantity of products, this is a good solution. In small companies, these systems usually rely on the completion, storage and review of paper-based records by employees. Traceability of the product can be achieved during the processing and storage of the product in the

plant (Archipelago, 2005). Paper traceability systems are cheap and changes can be easily made. However, if the number of records becomes too large, it will be time-consuming to retrieve records in the system (Petersen and Green, 2004).

Barcode traceability system: Bar code systems have been in use since the 1970s and are well established in the food industry (Petersen and Green, 2004). Bar codes can not only be used to label and identify raw materials and products through the supply chain, but can also be used to label location (e.g., docks, processing stations) or individual pieces of equipment (e.g., weigh scales, processing equipment). Barcode systems rely on the use of hand held scanners for reading bar codes and inputting additional data, printers for re-labeling and a coordinated computer system to manage the information. The system can be implemented at various levels, from reading information on incoming raw materials and labeling of final product (with all other records being paper based), to a fully integrated traceability system for all operations (Archipelago, 2005).

Radio Frequency Identification (RFID) Tags: RFID systems use radio waves of specific frequencies to read, and/or modify data stored in electronic circuits or a microchip that is usually encased in durable plastic to form a “tag”. The RFID system consists of three components, the RF tag, the transceiver or scanner, and a computer. The transceiver, the tag emits a radio signal that is picked up by transceiver and decoded to reveal the information contained in the tag. The transceivers can be incorporated into various types of equipment such as portals (doorways); handheld scanners; specific piece of equipment (e.g. weighting scales) and have even been built into the glove of the person who handles product boxes. RFID tags can be attached to product boxes and are used to carry the traceability information in a format that can be read automatically and at a distance. The advantage of this method is that the box needs only to be placed on a scale or passed through a detector for the identification information to be automatically determined and only additional information added (e.g. quality grades, weight etc.). This can be achieved by inputting the data via drop down menus on a touch screen interface. RFID tags are well suited to harsh environments where barcodes fail (Archipelago, 2005).

Table 1.2.1 Advantages and disadvantages of traceability systems

Traceability tools	Advantages	Disadvantages
Paper-based systems	- Based on existing quality assurance and stock control documentation systems. - Inexpensive to implement - Flexible in terms of the processing systems to which it can be applied.	- Processing and maintenance of data records is time consuming. - Trace-back of information is time consuming and difficult for paper based records. This is especially true where the process operations involve more than one raw material/ingredient.
Barcodes system	- Data input is easy and often menu led, minimizing potential errors. - Each scanner can be used to collect data from various process steps therefore minimizing capital expenditure and maximizing use of equipment. - Real time availability of records results in improved stock and process control.	- Requires capital expenditure for equipment in order to successfully implement. This is especially true where processing information is to be automatically logged and integrated with the scanned data. - Technology can be unreliable, so an additional paper based system is recommended as a back-up system.
RFID system	- Flexibility: the system can be customized to user's specific needs. The types of equipment, scanning system, database software etc. can be adapted to meet individual company's requirements. - Increased efficiency in data storage and easy access to a huge volume of complexity of data. - Easier data compilation and production of statistics summaries for business management. Storing data in a database makes it easier to query and summarize information. - Less labor required for data entry and maintenance (i.e., lower labor costs).	- Requires significant investments in hardware and software. But this should be evaluated against potential cost savings in material, labor and other resources. - Rely on either ID tags/ labels throughout process or Bar code scanning an additional capital cost. - Requires training for staff in new equipment and new processes. - May require higher level of computer expertise for some staff managing the systems. - Generally there is a higher comfort level with low-tech paper solutions and higher discomfort with change to electronic solutions.

Source: Archipelago (2005); Petersen and Green (2004)

Petersen and Green (2004) also group traceability systems as single database systems or multi-database systems. Most internal traceability systems are single database systems and external traceability systems are more often multi-database systems. The advantage of multi-database systems is that each link has a complete record of information in its system and can controls access rights to information. The disadvantage is that different standards in recordkeeping can be used, making communication between links in the supply chain difficult. Single database systems refer to information in the supply chain that is kept in a single database. The advantage of a single database system is that it is based on a common standard, which makes it easier and faster to retrieve information between the various links in the supply chain. An example of a single database system used for internal traceability is an ERP (Enterprise Resource Planning) system.

2.3. Principles of traceability implementation ³

Implementing a traceability system within a supply chain requires all parties involved to link the physical flow of products with the flow of information about them. Adopting industry standards for traceability processes ensures a common agreement on identification of the traceable items. This supports the visibility and continuity of information across the supply chain. Critical Tracking Events along with Key Data Elements for traceability of product movement in the supply chain consists of:

- *Product Receipt* (Unique Identification of Shipment linked to Unique Product Identification, Date Received, Origin of product).
- *Product Ingredient* (Unique Identification of ingredient along with Batch/Lot Number or Serial Number).
- *Product Creation* (Unique Identification of product, Batch/Lot Number or Serial Number).
- *Product Shipping* (Unique Identification of Shipment linked to Unique Product Identification, Date Shipped, Shipment Destination).
- *Pallet Configuration* (Unique Shipment ID with Unique Product ID aggregation, Batch/Lot Number or Serial Number, Quantity).

³ This section is basically adapted from NHI & GS1 (2011)

- *Consumer Unit Depletion and/or Point of Sale* (Unique Product ID, Batch/Lot Number link, Date Purchased, Quantity).

Supply chain traceability is the net result of two complementary business processes, referred to as external and internal traceability. External traceability involves the communication of product identity and transport information between trading partners, while internal traceability involves the association of input products with output products when an industry participant creates a new product.

External Traceability: All traceable items must be uniquely identified and this information should be shared between all distribution channel participants. External traceability for the seafood industry is primarily based on the case and consumer item level of the packaging hierarchy. At a minimum, the identification of products for the purpose of traceability requires:

- The assignment of a unique GS1 Global Trade Item Number (GTIN); and
- The assignment of a Batch/Lot Number, which includes location information if GLN's (Global Location Number) are not used.

To maintain external traceability, traceable item identification numbers must be communicated to distribution channel participants on product labels and related paper or electronic business documents. This links the physical products with the information requirements necessary for traceability.

Internal Traceability: Processes maintained within the organization to link the batch identity of raw materials to the batches of the finished goods.

When a product is combined with others, processed, reconfigured, or re-packed, the new product must have its own unique product identifier (i.e., GTIN). The linkage (auditable function) must be maintained between this new product and its original inputs such as batters, breadding, seasonings, marinades, salt, STPP, citric acid, packaging materials and many others to maintain traceability. The label showing the lot identification of the traceable input item should remain on the packaging until that

entire traceable item is consumed. This principle applies even when the traceable item is part of a larger packaging hierarchy.

Internal and External Traceability: End-to-end traceability requires that the processes of internal and external traceability be effectively conducted. Each traceability partner should be able to identify the direct source and direct recipient of traceable items. This is the "one step up, one step down" principle. This requires that participants in distribution channel collect, record, store, and share minimum pieces of information for traceability that are described in the sections that follow. To have an effective traceability system across the supply chain:

- Any item that needs to be traced forward or backward should be globally and uniquely identified, and;
- All distribution channel participants should implement both internal and external traceability practices.

Implementation of internal traceability should ensure that the necessary linkages between inputs and outputs are maintained. In order to support best practices for maintaining a traceability process there are five basic business processes that should be put in place among distribution channel participants. They include:

- Plan and organize how to assign, collect, share, and maintain information to ensure traceability.
- Determine how to align required master data for all products and distribution channel participants and other physical locations.
- Record traceability information as products are created and shipped and modified in form (critical tracking events).
- Request a trace using a least one of the four information sources listed:
 - GTIN or some form of the item identification;
 - GLN or some form of the traceability partners' name or attribute;
 - GLN of the physical location for the targeted product;
 - Dates or time periods for targeted product;
 - Lot number.
- Use the information provided to take the appropriate action as required.

The implementation of traceability systems should adopt industry standards for traceability processes to ensure agreement about identification of the traceable items. In the food sector, a food traceability system is fundamentally based on 4 pillars: product identification, data to trace, product routing, and traceability tools (Regattieri et al., 2007). Product identification step is fundamental, which shall include physical characteristics such as volume, weight, dimensions, and packaging. Other classes of information required deal with mechanical properties (shortness, condition of surfaces) and length of the life cycle. The second fundamental pillar concerns the data to trace. The characteristics of the information that the system must manage, for example related to kind (digits, strings, ranges, etc.) and number, or the confidentiality levels are absolutely relevant to correct design. A food product traceability system must take the production process into account, so the third pillar is product routing. The system must record “product life” along the supply chain, then through both production activities and movement or storage activities. Different technical solutions can be used in a traceability system (alphanumeric code, bar code, or RFID). Final choice must consider the degree of compatibility with the product and the production process, the degree of automation supported by the supply chain analyzed, and in general knowledge along the supply production channel.

2.4. Economic incentives of the implementation of traceability systems

Incentives for producers to undertake protective measures can be provided either through private quality control systems that work through the market (e.g., demand side shifts created through reputation or certification and labeling) or through public systems driven by public policy design (e.g., imposition of liability for damages, or direct regulation of processes or product quality) (Caswell and Henson, 1997). Identifying the economic incentives for introducing traceability systems is useful in understanding the ability of traceability to deliver net economic benefits. An economically justifiable amount of investment in implementing a traceability system is determined by estimating and weighing the benefits that the system can bring to the company (Golan et al., 2004).

According to NFI & GS1 (2010), partners in a supply chain could use various levels of product traceability to enable business needs such as:

- To comply with regulatory requirements and guidance on recalls
- To reduce business risks above and beyond legal compliance
- Product recall and withdrawal (notably to achieve a greater degree of precision, to demonstrate control, increase efficiency and reduce the cost of product recall or withdrawal)
- To comply with a trading partner's specifications
- Efficient logistics management
- Effective quality management
- To support product and/or patient safety
- To provide information to end users and trading partners
- To verify the presence or absence of product attributes (e.g., organic, dolphin sage, contains latex)
- Brand protection
- Product authentication
- Anti-counterfeit policies
- Visibility in supply and demand chain

Companies have three general objectives in developing and maintaining traceability systems (Wang and Bravo, 2010). First, a system is designed to improve supply management. By tracking production, inventory, and sales, a system provides information for finding the most efficient approach to coordinate logistics activities. Second, a system is designed to assure quality management. By tracking product movements, a system isolates the sources of potential hazards, clarifies liability, and limits the extent of risk associated with a food safety failure. Third, a system is designed to facilitate marketing management. By tracking product attributes desired by consumers, a system differentiates the products among others and creates new market opportunities. Suppliers are thus able to attain higher profits, cost-wise, from business environment with lower costs and less risk; and, revenue-wise, from a market position with better margins.

3. Supply chain of seafood products

Seafood is a common term to indicate all edible fisheries and aquaculture products harvested from any aquatic environment, excluding seaweeds (Anderson, 2003). Seafood supply chains vary from countries and regions that correspond to socio-economic, environmental conditions and cultural differences. In addition, there are differences in the diversity of fish species and products as well as harvesting techniques (industrial production, artisanal production, aquaculture or capture). Fish supply chain can also vary in complexity depending on the level of integration of the different links and the ownership of the entire production process, i.e. horizontally or vertically (UNEP, 2009). Usually, the shorter the physical distances from primary producer to consumer is more transparent the supply chain. Despite the complex of the chain, the seafood supply chain may involve the major participants from fishermen, intermediaries, processors, distributors, retailers and consumers.

3.1. Introduction of fishery sector

Fisheries remain the key factor ensure food security for millions of people, a bulwark of local employment, and a significant factor in the global economy. About one billion people – largely in developing countries – rely on fish as their primary animal protein source, and an estimated of 35 million people are directly engaged, either full- or part-time, in fishing and aquaculture (WRI, 2004). According to FAO (2014), global fish production has grown steadily in the last five decades, global capture fishery production in marine water represented 79.7 million tons in 2012 and food fish aquaculture expanded at an average annual rate of 6.2 percent in the period 2000 – 2012. World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 19.2 in 2012.

Table 1.3.1 World fisheries and aquaculture production and utilization

	2007	2008	2009	2010	2011	2012
	<i>Million tons</i>					
Total capture fisheries	90.8	90.1	90.1	89.1	93.7	91.3
Inland	10.1	10.3	10.5	11.3	11.1	11.6
Marine	80.7	79.9	79.6	77.8	82.6	79.7
Total aquaculture fisheries	49.9	52.9	55.7	59.0	62.0	66.6
Inland	29.9	32.4	34.3	36.8	38.7	41.9
Marine	20.0	20.5	21.4	22.3	23.3	24.7
Total world fisheries	140.7	143.1	145.8	148.1	155.7	158.0
Human consumption	117.3	120.9	123.7	128.2	131.2	136.2
Non-food uses	23.4	22.2	22.1	19.9	24.5	21.7
Population (<i>billions</i>)	6.7	6.8	6.8	6.9	7.0	7.1
Per capita food fish supply (<i>kg</i>)	17.6	17.9	18.1	18.5	18.7	19.2

Source: Food and Agriculture Organisation of the United Nations - FAO (2014)

According to FAO (2014), fish products are among the most traded food commodities worldwide. In 2012, about 200 countries reported exports of fish and fishery products. The fishery trade is especially important for developing nations, in some countries representing more than half of the total value of traded commodities. Unfortunately, unsustainable fishing is one of the most serious problems in the world fishery. The proportion of assessed marine fish stock fished within biologically sustainable⁴ levels declines from 90 percent in 1974 to 71.2 percent in 2011, when 28.8 percent of fish stocks were estimated as fished at a biologically unsustainable level and, therefore, overfished. Of the stocks assessed in 2011, fully fishes stocks accounted for 61.3 percent and underfished stocks 9.9 percent.

⁴ Stocks fished at biologically unsustainable levels have abundance lower than the level that can produce the maximum sustainable yield – MSY (FAO, 2014).

3.2. Seafood supply chain

Seafood product often follows a long and winding path from water to consumer. It is often shipped on long distances, via multiple ports and changed hands among various brokers, processors and retailers before it finally reaches the consumer's plate (Magera and Beaton, 2009; Fish2.0, 2015). A fish supply chain can be generally described as a set of interdependent fishers, agents, processors, distributors and wholesalers/retailers/food services those who work together to supply a fish derived product to the consumer (UNEP, 2009). The following graphic depicts a simplified seafood supply chain that brings product from aquatic environment to the end consumer.

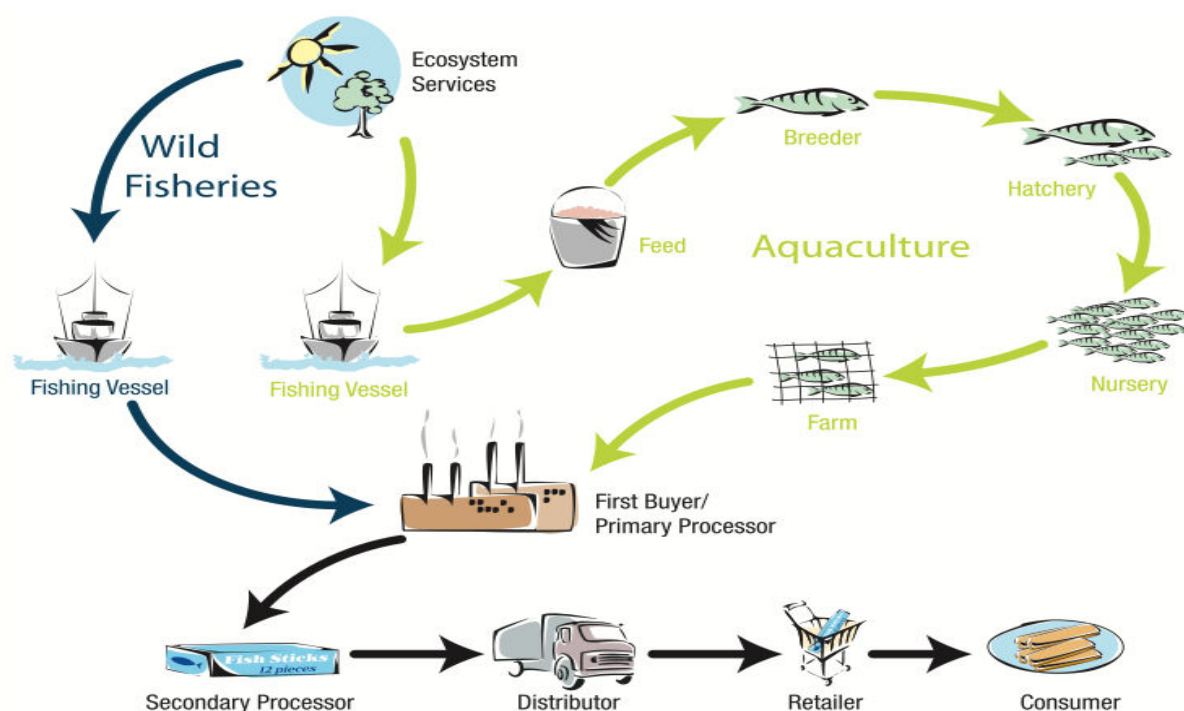


Figure 1.3.1 A simplified seafood supply chain

Source: Magera and Beaton (2009)

Seafood supply chain can be complex and involve many participants in supply chain from primary producer to end-consumer (Boyle, 2012; UNEP, 2009; Magera and Beaton, 2009; Archipelago, 2005). The upstream stages of the chain (water-to-buyer)

for wild harvest and aquaculture are quite different while the downstream stages (post primary processor) are similar. Intermediaries such as transporters and cold stores that have custody of the product without purchasing or producing the product may also be involved between chain partners. The supply chain pathway can be varied for wild harvest and farmed fish.

Table 1.3.2 Elements of water to buyer pathway for wild harvest

Actor	Activities
Vessels	The vessel harvest seafood product. Basic processing operations may be carried out on board such as heading, bleeding, gutting, grading and freezing. Catch may be discharged by the vessel or by offloading companies. Harvesters are responsible for meeting a number of fisheries management data requirements, some of which are also require for traceability.
Packer	A packer is a transport vessel that collects fish from one or more vessels and delivers it to a land based facility or transporter. Pooling of product is typical on packers, except in most shellfish fisheries where product is labeled and physically kept separate.
Off-loader	The off-loader is a business that discharges catch from a vessel. The off-loader may carry out unit transformations (e.g. repacking), grading and sorting.
Net pen	Live catch from vessels may be placed into net pens for storage until sale. Net pens are typically maintained by the vessel.
Truck	The truck is the land based transporter of seafood products. The truck may include other forms of transportation such as air transport. Documentation of shipments are made on a Bill of Loading.

Source: Archipelago (2005)

Despite the diversity of products and regional locations, the seafood supply chain consists of the major actors such as fishermen (including fish harvesters and fish farmers), intermediaries, processors, distributors, retailers and consumers. The primary producer of fish supply chain varies in relation to the nature of the fisheries. For example, in capture fisheries, the supply chain begins with the fishers who harvest the fish and with the hatchery where larvae are produced in the aquaculture fisheries. Intermediaries, their role is to connect the producers with the processors. Intermediaries can include agent or sub-agent (uniquely collecting fish at the landing point) and suppliers' agents who may be involved in some pre-processing including,

sorting sizes and quality, cleaning and gutting fish or shelling prawns. Depending on the complexity of the final seafood product and sophistication of the beginning of the supply chain, there may be a secondary processing phase such as a breeding or cooking process.

Table 1.3.3 Elements of hatchery to processor pathway for farmed fish

Actor	Activities
Feed manufacturer	The fish feed manufacturer manufactures feed for brood stocks, hatcheries and fish farms.
Breeder	Breeders are establishments that maintain brood stocks, often based on selection for specific characteristics, from which they collect eggs for hatcheries. Prior to dispatch, breeders may carry out operations such as quality grading.
Hatchery	Hatcheries are establishments that receive eggs from breeders and rear them through the hatching & juvenile phases until dispatch to a grow-out facility.
Farm (Grow-out)	Farms receive fish from hatcheries and rear them during the grow-out stage until dispatch to the slaughtering/processing link.
Live fish transporter	Live fish transporters may operate at two stages in the farmed fish supply chain: 1) transport between hatcheries and fish farms; 2) transport between fish farms and processors.
Transporter	In the upstream portion of the supply chain covered by this project, transporters transport fish slaughtered on-farm to the processing plant.

Source: Archipelago (2005)

If the destination of the product is international markets, exporter and importer control the movement of the goods through international borders. Distributors purchase the products and re-sale them to wholesalers, food service companies and retailers. The distributor and wholesales stage can be merged in some cases. Retailers purchase final products from wholesales before selling to consumers. Large retailers may bypass wholesalers and buy directly from exporters. Some wholesalers also have a retail operation (UNEP, 2009).

3.3. Seafood traceability

Seafood products represent a valuable source of nutrients of fundamental importance for diversified and healthy diets. Some of typical questions such as *“How was this fish caught or farmed?”* or *“where did this shrimp come from?”* may appear in the consumers’ mind when they are in front of shelves in supermarket. In other words, today consumers are increasingly demanding information and assurance about the safety and sustainability of seafood products (Magera and Beaton, 2009). To fulfill such needs, traceability is an effective tool to help companies to provide consumers with information about source and processing of products throughout the supply chain (Hjort and Stern, 2004). The authenticity of claims or certifications, such as wild fish harvested only from sustainable stocks or dolphin-safe tuna, also depends upon proper documentation throughout the supply chain. As consumers become more sensitive to environmental concerns, fish can have a higher price, if marketed according to where, when and how it was caught (TEEB, 2010b).

3.3.1. Business case for seafood traceability

A not traceable seafood product is difficult to recall if it was found to be unsafe for consumption and cannot be proved its legal source that meet social and human rights standards, and/or meets the sustainable sourcing commitment of a company. By selling products without proper traceability documentation and protocols in place, companies are put at legal and reputational risks (Boyle, 2012). It is important to mention that not only risks avoidance makes traceability important, the recent media attention to the topic creates opportunities for companies that have implemented traceability system to actively promote their product’s attributes such as social and fair trade compliance, engaging in fishery improvements, and supporting small-scale entrepreneurial ventures in the developing world.

Demand for seafood traceability originates from multiple sources, including consumers, retailers, government agencies and nonprofits organisations focused on public health and environmental sustainability. Fish2.0 (2015) summarizes key drivers for

traceability implementation: growing market risk of illegal fishing; risk of seafood fraud; need for sustainability information to manage stocks; expanding market and regulatory requirements; shifting consumer attitudes, need for more efficient operations management. The implementation of traceability systems also brings benefits to a company in terms of meeting legislations, achievement of consumer expectation, minimizing losses during a product recall (Hjort and Stern, 2004). In the thin margin seafood industry, where cents per pound makes the difference between profit and loss, traceability can add value to products by giving them an origin story and thus de-commoditizing them (Fish2.0, 2015).

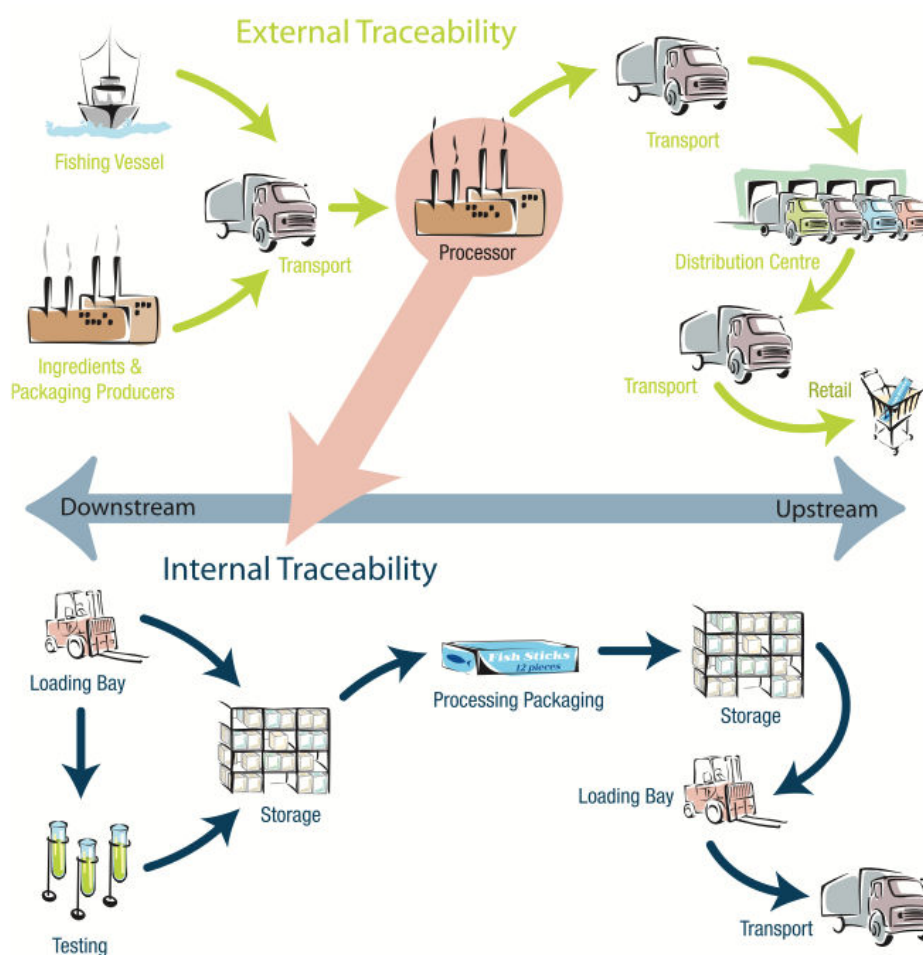


Figure 1.3.2 Internal and external traceability systems: scopes and relationships

Source: Magera and Beaton (2009)

According to the Archipelago (2005), the cases of implementation of traceability systems are diverse and inter-linked: improved supply chain management; improving aquaculture production/ management practices; prerequisite for market access; improved health and safety assurance and improved recall effectiveness; improved product quality and quality assurance; verifying eco-labeling claims; supporting fisheries monitoring efforts; supporting enforcement efforts; differentiating seafood as a globally competitive brand. Globally, the implementation of traceability systems within seafood industries is being driven both by compliance-driven factors – as regulatory authorities respond to societies growing desire to know where food comes from and whether it is safe to consume; as well as value-driven factors – as industry partners work to remove inefficiencies in supply chains and build quality and safety as brand values. There is rising evidence that tangible business value can be created through implementing effective traceability programs, regardless of the primary driving force.

3.3.2. Challenges in seafood traceability

To some degree, the concept of traceability is not new to the seafood industry. Or it was not until the last decade – with developments in global markets, food scandals, and potential acts of bioterrorism – that traceability has become an important issue affecting the entire food supply chain (Petersen and Green, 2004). Today, lack of traceability remains to be a serious facing issue in the seafood sector (Pramod et al., 2014; Warner et al., 2013; Donnelly and Olsen, 2012). On the one hand, as seafood is the world most traded food commodity (FAO, 2012), attributes like safety, legality and sustainability are very vital, but on the other hand, fish is among the most challenging food products to trace due to its complexity and globalized supply chain (Magera and Beaton, 2009). Across Europe and America, about 50 percent of seafood products could not be traced back to origin (Donnelly and Olsen, 2012). The OCEANA investigation released that one-third of seafood was mislabeled worldwide (Warner et al., 2013).

Traceability in the seafood supply chain implies that a consumer unit of seafood at a sales point can be traced throughout the supply chain back to its point of harvest by a

vessel or on a farm (Boyle, 2012). The global seafood industry faces an especially difficult traceability challenge given its long and complex supply chain. Determining product origin can be difficult since tons of fish are caught far offshore, and once processed, similar seafood species can be impossible to differentiate without traceability data (Fish2.0, 2015).

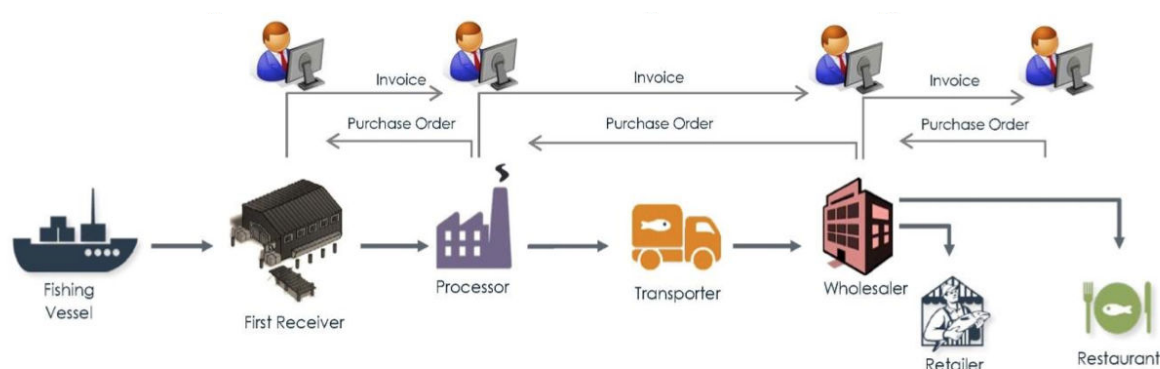


Figure 1.3.3 Manual process and key information exchange points

Source: Fish 2.0 (2015)

There are many reasons why the seafood industry does not have fully traceable supply chains. The mislabeling of seafood products can happen at any step of the supply chain – from fishermen, to collector, to processor, or even at the restaurant. Information about the product is often lost during transfer between agents in the supply chain when mixing individual batches of product at points (Hjort and Stern, 2004). Seafood supply chains are among the most fragmented of all food supply chains, with some products changing hands 5 to 15 times before reaching the consumer (Fish2.0, 2015). In addition, factors as geography, resources and business challenges are between the other reasons the seafood industry does not have one hundred percentages of traceable supply chain (Boyle, 2012).

Seafood often visits multiple ports, travels long distances, and changes hands among various brokers, processors, and retailers (Magera and Beaton, 2009). A large amount of data is recorded by individual companies for each product, but not all this information

is relevant or useful to every company within processing chain. For example, a fishing boat would keep records of location, amount of each species, and time the fish was caught. However, the only information that is of interest to a processor would be the species, quality, location and date of capture of the fish (Hjort and Stern, 2004). In addition, seafood is a globally traded commodity, and language and technological barriers hinder the uses of standardized electronic systems for full traceability within chains (Boyle, 2012).

3.3.3. Requirements for seafood traceability in major markets ⁵

The international seafood trade accounts for ten per cent of total agricultural exports and one per cent of world trade in value terms (FAO, 2012). Need for seafood products is continuously increasing due to the growth of population in the world and globalization of food supply chain. Particularly, the demand for seafood products has doubled over the last 30 years and is projected to continue growing at 1.5 percent per year through 2020 as per capita fish consumptions rises (WRI, 2004). Because of the importance of traceability to provide information related to a single product, some major seafood markets such as UE, US, Japan have developed traceability standards as mandatory and/or voluntary requirements.

The European Union (EU) has required traceability records for seafood since 2005. The principles, requirements and procedures are laid out neatly in a series of regulations known as the General Food Law, or Regulation (EC) No 178/2002. The mandatory traceability requires all producers of food and feed records be able to identify the immediate previous supplier and the immediate subsequent buyer. This principle is called “one up – one down.” The general food law does not have an extraterritorial effect outside the EU. This means that a U.S. company, for example, exporting to EU countries is not required by the food law to be able to trace its products before entering the EU. However, the EU importer has to be able to identify its immediate previous supplier (the last U.S. company) and make sure that the imported product complies with other relevant requirements in the EU food law (e.g., food standards, labeling standards,

⁵ This presentation is basically adapted from Boyle (2012); Archipelago (2005); Hjort and Stern (2004); Magera and Beaton (2009).

country of origin standards etc.). Some EU food business operators request trading partners to meet the traceability requirements and even go beyond the “one up – one down” principle. Some importers are even requesting that international companies adopt common electronic product identifier such as GS1 (EAN-UCC) bar codes and/or radio frequency identification (RFID) tags (Petersen and Green, 2004).

In the United States, the Public Health Security and Bioterrorism Preparedness and Response Act (known as the U.S. Bioterrorism Act) has generated regulations requiring establishment and maintenance of chain of custody records by persons who manufacture, process, pack, transport, distribute, receive, hold or import food into the U.S. The U.S. Country of Origin Legislation of 2002 (or COOL) also calls for seafood products to carry labels identifying both the country of origin and the method of production (for example, whether the fish was wild-caught or farmed). Starting on September 30th, 2008, COOL also requires that all suppliers be able to validate the claims through possession or legal access to one-up one-down documentation unique to each transaction. These records must also be kept for two years.

Importers of seafood into the U.S. are required by law to notify the FDA prior to receiving a shipment. Most of the requirement is data usually provided by importers or brokers to the Bureau of Customs and Border Protection. When food arrives in the U.S., the prior notice must be submitted electronically within five days and two hours before arrival, depending upon transportation method. The notice must contain the following information:

- Identification of the submitter, including name, telephone and fax numbers, e-mail address and firm name and address;
- Entry type and CBP identifier;
- The identification of the food article, including complete FDA product code, the common or usual name or market name, the estimated quantity of the smallest package size to the largest container, and the lot or code numbers or other identifier (if applicable);
- The identification of the shipper, except for food imported by international mail;

- The country from which the food is shipped or, if the food is imported by international mail, the anticipated date of mailing and country from which the food is mailed;
- The anticipated arrival information (location, date, and time) or, if the food is imported by international mail, the U.S. recipient (name and address);
- The identification of the carrier and mode of transportation, except for food imported by international mail; and
- Planned shipment information, except for food imported by international mail.

Japan currently does not have specific traceability regulations for seafood. After an episode of Bovine Spongiform Encephalopathy (BSE) in 2001, stringent traceability requirements were enacted for beef imports, and there are strong indications that similar rules will be enacted for seafood (Petersen and Green, 2004). Along with a rise in food safety awareness, the Japanese public has also begun to express concern about seafood sustainability. The Japan Fisheries Association has responded by developing its own chain of custody eco-label known as “Marine Eco-Label Japan”. A number of labeling laws require a sticker describing the country of origin and the method(s) of production to be attached to each lot of imported seafood. For example, the Food Sanitation Law requires the following information:

- Name of the product;
- Name and address of the processor;
- Lot identification;
- Date of import;
- The number of import notice given to the government;
- Ingredients and food additives used in its manufacture; and
- Any inspection records related to the lot

Canada has no specific requirement regarding traceability of seafood products. Fish and fish products are subject to the “Fish Inspection Act and Regulations” that contains requirements for wholesomeness, labeling, packing, grading and health and safety. The Canadian Food Inspection Agency’s Fish Inspection Directorate (FID) administers Canadian regulatory requirements for imported fish and fish products. The Canadian importers of fish products must have an import license issued by the Canadian Food

Inspection Agency and must notify the closest Canadian Food Inspection Agency fish inspection office in writing when they import fish. Importers are required to notify FID prior to import, stating:

- Type and quantity of product;
- Name of the producer;
- Country of origin; and
- The storage location for each product in a shipment.

Other important Canadian packaging and labeling requirements for fish and fish products are:

- Shipping containers for fresh or frozen fish must be stamped or stenciled on one end with all code markings that identify the packer and date of packing; and
- General labeling requirements for fish and fish products in consumer packages include, but are not limited to:
 - + Mandatory information in both French and English;
 - + List of ingredients (including additives);
 - + Name and address of the packer or distributor;
 - + Common name of the product; and
 - + Weight (in metric units)

China is the world's largest producer and exporter of seafood worldwide. This populous Asian nation also imports large volumes of seafood products every year. Recently, seafood products processed in and exported from China have received negative media attention due to contamination and other food safety scares. However, because China's economic engine depends on export markets, the Chinese government has responded aggressively, promising to eventually adopt U.S. and European Union regulatory standards. Many of these regulations are administered by The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. Effective as in June 2003, the Chinese Regulations on Inspection and Quarantine of Import and Export Aquatic Products apply to fish and fish products, with the exception of live fish, whether exported for direct consumption or for further processing in China. Under these regulations, seafood products must be clearly labeled both in Chinese and English, indicating the following:

- Product Identity: including common name, scientific name and product specifications;
- Production identity: including production data/code, which must clearly identify the year, month and day of production, and batch code/lot number.
- Preservation requirements: for example, keep frozen.
- Processing establishment: including establishment name and CFIA registration number
- Country of destination: must state “People’s Republic of China”.
- Production method and fishing region.

In summary, seafood traceability is regulated in major markets to ensure their tracing and tracking. The European Union has mandatory traceability requirements for all seafood in General Food Law (Regulation EC-178/2002). In addition, regulation EC - 1005/2008 requires traceability for seafood product to prevent illegal, unreported and unregulated fishing (IUU). In the America, the U.S. Country of Origin Legislation of 2002 (or COOL) calls for labeling seafood products. The labels must identify both the country of origin and the method of production. Moreover, the U.S. Bioterrorism Act has adopted regulations that require establishment and maintenance of chain of custody records by persons who manufacture, process, pack, transport, distribute, receive, hold or import food into the United States (Magera and Beaton, 2009). “One up, one down” is the simplest model of external traceability, and the minimum requirement of traceability regulations in these markets.

3.4. Biodiversity loss in marine ecosystems

Life began in oceans and continues to thrive in its diverse habitats. Oceans cover 71% of our planet’s surface and make up 95% of all the space available to life. The marine environment is particularly rich in biodiversity (WWF, 2015). With as many as 100 million species (about 9 per cent of all species) have been identified from the tiniest bacteria to the largest animal ever lived on Earth - the blue whale (UNEP, 2012). In which, more than 20,000 species of fish are currently known (Bishop et al., 2008) and new species are being discovered all the time.

The oceans have been considered an inexhaustible source of fish for the centuries. But just over the last few decades, human activities have been pushing oceans to their limits. As a result, marine ecosystems will be very different from today's, with few large marine predators, and freshwater biodiversity will be severely reduced almost everywhere (Jenkins, 2003). Indeed, the loss of biological diversity in the oceans is a serious issue faced by fisheries industry worldwide. Almost three-fourth fisheries resources are in a stressed situation as 10 percent of global fish stocks or species groups are significantly depleted; nearly 25 percent are overexploited, depleted or recovering from depletion; and 52 percent are fully exploited (FAO, 2004). Worm et al. (2006) conclude that marine biodiversity loss is increasingly impairing the ocean's capacity to provide food, maintain water quality, and recover from perturbations.

3.4.1. Effects on seafood business operations

From a consumer's point of view – at least in most developed nations – the sad condition of fish stocks is not obvious (WRI, 2004). Some consumers believe that there is still plenty of fish available in markets and restaurants, although the types may have changed and the prices may be higher. So “*are we really running out of fish?*” or “*Are coastal ecosystems nearing collapse?*” Unfortunately, the answer is absolutely yes as the fisheries worldwide are going to completely collapsing by the year of 2048 unless the current situation improves (Worm et al., 2006).

The collapse of the population of Atlantic cod off the coast of eastern Canada is a classic example of the real phenomenon (MEA, 2005). This collapse forced the closure of the fishery after hundreds of years of exploitation. Until the late 1950s, the fishery was exploited by migratory seasonal fleets and resident inshore small-scale fishers. From the late 1950s, offshore bottom trawlers began exploiting the deeper part of the stock, leading to a large catch increase and a strong decline in the underlying biomass. Internationally agreed quotas in the early 1970s and, following the declaration by Canada of an Exclusive Fishing Zone in 1977, national quota systems ultimately failed to stop and reverse the decline. The stock collapsed to extremely low levels in the late 1980s and early 1990s, and a moratorium on commercial fishing was declared in June

1992. A small commercial inshore fishery was reintroduced in 1998, but catch rates declined and the fishery was closed indefinitely in 2003. The impacts of decline of fish catches are being painfully felt with some 40,000 people that lost their jobs including 10,000 fishermen (WWF, 2015).

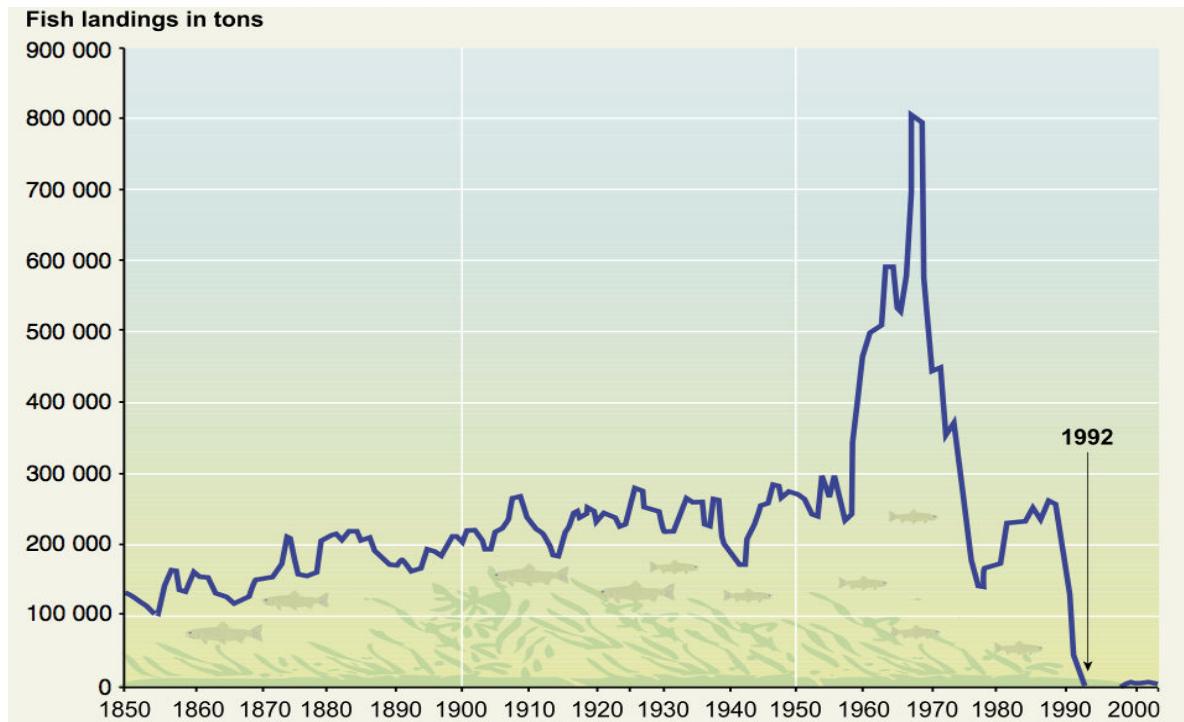


Figure 1.3.4 Collapse of Atlantic Cod stocks off the East Coast of Newfoundland in 1992

Source: The Millennium Ecosystem Assessment - MEA (2005)

From the business operation point of view, the main reasons for the seafood sector to engage with the issue of biodiversity include: (1) securing supplies of target fish and (2) reputation and access to markets (Bishop et al., 2008). The loss of biodiversity in marine ecosystem may cause significant risks to the businesses at least related to security of supply of raw material and to satisfaction of customers' expectations on sustainable sourcing (ISIS and F&C, 2004; WEF, 2010; TEEB, 2010b; Hanson et al., 2012). For instance, Unilever – an international manufacture of food – confronted a problem as the user of a wild biological resource vulnerable to over-harvesting – namely fish. Cod is the main fish species used in the company's premium frozen food

products. In the 1990s, cod stocks declined precipitously and totally collapsed in the western North Atlantic as described above, due to mismanagement and overexploitation. As a result, cod prices have increased substantially since the early 1990s by over 50% between 1996 and 2000. These dramatic price increases reduced the profit margins in Unilever's cod-related products by about 30% (ISIS and F&C, 2004).

Consumers influence the interactions between fisheries and biodiversity conservation through certification labeled on products (Jenning et al., 2014). In order to satisfy customer's expectations on sustainable sourcing, actions for conservation of biodiversity have been integrated into strategy of some leading companies from seafood supply chain. For example, as one of the largest single buyers of fish in the United States, McDonald's USA announced that they would become the first national restaurant chain to adopt the Marine Stewardship Council's blue eco-label on their fish packaging in restaurants nationwide. Sustainable fish sourcing is in addition part of the company broader commitment to sustainable sourcing and hundred percent of all fish sold in their US restaurants have been certified sustainable (MSC, 2013). Another case, Wal-Mart is the world's largest retailer now purchases only farmed shrimp certified at Global Aquaculture Alliance standards. Wal-Mart has recently committed to source only wild-caught fresh and frozen fish for North American stores from fisheries certified by the Marine Stewardship Council (WEF, 2010).

3.4.2. Drivers of biodiversity loss in marine ecosystems

The life in the oceans is being severely threatened by the major combined effects of unsustainable fishing (poor fisheries management, pirate fishing, massive bycatch, destructive fishing practices), aquaculture (chemical inputs, disease and parasites, escapes, feed, nutrient pollution and carrying capacity, social issues, land conversion and degradation), inadequate protection (not enough protection and lack of proper management, conflicting priorities, sensitive habitats at risk), pollution (oil, fertilizers, seas of garbage, sewage disposal, toxic chemicals), climate change (coral bleaching,

stormy weather, moving homes, altered lifestyles, rising sea levels, decreased mixing, acidic oceans) tourism and development, shipping (WWF, 2015; Rogers and Laffoley, 2011; UNEP, 2012).⁶ In which overfishing is the most significant immediate threat to marine biodiversity (TEEB, 2010b; MEA, 2005).

Fishing has a significant impact on ocean ecosystems above and beyond simply removing massive amounts of biomass and depleting individual species (MEA, 2005). Fishing targets are top predators, which are also large fishes in the ocean. As much as 90% of such fishes – sharks, tuna, marlin, and swordfish – have been removed by industrial fishing (FAO, 2014). Overfishing of these large species has changed the composition of the oceans, modified interactions among species, and resulted in the targeting of previously less desirable species that feed lower in the food web (MEA, 2005). Widespread collapses, overfishing of top predators, and declining catches are all symptoms of seriously disrupted ocean ecosystems. The ability of an ecosystem to absorb threats or to be resilient may be compromised with such massive disruption to the integrity of the natural system (MEA, 2005). Overfishing continues to be a major problem, with an increasing percentage of fish stocks overexploited, depleted or collapsed, and inappropriate fishing practices causing damage to habitat and non-target species (CBD, 2014).

Fishing industries cause biodiversity loss directly through excessive and illegal resource use and indirectly through bycatch and habitat loss (Lenzen et al., 2012) in which overexploitation is the most significant immediate threat (TEEB, 2010b; MEA, 2005). As fishing expanded across the open ocean, the proportion of depleted stocks rose from 4% in 1950 to 25% in 2000, while the “undeveloped” stocks plummeted from 65% to 0 (MEA, 2005). As a result, 53% of the world’s fisheries are fully exploited, and 32% are overexploited, depleted, or recovering from depletion; most of the top ten marine fisheries, accounting for about 30% of all capture fisheries production, are fully exploited or overexploited; and several important commercial fish populations have declined to the point where their survival is threatened (FAO, 2014; WWF, 2015).

Illegal, Unreported and Unregulated fishing (IUU or pirate fishing) is a serious global problem that contributes to overfishing, creates unfair competition, and threat marine

⁶ See appendix 1 for further detail of drivers of biodiversity loss in marine ecosystems.

ecosystems. Motivated by economic gain, IUU fishing takes advantage of corrupt administrations and exploits weak management regimes, especially those of developing countries lacking the capacity and resources (FAO, 2014). Pirate fishing can lead to increased pressure on endangered fish species by increasing the number of fish caught. Pirate fishing represents approximately 20% of the world's catch and as much as 50% in some fisheries (NOAA Fisheries, 2016). Rough estimates indicate that IUU fishing catches 11-26 million tons of fish each year, at an estimated value of US\$ 10 – 23 billion (Agnew et al., 2009).

The harm that fishing can cause to target fish is substantial, but the damage does not end there. The world's fleets harvest a large number of fish and other animals besides the particular species being targeted – animals that are generally referred to as bycatch. Some of this bycatch is retained for sale, but a portion of it – often a large portion – is returned to the sea, usually dead or dying (so-called “discards”). Bycatch and discards, and the associated high mortality of species, such as marine turtles, present one of the major challenges facing sustainable fisheries today. The latest FAO estimates that total marine discards is at least 10 million metric tons of animals – but this figure underestimates the number of marine mammals, turtles, and seabirds caught as bycatch, which can be substantial in certain fisheries (WRI, 2004).

By-catches can affect biodiversity through impacts on top predators, the removal of individuals from many species, or by elimination of prey (WWF, 2015). The by-catch issue is also one of waste; the millions of tons of protein dumped in the ocean (Hall et al., 2000) that represents 40 percent of global marine catches (Davies et al., 2009). Large industrial vessels, small artisanal boats, coastal fisheries, high seas fisheries... all around the world, catch fish far more than needed or wanted. The main reason why bycatch occurs is represented by modern fishing gear that is very strong, often covering an extensive area and being highly unselective – that means that it catches not only the target species but also many other creatures (WWF, 2015).

The expansion of fishing efforts in the offshore water is expected to increase production volume. Fishing fleets with modern and more efficient fishing equipment are able to fish at greater and greater distances from coastal and in deeper and deeper waters as inshore fisheries have been depleted (MEA, 2005). Though, there is no potential for

increases in production because most of the stocks are fully fished or overfished. In fact, the marine fish catch has leveled off in recent years except in the Asia-Pacific region. The global fish production in marine water has reached its peak in the mid-1990s and then began to decline after grown steadily over the last century. As a result, the global fishing fleet is 2-3 times larger than what the oceans can sustainably support (WWF, 2015). In other words, people are taking far more fish out of the ocean than can be replaced.

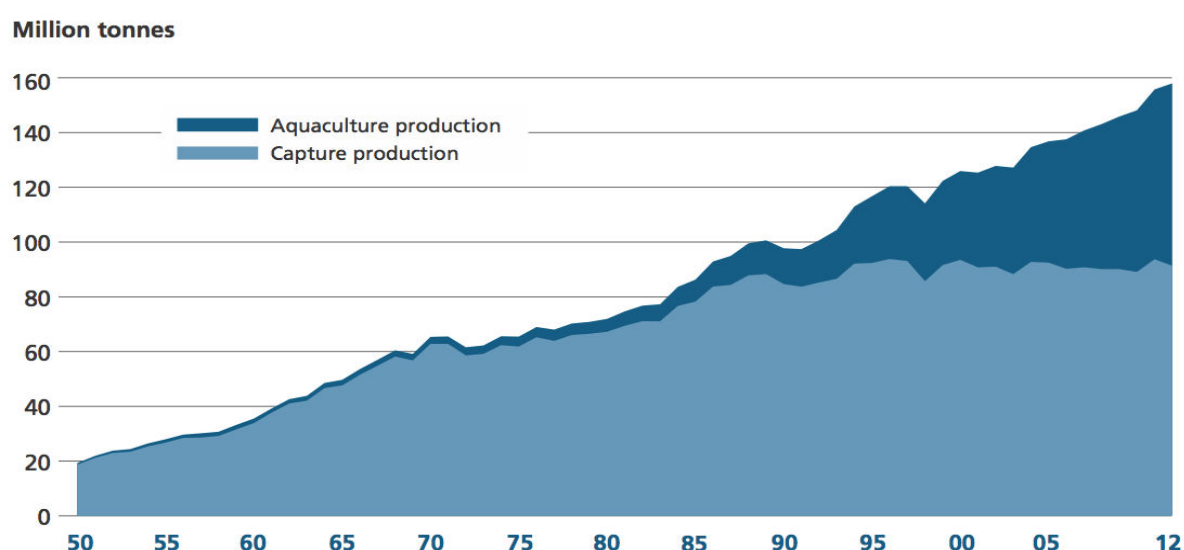


Figure 1.3.5 World capture fisheries and aquaculture production

Source: Food and Aquaculture Organization of the United Nations - FAO (2014)

In reality, the development of fish farming has supported the explosive growth in demand for seafood. By 2009, global aquaculture production had risen to 51 million tons while the global total fish catch remained below 90 million tones (FAO, 2012). The aquaculture production is contributing to the growing share of international trade in fishery commodities in both low value species (tilapia, catfish) and high value species (salmon, seabass, seabream, shrimp and prawns, bivalves and other molluscs). Together with the role of food security, aquaculture has pushed the demand for, and consumption of, species that have shifted from being primarily wild-caught to being primarily fish

farmed. In 2012, aquaculture offered about 49 percent of the fishery output for human consumption – impressive growth compared with its 5 percent in 1962 and 37 percent in 2002 (FAO, 2014).

Yet, the fish-farming sector faces a growing dilemma: it needs to feed a rapidly growing and increasingly affluent global population while also conserving biodiversity and sustainably management of natural resources on an increasingly depleted planet (TEEB, 2010a). Aquaculture has significant benefits for many people and economies, but there are disadvantages: large quantity of wild-caught fish used for feeding, mangroves in coastal areas are lost as fish farms are created, and significant amount of chemicals and pharmaceuticals (including antibiotics) that are used and discharged to the environment (FAO, 2011). Other fish farming impacts arise from the introduction of invasive alien species, pollution of soil and water. Therefore, it is challenging to balance the increased demand for seafood, restoration of depleted wild fisheries, grow of aquaculture, promotion of health of fresh and coastal waters.

4. Conclusion to the chapter

Historically, oceans have been considered an inexhaustible source of fish. Unfortunately, the world's fisheries are facing the danger of completely collapsing by the year of 2048 (Worm et al., 2006) or the year of 2114 (Jaenike, 2007). The life in the ocean is being so severely threatened due to the combined effects of climate change, overexploitation, pollution and habitat loss (Rogers and Laffoley, 2011), commonly referred as drivers of biodiversity loss (CBD, 2006). Lack of traceability is another serious facing issue in the seafood sector (Pramod et al., 2014; Warner et al., 2013; Donnelly and Olsen, 2012). As the most globally traded food commodity (FAO, 2012), certain attributes of seafood product in terms of safety, legality and sustainability are very vital. Unfortunately, fish are among the most challenging food products to trace due to its complexity and globalized supply chain (Magera and Beaton, 2009).

From the business perspective, the lack of information of seafood products and the loss of biodiversity in the marine ecosystems may pose significant risks to the businesses at least related to security of supply of raw material and to satisfy customers expectations on sustainable sourcing (ISIS and F&C, 2004; WEF, 2010; TEEB, 2010b; Hanson et al., 2012). These risks lead seafood businesses to develop action plans to cope with an issue gaining the worldwide attention - the sustainable development. Moreover, ensuring traceability and improving the performance of biodiversity management can help enterprises avoid potential business risk and, at the same time bring business advantages. The next chapter presents in specific the biodiversity business interactions as well as the role of traceability systems in the green supply chain management framework.

CHAPTER 2

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This chapter reviews the studies on green supply chain management, traceability and biodiversity business management. The aim of the chapter is to track the contribution of previous works in the disciplines and provide the foundation background for the development of models of this thesis, which are presented in the next chapter. Materials for this section come from peer review papers, books, theses, conference proceedings and white reports published and unpublished by organizations. The chapter begins with concepts of business sustainability and supply chain management. Traceability and ecological concerns in green supply chain management are discussed afterward. The subsequence sections present the literature on traceability and management of biodiversity business.

1. Green supply chain management

The concept of green supply chain management (GSCM) is to integrate environmental thinking into supply chain management (Chin et al., 2015). The “green” component of supply chain management involves the influence and relationships between supply chain management and environment management. Therefore, GSCM has its roots in both environment management and supply chain management literature (Srivastava, 2007). The scope of GSCM ranges from green purchasing to integrated supply chains flowing from suppliers to manufactures to customers, and reverse logistics (Zhu and Sarkis, 2004). Under sustainability point of view, GSCM focuses on two of the three Ps (profit, planet and people) in the triple bottom line, i.e. profit and planet, while people issues are normally not included in this concept (Halldorsson et al., 2009). The next subsection presents a brief overview of sustainability concerns in supply chain management that explains why GSCM is gaining increasing interest among researchers and practitioners.

1.1. Business sustainability and supply chain management

The term of sustainability and its trend in business operations are the first to be discussed. Sustainability concerns have been receiving attention from businesses for at

least thirty years. One of the reasons is the increasing expectation from consumers and stakeholders for companies to be full responsible for their business operations (Seuring and Muller, 2008). Sustainability is commonly defined as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Early sustainability initiatives tended to focus on environmental issues. Nowadays the scope of sustainability involves a triple bottom line including environment, economic, and social dimensions.

Hassini et al. (2012) define business sustainability as the ability to conduct business with a long-term goal of maintenance of a well-being economy, environment and society. Business sustainability initiatives are often closely associated with corporate social responsibility initiatives (Ahi and Searcy, 2013). The key characteristics of business sustainability may be expressed as: economic focus, environmental focus, social focus, stakeholder focus, volunteer focus, resilience focus, and long-term focus.

In today's global economy, most companies are a part of at least one supply chain and competition is becoming less “firm vs. firm” and more “supply chain vs. supply chain” (Hult et al., 2007). A supply chain encompasses all activities related to the flow and transformation of goods from raw materials to final product for end users, as well as associated information flows (Handfield and Nichols, 1999; CSCMP, 2014). Initially, supply chain management focused primarily on material flows. The growing interest in supply chain management has led to the development of numerous definitions to describe it. Based on literature review, Ahi and Searcy (2013) summarize the key characteristics of supply chain management that may be expressed as: flow focus, coordination focus, stakeholder focus, relationship focus, value focus, efficiency focus and performance focus.

Ashby et al. (2012) investigate systematically the discipline of supply chain management in the connection with sustainability literature. The successful integration of economic, environmental and social sustainability goals has been at the forethought of leading supply chain and operation management (Fahimnia et al., 2015). This

emergent field has been growing for at least 20 years from the period of the late 1980s and early 1990s of the past century and is well into its third decade of investigation. The topic of sustainability in the context of supply chain management has been discussed using a number of terms in the literature. The two used terms that most closely link sustainability and supply chain management concepts are sustainable supply chain management (SSCM) and green supply chain management (GSCM).

From a literature review on the field of sustainability and supply chain management, Seuring and Muller (2008) develop a conceptual framework for sustainable supply chain management that includes triggers for SSCM, supplier management for risks and performance, and supply chain management for sustainable products. Accordingly, sustainable supply chain management is defined as *“the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirement”*.

Carter and Rogers (2008) use conceptual theory to introduce the term of sustainability to the field of supply chain management and prove the relationship among environmental, social and economic performance within a supply chain management context. In the model, four supporting facets of facilitators of SSCM are identified, i.e. strategy, risk management, organizational culture and transparency. The strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains. Gold et al. (2010) explore the role of SSCM as a catalyst of generating value inter-organizational resources and thus possible sustained inter-firm competitive advantage through collaboration on environmental and social issues. Hassini et al. (2012) review the literature on SSCM during the period 2000 – 2010, and then provide frameworks for SSCM and performance measures with case study illustration.

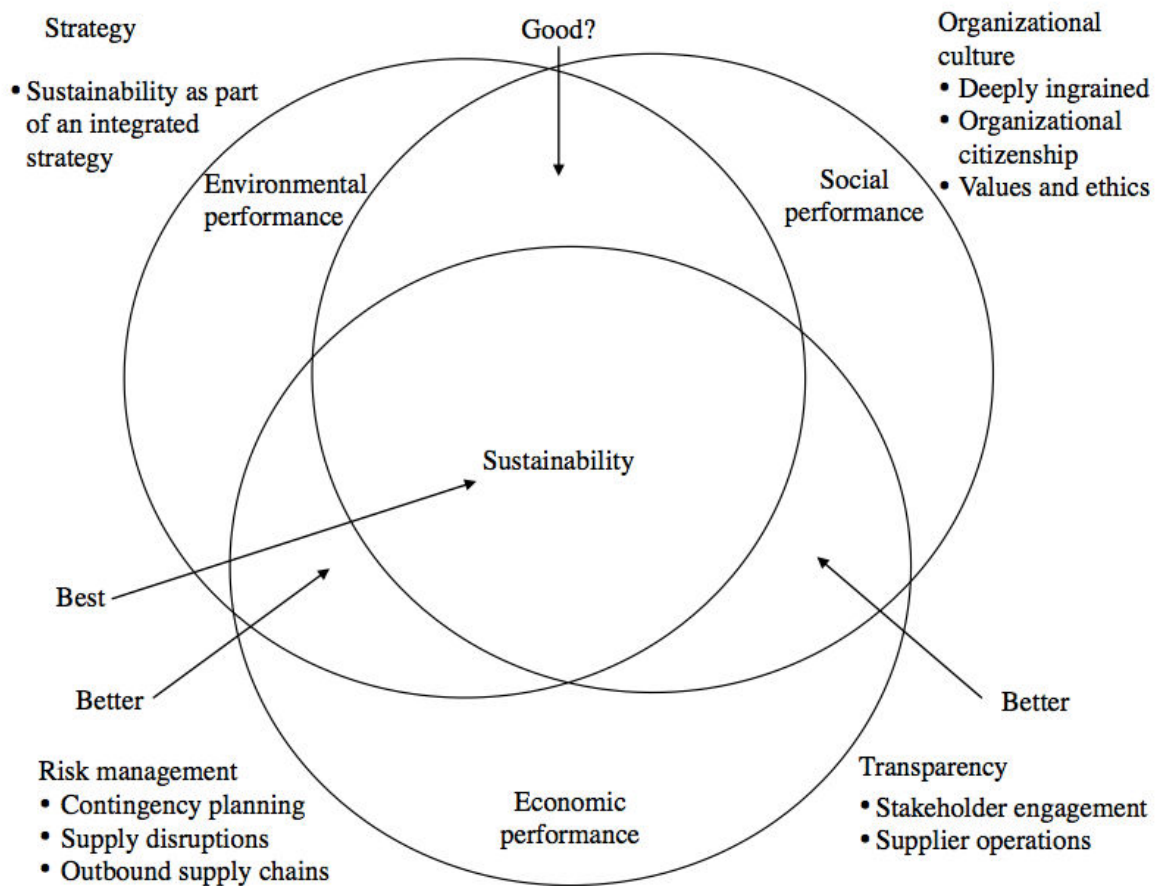


Figure 2.1.1 Sustainable supply chain management

Source: Carter and Rogers (2008)

Sustainable supply chain management (SSCM) and green supply chain management (GSCM) may be confused as both concepts integrate environmental consideration into supply chain management. A review on definitions for green and sustainable supply chain reveals a total of 22 definitions for green and 12 definitions for sustainable ones (Ahi and Searcy, 2013). The authors also conclude that the definitions of GSCM is generally narrowly emphasized on the characteristics of environmental, flow, and coordination focuses while SSCM essentially is an extension of GSCM and includes a

triple bottom line, i.e. environmental, economic and social dimensions to sustainability. GSCM is defined as “*integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life*” (Srivastava, 2007).

Implementation and performance assessments are the core topics in GSCM research (Zhu et al., 2013; 2012; 2008a, b, c; 2007a, b; Zhu and Sarkis, 2004). For example, Zhu et al. (2007b) explore the green supply chain implementation of various manufacturing industrial sectors in China and examine the links between GSCM initiatives and performance outcomes. De Giovanni and Vinzi (2012) investigate the relationships between environmental management and performance. Sarkis (2003) identifies and structures the primary strategic and operational elements of a framework that will help managers to evaluate green supply chain alternatives. Muduli et al. (2013) attempt to explore various behavior factors effecting GSCM practices.

Various issues related to GSCM have been investigated by applying organizational theories (Sarkis et al., 2011). A review of recent GSCM literature under broad of organizational theories, with a special emphasis on investigation of adoption, diffusion and outcomes of GSCM practices (Complexity theory, Ecological modernization, Information theory, Institutional theory, Resource based-view, Resource dependence theory, Social network theory, Stakeholder theory and Transaction cost economics) and identifies promising organizational theories for GSCM research (Diffusion of innovation theory, Path dependency theory, Social embeddedness theory, Structuration theory, and Agency theory).

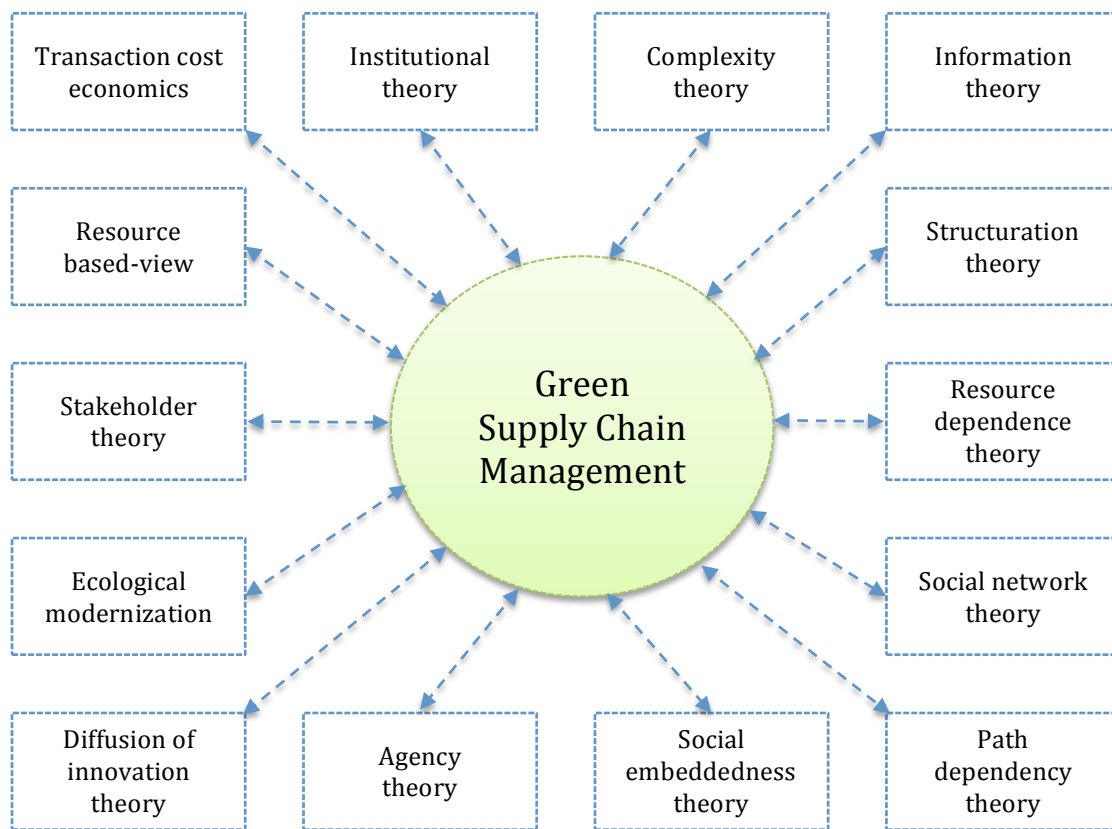


Figure 2.1.2 GSCM and Organizational theories

Carter and Easton (2011) conduct a systematic review of the sustainable supply chain management literature, mainly focusing on logistics and supply chain management journals of a 20-year time frame. The authors find that while more than 87 percent of articles did not employ a theoretical lens during 1991-2000, this omission dropped to just over 33 percent during 2001-2010. Accordingly, stakeholder theory has been the most prevalent, followed by the resource-based view, and the closely aligned natural resource-based view theory. Interesting fact is that transaction cost economics is one of the lesser-used theories in the SSCM literature.

Table 2.1.1 Theoretical lenses to examine the sustainability

Theoretical lens	Percent (Full time period) (%)	Percent (2001 – 2010) (%)	Percent (1991 – 2000) (%)
Transaction cost economics	6.25	8.33	3.13
Resource-based view	11.25	16.67	3.13
Knowledge-based view/ organizational learning	2.50	4.17	0.00
Stakeholder theory	21.25	35.42	0.0
Other	31.25	45.83	9.38
Multiple lenses	21.25	33.33	3.13
None	55.00	33.33	87.50

Source: Carter and Easton (2011)

Drivers and barriers to implementation of GSCM are also important aspects of the field. Walker et al. (2008) explore factors that drive or hinder organizations to implement green supply chain management initiatives, identifying the main categories of internal and external drivers including organizational factors, regulation, customers, competitors and society. Zhu and Sarkis (2006) compare drivers and practices of GSCM in China, focusing on three typical sectors, automobile industry, thermal power plants and electronic industry. Govindan et al. (2014) identify barriers to the implementation of a GSCM based on procurement effectiveness. Mathiyazhagan et al. (2013) use qualitative analysis of the barriers on GSCM implementation.

Green supply chain management includes all supply chain activities and takes into account both environmental consideration and more traditional economic considerations (Halldorsson et al., 2009). Integrated ecological concerns, green supply refers to the way in which innovations in supply chain management and industrial purchasing may be considered in respect of the environment (Green et al., 1996). Fahimnia et al. (2015) present a thorough bibliometric and network analysis that provides insights on the topic by reviewing over 1000 published studies on green

supply chain management. The next section reviews on how GSCM address in particularly environmental issues.

1.2. Ecological concern in GSCM

“Eco-efficient based green supply chain management (EE-GSCM)” is the theme of international workshop that was held at the Department of Business and Economics, University of Southern Denmark, Odense, Denmark. EE-GSCM is also the main theme of a special issue of European Journal of Operational Research in 2014. In the editorial letter, the editors (Kannan Govindan, Joseph Sarkis, Charbel Jose Chiappetta Jabbour, Qinghua Zhu, Yong Geng) indicate that industries are striving hard to improve their sustainable development through many strategies as environmental management systems, green and lean manufacturing, eco-effectiveness and efficiency in maintaining their place in today’s competitive environment. Among these strategies, eco-efficiency gained considerable attention among researchers and practitioners due to its high momentous benefits over a firm’s operational performance.

The term of eco-efficiency was defined as *“eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth’s estimated carrying capacity”* (Schmidheiny, 1992). While supply chains have been extended through lean and green initiatives, there is still a need to integrate eco-efficiency in supply chains in order to balance and focus on both economic and environmental aspects. Despite the proliferation of research, not a study addresses issues such as an eco-efficiency-based green supply chain, reverse supply chain, closed loop supply chain, and carbon footprint-based supply chain.

The review on eco-efficiency based GSCM can be found in the editorial letter. For example, Sarkis and Cordeiro (2012) use a bads-goods data envelopment analysis (DEA) model to determine joint ecological and technical efficiencies of the fossil-fueled electricity-generating plants in the United States. Zhu et al. (2011) investigate whether

different Chinese manufacturer clusters different in their extent of implementation of GSCM exist from this ecological modernization perspective. The authors also examine if Chinese manufacturers' awareness of domestic and international environmental energy savings and pollution reduction-oriented compliance is related to GSCM implementation and whether a mediating effect of regulatory pressure plays a significant role.

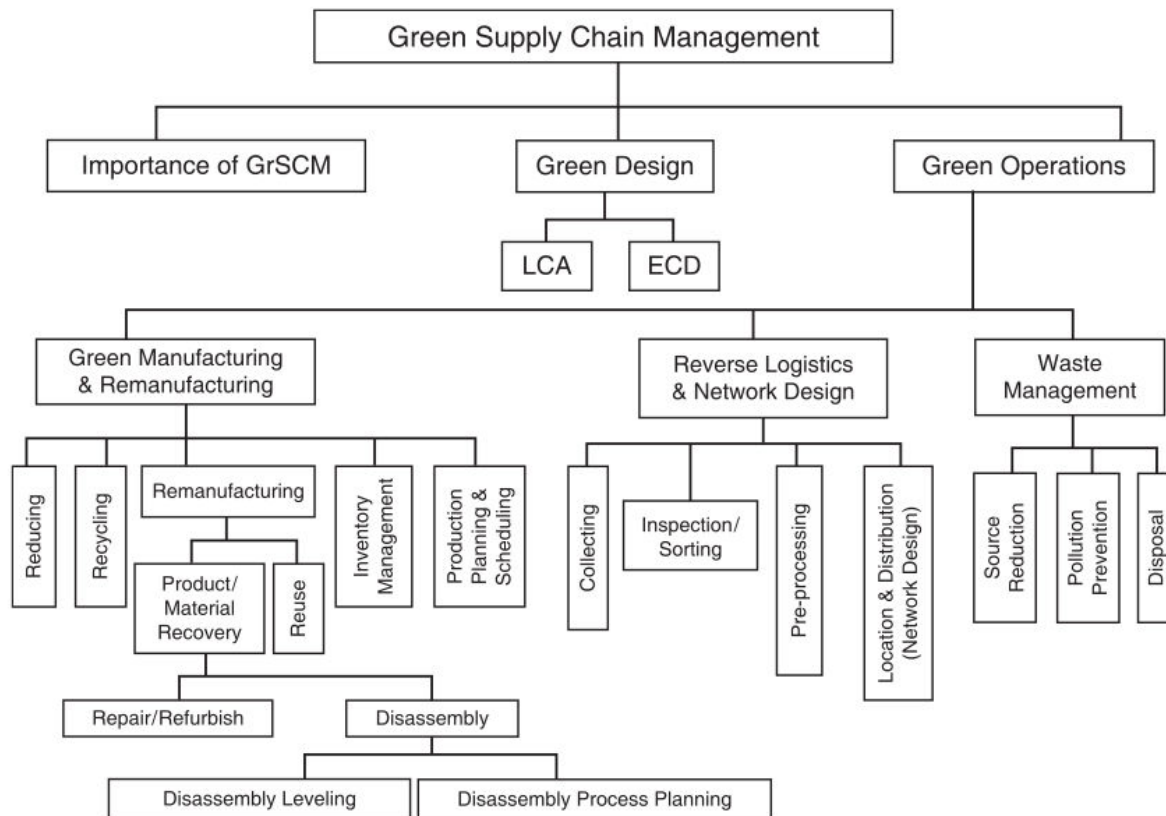


Figure 2.1.3 Classification based on problem context in supply chain design

Source: Adapted from Srivastava (2007)

Environmental focus was addressed in 21 of the 22 definitions of GSCM (Ahi and Searcy, 2013). Based on the problem context in supply chain design, the existing GSCM literature can be classified into three broad categories, i.e. the importance of GSCM, green design and green operations (Srivastava, 2007). Accordingly, the basic reason to

invest in green can be resource saving, waste eliminating and productivity improving. Green design may be looked from the viewpoint of environment conscious design taking life-cycle assessment of the product/process into account. Similarly, green operations involve all operational aspects as reverse logistics and network design (collection; inspection/ sorting; pre-processing; network design); green manufacturing and remanufacturing (reduce; recycle; production planning and scheduling; inventory management; remanufacturing: re-use, product and material recovery) and waste management (source reduction; pollution prevention; disposal).

Green purchasing, industrial ecology and industrial ecosystems were not included in the review by Srivastava (2007), but green purchasing is one main aspect, in some case considered as the complete, of GSCM practices implementation (Walton et al., 1998). Min and Galle (1997) presents the applications of green purchasing strategies. Large and Thomsen (2011) analyze the effectiveness of different approaches used for extension of sustainable practices of suppliers. Hoejmose et al. (2012) examine the conditions under which firms in the business-to-business (B2B) sector implement environmental processes into their individual buyer-supplier relationships. Carter et al. (1998) presents a reliable and valid scale used to measure environmental purchasing and examine the company specific factors that impact these activities. Carter et al. (2000) empirically test the effect of environmental purchasing on firms performance. Yen and Yen (2012) explore the effects of critical drivers on firms' adoption of green purchasing.

Zhu et al. (2008a) empirical investigate the construction of and the scale for evaluating green supply chain management practices implemented among manufacturers. The GSCM practices implementation includes five factors (internal environmental management, green purchasing, cooperation with customers, eco-design and investment recovery) and performance outcomes as environmental performance, economic performance and operational performance. The environmental performance factor is measured by six items, i.e. reduction of air emission, reduction of waste water, reduction of solid wastes, decrease of consumption for hazardous/ harmful/ toxic

material, decrease of frequency for environmental accidents, and improvement of an enterprise's environmental situation.

1.3. Traceability in GSCM

Obviously, the food is in the focus of traceability research. Based on the literature review, Kraisintu and Zhang (2011) indicate that 61% of the reviewed papers discuss traceability of food or food supply chain. Effective food traceability system is important for food supply chain that should provide consumers and others interested bodies with information on a product (characteristics, country of origin).

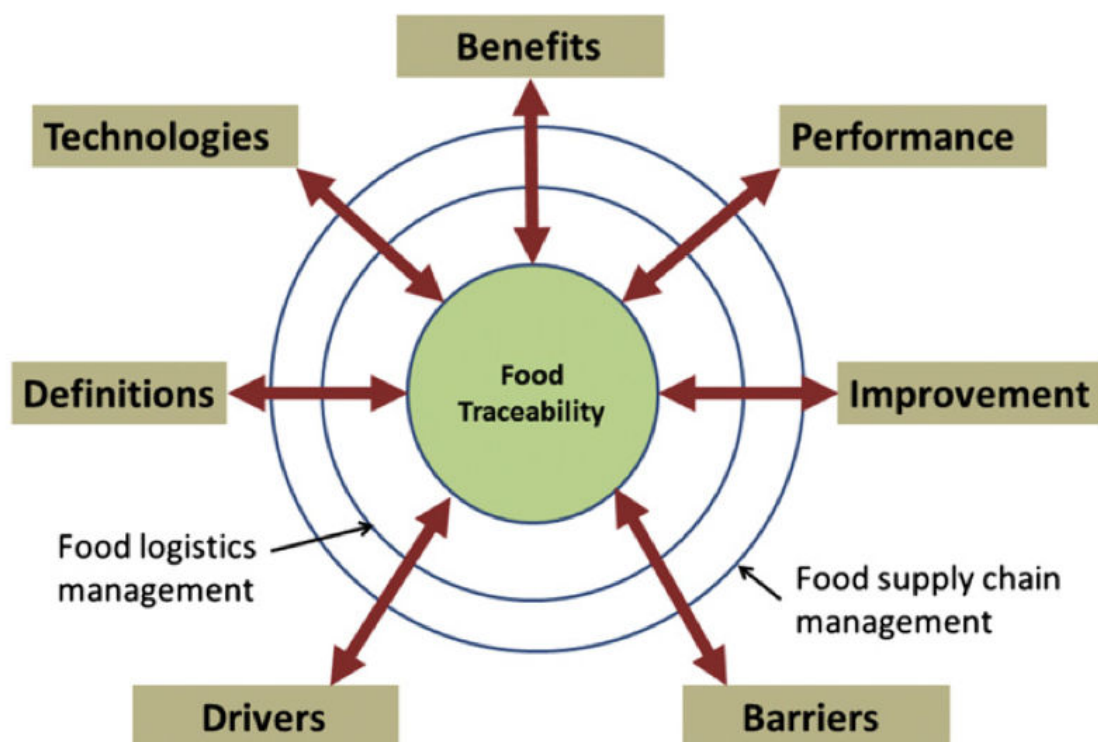


Figure 2.1.4 Traceability within supply chain management

Source: Adapted from Bosona and Gebresenbet (2013)

The initiative of food traceability is mainly connected with food quality and safety assurance, but rarely with business development and logistics improvement issues. However, the linkage between qualitative information and physical flow is the key factor in developing effective and efficient traceability and this issue should be considered from logistics management point of view. Packaging, data transmitting, food recalls are associated not only with traceability practices but also with logistics system management. Based on discussions, the attention to traceability in relation to its capacity to boost information connectivity in supply chain and reinforce logistics process as well as food supply chain management, Bosona and Gebresenbet (2013) have proposed a new comprehensive definition of food traceability as an integral part of logistics management in food and agricultural supply chain.

Packaging is part of logistics operations in supply chain, the use of primary-consumer-packing and appropriate labeling techniques should be into attention of logistics management. By integrating logistics information systems, with traceability devices and IT application, an efficient collaborate environment is integrated, where supply chain partners can exchange real-time logistics information via web-based visualization of logistics process (Bosona and Gebresenbet, 2013). Food recalls are associated not only with information problems but also with logistics problems (McCallum, 2012). The lack of coordinated logistics operations definitely affects the product flow from farm to fork and consequently the efficiency of food traceability efforts. In other way, the development and implementation of IT-supported food traceability system could improve operational planning and increase efficiency of food logistics processes. Such important facts indicate that food traceability activities are basically embedded in logistics systems.

Indeed, traceability is an interdisciplinary research field, and it spans the natural science as well as the social sciences. In the supply chain management research field, different studies address the issue related to the traceability: logistics management, inventory management, risk management, supply-side management, production differentiation, distribution systems, and decision support systems (Karlsen et al.,

2013). In the quality management field, quality control, quality improvement, quality assurance systems, and quality management systems have been studied.



Figure 2.1.5 Fields of studies in traceability and supply chain management

Source: Karlsen et al. (2013)

The design of a traceability system requires a thorough rethinking and reorganizing of the whole food supply chain. Dabbene et al. (2014) present a comprehensive literature review on the aspects of supply chain management that is influenced by traceability. They analysis how traceability concepts, requirements and technologies influence modern supply chain management. Accordingly, the ability of a traceability system to monitor the composition and the position of each lot in the production and supply chains represents a very powerful tool that can be used to define new management objectives and to improve the overall performance of the food supply chain.

Firms in different industries have implemented traceability systems to increase supply chain performance. Kraisintu and Zhang (2011) analyzed the contribution of traceability to creation of a sustainable supply chain management by identifying effects on economic perspective, social perspective and environmental perspective and the mechanism on how traceability can create sustainability by identifying relationship among three perspectives.

Traceability has both negative and positive effects on the economic dimension. Positive effect refers to any process or activity enabling monetary gain or protection from monetary loss. Of course, the implementation of traceability systems always increases costs. Traceability for social sustainability contributes to increase social welfare. In environmental dimension, traceability contributes to environmental welfare that may directly or indirectly create positive effects.

Table 2.1.2 Effects of traceability on sustainable supply chain management

Dimension	Positive effects
Economic performance	Cost saving (recall, inventory, labor, transaction, transport, coordination cost)
	Increasing profit/ revenue (increasing of consumers' WTP, better order prediction, better product replenishment)
	Sales reduction protection (recall, customers' expectations)
Social performance	Consumer protection (from unsafe products, consumers' welfare)
	Animal protection (avoid animals abuse)
	Local business protection (protection of domestic farm business)
	Public protection (reducing public medical cost)
	Competition protection (from anti-competitive acts)
Environmental performance	Labor protection (preventing child labor abuse)
	Preventing illegal fishing and avoid extinction of some fish species
	Preventing air/soil/water pollution
	Protecting environmental resources
	Control Genetically Modified Organism (GMO) products not to contaminate natural plant

Source: Kraisintu and Zhang (2011)

Business for Social Responsibility (BSR) developed a guide to traceability: a practical approach to advance sustainability in global supply chains. Research within the guide revealed that traceability is a tremendously impactful tool for advancing sustainability objectives, but it still has a long way to go before it is an integral part of sustainable supply chain management (UNGC, 2014). The findings are based on a review of publically available information, literature and case studies about supply chain

traceability; an analysis of existing traceability schemes; and interviews with individuals at companies, traceability schemes and NGOs who have significant experience in traceability.

2. Traceability and transaction governance

Consumers are demanding more and more information associated with the sustainability, corporate social responsibility, ethical sourcing and traceability from the commodities they are going to buy. There is no doubt that the lack of product origin information and supply chain transparency may pose significant risks and/or unforeseen effects for consumers. Thus, traceability systems have often been implemented as a solution to reduce asymmetry information (Hobbs et al., 2005). The introduction of traceability systems can improve risk management, supply chain management and marketing (Wang and Bravo, 2010); fulfil requirements including the sustainability and reduce transaction costs (Golan et al., 2004); and increase vertical coordination in the supply chain (Banterle and Stranieri, 2008). Generally, the implementation of traceability can make changes in transaction characteristics as well as transaction costs that lead to variation in transaction governance structure of the firms (Banterle et al., 2006).

2.1. Research on traceability in literature

Traceability has become an ongoing concern for consumers, business managers, public policymakers, and special interest groups because of recent food safety crises. Different organizations such as the International Organization of Standardization (ISO), the Food and Agriculture Organization (FAO), and the European Community (Regulation EC 178/2002) offer different definitions of traceability. A complete traceability system should address the tracing, tracking of product and the associated complete product history information throughout the supply chain (Bosana and Gebresenbet, 2013).

In general, it is possible to distinguish two differences traceability systems, i.e. mandatory and voluntary. Mandatory traceability system is regulated in legal

framework by public policy and voluntary one is introduced by private sector. These traceability systems have different economic effects for the firms involved in a supply chain. According to mandatory traceability system, economic agents have to register the flow of goods along supply chain with an appropriate documentation procedure (Banterle et al., 2006). Therefore, economic agents have to document from whom they buy the raw materials and to whom they sell the processed products. This system can be called “supply chain traceability”, but it does not allow an individual product to be tracked back to the specific agricultural raw materials from which it came. The voluntary traceability systems allow traceability at both the level of the agents involved in the supply chain traceability and at the level of single firm organization that can be called “product traceability”, separating the different batches of raw materials in the production processes of the firm (Banterle et al., 2006). In this way, firms are able to reconstruct the complete history of a specific product, so each product can be traced back to the relative agricultural raw materials.

Shortly, traceability refers to the ability to trace and follow a product throughout all of the stages of its production from raw material to consumption (ISO 22005: 2007). To be effective, traceability must be managed by establishing of a traceability system (Moe, 1998), which constitutes a record-keeping system that is designed to track the flow of products or product attributes not only through internal production processes but also through external supply chains (Golan et al., 2004). Internal traceability refers to the ability to keep track of what happens to a product, its components and packaging within a company or production facility, while external traceability refers to such activities in the entirety or part of a supply chain (Petersen and Green, 2004). Firms can implement paper-based and/or electronic traceability systems. The use of paper-based traceability systems may be inexpensive and feasible for small businesses with limited product lines (Magera and Beaton, 2009), whereas electronic traceability systems can be divided into barcode and radio frequency identification (RFID) systems, both of which allow large amounts of information to be managed.

The main characteristics of traceability systems depend on their breadth, depth and precision (Golan et al., 2004). *Breadth* refers to the amount of information recorded, for example: feed ingredients, production methods, processing methods, etc.; *depth*

describes which sectors are involved in the food supply chain; *precision* is the degree of assurance with which the system can pinpoint the movement of a specific product, for example: tracing of a specific animal, a lot of animals, or a farm. In the context of a supply chain, traceability systems operationalize the dimension of information, with an emphasis on five factors regarding a product under consideration, i.e., what (the unit of analysis), who (the actors), where (the locations), when (the events), and how (the methods) (Wang and Bravo, 2010). From the perspective of information management, according to Van Dorp (2002) traceability system includes three layers: item coding (the physical layer); information architecture (information layer), and planning and control (the control layer).

Trautman et al. (2008) conduct a comprehensive review on traceability research from the literature. According to the review, there have been realized numerous studies on different aspects of traceability (tracking and tracing), on benefits and costs for the implementation of traceability systems. The studies address some of the key objectives: the impact of changing consumer behavior on market participants; how incentives might influence supplier participation in traceability; impact of regulatory changes on suppliers; response to crises; and technical description of a traceability system. As regarding the method, studies use a range of methods from qualitative such as literature reviews, surveys of primary producer, processor and/or retailers, to consumer segmentation analysis and/or estimation of consumer willingness to pay, or fitting a statistical or economic model to form firm behavior in response to crises or food outbreaks, new regulations, and/or consumer behavior. Several studies that focus on impact of traceability and changing behavior on firms tend to take a farm-to-fork perspective on traceability.

Six key findings from previous researches on traceability have also been outlined by Trautman et al. (2008). *First*, the results of the studies on consumer perception of food safety and process attributes suggest that consumers do not value traceability *per se*, but rather see traceability as a mean to deliver desired product or process attributes. *Second*, retailers may regard traceability programs as opportunity to intensify the level of product differentiation and brand competition from the shelves. *Third*, primary producers' incentives to adopt a traceability systems are driven by factors such as

efficiencies through improved supply chain management, food safety/quality control, meeting requirements for accessing foreign markets. *Fourth*, regulatory changes may drive adaptation of traceability system among retailers and suppliers. *Fifth*, food safety outbreaks and crises like BSE, Salmonella and E. coli may stimulate improvement of coordination among industry stakeholders. *The last one*, numerous studies have identified opportunities and challenges associated with traceability, such as costs of maintaining animal identification systems, cost of segregating products as it goes through the supply channel and market opportunities associated with improved supply chain control.

Previously traceability works have focused generally on 4 approaches (Wang and Bravo, 2010). The market-based approach studies the costs and consumers' WTP relationships. The marketing approach focuses on product positioning and consumer behaviors to raise consumer perceived values. The industrial engineering approach is concentrated on processes and technological improvements to reduce traceability costs. The transaction cost approach focuses on exchange relationships between consumers and suppliers and acts on the other factors, disturbances, or uncertainty.

2.2. Traceability and transaction governance

Supply chain improvement, food safety control and access to foreign market segments are strong incentives for primary producers and processors to participate in programs with traceability features (Trautman et al., 2008; Golan et al., 2004; 2003). Because of market failure, traceability systems are thus part of food safety policies introduced for reducing consumers' information asymmetry with respect to food safety and food quality attributes (Hobbs et al., 2005). The main functions of traceability systems can be clarified as ex-post reactive systems that allow the tracing of affected products in the event of a problem, ex-post systems that facilitate the allocation of liability, and information systems that provide ex-ante quality verification (Hobbs, 2004).

The implementation of food traceability system can reduce *ex post* costs; enhance food safety; and decrease information costs for consumers (Hobbs et al., 2005). One benefit

of traceability systems represents the optimization of transaction costs between agents, because it increases transparency within the supply chain, which may make lower price (Trautman et al., 2008). Aside from these benefits, the introduction of traceability systems also requires costs. Traceability costs arise from activities related to the product differentiation and recordkeeping. The costs of product differentiation is associated with managing an item coding system that enables tracking units to be separated and preserved their unique identities. The costs of recordkeeping relate to managing the information architecture that collects and maintains information on products and product attributes (Van Dorp, 2002).

There can be summarized three dominant benefits of a traceability system and namely: (i) food safety and quality control thanks to introduction of production rules and specific monitoring activities throughout the chain; (ii) increased consumer demand and confidence due to product differentiation with more credence attributes; and (iii) the benefits of efficiency gains in supply management are due to increased transparency at all stages (Golan et al., 2004). With regard to this last aspect, a firm promotes the introduction of traceability system in the supply chain and involves the other economic agents of the chain. This firm thus becomes responsible for the system, managing the information flow and may increase in vertical coordination among the economic agents (Banterle et al., 2006).

From the literature review, a key limitation is that there is very little data collected in quantifying the economic impact on stakeholders of traceability, at the farm to processor stages as well as processor to retail stages of traceability (Wang and Bravo, 2010). Transaction cost economics refers to analysis the effect of the implementation of traceability systems on transaction governance structure in the supply chain. The next section present the theoretical background of transaction cost economics.

2.3. Transaction cost economics

The theoretical framework of transaction cost economics (TCE) is often used to analyze the organizational changes (Williamson, 1979; 1985). Transaction costs that are always

present in markets incur in making an economic exchange, in the different ways of vertical coordination and even in vertically integrated firms (Coase, 1937; 1992) because of information asymmetry, bounded rationality and opportunism (Williamson, 1996). Economic subjects try to minimize transaction costs by developing new forms of transaction governance that allow reduction of such costs.

2.3.1. Evolution of transaction cost economics

Transaction cost economics program is the product of two recent and complementary fields of economics research. The first one is the New Institutional Economics and the second one has been described as the “new economics of organization” (Moe, 1984; 1990). A key conceptual move for both was to push beyond the theory of the firm as a production function (which is a technological construction) into a theory of the firm as a governance structure (which is an organizational construction).

From a neoclassical economics perspective, the market is assumed to be efficient and is always “best” at providing goods and services. This implies that it is always cheaper for firm to procure externally what it requires from the market, consequently producing nothing internally. The market is a “marvel” (Hayek, 1945) with prices mechanism that portrays such a frictionless business environment. A firm is regarded as a production function that selects through alternatives to minimize input costs and maximize consumer utility. The invisible hand coordinates all consumers, firms, and economic activities moving toward an optimized status of equilibrium, so that the market is looked like “ocean of unconscious cooperation” (Coase, 1937). Unfortunately, this ideal is not always available in the practical business world.

In contrast to neoclassical microeconomic theory, transaction cost economics assumes that markets are not in fact perfectly efficient or costless through the price mechanism - there always exist costs (contracting, procurement, etc.) in arranging commerce that added to the direct cost of the goods. According to Coase (1937) entrepreneurs could avoid these transaction costs of the market by producing internally under hierarchical governance and a boundary of a firm. Based on Coase’s earlier works on transaction

costs, Williamson provides specification of the variables that inform the decision whether or not to “make or buy” and behavioral assumptions in decision-making process.

In a world with positive transaction costs, exchange agreements must be governed, and contingent on the transactions to be organized, some forms of governance may be better than others (Tadelis and Williamson, 2010). The choice of the coordination mechanism depends on transaction costs, e.g. the cost of collection of market prices information, cost of negotiating and drafting of contracts, and the cost of ensuring compliance with the terms of the contract (Williamson, 1996). Transaction cost economics is thus to explain the structure of firms.

2.3.2. Transaction cost

Transaction cost is a cost incurred in making an economic exchange. A transaction occurs when a product or service is transferred through an interface between two separate parties. Ideally, the product or service moves smoothly costless with a constant full speed. However, Coase (1937) argued that transaction costs are often positive as frictions. In Coase’s ideas, it is costly to organize production through the price mechanism, an actor needs to first discover relevant prices in the market, and then negotiate and conclude a contract with another actor for each exchange transaction. Transaction costs can be classified in three main categories depending on where they arise in the transaction: search costs; negotiating costs; and monitoring and enforcement costs (Hobbs, 1996).

- *Search and information costs* are costs such as those incurred in determining that the required good is available on the market, which has the lowest price. These costs arise *ex ante*, and are related to the level of transaction transparency and limited rationality of economic agents within a market.

- *Bargaining costs* are the costs required to come to an acceptable agreement with the other party to the transaction, drawing up an appropriate contract and so on.

Negotiating costs take place during transactions, and are mainly connected to the difficulty in settling agreements.

- *Policing and enforcement costs* are the costs of making sure the other party sticks to the terms of the contract, and taking appropriate action if this turns out not to be the case. These costs occur after the exchange has been negotiated, and are correlated to the level of bilateral dependency among subjects as a consequence of specific investment necessary as per transaction conditions.

Transaction costs can also be considered as the “costs of running the economic system” (Arrow, 1969). Such costs are distinguished from production costs with which is the cost category with which neoclassical analysis has been preoccupied. Transaction costs are the economic equivalent of friction in physical systems. The manifold successes of physics in ascertaining the attributes of complex systems by assuming the absence of friction scarcely require recounting. Such a strategy has obviously appealed to the social sciences. Unsurprisingly, the absence of friction in physical systems is cited to illustrate the analytic power associated with “unrealistic” assumptions (Williamson, 1985).

2.3.3. Implication of transaction cost economics

The theoretical framework of transaction cost economics is often used to analyze the organizational changes (Williamson, 1979). Transaction cost economics poses the problem of economic organization as a problem of contracting. One particularly relevant facet of TCE is that of the bounded rationality of actors, which occurs due to limits associated with communication and information processing capabilities, and relatedly, the potential for opportunistic behavior (Williamson, 1985). Such perceptions of opportunistic behavior can be exacerbated as firms source from distant suppliers and as supplier and other members of the supply chain make claims regarding how their products are manufactured (Carter and Easton, 2011). Carter and Easton (2011) also indicate that bounded rationality and perceptions of opportunism within the context of sustainable supply chain management influence the decision on supply chain governance structures. The governance structure chosen to conduct specific transactions, with specific characteristics, affect the organizational efficiency in terms of

minimization of the sum of production and transaction costs including search costs, bargaining costs and enforcement costs.

3. Performance of biodiversity management

A number of tools and initiatives have been created to support business engagement on biodiversity and ecosystem services across a wide range of sectors (UNEP, 2010). These include those related to emerging themes such as payments for ecosystem services, biodiversity offsets and banking, and generic tools on biodiversity to inform decision-making. According to EarthWatch Institute, the key considerations in developing a biodiversity conservation performance measurement system are what to measure and why, where, when, to and by whom (EWI, 2006). Grigg et al. (2009) develop the Ecosystem Services Benchmark that is valuable to companies being evaluated, enabling them to measure and track their performance and identify key areas for improvement. Hanson et al. (2012) introduce the Corporate Ecosystem Service Review to help businesses develop strategies for managing risks and opportunities arising from their dependence and impact on ecosystems. In general, in order to assess the biodiversity management, a company needs to have access to a wide range of ecological data, including geographically referenced biodiversity datasets combined with site surveys (IUCN, 2014).

3.1. Management of biodiversity business

Business activities play a major role in biodiversity loss, and stakeholders continuously increase the pressure on firms to reduce the impacts on ecosystems (Houdet et al., 2012; Abbott et al., 2002). The role of business on the protection of biodiversity and ecosystems has been investigated throughout assessment of a vast number of documents from governments and civil society (Van den Burg and Bogaardt, 2014). The authors find that businesses are expected to play a role in the protection of biodiversity and ecosystem services – public goods and little expectation from consumers and/or citizen pressure. In contrast, businesses emphasize that they alone cannot be made responsible for the protection of ecosystems and biodiversity and plea for government

intervention from, for example, the enforcement of existing regulations or the establishment of new standards. Jones and Solomon (2013) seek to problematize “accounting for biodiversity” and to provide a framework for analyzing and understanding the role of accounting in preserving and enhancing biodiversity on the Planet Earth. They find that the problems underlying accounting for biodiversity fall into four broad categories: philosophical and scientific problems, accountability problems, technical accounting problems, and problems of accounting practices.

Table 2.3.1 Core and Additional Performance Indicators on Biodiversity

Core Indicators	Additional Indicators
EN11 Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.	EN13 Habitats protected or restored
EN12 Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.	EN14 Strategies, current actions and future plan for managing impacts on biodiversity.
	EN15 Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk.

Source: Global Reporting Initiative (2007)

Lähtinen et al. (2016) study how companies address biodiversity and ecosystem services in supply chain management. Accordingly, companies tend to disclose indirect biodiversity and ecosystem services impacts over direct ones, to focus on the supply chain in upstream activities rather than in downstream operations. Houdet et al. (2012) analysis of business strategy regarding biodiversity seeks to be complementary to mechanisms and measures for biodiversity conservation. Potdar et al. (2016) evaluate the performance of business organizations in reporting the biodiversity related environmental performance indicators as per the GRI reporting framework and the initiatives undertaken by these organizations for the conservation of biodiversity. The Table 2.3.1 gives an overview of the core (relevant to most reporting organizations) and

additional (of interest to most stakeholders) Biodiversity Performance Indicators in the GRI Guidelines.

Businesses can integrate biodiversity concerns into their environmental management systems (theebi.org - a). According to the European Business & Biodiversity Campaign, the biodiversity management process could be implemented through the four phases of the cycle, i.e., (1) exploring company's status quo and biodiversity linkages; (2) analyzing company's biodiversity linkages; (3) integrating biodiversity policies, programs and activities; and (4) monitoring and communicating (EBBC, 2013).

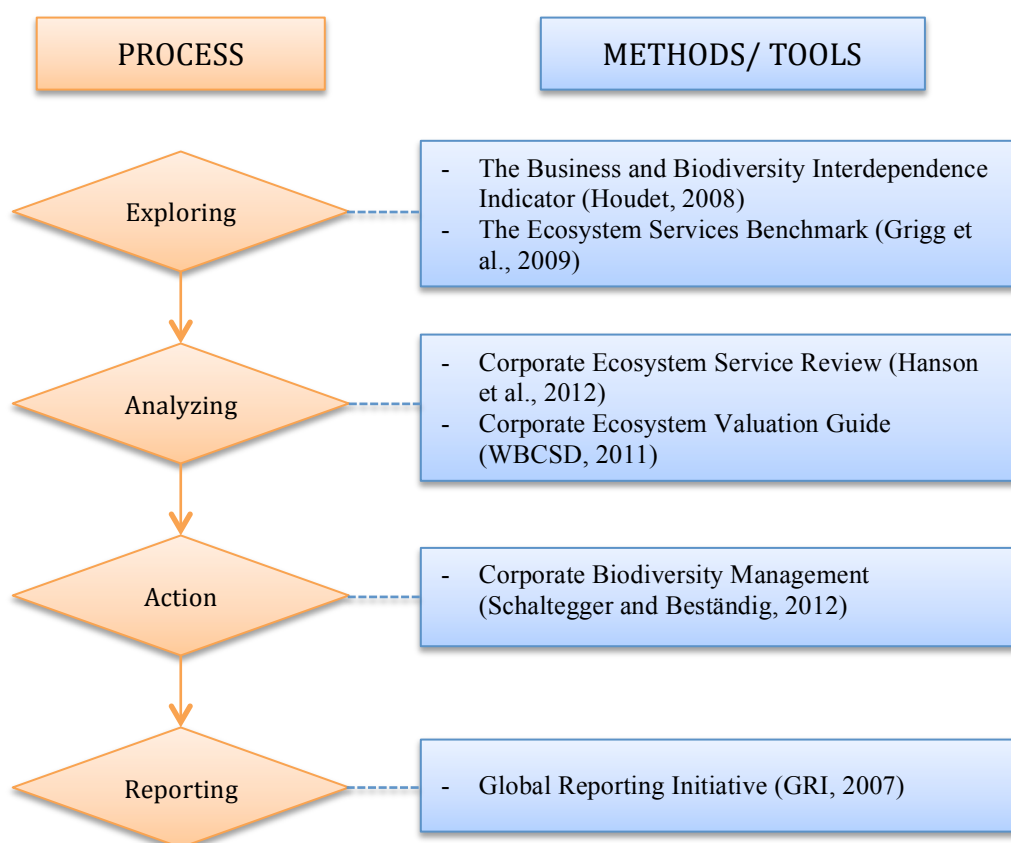


Figure 2.3.1 Process and methods/ tools for implementing biodiversity management

The Figure 2.3.1 indicates recommended methods and tools with respect to each step in the process for implementing biodiversity in management. The Business and Biodiversity Interdependence Indicator (BBII) was developed by the Orée Institute to

help companies to perform a self-assessment in order to determine direct and indirect interactions with biodiversity and ecosystems (Houdet, 2008). The Ecosystem Services Benchmarking tool was developed by the Natural Value Initiative designed to evaluate investment risk and opportunity associated with biodiversity and ecosystem services impacts and dependence (Grigg et al., 2009). The European Business & Biodiversity Campaign also offers the Biodiversity Check that provides a first overview on the company's relation to biodiversity regarding opportunities, impacts and risks (EBBC, 2013). Next subsequences paragraphs present in detail of each phrase.

3.1.1. Biodiversity business interdependency

The key value of biodiversity lies in its role in ensuring the functioning of ecosystems and their ability to provide services to humans and other living organisms (GRI, 2007). Thus the loss of biodiversity is a threat to the functioning of economy, human society, and our planet (TEEB, 2008). Nevertheless, human activities are causing Earth's major extinction event – an accelerating decline of the world's stocks of biological diversity at rates 100 to 1,000 times pre-human levels (Pimm et al., 1995). Of which business activities are considered as one of major cause of loss of biodiversity (Houdet et al., 2012). In the absence of major changes in policy and human behavior, human effects on the environment will continue to alter biodiversity (Chapin et al., 2000).

If there is no biodiversity, there is no business (IUCN, 2014). Indeed, a company may have a two-way interaction with biodiversity encompassing the impact of company on biodiversity and the impact of biodiversity on company (ISIS and F&C, 2004). On the one hand, companies have impacts on biodiversity through their core operation. On the other hand, companies also depend on biodiversity and ecosystems services as key inputs to products and production processes (TEEB, 2010a). Both the impact and dependence can be direct from a vast array of fields through company activities and/or indirect via its supply chain.

The key aspects of the relationship between businesses and biodiversity can be visualized in the figure 2.3.2 below. It is crucial to remind that companies depend on biodiversity and have an impact on biodiversity at the same time.

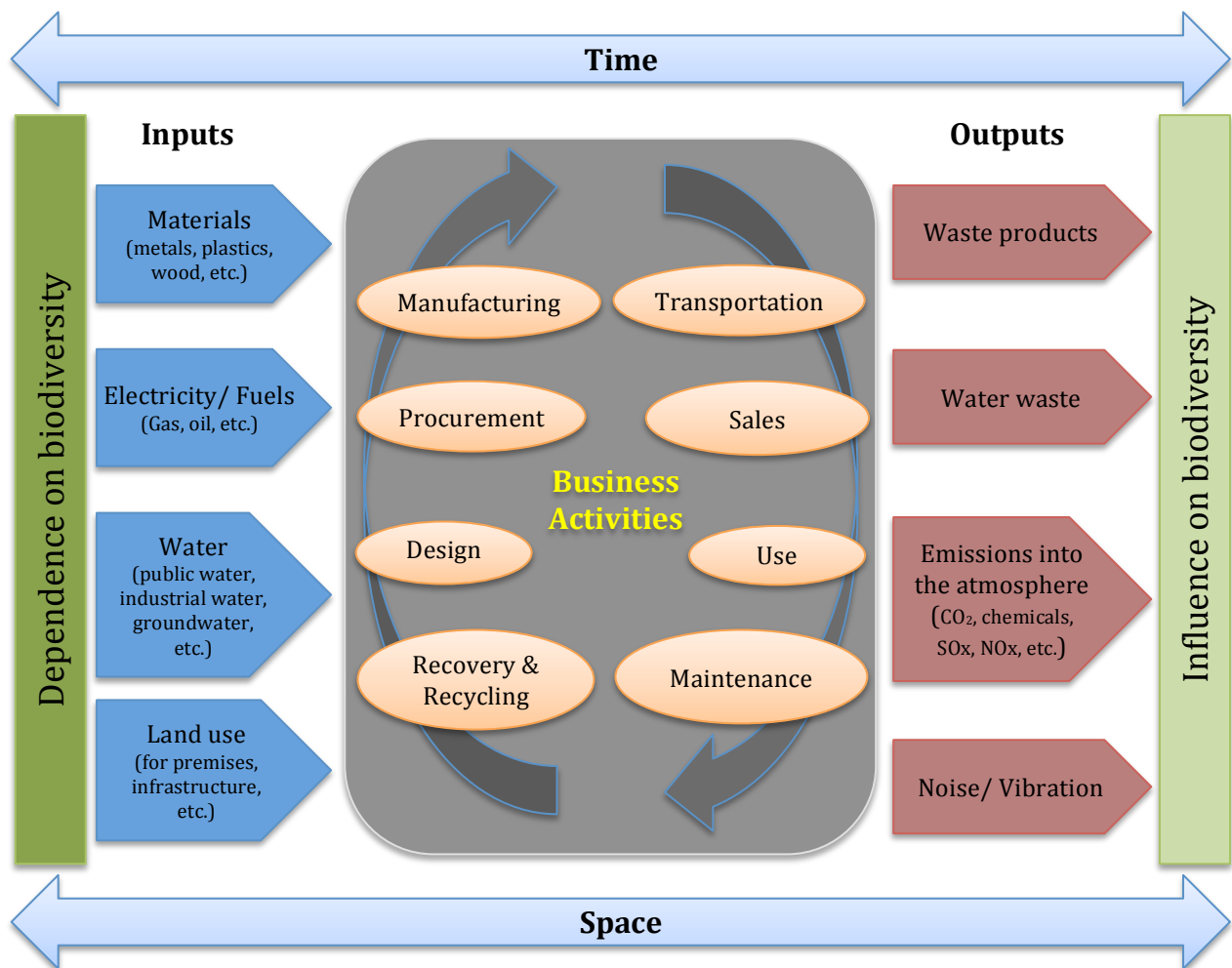


Figure 2.3.2 Relationship between business activities and biodiversity

Source: ICF GHK, adapted from Mitsubishi Global Environmental Portal [*in EC, 2015*]

A company needs to understand its level of dependence and impact on biodiversity and ecosystem services because the ecosystem services represent source of business risk or opportunity on which a company highly depends upon and/or highly affects it. For instance, if a company highly depends upon an ecosystem service and that service becomes scarce or degrades, then the company may face business risk in the form of higher input costs or disruption of operations. If a company negatively affects an ecosystem service by depleting or degrading it, then the company's actions may pose regulatory or reputational business risks. Conversely, if a company positively influences an ecosystem service by supplying or enhancing it, then the company's actions may give rise to possible new business opportunities or reputational benefits (Hanson et al., 2012).

3.1.1.1. Evaluating dependence

To help managers evaluate whether or not their company depends on an ecosystem service, the following questions can be asked when evaluating dependence:

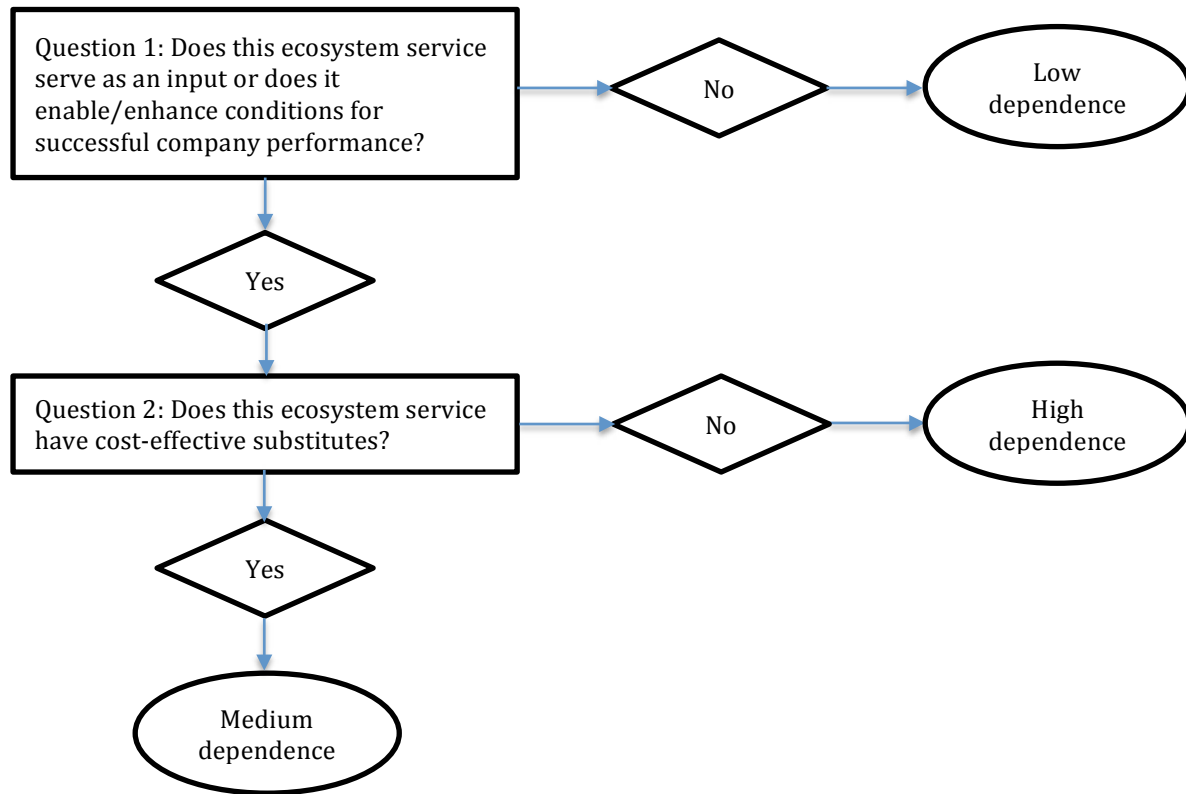


Figure 2.3.3 Questions to ask for evaluating dependence

Source: Hanson et al., 2012

A company depends on an ecosystem services if that service functions as an input or if it enables, enhances, or influences environmental conditions required for successful corporate performance. For example, timber is an input for wood product manufacturers. Freshwater is an input for beverage companies and many others. The degree to which a company depends on an ecosystem service is a function of whether or not there is a cost-effective substitute for that service. If there is no such substitute, then the company is considered to be highly dependent upon that service. Beverage manufacturers and hydro-electricity facilities, for instance, are highly dependent upon freshwater because there is no substitute for this ecosystem service. Substitutes may

exist, however, for some services. For a business located on a coast, a sea walk might provide the storm surge protection that a coral reef would have provided. Concrete or steel can fill in for wood in construction. Nevertheless, whether or not these are cost-effective substitutes will vary by company (Hanson et al., 2012).

3.1.1.2. Evaluating impact

To help managers evaluate whether or not their company impacts an ecosystem service, the following questions can be asked when evaluating impact.

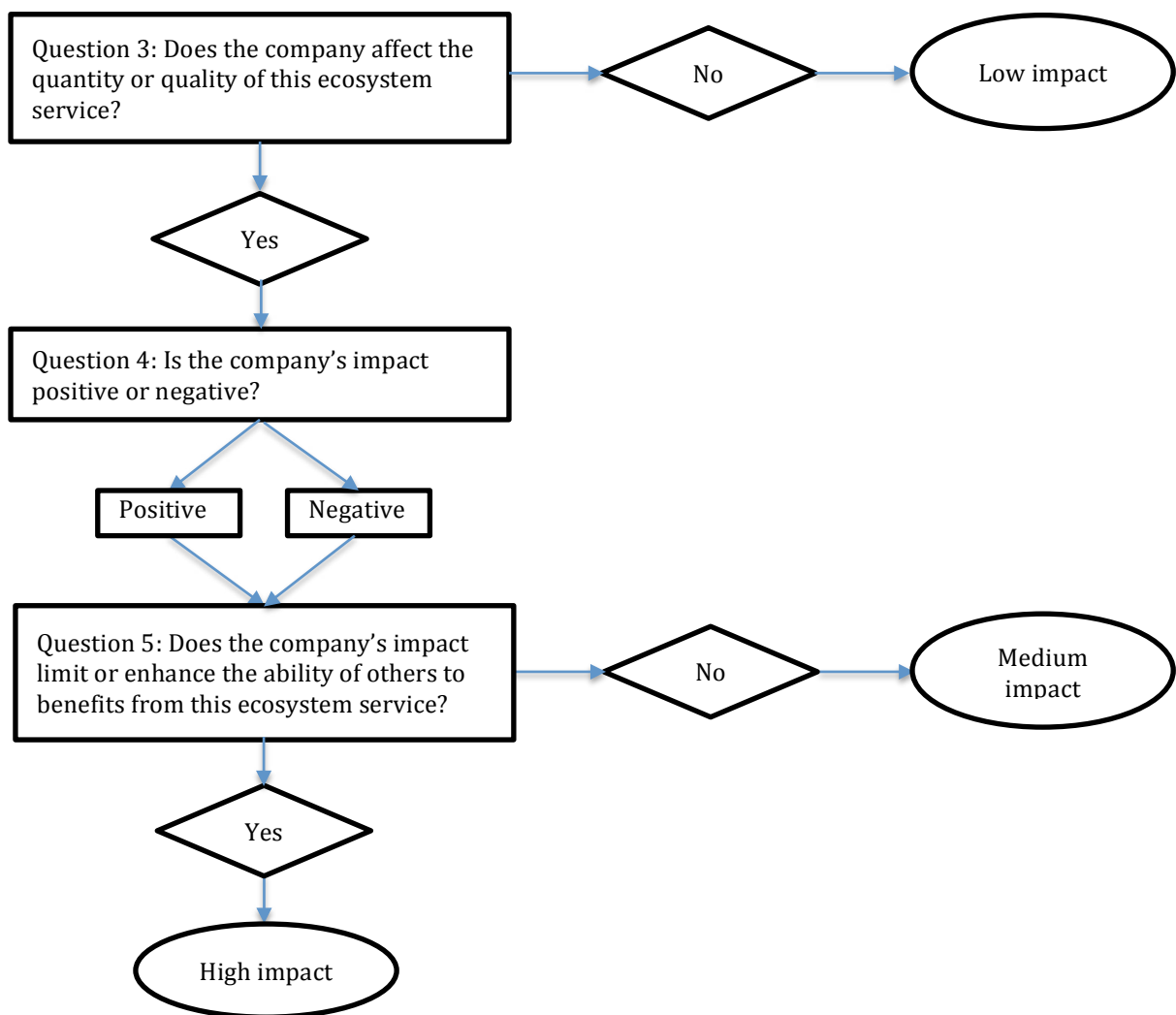


Figure 2.3.4 Questions to ask for evaluating impact

Source: Hanson et al. (2012)

A company impacts an ecosystem service if it affects the quantity or quality of that service. For example, a forest plantation affects the quantity of freshwater in its watershed. A business that fills in wetlands in order to construct a new facility may affect the quantity of water runoff and aquifer recharge.

A firm in the extractive industries may affect the quality of a location's recreation services by damaging the landscape or otherwise disturbing an ecosystem valued by hikers, campers, and others. The impact is positive if the company increases the quantity or quality of the ecosystem service. For example, a forest products company increases the quantity of timber and wood fiber because their forests actually supply these services. Under the appropriate management regime, the company's forest could increase the quality of wild game hunting and recreational services as well. The impact is negative if the company decreases the quantity or quality of the ecosystem service. For example, agribusiness can reduce the quantity of freshwater in a watershed. By removing mangroves, a coast hotel or shrimp farm can decrease the quality of shoreline protection. The degree to which a company impacts an ecosystem service in a manner that might pose a business risk or opportunity for itself is a function of whether or not the impact limits or enhances the ability of others to benefit from the service. Beneficiaries could include indigenous people, farmers, local communities, other businesses, or, in the case of cultural services, people living on the other side of the world who value endangered species (Hanson et al., 2012).

3.1.2. Biodiversity business: risk and opportunity

Changes in biodiversity subsequently alter ecosystem process and change the resilience of ecosystems to environmental change (Chapin et al., 2000). Such potential changes of ecosystems may have a serious impact on stakeholders involved and on businesses activities from the intervention area (GRI, 2007). Consequently, the loss of biodiversity can pose significant risks on businesses. Business risks that arise through the interactions between business activities and biodiversity may include: access to land, reputation, access to capital, access to markets, security of supply, relations with regulators and liabilities (ISIS and F&C, 2004; Hanson et al., 2012). Biodiversity loss is therefore one of the risks to keep on radar (WEF, 2010), even though it is difficult to

measure and to translate biodiversity loss into an individuated risk that can cause firms to behave differently (Dempsey, 2013).

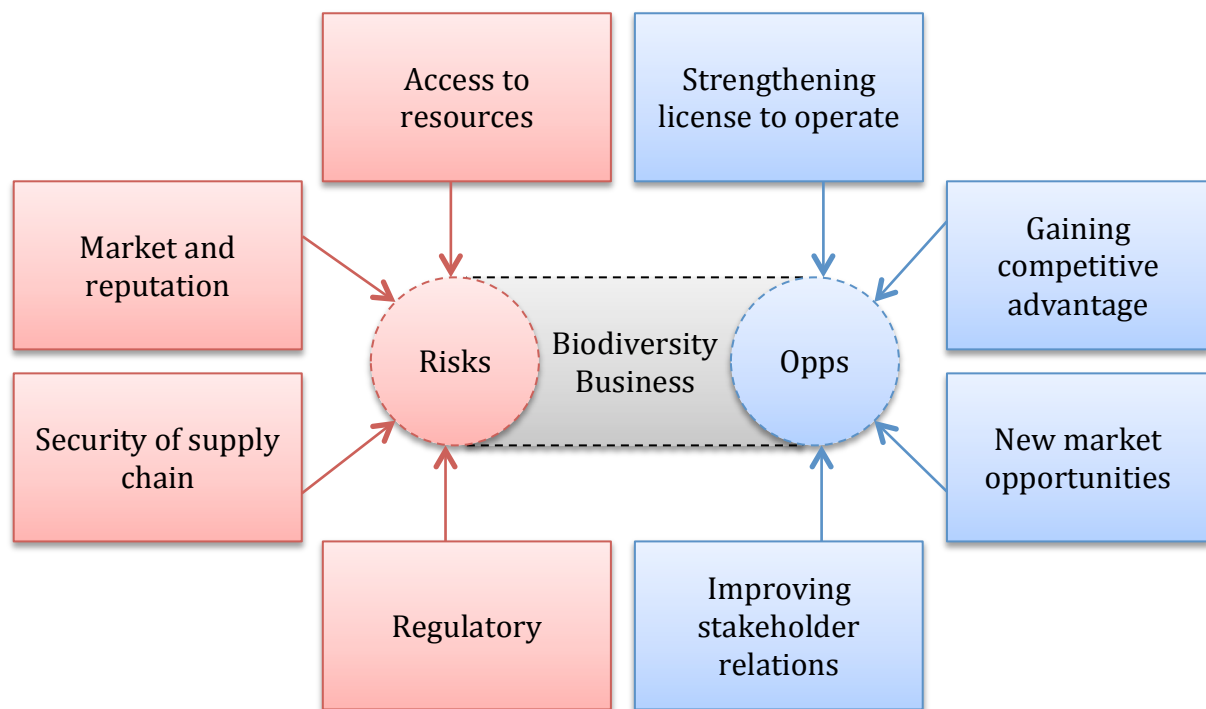


Figure 2.3.5 Biodiversity business: risks and opportunities

By proactively taking biodiversity risks into account, companies can obtain many benefits in terms of protecting their operational license, gain competitive advantage, improve stakeholder relations, gain new markets opportunities, long-term stability of operations (GRI, 2007; TEEB, 2010a). Businesses can also demonstrate leadership in support for and reform of public policy that seeks to raise industry environmental performance standards in order to gain first-mover advantages (MEA, 2005). These include the supply of commodities and services according to emerging standards of biodiversity-friendly production, supported by independent certification or assurance mechanisms, as well as the supply of ecosystem restoration and management services to both public and private customers. In addition, other investors and entrepreneurs are discovering that biodiversity conservation can form the basis of new profitable business models (Bishop et al., 2008).

The Corporate Ecosystem Services Review (Hanson et al., 2012) is a tool for strategy development that helps business identify risks and opportunities arising from the interdependence of business activities on ecosystems. Biodiversity and ecosystem valuation refers to a process of better-informed business decision-making by explicitly valuing both ecosystem degradation and the benefits provided by ecosystem services and biodiversity. The World Business Council for Sustainable Development developed the Corporate Ecosystem Valuation (CEV) guide for companies to streamline this process (WBCSD, 2011). Indeed, ecosystem degradation can pose a number of risks to corporate performance but create new business opportunities as well. Changes in the quantity of biodiversity and ecosystem services can pose general types of business risks and opportunities: operational, regulatory and legal, reputational, market and product, and financing (Hanson et al., 2012).

Table 2.3.2 Biodiversity business: risk and opportunity

Type	Risk	Opportunity
Operational: day-to day company activities, spending and process.	- Increased scarcity or cost inputs - Reduced output or productivity - Disruption to business operations	- Increased efficiency - Low-impact industrial processes
Regulatory and legal: Influence of government policies and laws	- Extraction moratoria - Lower quotas - Fines; User fees - Permit or license suspension - Permit denial; Lawsuits	- Formal license to expand operations - New products to meet new regulations - Opportunity to shape government policy
Reputational: company brand, image and relationships with stakeholders.	- Damage to brand or image - Challenge to social “license to operate”	- Improved or differentiated brand
Market and product: product and service offerings, customers preferences	- Changes in public sector customer preferences - Changes in private sector customer preferences	- New products or services - Markets for certified products - Markets for ecosystem services - New revenue stream from company-owned or managed ecosystems
Financing: cost and availability of capital from investors	- Higher cost of capital - More rigorous lending requirements	- Increased investment by progressive lenders and socially responsible investment funds

Source: Hanson et al. (2012)

Increased insufficiency and cost of raw materials such as freshwater, fish or timber, disruption of business caused by natural hazards exacerbated by loss of ecosystem services, higher insurance costs for disasters such as flooding, increasing costs of natural services as they become scarce all give rise to potential operational risks (Grigg et al., 2009). In addition, penalties arising from the emergence of new government policies such as taxes and moratoria on natural resource extraction and rationing of scarce resources give rise to regulatory and compliance risk. Exposure from media and non-governmental organisation campaigns, shareholder resolutions and changing customer preferences can give rise to reputation risk.

Table 2.3.3 Factors in assessing risk and opportunity

To assess	Question
Operational risk	- Is the company particularly dependent on ecosystem services such as water, natural pollinators, which are likely to become scarce? If reliant on such services, are there substitutes? - Do product or ingredients that may be impacted by shortages in such services form a significant volume or value for the business? - Is this giving rise to conflict over source use? - Is the company dependent on a small number of customers who could impose stringent performance requirements on them?
Reputational risk	- Is the company sourcing from areas in, near or containing areas of known ecological sensitivity either protected by law or highlighted by key stakeholders, e.g. NGOs, as important? If not known, this remains a risk. - Does the company have strong relationships with key stakeholders such as NGOs?
Regulatory and compliance risk	- Does the company source raw material from regions that have laws or regulations, which limit or require payments for source use?
Market differentiation opportunity	- Can the company differentiate its brand or product through improved environmental efficiencies? - Is market demand increasing or declining for goods produced with efficient resource inputs?
New revenue streams opportunity	- Does the legal and operating environment allow investigation into new sources of revenues, e.g. organic products, carbon credits or water rights?

Source: Grigg et al. (2009)

Hanson et al. (2012) also suggest a process for identifying risks and opportunities. The process starts by summarizing the company's dependence and impact on one of its priority ecosystem services and then briefly reviews the trends in that service. Grigg et al. (2009) particularly outline a number of questions that can be used to evaluate the level of risk and opportunity within a company.

Biodiversity issues that are not adequately addressed may impose risks on business. A company's position in the marketplace, indeed its profitability, can be threatened by risks as: challenges to its legal license, disruption of its supply chain, damage of the brand, consumer boycotts and campaigns by environmental NGOs, third party claims for environmental liabilities, poor staff morale (Abbott et al., 2002). Conversely, addressing biodiversity issues provide multiple opportunities. Indeed, 59 percent of executives see biodiversity as more an opportunity than a risk for their company (McKinsey, 2010). Accordingly, they identify a variety of potential opportunities, such as bolstering corporate reputations with environmentally conscious stakeholders by acting to preserve biodiversity and developing new products or ideas from renewable natural resources.

3.1.3. Corporate biodiversity practices ⁷

The goal of a business case for biodiversity is both to conserve biodiversity and to increase the economic success of the company. This goal can be achieved through targeted, voluntary biodiversity conservation measures that go beyond the legal requirements. This is often aided by intelligently and efficiently complying with existing government regulations, such as wastewater limits. When developing a business case for biodiversity it is important to note that the processes impacting business success can contain both a market and a non-market component.

Since a business case is the result of a strategic management process and does not occur automatically, it is crucial to carefully set up a biodiversity management program. With

⁷ This section is basically adapted from Schaltegger and Beständig (2012)

a systematic analysis of the business case drivers, there can be found specific opportunities to combine the conservation of biological diversity with business success. Depending on how corporate activities are developed, they are positively or negatively influenced by the business case. Drivers of a business case for biodiversity include variables such as costs, sales and price, risk mitigation, reputation and brand value and innovation.

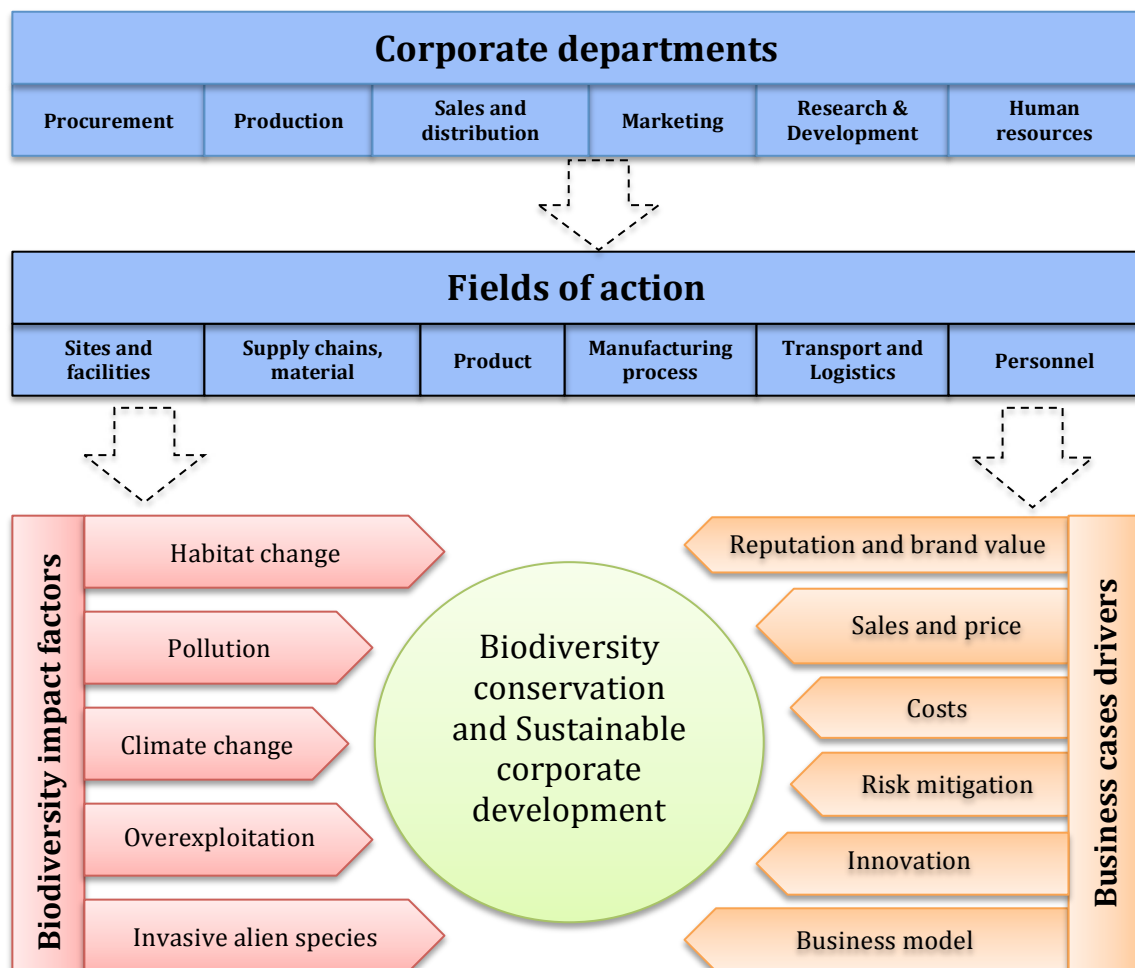


Figure 2.3.6 Corporate biodiversity management flow diagram

Source: Schaltegger and Beständig (2012)

The management cycle can help a company to develop a process to make operational its biodiversity management strategy. This orientation enables a company to develop measures that will have a positive impact on both biodiversity and sustainable corporate development in each corporate department. It is necessary for each company to analysis its processes in a particular field of action in order to determine what influences there might be on the drivers of a business case.

Through the development and use of company sites, building or through emissions, etc., businesses directly affect biological diversity. In addition to location development and supply chain management, corporate biodiversity management encompasses further fields of action. Business success and impact factors on biodiversity can be managed by implementing the necessary strategies. The following is a list of the most important fields of actions with description for corporate biodiversity management.

Table 2.3.4 Field of action for biodiversity management

Field of action	Description
Sites and facilities	The construction and use of office buildings, production halls or car parks change the existing habitat and affect biodiversity. Additionally, construction and use of commercial facilities acts as greenhouse gas sinks and sources. For instance, if a wetland is to be used as a company site and is drained and dried, vital ecosystems will be destroyed while greenhouse gases are emitted into the environment. Similarly, clear cutting a section of forest destroys the animal and plant kingdoms together with a natural CO ₂ sink. In the initial transformation of raw materials to useable construction materials, extracting rock from quarries or ploughing grasslands heavily impact plant and animal habitats.
Supply chain, commodities and materials	The types of used commodities and raw materials also impact biodiversity. For example the acquisition of minerals, energy, agricultural products, fish, wood, medicinal herbs or plants – genetically modified or not – impacts regions that often do not belong to the businesses that benefit from them. Such unintended consequences can be reduced or avoided altogether by implementing the appropriate supply chain management. The supply chain management is the starting point for regulating extraction methods as well as the quantity and quality of purchased materials.

Product	Depending on product or service design, the final product will have a greater or lesser impact on biodiversity. Negative impacts can be reduced in a number of ways, including changing the service design or by substituting, reducing and recycling materials used in the production. Positive effects can also be created by using raw materials in products that contribute to the conservation of biological diversity, such as the use of older types of grain or juices from traditional mixed-crop orchards. Product design can also be more than eco-design, especially when it is a part of “caused-related marketing”, a method that enables the manufacturer to combine products sales with donation for specific projects. Consumer protection aspects can be combined with biodiversity protection.
Production and manufacturing processes	Resource consumption and emissions, such as wastewater, airborne pollutants or greenhouse gas, are generally hazardous for biological diversity. Therefore, optimizing production processes is usually an effective contribution to protecting biodiversity. Additionally, an improved process design can reduce the necessary net input of raw materials and energy. This often results in lower production costs.
Transport and logistics	Transporting raw materials and manufactured products as well as business travels leads to emission of greenhouse gases and dust. Transportation infrastructure can fragment habitats, reducing their functionality and impeding natural genetic exchange. Furthermore, increasing goods transportation enables non-native species to invade new habitats, thereby displacing species native to the area.
Personnel	A sustainable biodiversity management system will be all the more successful when the employees are convinced of it and are allowed to actively take part in achieving its goals. They are the ones who are taking the decision on a day-to-day basis and who are implementing management strategies. In addition, employees volunteering time help protect biological diversity. When the necessary structures are created and volunteer programs are promoted, it can strengthen employee corporate identity.

Source: Schaltegger and Beständig (2012)

The corporate biodiversity management involves the methodical design of processes, products and projects to ensure business success and conservation of biodiversity. The basis of corporate biodiversity management is the business-specific relationship between the company and biodiversity. However, finding these relationships is more difficult due to complexity and three levels extension of biodiversity (ecosystem, species, and genetic pool). In addition, finding the business-specific relationships between a company and biodiversity can require some scientific expertise.



Figure 2.3.7 Taking action on biodiversity

Source: McKinsey & Company (2010)

What companies are taking action on biodiversity? Well, one of the most frequently chosen actions is seeking to identify new products or ideas to reduce use of renewable natural resources. In addition, about 53 percent of executives in the survey say their companies are taking action to address biodiversity issues. Among all respondents, only a quarter have a formal biodiversity policy or strategy, and only 22 percent have formal targets. Among those with any formal target, 62 percent have operational ones, and only 27 percent have financial ones (McKinsey, 2010).

3.1.4. Biodiversity performance reporting

Reporting is a tool for sharing information with stakeholders about an organization's activities, impact, and performance on biodiversity. Financial reporting alone no longer satisfies the needs and expectations of shareholders, customers, communities, and other stakeholders for information about the overall performance of a business. Effective reporting should communicate the organization's relationship with biodiversity, its approach to managing impacts, and results achieved. The Global Reporting Initiative is the commonly accepted framework for reporting on the triple bottom line of sustainability that assures credibility, consistency, comparability and low costs of communicating (GRI, 2007).

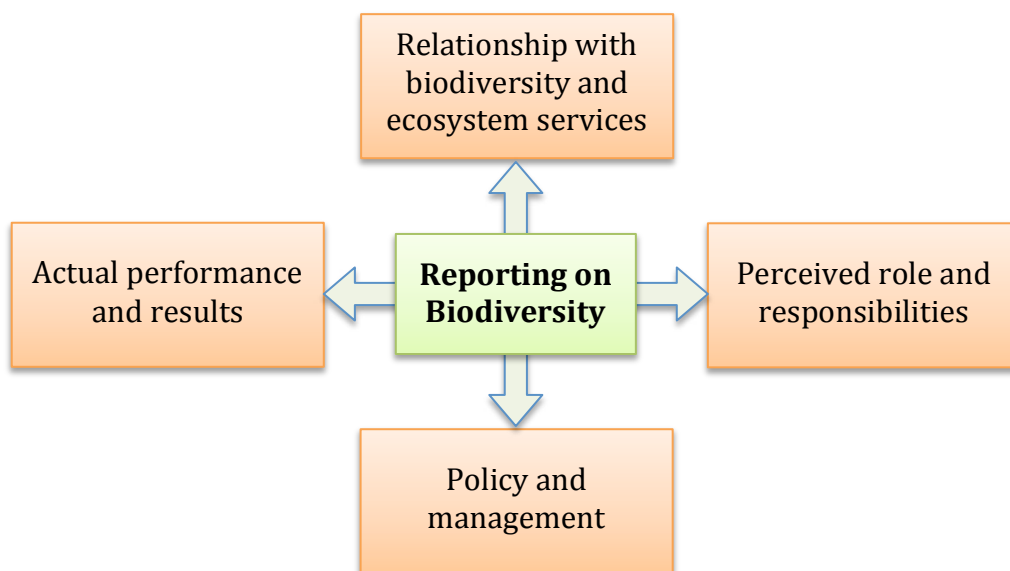


Figure 2.3.8 Tell a story of biodiversity management

Source: Global Reporting Initiative – GRI (2007)

Combination of the four elements provides an outline of the key points in telling the story of biodiversity.

Table 2.3.5 Elements of biodiversity management report

Element	Description
Relationship with biodiversity and ecosystem services	The starting point for telling the story on biodiversity is the nature of the relationship between the organization's activities and biodiversity. This will define the nature of expectations on the organization and the resulting approaches to be implemented and performance goals to be achieved. In its reporting, an organization could communicate its understanding of how its activities affect biodiversity and, in turn, ecosystem services. Determining the nature of this interaction involves analyzing the ecosystem services that are important for an organization and its stakeholders and the biodiversity upon which those services depend.
Perceived role and responsibilities	The second element lies in placing the organization's approach and performance in the context of its perceived roles and responsibilities. For many stakeholders, the CBD objectives as well as other points expressed in international agreements and national laws will be key reference points against which the organization can explain its performance. In particular, an organization should consider reporting its role and responsibilities regarding conservation and sustainable use of biodiversity, and fair and equitable sharing of benefits (CBD objectives).
Policy and management approach	When the relationships to biodiversity and ecosystems and its role and responsibilities have been identified, the organization can start to report the specific policies and management approaches that are put in place to guide day-to-day activities. In communicating these, an important aspect is how they relate to an ecosystem approach (a "strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way").
Performance and results	The last element is to communicate the results achieved. Reporting on an organization's performance in relation to biodiversity will involve the use of indicators, including the GRI Environmental Performance Indicators, which specify the common information to be reported, and organization-specific biodiversity indicators. For most organizations, performance will be a combination of describing results achieved with respect to policy goals and describing absolute changes seen in the key areas impacted.

Source: Global Reporting Initiative – GRI (2007)

The process of biodiversity business management could be implemented through a cycle of four phases. At the start phase, the company needs to understand its status quo with regard to sustainability and the most important part of this step is the assessment of the dependence and impacts on biodiversity. Business biodiversity linkages analysis consists of an investigation of the biodiversity risks and opportunities during the

second phase. The third phase entails the action that the company takes after an analysis of its interdependence on biodiversity that might include drafting a new policy on biodiversity, integrating biodiversity into management systems, improving company's interdependence on biodiversity, collaborating with stakeholders. The final step is to make up reporting of the actions to the larger public that can be done via a sustainability report or press release (EBBC, 2013).

The model of biodiversity business management from Ricoh – a global technology company – is a good case to illustrate how a company manages its interrelationships with biodiversity (*see detail in appendix 2*). Ricoh preserves biodiversity by maintaining and improving the self-recovery capabilities of the global environment through its business activities as well as social contribution activities (Rico, 2009). The Group has clearly formulated the biodiversity policy with the aim to reduce the impact of business activities on biodiversity and engage proactively in its protection. Their biodiversity policy basically include eight highlight points, i.e. biodiversity management tasks, understanding and reducing impact, implementation, development of new technologies, working with local communities, involving each person, expanding the scope of company' activities, and communication.

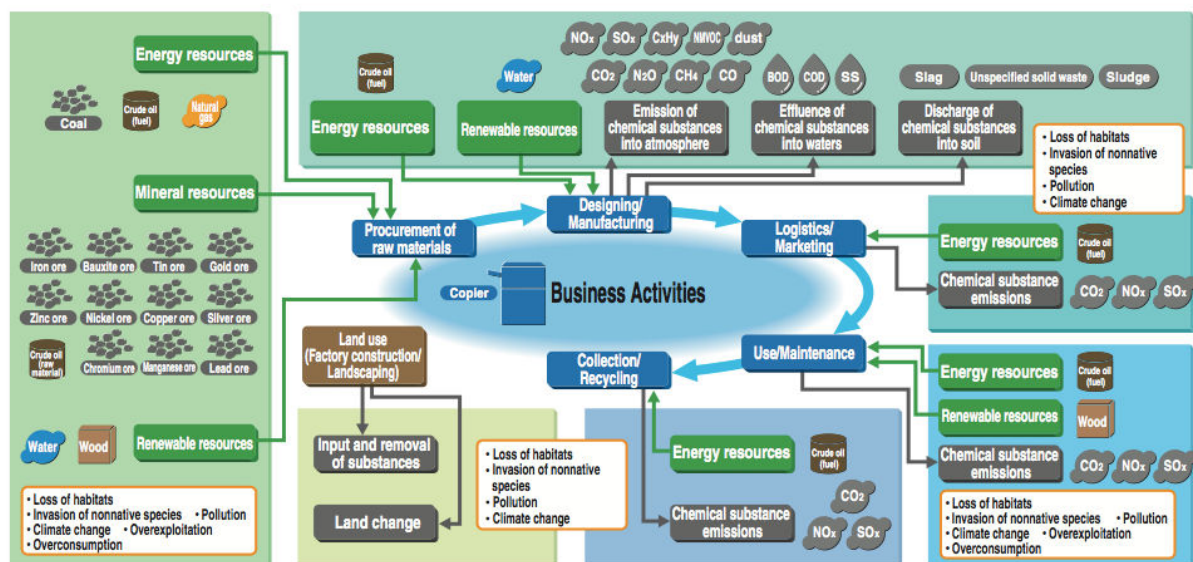


Figure 2.3.9 Map of Corporate Activities and Biodiversity

Source: Adapted from RICOH (2009)

The Ricoh Group created a map to show the exact relationship between their business activities and biodiversity. The “Map of Corporate Activities and Biodiversity” shows at a glance the relationship between corporate activities, such as product lifecycle and land use, and biodiversity. From the map, they learned that the copier industry has a large dependence on variety of resources such as energy, mineral, wood, water, land-used. At the same time, business activities influence the ecosystem during procurement of raw materials (e.g., paper pulp and metals) and during manufacturing (particularly in regard to water resources). These interactions cause the loss of biodiversity (loss of habitats, invasion of nonnative species, pollution, climate change, overexploitation, overconsumption). The Group uses the information from the map in their conservation activities in close cooperation with each business division.

3.2. Performance measurement methods

In the scholar literature, some previous works have proposed different approaches to measure biodiversity business management of firms such as nominated efforts from the Orée-IFB Working Group (Houdet, 2008), the European Business and Biodiversity Campaign (EBBC, 2013); the International Council of Mining and Metals (Globalbalance, 2014), the Ecosystem Services Benchmark (Grigg et al., 2009).

The Orée-IFB Working Group developed the Business and Biodiversity Interdependence Indicators (BBII) in the cooperation with the Masters Degree program in Environmental Sciences and Engineering at the University of Paris-Diderot. The main goal of the BBII is to highlight the direct and indirect interactions between businesses and the living world (Houdet and Weber, 2007). The method was designed to make it straightforward for business to perform assessments themselves. Accordingly, criteria are grouped in the five categories related to living systems, business strategies, compensatory measures, impacts on biodiversity and current markets. For each criterion, the analysis offers four options from “not concerned” to “strongly concerned”. A pentagram of the results of each self-assessment can be developed to provide a global picture of a business’s own understanding of its interdependence with biodiversity. The BBII method can also be used to compare the views of different companies within the same sector as well as to

analyze the similarities and dissimilarities among different sectors or among employees within a particular company (Houdet, 2008).

The European Business and Biodiversity Campaign offer a set of corporate biodiversity indicators. The set of basic key figures is designed to track the direct and indirect impacts of the company on biodiversity including several functional areas: strategy, stakeholders, headquarters, procurement, product development and manufacturing, transport and logistics, end product, marketing and human resources. These indicators are based on the requirement of the environmental management systems EMAS and ISO14001. Environmental aspects such as energy consumption, water consumption or emissions are “traditionally” included in Environmental Management Systems. Though key indicators do not measure the risks and opportunities nor the economic value of ecosystem services for the company, they have been recognized as beneficial for environmental performance by reducing the negative impact on biodiversity caused by climate change, emissions/ pollution or overexploitation of natural resources such as water (EBBC, 2013).

The International Council of Mining and Metals examine its members in terms of the maturity and extent of implementation of biodiversity management systems. The members were reviewed against ten assessment criteria identified in consultation with industry experts which comprised: 1) commitments, 2) risk assessment, 3) impact assessment, 4) biodiversity management, 5) resourcing, 6) closure planning, restoration and sale, 7) supporting conservation actions, 8) stakeholder engagement, 9) biodiversity monitoring and 10) public reporting. Under each criteria, companies can score one of five different levels of performance, allowing the maturing of ICMM member’s approach to biodiversity management to be assessed (level 5 being the most mature). The review was based on publicly available information, interviews with members and a review, on a sample basis, of internal company documentation and data supplied by the company. Members’ activities on three emerging issues: ecosystem services, biodiversity offsets and commitments to “no net loss or net positive impact” were also explored (Globalbalance, 2014).

The Ecosystem Services Benchmark (Grigg et al., 2009) focuses exclusively on a company's impact and dependence on biodiversity and ecosystem services within the agricultural supply chain. The structure of the benchmark consists of five broad categories of performance, including Competitive Advantage (value creation, ensuring sustainability of supply), Governance (responsibility, risk assessment, stakeholder engagement), Policy and Strategy (policy and strategy framework, standard setting), Management and Implementation (supplier engagement, capacity building, assurance, coverage), and Reporting (supply chain monitoring, quantitative targets, reporting, public affair and lobbying). The benchmark evaluates company performance against specific criteria, which represent the different categories of a strong management system. For each criteria, companies are evaluated against four performance levels reflecting the spectrum of current practice, from "no apparent activity to manage the issue" (Level 1) through "current strong performance" to perceived best practice (Level 4). The benchmark approach has a number of strengths: consistency, increase access to information, measures response, guidance on performance improvement. However, it also has a number of limitations: subjectivity, risk exposure, performance versus process, evidence-based analysis, scale and products, resource intensive (Grigg et al., 2009).

From the literature review, the table 2.3.6 below presents a list of indicators used to measure biodiversity management and corresponding references. These indicators are core to develop Key Performance Indicators in the model.

These methods have contributed to establish a starting-point in assessing the interaction between businesses activities and biodiversity as well as to measure the performance of biodiversity management. They can help a company to implement the management of biodiversity with the aim to reduce the impact on and potential risks from biodiversity and the related ecosystem services. However, lack of quantitative data and subjectivity are major limitations of these approaches. For instance, although the reviewers gathered quantitative data where possible, not all companies were able to provide sufficient data; and it is inevitable that some subjectivity is inherent when qualitative data are used (Globalballance, 2014).

Table 2.3.6 Indicators used to measure biodiversity management performance

Description of key performance indicators	Reference
Company evaluates its impacts on biodiversity	Houdet, 2008; Grigg et al., 2009
Company evaluates its dependence on biodiversity	Houdet, 2008; Grigg et al., 2009
Company assesses risks associated with biodiversity	Hanson et al., 2012
Company assesses opportunities associated with biodiversity	Hanson et al., 2012
Company integrates biodiversity consideration into its strategies	Houdet, 2008
Biodiversity management plays a role in its environmental management system	EBBC, 2013
Company develops policy/ project/ plan for biodiversity conservation	Schaltegger and Beständig, 2012
Company has commitments for biodiversity conservation from senior management	Globalbalance, 2014
Company allocates resources to ensure biodiversity management implementation	Globalbalance, 2014
Company guarantees the fair and equitable sharing of benefits from the genetic resources used	EBBC, 2013
Company commits to the voluntarily compensation for the impacts of its activities	Houdet, 2008
Biodiversity issues are managed at site-level including in the design of its facilities: offices, production site, storage, showroom, etc.	Schaltegger and Beständig, 2012; Globalbalance, 2014
Company ensures sustainable sourcing of raw materials	Schaltegger and Beständig, 2012
Suppliers are engaged in the company's biodiversity policy	EBBC, 2013
Product design includes reducing consumption of natural resources and carbon footprint	EBBC, 2013
Manufacturing processes aim to reduce emissions, water and energy consumption	EBBC, 2013
Staffs undergoes training and participates in terms of saving energy, water, etc.	Schaltegger and Beständig, 2012; Globalbalance, 2014
Company develops collaborations with external stakeholders including the local community in biodiversity conservation.	EBBC, 2013
Company analyzes feedback related to biodiversity from customer, stakeholder, and suppliers.	EBBC, 2013
Company publications for stakeholders including shareholders, customers, suppliers, NGOs improved in terms of biodiversity management, public reporting.	Globalbalance, 2014; EBBC, 2013

The pointed above limitations are understandable because measuring the performance of biodiversity management is a challenging work in reality. Part of the matter is that evaluating the health of an ecosystem itself is extremely difficult and biodiversity is not only an environmental issue, but also much a social issue. In addition, the complex inter-relationship between genes, species and ecosystems, and business activities that rely on and benefits from them mean that biodiversity concerns are inseparable from concerns over other issues. The next challenge is to find a set of Key Performance Indicators (KPIs) that can be integrated into an environmental management system and allow a company to measure its impact on biodiversity, assess whether its exposure to risk is changing, set realistic and appropriate targets for performance improvement that will manage or reduce the levels of risk and satisfy other stakeholders by managing a full range of risks and impacts (ISIS and F&C, 2004).

To overcome the limitations in terms of insufficient quantitative data and allow room for subjectivity due to complex interaction between businesses activities and biodiversity, this study proposes a model for measuring performance of biodiversity management with the application of fuzzy logic. The fuzzy logic operations would be presented in the methodology chapter. The next section reviews the application of fuzzy logic in operations management research.

3.3. Fuzzy logic in operations management

One of the most important areas in operations management is probably the decision making where the human factor enters with all its vagueness of perception, of subjectivity, of attitudes of goals and of conceptions (Zimmerman, 1983). For instance, the main inputs for evaluation process in multicriteria decision making are the evaluator's perceptions of importance of the selected attributes and firm's performances with respect to these attributes. It is very difficult to obtain exact assessments from the evaluators because these assessments are often subjective in nature. Thus forcing the evaluators to express their opinion in pure numeric scales does not allow any room for subjectivity. The subjectivity of human thinking and belief can be better expressed by using linguistic terms such as "low importance" or "excellent performance".

To allow linguistic expressions in the model, Zadeh (1965) proposed the fuzzy set theory that is considered as a new tool for a proper modeling of problems that are not easily be cast into classical mathematical models. According to Zimmerman (1983), the fuzzy set theory is applied in operational research because of the vague phenomena, vague relations, the modeling of problems, the vagueness of information, and the heuristic algorithms. Especially, fuzzy set theory can be primarily used in operational research in three different ways: (a) as a language to model appropriately problems and situations which contain fuzzy phenomena or relationships; (b) as a tool to analyze such models in order to get a better insight into structures of problems and models; (c) as an algorithmic tool to make solution procedures more stable or faster (Zimmerman, 1983).

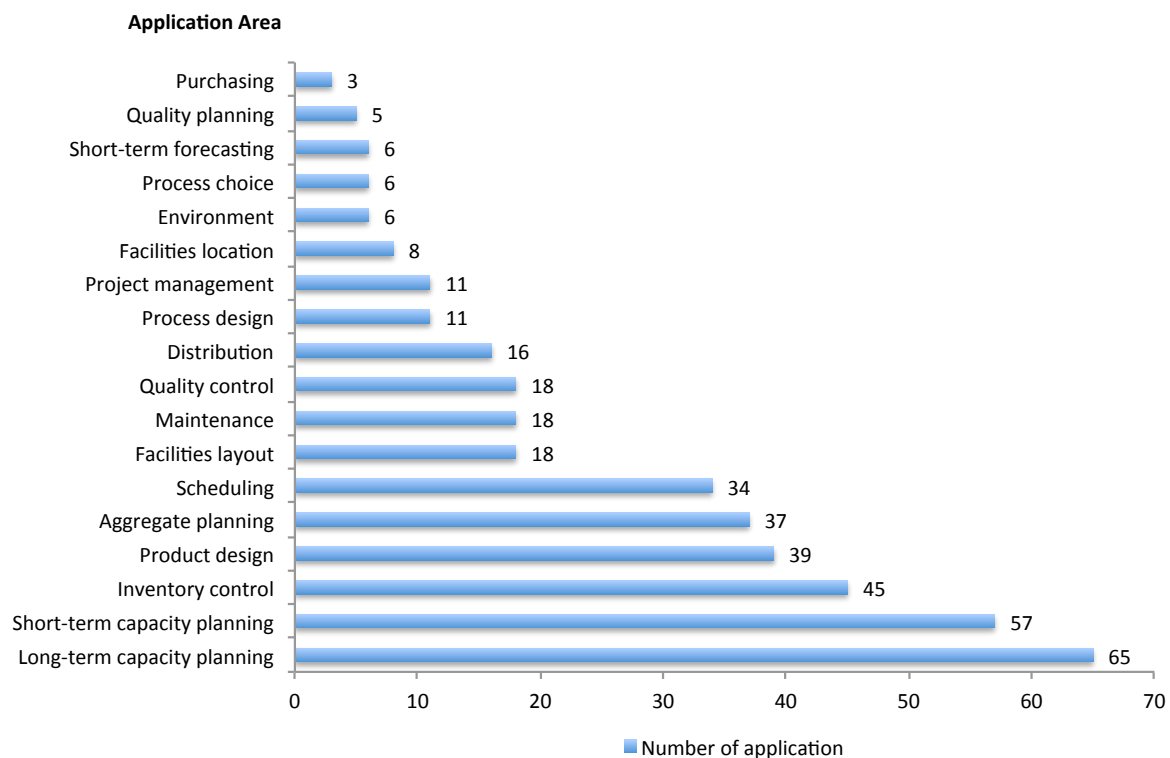


Figure 2.3.10 Fuzzy logic applications in production and operations management

Source: Wong and Lai (2011)

Research on fuzzy set theory in production management has grown in recent years (Guiffreda and Nagi, 1998; Wong and Lai, 2011). In specific, Guiffreda and Nagi (1998) observe that fuzzy set theory has been applied to most traditional areas of production

management research such as quality management, project scheduling, facility location/layout, aggregate planning, production/ inventory planning, forecasting. Wong and Lai (2011) take a survey of the application of fuzzy set theory in production and operations management. The authors find that the most popular applications are capacity planning, scheduling, inventory control, and product design.

From the performance management perspective, Gurreea et al. (2014) focus on analysis of the relationship between fuzzy logic and performance measurement management. The analysis has shown that the main application of fuzzy logic within the performance measurement field is the uncertainty delimitation through dealing with both inaccuracy and non-clear characteristics from many of the information that is needed to be carried out for a good assessment. In the most cases, the inaccuracy factor comes from human valuations and experts' opinions that complete the measurement process, and it is added to the own need of dealing with the subjectivity inherent to human beings judgements (Gurreea et al., 2014).

4. Conclusion to the chapter

Business sustainability is an inter-driver of the implementation of traceability, green supply chain management and corporate biodiversity management (see figure 2.4.1. below). In general, sustainability performance includes economic, environment and operation dimensions that represent the outcomes of GSCM practices implementation drivers, i.e. internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery (Zhu et al., 2008a; Zhu and Sarkis, 2006). Sustainability is one of the ten drivers of food traceability that have been identified in the literature, i.e. legislation, food safety, quality, sustainability, welfare, certification, competitive advantages, bioterrorist threats, production optimization, and chain communication (Karlsen et al., 2013). MEA (2005), GRI (2007), Hanson et al. (2012) describe climate change, land-use change, habitat degradation, introduction of new species, overexploitation of resources, pollution as the direct drivers of biodiversity degradation.

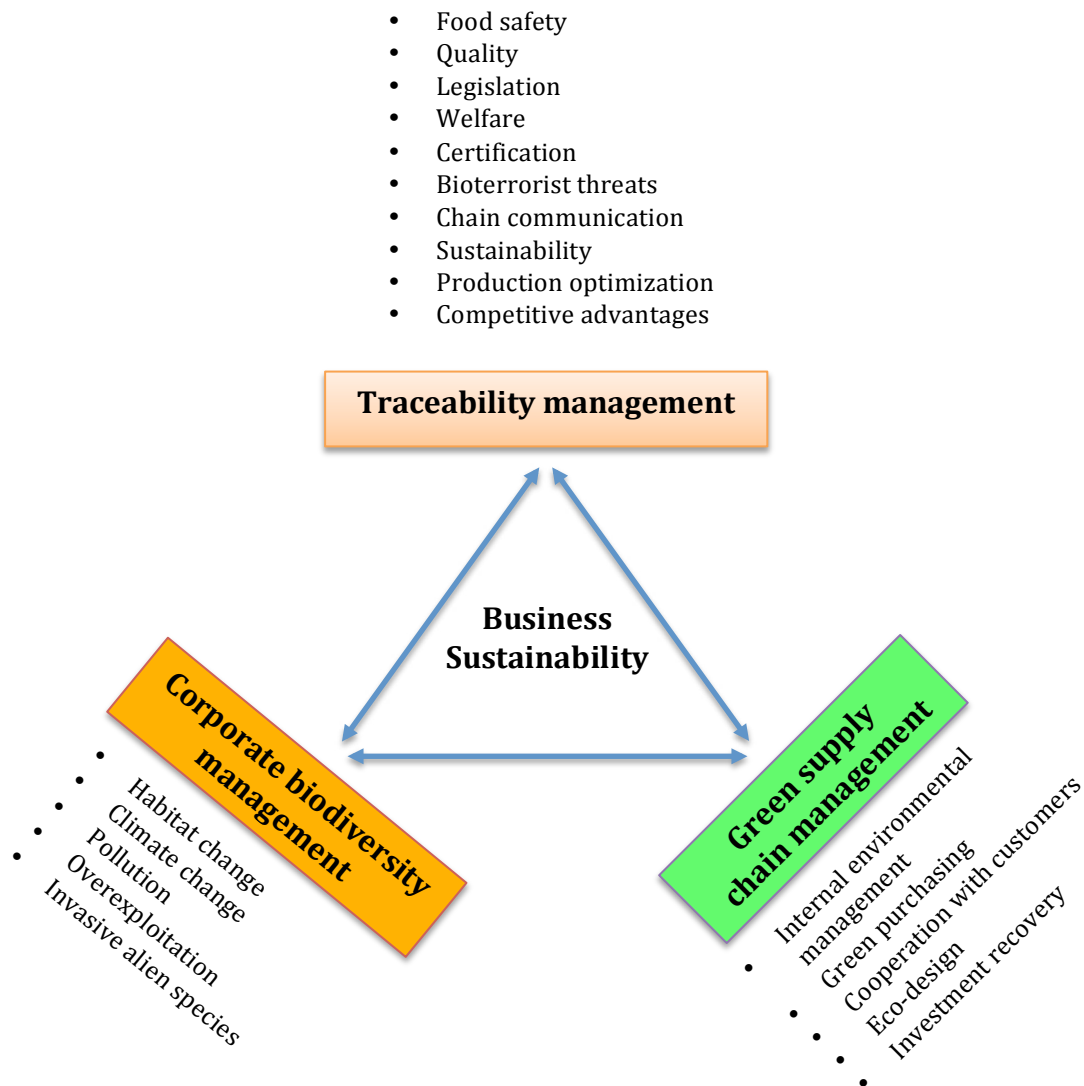


Figure 2.4.1 Business sustainability as an inter-driver

Ensuring functioning of ecosystems and their ability to provide services to humans and other living organisms represents the key value of biodiversity. In other words, biodiversity forms the foundations and fabric of life on Earth, but it is eroding beneath the feet of human activity. Businesses may affect biodiversity either directly by their core operations or indirectly through partners' activities in their supply chain. Therefore, the impact to biodiversity needs to be managed along the chain. The effects of implementing traceability systems on perspectives such as economic, society and environment make also a contribution to the sustainability performance in supply chain (Kraisintu and Zhang, 2011). Indeed, traceability is a tool for companies to prove claims and attributes of sustainable products (UNGC, 2014). Taking environmental elements

and traceability systems into account as the most important components (Bosona and Gebresenbet, 2013), green supply chain management (GSCM) practices offers a framework to maximize overall environmental profit by adopting a life cycle approach through product design, material selection, manufacturing, and sales and recovery (Dashore and Sohani, 2013; Guang Shi et al., 2012; Zhu and Sakis, 2004).

Given that GSCM and traceability implementation have emerged as important organizational philosophies in the ecological business calendar. The findings from this review reveal that the literature does not point sufficient attention to linkage between biodiversity management, traceability implementation and green supply chain management. The scope of GSCM has ranged from green purchasing to integrated supply chains flowing from supplier to manufactures to customer, and reverse logistics (Zhu and Sarkis, 2004). Even though, some aspects of biodiversity management such as habitat change and/or invasive alien species are rarely addressed in GSCM practices implementation as well as traceability chain management. Thus, further investigating the relationships between GSCM, traceability implementation and biodiversity management is necessary.

Lack of product origin information and supply chain transparency may pose significant risks and/or unforeseen effects for consumers. The issue of missing information on a product may arise at different stages of the supply chain: material sourcing stage, processing stage, and distribution. Traceability systems have often been implemented as a solution to reduce asymmetry information. Most studies have focused on analyzing the drivers, functions (tracing and tracking) and costs and benefits of traceability implementation. The introduction of traceability systems can improve risk management, supply chain management and marketing and fulfil international requirements. Another effect of traceability systems introduction is changes that may appear in the coordination level in the supply chain. Further research has to investigate the effect of traceability systems implementation on variations in the relationship between economic agents along the supply chain.

Biodiversity is absolutely necessary to the present and future operations of all types of businesses regardless of their size, sector, or location. Companies depend on biodiversity as key inputs to their production processes while they simultaneously

affect biodiversity through output elements. Therefore, the loss of biodiversity poses significant risks on businesses that must be kept on radar. The biodiversity business interactions may be small or large, negative or positive, direct or indirect, but these are inevitable. Even so, measurement of biodiversity management is extremely challenging due to complex interrelationship between biodiversity (genetic diversity, species, habitats, etc.) and businesses activities (procurement, manufacturing, transportation, sales, etc.). Lack of sufficient data and subjectivity in the evaluator's preferences are major limitations of works in literature.

Ideally, measures of conservation performance should relate directly to the state of biodiversity (e.g. habitat area, tree species diversity, species population size or index, breeding productivity, survival rate, carbon sequestration rate). Such measures enable direct quantitative biodiversity audits to be carried out, of for example, the impacts of a project, program or entire organization's activities. However, monitoring the state of biodiversity is often difficult, costly and time-consuming activity. Unsurprisingly, many conservation performance systems focus on measures of achievement with indirect performance indicators (EWI, 2006). The lack of comprehensive methodologies, which can be easily communicated to policy and decision-makers, for providing economic valuation for biodiversity and ecosystem services has hampered efforts to protect, maintain and enhance habitats and species (Jones-Walters and Mulder, 2009). To fill these gaps of knowledge in terms of insufficient quantitative data and the subjectivity in evaluation process, there is a need to develop a measurement model that allows some degree of vagueness in the evaluators' judgements. Fuzzy logic is one of appropriate approaches to get a better insight into structure of biodiversity business problem.

Business activities are considered the major cause of biodiversity loss. Sustainability has become an increasingly significant performance to serve better customer and to maintain competitive advantage for companies and supply chain. Business sustainability model should be implemented throughout the chain from the first-tier suppliers to the final consumer. For this reason, the present research direction is to address biodiversity corporate management, traceability implementation and green supply chain management and links among them. That is the main contents in the next chapter – research models.

CHAPTER 3

RESEARCH MODELS

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A total of three models are developed in order to archive a particular research objective. The first model for measurement the performance of biodiversity business management is elaborated using linguistic variables under fuzzy set theory (Zadeh, 1965; 1975). The model is based on the studies of Orée-IFB Working Group (Houdet, 2008), the European Business and Biodiversity Campaign (EBBC, 2013), the International Council of Mining and Metals (Globalbalance, 2014), the economics of ecosystems and biodiversity (TEEB, 2010b), Schaltegger and Beständig (2012). The second model that is constructed to link biodiversity management, traceability and green supply chain management and is based on studies of Srivastava (2007), Zhu and Sarkis (2004); Seuring and Muller (2008), and works of Zhu et al. (2005; 2011; 2013). The third model studies the effects of the implementation of traceability systems on variations in the relationship between economic agents along the supply chain in the context of a transaction cost analysis framework (Williamson, 1985; 1996). This model is based on the empirical research from Banterle and Stranieri (2008); Vinholis et al. (2012) and Wang and Bravo (2010).

1. Measurement of the performance of biodiversity management (Model 1)

The impacts of business activities on biodiversity may be small or large, negative or positive, direct or indirect, but these impacts are inevitable. There is no doubt that measuring the performance of biodiversity management is an extremely difficult work due to the nature of complex nature of the relationship between businesses activities (procurement, manufacturing, transportation, sales, etc.) and biodiversity (genetic diversity, species, habitats, etc).

As presented in the chapter 2, the existing literature describes different approaches to measure biodiversity management performance. For example, the Orée-IFB Working Group develops the business and biodiversity interdependence indicators (BBII) that enable companies to perform self-assessments (Houdet, 2008). The European Business and Biodiversity Campaign offer a set of corporate biodiversity indicators (EBBC, 2013). The European Centre for Nature Conservation recommends the European biodiversity standard (ECNC, 2012). The International Council of Mining and Metals examines its members in terms of the maturity and degree of implementation of biodiversity

management systems (Globalbalance, 2014). Lack of sufficient data and subjectivity of human thought in evaluation process are the major limitations of the above mentioned measurement methods. In order to allow some degree of incomplete quantitative data and subjectivity, this study suggests a measurement model with fuzzy logic approach.

This study adopted the definition of biodiversity from the United Nations Convention on Biological Diversity that says *“the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”* (CBD, 1992). The biodiversity loss is described as the degradation of biodiversity caused by severely exhausted stocks of resources or other bio-services with potential irreversible consequences for the environment (WEF, 2010). The most common recognized direct drivers viewed as threats to biodiversity include: invasive alien species, climate change, pollution, habitat degradation, and overexploitation of resources (GRI, 2007). Together with direct drivers, indirect factors such as demographic, economic, socio-political, cultural, religious, scientific and technological factors may change biodiversity (CBD, 2006).

The model defines the performance of corporate biodiversity management as *“an evaluation for any firm of its effort and/or achievement against the loss of biodiversity, i.e., reducing invasive alien species, climate change, pollution, habitat degradation, and overexploitation of resources”*. The model consists of two main components: identification of the key performance indicators (KPIs) and evaluation of the performance of firms with respect to the identified indicators and ranking.

1.1. Key Performance Indicators (KPIs)

The Key Performance Indicators represents a way of presentation and managing complex information in a simple and clear manner, which can support future actions and be comprehensively communicated to internal and/or external stakeholder as appropriate. The compliance with the key performance indicators is critical to be evaluated as it illustrates the progress of a firm in achieving its objectives or its

progress towards critical performance improvement (KNU, 2015). The process seeks to generate indicators that (a) relate to the actual or predicted significant impacts of operations, (b) measure progress towards a targeted goal, and (c) are useful in reporting site-level and company-level performance with respect to preventing impacts and promoting conservation (theebi.org - b). Although individual indicators vary from project to project, “good” indicators often follow the SMART philosophy: Specific, Measurable, Achievable, Relevant and Timely.

- *Specific*: Objectives must be clear and precise so that all stakeholders have a consistent understanding of what is planned.
- *Measurable*: It is vital to be able to clearly determine whether or not an objective has been reached. This can be done if measurable units are used to define the objective.
- *Achievable*: It must be possible to achieve the objectives.
- *Realistic*: Objectives should not be aspirational, such as to reverse all previous forest loss within a region.
- *Timely*: It is important to set a time period for reaching the objective, to help prioritize and plan actions.

To be able to manage the business biodiversity interactions, a firm should identify which ecosystem services are key to its operations and understand how operations influence environment through the supply chain (GRI, 2007). A standard method is to do a baseline survey of the flora and fauna within a given area and to undertake periodic monitoring of selected “indicator” species. The advantage of the method is that it can demonstrate when the number or health of an individual species has declined, helping significantly to flagship species upon which the company’s operations have an impact. However, such approach has several disadvantages for companies: (1) the required survey and monitoring is expensive, time-consuming and requires specialist expertise; (2) there may be requirement to set up a “control” at site and consequently additional costs; results being often inconclusive; and (3) the survey may not address wider issues of social impacts and ecosystem health that constitute a large proportion of the company’s biodiversity risks. Moreover, even if species is shown to decline at a site,

this does not necessarily mean that it results from the company's activities (ISIS and F&C, 2004). Unsurprisingly, many biodiversity conservation performance systems, therefore, focus on indirect measures of achievement.

Table 3.1.1 List of indicators and sub-indicators in the model

Indicator	Sub-indicator	Description
Biodiversity Business Assessment		Company assesses interactions between its activities with biodiversity.
	Impact evaluation	Company evaluates its impacts on biodiversity.
	Dependence evaluation	Company evaluates its dependence on biodiversity.
	Risk assessment	Company assesses risks associated with biodiversity.
	Opportunity perception	Company assesses opportunities associated with biodiversity.
Biodiversity Management Policy		Company states biodiversity management policy in its activities.
	Integrating into strategy	Company integrates biodiversity consideration into its strategies.
	Part of EMS	Biodiversity management plays a role in company environmental management system.
	Biodiversity action plans	Company develops policy/ project/ action plan for biodiversity conservation.
Biodiversity Conservation Commitment		Company commits to biodiversity conservation.
	Senior commitment	Company's senior management commitments to biodiversity conservation.
	Allocation of resources for implementation	Company allocates resources to ensure biodiversity management implementation.
	Sharing benefits	Company guarantees the fair and equitable sharing of benefits from the genetic resources used.
	Voluntary compensation for the impact	Company commits to voluntary compensate its impact on biodiversity.
Biodiversity Stewardship Practices		Company implements biodiversity management in the practices of operations.
	Site-level impact management	Biodiversity issues are managed at site-level being included in the design of company's facilities: offices, production site, storage, showroom, etc.
	Green purchasing	Company ensures sustainable sourcing of raw

	materials.
Supplier engagement	Suppliers are engaged in the company's biodiversity policy.
Product design	Product design aims to reduce consumption of natural resources and carbon footprint.
Reduction of emissions, water, energy consumption	Manufacturing processes aim to reduce emissions, water and energy consumption.
Employee training and participation	Staff undergoes trainings and participate in saving energy, water, etc.
Biodiversity Performance Reporting	Company makes public the report about biodiversity management.
Collaboration with stakeholder	Company develops collaborations with external stakeholders including the local community in biodiversity conservation.
Feedback analysis	Company analyzes feedback on biodiversity received from customer, stakeholder, suppliers, etc.
Public reporting	Company publications for stakeholders, including shareholders, customers, suppliers, NGOs improve in terms of biodiversity management and public reporting.

Biodiversity business management process can be implemented through four phases of the cycle, i.e. exploring company's status quo and biodiversity linkages; analyzing company's biodiversity linkages; integrating biodiversity policies, programs and activities; and monitoring and communicating (EBBC, 2013). Therefore, indicators that are proposed to measure the performance of corporate biodiversity management should convey these actions of businesses. A set of potential indicators is listed in Table 3.1.1. These indicators have been identified from the literature review as presented in the previous chapter. There are twenty indicators in the model, which use to measure the performance of corporate biodiversity management. These indicators are categorized into five Key Performance Indicators named: Biodiversity Business Assessment, Biodiversity Management Policy, Biodiversity Conservation Commitment, Biodiversity Stewardship Practices, and Biodiversity Performance Reporting.

1.2. Measurement procedure

Now, that the first task of identifying key performance indicators (KPIs) is completed, it is necessary to develop a procedure that allows measuring and comparing the performance of firms. To develop such a mechanism, there are required inputs from two perspectives: the importance of each indicator and the performance ratings with respect to KPIs.

Without any doubt, most of information required to measure the performance of corporate biodiversity management is very difficult to quantify. Publicly reports are crucial sources of information in the assessment process. However, the review that relies largely on company-provided information may lead to biases (Grigg et al., 2009). Typically, evaluators made efforts to gather quantitative data where possible, but not all companies were able to provide sufficient data (Globalbalance, 2014). For example, company rarely provides detail on the regions from which the company sources products and raw material (Grigg et al., 2009). In such circumstances of insufficient quantitative data, qualitative data and/or the judgments of evaluator are used instead. As a result, subjectivity is unavoidable.

Given the bounded of human thought for the complexity of things, people usually cannot give the accurate judgments for the things. Imprecision may arise from a variety of reasons: unquantifiable information, incomplete information, unobtainable information and partial ignorance (Gumus, 2009). Measuring the performance of corporate biodiversity management typically face the challenge of vagueness, ambiguity, and uncertainty situations. Evaluators encounter difficulties to provide precise assessment under inadequate quantitative data environment. They are then forced to express their opinion in pure numeric scales that leave no room for subjectivity. Instead, the evaluators may feel more confident to give interval judgments rather than expressing their preferences in the form of single numerical values. Accordingly, linguistic terms such as “low importance” or “excellent performance” can be better in use to capture a range of numerical values. Therefore, the model proposes to use linguistic variables under fuzzy set theory (Zadeh, 1965) for measuring the performance of corporate biodiversity management, instead of crisp numbers.

To deal with vagueness and allow linguistic expressions of human preferences, Zadeh (1965) first introduced the fuzzy set theory, which addressed the rationality of uncertainty due to ambiguity. One of the principal contributions of fuzzy logic is providing basis for a progression from binarization to graduation, from binarism to pluralism, from black and white to shades of gray (Zadeh, 2015). The benefit of extending traditional crisp analysis methods to fuzzy techniques is the strength in solving real-world problems, which inevitably entail some degree of imprecision and noise in the variables and parameters measures and processes for the application (Kahraman et al., 2003). In the performance measurement field, fuzzy logic has been widely used to delimitate the uncertainty through dealing with both inaccuracy and non-clear characteristics from many of the information needed to carry out a good assessment (Gurrea et al., 2014). The fundamental background of fuzzy logic that adapted from Zadeh (1965; 1975), van Laaehoven and and Pedrycz (1983), Kahraman et al. (2003), and Zimmermann (2010) are briefly presented in the methodology chapter. Here, a measurement process is proposed that consists of seven major steps, each step being explained below.

Step 1: Assignment of indicators according to their importance and of company's performance against indicators

Linguistics variables are used to elicit the evaluator's preferences in order to capture subjectivity. The firm's evaluators are required to express their perception of the importance of the indicator in linguistic terms, i.e., Very low importance, Low importance, Moderate importance, High importance and Very high importance. This elicitation procedure is shown in *Table 3.1.2*.

Table 3.1.2 Elicitation procedure for indicators importance ratings

This is a list of the attributes that have been identified as being relevant for biodiversity performance. Please specify the importance of each attribute as: "VL: Very Low", "L: Low", "M: Moderate", "H: High" and "VH: Very High"

Indicators and sub-indicators	Importance				
	VL	L	M	H	VH
Company assesses interactions between its activities and biodiversity.	VL	L	M	H	VH
Company evaluates its impacts on biodiversity.	VL	L	M	H	VH
Company evaluates its dependence on biodiversity.	VL	L	M	H	VH
Company assesses risks associated with biodiversity.	VL	L	M	H	VH
Company assesses opportunities associated with biodiversity.	VL	L	M	H	VH
Company states biodiversity management policy in its activities.	VL	L	M	H	VH
Company integrates biodiversity consideration into its strategies.	VL	L	M	H	VH
Biodiversity management plays a role in company environmental management system.	VL	L	M	H	VH
Company develops policy/ project/ action plan for biodiversity conservation.	VL	L	M	H	VH
Company commits to biodiversity conservation	VL	L	M	H	VH
Company's senior management commit to biodiversity conservation	VL	L	M	H	VH
Company allocates resources to ensure biodiversity management implementation.	VL	L	M	H	VH
Company guarantees the fair and equitable sharing of benefits from the genetic resources used.	VL	L	M	H	VH
Company commits to voluntary compensate its impact on biodiversity.	VL	L	M	H	VH
Company implements biodiversity management in the practices of operations.	VL	L	M	H	VH
Biodiversity issues are managed at site-level being included in the design of company's facilities: offices, production site, storage, showroom, etc.	VL	L	M	H	VH
Company ensures sustainable sourcing of raw materials.	VL	L	M	H	VH
Suppliers are engaged in the company's biodiversity policy.	VL	L	M	H	VH
Product design aims to reduce consumption of natural resources and carbon footprint.	VL	L	M	H	VH
Manufacturing processes aim to reduce emissions, water and energy consumption.	VL	L	M	H	VH
Staff undergoes trainings and participates in saving energy, water, etc.	VL	L	M	H	VH
Company makes public the report about biodiversity	VL	L	M	H	VH

management.					
Company develops collaborations with external stakeholders including the local community in biodiversity conservation.	VL	L	M	H	VH
Company analyzes feedback on biodiversity received from customer, stakeholder, suppliers, etc.	VL	L	M	H	VH
Company publications for stakeholders, including shareholders, customers, suppliers, NGOs improve in terms of biodiversity management and public reporting.	VL	L	M	H	VH

The evaluators are also demanded to express their assessments regarding the performance of their company with respect to the pertinent criteria in linguistic terms, i.e. Excellent performance, Very good performance, Good performance, Fair performance or Poor performance. This elicitation procedure is shown in *Table 3.1.3*.

Table 3.1.3 Elicitation procedure for biodiversity performance ratings

The below table, please specifies assessments of how your company performs with respect to each indicator as: “EX: Excellent”, “VG: Very Good”; “G: Good”, “F: Fair”, “P: Poor”

Indicators	Performance				
	P	F	G	VG	EX
Company evaluates its impacts on biodiversity.	P	F	G	VG	EX
Company evaluates its dependence on biodiversity.	P	F	G	VG	EX
Company assesses risks associated with biodiversity.	P	F	G	VG	EX
Company assesses opportunities associated with biodiversity.	P	F	G	VG	EX
Company integrates biodiversity consideration into its strategies.	P	F	G	VG	EX
Biodiversity management plays a role in company’s environmental management system.	P	F	G	VG	EX
Company develops policy/ project/ action plan for biodiversity conservation.	P	F	G	VG	EX
Company’s senior management commit to biodiversity conservation.	P	F	G	VG	EX
Company allocates resources to ensure biodiversity management implementation.	P	F	G	VG	EX

Company guarantees the fair and equitable sharing of benefits from the genetic used resources.	P	F	G	VG	EX
Company commits to voluntary compensate its impact on biodiversity.	P	F	G	VG	EX
Biodiversity issues are managed at site-level being included in the design of company's facilities: offices, production site, storage, showroom, etc.	P	F	G	VG	EX
Company ensures sustainable sourcing of raw materials.	P	F	G	VG	EX
Suppliers are engaged in the company's biodiversity policy.	P	F	G	VG	EX
Product design aims to reduce consumption of natural resources and carbon footprint.	P	F	G	VG	EX
Manufacturing processes aim to reduce emissions, water and energy consumption.	P	F	G	VG	EX
Staff undergoes trainings and participate in saving energy, water, etc.	P	F	G	VG	EX
Company develops collaborations with external stakeholders including the local community in biodiversity conservation.	P	F	G	VG	EX
Company analyzes feedback on biodiversity received from customer, stakeholder, suppliers, etc.	P	F	G	VG	EX
Company publications for stakeholders, including shareholders, customers, suppliers, NGOs, improve in terms of biodiversity management and public reporting.	P	F	G	VG	EX

Step 2: Fuzzification of the importance weights and performance ratings

Using the appropriate fuzzy membership functions, the linguistic terms are converted into fuzzy numbers for stating the importance of indicators and performance ratings. In the present work, the perceptions of evaluators are solicited in two areas: importance weight of indicator, and performance ratings using selected indicators. Thus, two fuzzy membership functions must be defined, i.e. one for assessment of the indicator weights and another one for performance ratings.

The linguistic scales for the membership functions of importance weightings are illustrated in *Table 3.1.4*:

Table 3.1.4 Linguistic terms for indicator importance weighting

Linguistic expression		Fuzzy numbers
Very low	(VL)	(0.0, 0.2, 0.4)
Low	(L)	(0.2, 0.4, 0.6)
Moderate	(M)	(0.4, 0.6, 0.8)
High	(H)	(0.6, 0.8, 1.0)
Very High	(VH)	(0.8, 1.0, 1.0)

For instance, if the importance of indicator *“Company evaluates its impacts on biodiversity”* is evaluated “High” then the corresponding fuzzy number is (0.6, 0.8, 1.0), according to the linguistic scales of *Table 3.1.4* above.

The linguistic performance scale for the membership functions of performance ratings is described in *Table 3.1.5*:

Table 3.1.5 Linguistic terms for performance rating

Linguistic expression		Fuzzy numbers
Poor	(P)	(1, 1, 3)
Fair	(F)	(1, 3, 5)
Good	(G)	(3, 5, 7)
Very good	(VG)	(5, 7, 9)
Excellent	(EX)	(7, 9, 9)

For performance assessment, if one evaluator believes that the performance of his/her company with respect to indicator *“Product design aims to reduce consumption of natural resources and carbon footprint”* is “Very Good”, for example, then the corresponding fuzzy number is (5, 7, 9) according to the linguistic scales of *Table 3.1.5*. The fuzzification of the importance rating and performance assessing from the linguistic terms into fuzzy numbers is converted in the same manner for all of indicators.

Step 3: Determining fuzzy important weights

The linguistic importance weight of each node of the tree refer to *Figure 3.1.3* has been translated into fuzzy weights using the linguistic scales referred to in *Table 3.1.4*. The fuzzy importance weights at the end nodes of each branch are then calculated by tracing down all the nodes on that branch. For example, the importance of the end node of the first branch “*Allocation of resources for the implementation*” is computed by multiplying the importance rating of “*Allocation resources*” by importance rating of “*Biodiversity Conservation Commitment*”. The importance weights of the other indicators are calculated in the same manner.

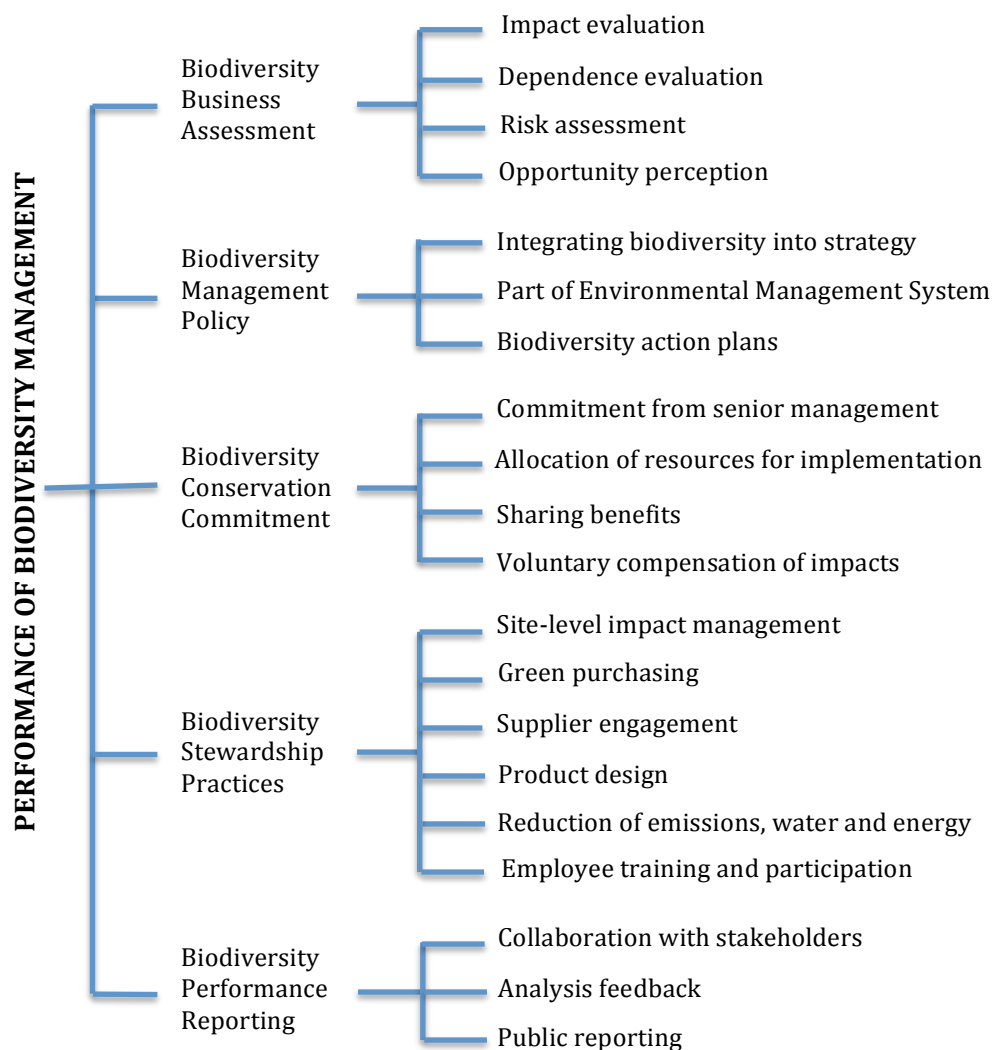


Figure 3.1.1 Hierarchy of performance indicators and sub-indicators

Step 4: Calculating aggregated fuzzy weights

The importance indicator ratings for each evaluator D_k ($k = 1, 2, \dots, K$) of each firm $F_i = \{F_1, F_2, \dots, F_m\}$ with respect to n criteria $C_j = \{C_1, C_2, \dots, C_n\}$ is described as triangular fuzzy number $\tilde{w}_{jk}$. Then the aggregated fuzzy weights $\tilde{w}_{jk}$ for each indicator are calculated as $\tilde{w}_j = (w_{jl}, w_{jm}, w_{ju})$, where:

$$\begin{aligned} w_{jl} &= \min_k \{w_{jkl}\} \\ w_{jm} &= \frac{1}{K} \sum_{k=1}^K w_{jkm} \\ w_{ju} &= \max_k \{w_{jku}\} \end{aligned}$$

Hence, we have an aggregated fuzzy importance weights matrix

$$\tilde{W}_{n \times 1} = \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \dots \\ \tilde{w}_n \end{bmatrix}$$

Step 5: Setting up fuzzy performance matrix

The self-assessment of firm's performance with respect to the KPIs has been converted into fuzzy performance in the step 2. Let $\tilde{r}_{ij}$ denotes the fuzzy performance rating of firm i with respect to indicator j , then the fuzzy performance matrix for the firms, denoted $\tilde{R}$, is as follows:

$$\tilde{R}_{m \times n} = \begin{matrix} & \begin{matrix} C_1 & C_2 & & C_n \end{matrix} \\ \begin{matrix} F_1 \\ F_2 \\ \\ F_m \end{matrix} & \left| \begin{array}{cccc} \tilde{r}_{11} & \tilde{r}_{12} & \dots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \dots & \tilde{r}_{2n} \\ & & & \\ \dots & \dots & & \dots \\ \tilde{r}_{m1} & \tilde{r}_{m2} & \dots & \tilde{r}_{mn} \end{array} \right| \end{matrix} \quad \begin{matrix} i = 1, 2, \dots, m \\ j = 1, 2, \dots, n \end{matrix}$$

Step 6: Computing the aggregated fuzzy scores

The aggregated fuzzy score $\tilde{S}$ is computed by multiplying the fuzzy performance matrix $\tilde{R}$ with the aggregate weights matrix $\tilde{W}$ of evaluation indicators.

$$\tilde{S}_{m \times 1} = \tilde{R}_{m \times n} \otimes \tilde{W}_{n \times 1} = \begin{bmatrix} \tilde{r}_{11} & \tilde{r}_{12} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & \tilde{r}_{22} & \cdots & \tilde{r}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{r}_{m1} & \tilde{r}_{m2} & \cdots & \tilde{r}_{mn} \end{bmatrix} \otimes \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \cdots \\ \tilde{w}_n \end{bmatrix} = \begin{bmatrix} \tilde{s}_1 \\ \tilde{s}_2 \\ \cdots \\ \tilde{s}_m \end{bmatrix}$$

Where $\tilde{s}_i = \sum \tilde{r}_{ij} \otimes \tilde{w}_j, i = 1, 2, \dots, n; j = 1, 2, \dots, m$, yields firm i 's aggregated fuzzy score for all the pertinent indicators.

Step 7: Defuzzification and ranking

The last step involves converting the aggregated fuzzy scores into crisp scores and then ranking firms according to their crisp scores. In this study the Center of Area (COA) defuzzification approach is applied to translate fuzzy numbers into real numbers. For a triangular fuzzy number (l, m, u) , the center of area is calculated as:

$$s_j = \frac{(l_j + m_j + u_j)}{3}$$

The highest biodiversity performance rank is assigned to the firm that showed the best overall crisp score. The results from an empirical investigation in the Vietnamese seafood supply chain would be presented in the chapter 5.

1.3. Summary

The complex inter-relationship between genes, species and ecosystems and businesses activities that rely on and benefit from them proves that biodiversity concerns are inseparable. Even though, the public good characteristics, i.e. non-excludability and non-rivalry, of biodiversity often lead businesses to weaken their motivation for

adopting environmentally responsible behavior. In addition, measuring the performance of corporate biodiversity management is extremely challenging due to complex nature of the relationship between businesses activities and biodiversity.

Lack of sufficient data and subjectivity of human thought in evaluation processes are considered the major limitation of the existing approaches. To allow for some degree of subjectivity in evaluators' choices, the fuzzy set theory is applied to develop the model methodology using five Key Performance Indicators, i.e. Biodiversity Business Assessment, Biodiversity Management Policy, Biodiversity Conservation Commitment, Biodiversity Stewardship Practices, Biodiversity performance Reporting and twenty sub-indicators. Fuzzy logic operations are used to calculate scores and ranking under a step-by-step procedure.

The first model addresses to a small part of the overall issues by focusing on how to measure the performance of corporate biodiversity management. The next question is how to improve the performance of corporate biodiversity management. Biodiversity management should be implemented not only at focal companies but also at partners along supply chain because of the interactions between businesses and biodiversity occur throughout the supply chain. In other words, the supply chain management should be the starting point for establishing actions from sites and facilities; supply chain, commodities and materials; product; production and manufacturing process; transport and logistics; and personnel subject to reduce habitat transformation, climate change, invasive species, overexploitation and pollution (Bestanding and Schaltegger, 2012).

Taking environmental elements into account, green supply chain management (GSCM) practices offer a framework to maximize overall environmental performance and economic performance (Dashore and Sohani, 2013; Guang Shi et al., 2012; Zhu and Sakis, 2004). Even though, some components of biodiversity such as habitat change and/or invasive alien species are rarely addressed in GSCM analyses. As an attempt to extent the scope of GSCM, the next section presents a model that integrates biodiversity elements (species, population, ecosystems, genes) into GSCM framework, of which traceability is an important facet (Bosona and Gebresenbet, 2013).

2. Biodiversity management, GSCM and traceability (Model 2)

Rise of ecological concern from different groups has increased the demand for friendly environmental products (ECNC, 2012). Under stronger pressures from customers through to stakeholders, competitors, governments and other social and environmental organizations, companies need to be good in environmental performance by supplying sustainable products (Seuring and Muller, 2008). These interest groups require application of friendly environmental characteristics to the whole product life cycle, from raw materials to processing to end-user consumption. Hence, the strongly cooperation between partners within supply chain is very importance in order to get deeper information about flows, including sustainable attributes of a product. From this point of view, green supply chain management has become an innovative organizational philosophy to reduce environmental risks and comprehensively addressed to the sustainability (Dashore and Sohani, 2013).

As an important component in supply chain management (Bosona and Gebresenbet, 2013), traceability contributes to sustainability. Kraisintu and Zhang (2011) identify the contributions of traceability to sustainable supply chain management by reviewing effects of traceability on economic, environmental and social aspects. According to this study, traceability contributes to environmental welfare in terms of preventing illegal fishing and avoiding fishing extinction; improving environmental resources; prevent pollution; and controlling Genetically Modified Organism (GMO) products. Myae and Goddard (2012) examine the importance of traceability in verifying environmentally sustainable production practices. Traceability also represents an essential tool to safeguard public and animal health and to valorize typical production systems (Dalvit et al., 2007).

The following figure depicts the connection between green supply chain management practices, traceability implementation and the performance of biodiversity management.

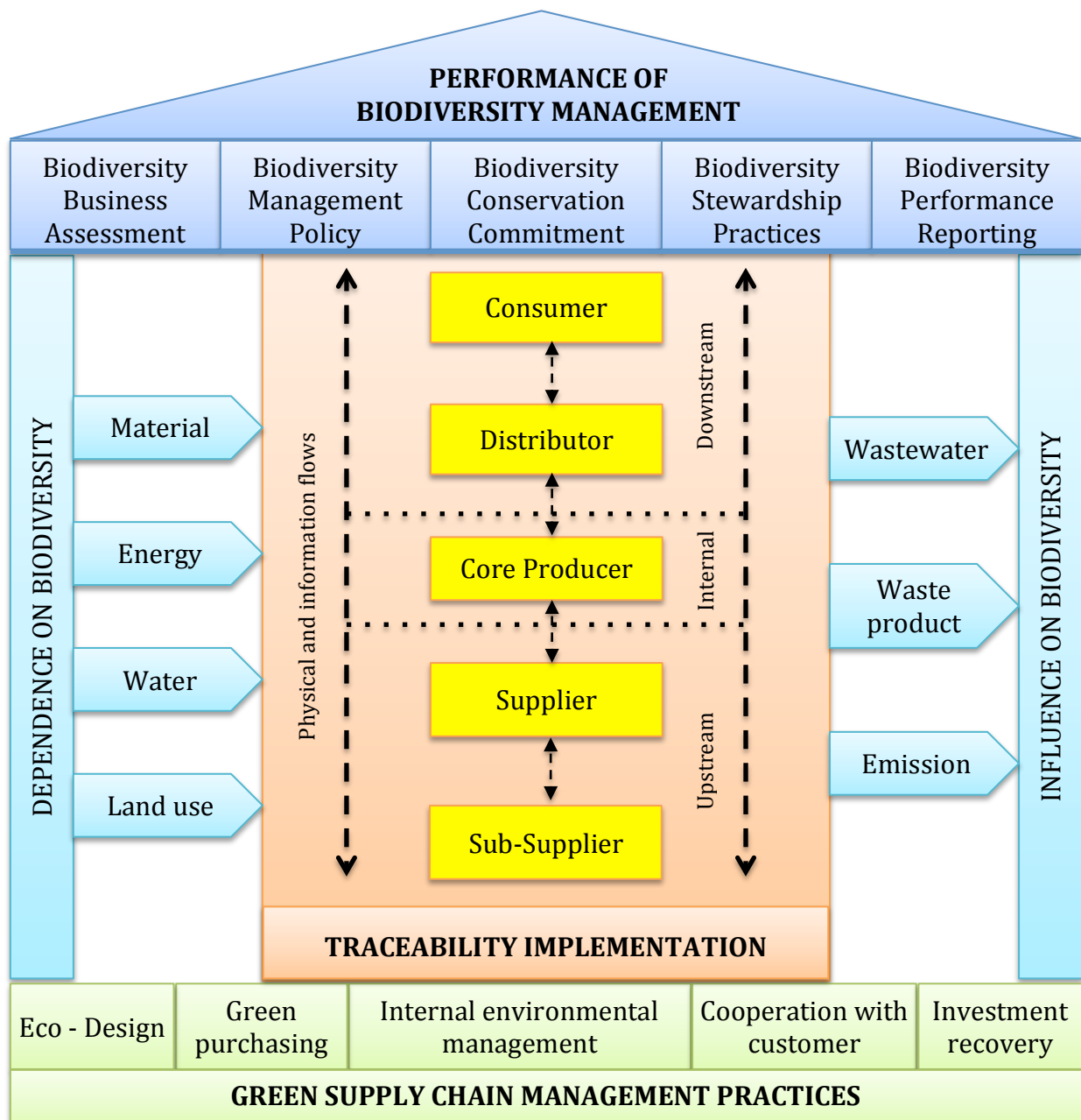


Figure 3.2.1 GSCM, traceability and biodiversity management

In general, it is argued that the GSCM practices have positive effects to the performance of biodiversity. GSCM practices include five dimensions: internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery (Zhu et al., 2008a; Zhu and Sakis, 2004). The performance of food traceability system can be evaluated by its ability to improve breadth, depth, precision and access to information (Golan et al., 2004; Bosona and Gebresenbet, 2013). The

indicators for measuring the performance of biodiversity management include Biodiversity Business Assessment, Biodiversity Management Policy, Biodiversity Conservation Commitment, Biodiversity Stewardship Practices and Biodiversity Performance Reporting. Sub-sections present propositions that make connections between these elements.

2.1. GSCM and biodiversity

Companies may have direct impacts on biodiversity and/or indirect effects through their supply chain partners (GRI, 2007). Increasing consumer demand for ecological friendly products pressures firms to integrate environmental strategies into their business operations. Firms need to develop supply chain management systems to mitigate risks associated with the loss of biodiversity. Proactive environmental management may reduce the inherent risk of the events (Zsidisin and Siferd, 2001). GSCM practices implementation ranges from green purchasing to integrated green supply chains flowing from suppliers to manufacturers to customers, and closing the loop with reverse logistics (Zhu and Sarkis, 2004).

As an organizational innovation, GSCM contributes to improve environmental performance by reducing pollution because of less consumption of energy and resource (Zhu et al., 2011). GSCM measurement constructs (Zhu et al., 2008a; Zhu and Sarkis, 2004) encompasses five elements: internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery.

An internal environmental management is central to improving enterprises' environmental performance (Carter et al., 1998) by reducing waste and pollution (Melynk et al., 2003). Green purchasing is one of the main aspects of GSCM practices implementation (Walton et al., 1998) and it is defined as purchaser's involvement in supply chain management activities in order to facilitate recycling, reuse, and resource reduction (Carter et al., 1998). Green purchasing can have a significant effect on environmental performance through strategies associated with reducing, recycling and reuse of resources and waste elimination (Min and Galle, 1997; Walton et al., 1998). In

addition, environmental purchasing activities will be facilitated through increased coordination with suppliers as well as downstream members of the supply chain, including retailers (Carter and Carter, 1998).

Walton et al. (1998) identify several dimensions of change that are able to increase the effect of green purchasing on environmental results, and namely: materials used in product design for the environment; product design processes; supplier process improvement; supplier evaluation; and inbound logistics processes. Carter et al. (1998) validate a scale to measure environmental purchasing with six key factors, including top management support, middle management support, firm's mission, department goals, training for personnel to buy environmentally friendly input, and evaluation of purchasing management. The measurement items for green purchasing include: eco-labeling of products, cooperation with suppliers for environmental objective; environmental audit for suppliers' internal management; suppliers; ISO 1400 certification; and second-tier supplier environmentally friendly practice evaluation (Zhu et al., 2008a).

Eco-design is meant to address product functionality while simultaneously minimizing life-cycle environmental impacts (Zhu et al., 2008b). Eco-design is a critical factor governing the environmental impacts of a manufactured product since materials and processes are selected at the design stage (Lewis and Gretsakis, 2001). Investment recovery also is a critical aspect for GSCM practices implementation and aligns directly with environmental concerns with fiduciary responsibilities (Zsidisin and Hendrick, 1998). Companies developing environmental products need to work closely with suppliers and employ techniques such as environmental audits and supplier screening (Pujari et al., 2003). Better coordination and cooperation between suppliers and customers can also contribute to improve firm's environmental performance (Zhu et al., 2012). Therefore, it can be considered that GSCM has a positive effect on the performance of biodiversity management.

Proposition 1: GSCM practices implementation increases the performance of biodiversity management of firms.

2.2. Traceability and biodiversity

Sustainability is one of the drivers of traceability implementation (Karlsen et al., 2013). Traceability systems create a recorded chain of events identified at each stage of the product. In other words, the introduction of traceability system creates transparency in the supply chain through a reorganization of the material and informative associated with the flows (Banterle and Stranieri, 2008). Moreover, traceability is the fundamental engine that allows: (i) to response to legal requirements; (ii) to offer information on social and environmental aspects of the production; and (iii) to proof that related requirements are fulfilled (UNEP, 2009).

In the 1970s and 1980s hazardous waste exported from developed countries to developing countries caused serious environmental pollution. For example, end-of-life home appliances discarded in Japan are reused in Southeast Asia; end-of-life computers are reused in China. E-waste (waste electrical and electronic equipment) and its improper recycling methods have caused serious pollution. Shinkuma and Huong (2009) recommend that a traceability system should be established in order to ensure that E-waste scrap exported from Japan will be recycled at proper recycling facilities in China. Implementation of such a traceability system could help enforce proper handling for e-wastes and reduce pollution.

In the seafood sector, problem of illegal, unreported and unregulated fishing in world fisheries is considered a serious and increasing concern that results in overfishing and loss of biodiversity (Worm et al., 2006). For instance, illegal and unreported catches represent 20% to 32% by weights of wild-caught seafood imported to the USA in 2011 (Pramod et al 2014). Non-confrontation of IUU fishing can lead to non-accomplishment of both management goals and sustainability of fisheries. FAO (2001) recommends within the International Plan of Action to prevent, deter and eliminate Illegal, Unreported and Unregulated fishing (IPOA-IUU) by improving transparency of markets and allow traceability of fish and fish products to be used as a tool to stop IUU fish from entering the legitimate fish supply chain.

Most sustainability issues in the fisheries industry such as ill-adapted governance and institutions, open access, unfair fishing, IUU fishing, bad working conditions, lack of price transparency and information sharing etc. are concentrated at the level of production and first intermediaries/ processors (UNEP, 2009). Borit and Olsen (2012) argue that traceability systems can be designed to prevent illegal, unreported and unregulated fishing. Pramod et al. (2014) indicate that without routine transparency of fishing practices and traceability of seafood products, it is nearly impossible for concerned consumers or responsible businesses to avoid commerce with illegal products.

Jacquet and Pauly (2008) show that lack of traceability also results in significant problems as renaming and mislabeling in the global seafood chain. When labeling seafood, there are several factors to consider such as: species' identity; country of origin, production method, and potential eco-labels. The widespread mislabeling of seafood negatively affects consumers in terms of price, their ability to make eco-friendly purchases, and potentially their health. Moreover, mislabeling also contributes to the further erosion of fisheries, not only because consumers cannot make informed decisions on behalf of conservation, but also because mislabeling undermines import/export seafood regulations. Consequently, the mislabeling leads to consumer and government: economic and resources losses, discouragement of eco-campaigns, and health concerns.

The implementation of traceability system in seafood industry ensures safety and legality characteristics of seafood, as it records all products information through the seafood supply chain (Archipelago, 2005). The implementation of supply chain traceability contributes to reduction of overexploitation, natural resources usage and pollution as a result conserving biodiversity.

Proposition 2: The implementation of traceability has a positive effect on the performance of biodiversity management.

2.3. GSCM and traceability

In the simplest way, traceability refers to the ability to trace and follow a food product throughout all the stages from production to processing and distribution (Moe, 1998). According to Bosana and Gebresenbet (2013) complete traceability system should address tracing, tracking of products and the complete associated product history information throughout the food supply chain. In order to be effective, a traceability system should be designed to track the flow of product or product attributes through not only internal production processes, but also external supply chains (Golan et al., 2004). Internal traceability refers to the ability to keep track of what happens to a product, its ingredients and packaging within a company, while external traceability (including upstream backward and downstream forward) refers to the activities at some or all levels of the supply chain (Petersen and Green, 2004).

Usually, traceability is viewed as the ability to follow and identify a product unit or batch through all stages of production, processing and distribution in both forward and backward dimensions. A traceability system is mainly characterized by breadth, depth and precision (Golan et al., 2004). The breadth is the amount of information the traceability system records; the depth of a traceability system is how far back or forward the system tracks and the precision character of a traceability system reflects the degree of assurance with which the system can pinpoint a particular food product's movement. So, the information is considered the heart of the performance measurement process (Bosona and Gebresenbet, 2013). The performance of traceability system can be measured by its ability to improve the breadth, depth, precision and access of information. The term of access was determined as the speed with which tracked and traced information can be communicated to supply chain members (McEntire et al., 2010).

Traceability increases efficiency of supply chain management by assisting supply chain partners to work together to eliminate inefficient practices (UNEP, 2009). A business's traceability system is the key to find the most efficient ways of production, assembling, warehousing, and distribution of products (Golan et al., 2004). Therefore, the benefits of traceability systems for supply chain management are greater, the higher is the value of

coordination along the supply chain. In particular, traceability helps to increase the efficiency of supply chain management by reducing costs of supply-related activities mainly for logistics; providing information from raw inputs to products in the retailer; differentiating own food products from others with undetectable attributes; and enabling firms to manage their resources efficiently using traceability information systems. For example, when firms discover that bad products – items that are tainted, spoiled, or counterfeit – have breached their supply chain, the bad products must be quickly disentangled from good products, especially when consumer well-being is at risk. Central to this task is traceability (Wowak et al., 2016).

Improvement of supply chain management enables partners in the chain to increase cooperation and develop technical and economic competence (Golan et al., 2004). Moreover, supply chain management addresses to the inter-organizational aspect of product supply, being the core feature of product traceability (Engelseth, 2009). Sharing information between companies in the supply chain will lead to enhancement of accuracy and reduction of costs of traceability for the whole chain (Dabbene et al., 2014). Wowak et al. (2016) reveal that traceability is hindered by temporality (time pressures that strain a firm's ability to track products), supply chain permeation (supply chain flow characteristics that represent the degree of bad product infiltration), and product information ambiguity (product characteristics that create vagueness about what to trace). Thus, strongly linkage of input records with output records information within several steps of the supply chain, from suppliers to customers, is a critical requirement to ensure the traceability. So, it is believed that green supply chain management practices can improve traceability in the supply chain.

Proposition 3: GSCM practices implementation improves traceability in the supply chain

2.4. Summary

The businesses can reduce biodiversity loss and increase the traceability of products by expanding coordination between partners in the supply chain. As an environmental

organizational innovation, green supply chain management is able to improve environmental and economic performances of business operations, of which traceability implementation is an important facet of GSCM. This section presents an attempt to integrate biodiversity management into the scope of GSCM. GSCM practices implementation is argued to have positive effects on performance of biodiversity and traceability. In turn, the improvement of traceability is meant to have positive effect on the performance of biodiversity management.

As a finding from the model 1, performance of biodiversity management can be measured through five KPIs, i.e. biodiversity business assessment, biodiversity management policy, biodiversity conservation commitment, biodiversity stewardship practices and biodiversity performance reporting. Factors for measuring GSCM practices include internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery (Zhu et al., 2008a; Zhu and Sakis, 2004). Ability to improve the breadth, depth, precision and access of information in the supply chain is as measurement item for the performance of traceability system (Golan et al., 2004; Bosona and Gebresenbet, 2013).

Traceability system is becoming an integrated component of modern supply chains (Olsen and Aschan, 2010; Bosona and Gebresenbet, 2013). Its ability for tracing, monitoring and managing product flows through food supply chain contributes to sustainable production (Myae and Goddard, 2012). Moreover, as a key instrument of supply chain management, traceability enables tracking of products through the entire supply chain (Viaene and Verkebe, 1998). Epelbaum and Martinez (2014) indicate that food traceability systems ensure food supply chain integrity. Engelseth (2009) shows developing food product traceability as a complex undertaking dependent on information connectivity including a technical aspect of supply chain integration, and different from of knowledge, an organizational aspect of supply chain integration.

The implementation of food traceability system contributes to reduce *ex post* costs; enhance food safety; and decrease information costs for consumers (Hobbs et al., 2005). Furthermore, the introduction of traceability system significantly improves the performance of supply chain management (Trautman et al., 2008; Golan et al., 2004;

2003). A successful traceability system shall involve all economic agents within the supply chain. These agents become responsible for the system, managing the information flow and increasing in vertical coordination among the chain (Banterle et al., 2006). The next section further presents how the implementation of traceability systems affects transaction governance structure in the supply chain.

3. Traceability and transaction governance in supply chain (Model 3)

The implementation of traceability can make changes in transaction characteristics and transaction costs leading to variation in transaction governance structure of the firms (Banterle et al., 2006). Certainly, that fact brings to recognize economic exchange among supply chain agents, through the introduction of new models of vertical coordination and providing new transaction governance connected to implementation of specific supply chain agreements and centralization of the traceability system management. Golan et al. (2004) argue that introducing a traceability system make more transparent and efficient vertical relationships that can be achieved through a reorganization of the materials and informative flows along supply chain.

Transaction cost economics framework verifies the effects of traceability implementation within a supply chain coordination on variations in transaction characteristics, transaction costs and transaction governance. Under transaction cost analysis, a traceability system can be considered as a group of procedures and rules that can modify the organization's governance structure and reduce transaction costs (North, 1991; 1994). As well, the implementation of traceability engenders changes in the transaction characteristics on the level of asset specificity, the degree of uncertainty and the level of frequency (Banterle and Stranieri, 2008).

Concerning agricultural business, the nature of agricultural products and production means physical and human asset specificities likely play a less important role in agricultural transactions in comparison to the temporal and locational specificities associated with production, processing and distribution of foodstuffs (Masten, 2000).

Food perishability tends to aggravate contracting hazards between contracting parties, while geographic and process disparities between contracting parties tend to impede the administration and coordination of activities. In the highly capital – intensive production (proxy for asset specificity), the adaptation of traceability plays a positive role in the choice of hybrid forms of transaction governance (Vinholis et al., 2012). The variation in transaction governance strategies is also dependently on a series of factors as: characteristics of the firms (level of vertical integration, legal status, firm’ size, turnover); transaction uncertainty (quantity and accuracy of the information flow); long business relations (asset specificity as human, physical); monitoring costs (supplier activities and raw materials flow controls); contractual economic incentives (final product price, production rules enforcement, agent’s liability condition) (Banterle et al., 2006; Banterle and Stranieri, 2008).

In this model, the implementation of traceability systems is hypothesized to lead to a reorganization of transaction governance between firms in the supply chain. These reorganizations are connected to an augmentation in transaction asset specificity among the agents; a decrease level of transaction uncertainty and an increase in transaction frequency. A further reorganization of transactions is expected to shift from market to hybrid forms, and transactions that are organized through hybrid forms should engender enforcement of such forms by introducing economic incentives through an increase in the price of raw materials and/or provide more contractual support. The development of hypotheses is presented in next sub-sections.

3.1. Asset specificity

Asset specificity is the most important factor in adopting more cooperative forms of governance associated with the bilateral dependency of economic agents owing to the resources that are invested to conduct transactions (Williamson, 1985). The implementation of a traceability system can lead to further investments in order to control and ensure the quality of seafood products from “farm to table.” These specific

investments can take a variety of forms according to geographical, physical, human, temporal specificity and brand name capital (Williamson, 1996).

Geographical asset specificity refers to the closeness of certified suppliers arising from characteristics such as perishability and climatic conditions that influence the quantity and quality of fisheries products. In Vietnam, the Central Coastal areas, the Southern Delta and Mekong Delta River are the three most important regions of the seafood processing plants (CBI, 2012). The companies in the Central Coastal areas mainly source captured products and Pacific White shrimp that is a rapidly developing in these regions. Businesses in the Southern Delta region take advantages in terms of sourcing material from both the central and southern regions. In addition, this region has an important export harbor from which products are directly exported to the world's markets. In the Mekong Delta River, the number of processing plants has rapidly augmented since the cultured production of Black Tiger shrimp and Pangasius increased. In addition, this region can also benefit from the fisheries raw materials captured from the Gulf of Thailand and Eastern Archipelagic seas. At present, the region Mekong Delta River is the most important source of raw material for the Vietnamese seafood sector. Seafood processing plants are often located near the fish material sources to economize on inventory and transportation expenses.

Physical investments are often made in specialized equipment or tools required to produce a good for a particular customer, and is measured by the variation in processing facilities and the cost of implementation of the system (Banterle and Stranieri, 2008). Almost all Vietnam seafood companies have been HACCP certified (VASEP, 2016) because of requirements imposed by buyers from the export markets. In order to ensure seafood quality and safety as well as traceability, HACCP needs to be applied at all stages of the chain, but only the seafood processing companies have implemented this procedure. Poor implementation of procedures and principles of HACCP in companies at all levels is explained by the costly investments, required by the system, in modern technology, testing equipment and training of employees in quality

control awareness as well as enhancement of capacities and skills for quality management specialists. The introduction of a traceability system requires seafood companies to invest more capital, provide equipment inspection and maintain the quality of raw material as well as processing facilities in order to ensure the quality of the final processed products.

Regarding human asset specificity, one or both of the parties develop skills or knowledge that is specific to the buyer-seller relationship, which arises in a learning-by-doing fashion (Handfield and Bechtel, 2002). Human asset specificity refers to the level of acquaintance among the agents of the supply chain that is measured by the training that is necessary in order to introduce the system and the difficulty of substituting certified suppliers (Banterle and Stranieri, 2008). In the fisheries industry, fishermen, farmers and even collectors often operate without technical skills, only with a limited awareness about safety and low-quality materials that could affect the quality of the final product. Hence, processing companies need to intensively participate in the quality assurance of fish materials by supporting technical guidelines, offering training for farmers and ensuring that collectors foster the safety and quality of raw materials from the farm to the factory.

Intangible asset specificity refers to the certification and planning of a system (Banterle and Stranieri, 2008). Seafood companies do not ensure the quality of fish raw materials from their suppliers, as the processing factories cannot control the information flow that is related to the material from the landing to the factory. Some firms have sought to form a mode of direct purchase from farmers under a type of contract agreement. According to such a contract, the farmer is contractually obligated to supply a specific fishery cultured product in specific quantities and at specific quality standards that have been determined by the processing plant. In turn, the firm commits to supporting the technical facilities and agrees in advance to pay a certain price to the farmer for the output. Some large seafood firms are more vertically integrated, and they have developed their own farms in the supply chain.

The introduction of traceability can make changes in the assets specificity that can lead to variation in transaction characteristics and costs and transaction governance in the Vietnam seafood supply chain. Therefore, implementation of traceability system has resulted in more investment in human specificity, processing facilities, capital assets to control and ensure the quality of seafood products throughout the supply chain. Thus, the hypothesis can be formulated as:

Hypothesis 1: The implementation of traceability systems leads to an augmentation of assets specificity.

3.2. Transaction uncertainties

The level of uncertainty in a transaction depends on the information asymmetry, bounded rationality of agents and random nature of certain events (Akerlof, 1970). The uncertainty principally connects with the probability that subjects will fulfill their contractual obligations (Banterle et al., 2006). The variation in the degree of transaction uncertainty is measured by variations in supply chain transparency in terms of the timing, quantity and precision of the exchanged information (Banterle and Stranieri, 2008). Transaction costs increase when the degree of uncertainty arises.

The production of fisheries is highly uncertain because of seasonal characteristics, climatic changes and disease, which may lead to discontinuities in business. In addition, the perishability of fish products and basic operational practices of fisheries and collectors, significantly affect quality of supplied raw materials. Owing to a lack of technical skills and limitations in safety and quality awareness, some farmers and collectors can use banned chemicals in their production procedures as well as in the preservation of fish materials before transportation to companies (Loc, 2006). The introduction of a traceability system can decrease such uncertainties by providing proper data on quantity, quality, price and market information to economic agents within the seafood chain. In this sense, the hypothesis could be stated:

Hypothesis 2: The implementation of traceability systems leads to a decrease in transaction uncertainty.

3.3. Frequency of transactions

Frequency refers to the occurrence of an economic transaction—whether crudely recurrent or occasional (Williamson, 1985). Banterle et al. (2006) note that the introduction of a new governance of transaction should not lead to any variation in the frequency of transactions because of the perishability of the products and the seasonal nature of agricultural production. Besides, the effects of the frequency attribute are also related to reputation (Vinholis et al., 2012). With a greater number of transactions, the need for contractual safeguards to address unexpected events due to contractual incompleteness or opportunistic actions increases (Williamson, 1985). In addition, recurring transactions enable companies to develop their reputations and to cultivate a relationship of greater trust with agents. The frequency of transactions can be measured by the lapse time between transactions (Banterle et al., 2006).

The transactions between seafood processors and raw materials suppliers are generally informal relationships that are based on mutual trust. Thus, seafood companies should maintain the long-term business relationships that they have established with fish suppliers to retain transaction costs and ensure the quality of their raw materials. A hypothesis can be raised as:

Hypothesis 3: The implementation of traceability systems leads to an increase in transaction frequency.

3.4. Transaction costs

Transaction costs register an augmentation when there is an increase in the levels of frequency, uncertainty and asset specificity of transactions (Wang and Bravo, 2010).

The implementation of a traceability system increases transaction asset specificity, decreases relative levels of uncertainty and potentially leads to fluctuations in transaction costs. An increase in monitoring costs can be expected because of increased asset specificity after the introduction of a traceability system. A reduction in information costs can also be expected inasmuch, as the main aim of traceability is to increase information transparency within food supply chains. Nevertheless, it will be extremely difficult to estimate precisely the transaction costs because of the many complex organizational costs that are not measurable. In this regard, variation in transaction costs can be evaluated through changes in monitoring costs, as measured by the variation in supplier activity and the raw material controls (Banterle and Stranieri, 2008).

Seafood companies need to manage the safety and quality of the raw materials supplied by farms and/or fishing boats, storage and transportation to the factory. Indeed, seafood companies have been involved in production operations as well as in post-harvest preservation to prevent the types of cheating behaviors that can cause an increase in monitoring costs. Thus, the hypothesis can be formed as:

Hypothesis 4: The implementation of traceability systems leads to an increase in monitoring costs.

3.5. Reorganization of transactions

Traceability implementation leads to a reorganization of transactions in the supply chain connected to (1) growth in transaction assets specificity among the agents of the seafood supply chain that determines an increase in monitoring costs; (2) a decrease in the level of transaction uncertainty related to the higher level of transactions transparency and (3) an augmentation of transaction frequency. The processing plants often use economic incentives such as flexible price policies, quick payment, and premium price for traceable and quality materials to maintain the suppliers' loyalty and the firms' reputation. So the proxies used to assess the governance changes are related

to the adoption of price incentive, introduction of contracts, application of production rules and enforcement of liability degree based on the strengthening of vertical coordination. A hypothesis is:

Hypothesis 5: The implementation of traceability systems leads to shift transactions from market to hybrid forms, and transactions that are organized through hybrid forms should engender enforcement of these forms by introducing economic incentives through an increase in the price of raw materials and/or provide more contractual support.

Summing up, the introduction of traceability systems brings to recognize economic exchange among supply chain agents, through the applying of new models of vertical coordination and providing new transaction governance connected to implementation of specific supply chain agreements and centralization of the traceability system management (Banterle et al., 2006). The implementation of traceability also leads to more transparency along supply chain in terms of physical and informative flows of products. The firm that promotes the introduction of traceability acts as the leader of the supply chain, coordinating the activities of the other agents. The results of hypotheses testing would be presented in the chapter 5.

4. Conclusion to the chapter

This chapter presents the development of three models of the doctoral project. The first model is built to measure the performance of biodiversity management of enterprises with fuzzy set theory. The model consists of two main parts, i.e., identification of the Key Performance Indicators and measurement procedure. The second model suggests three propositions in terms of the connection between green supply chain management, biodiversity and traceability. The third model is to evaluate the impact of the implementation of traceability systems to transaction governance structure in the supply chain based on transaction cost economics. Five hypotheses have been developed in the model.

Measurement constructs for each of variables have also been recommended in the model. In general, GSCM practices can be measured by items such as eco-design, green purchasing, internal environmental management, cooperation with customer and investment recovery. The performance of biodiversity management has been developed from the first model that include biodiversity business assessment, biodiversity management policy, biodiversity conservation commitment, biodiversity stewardship practices and biodiversity performance reporting. The performance of traceability system can be evaluated by its ability to improve the breadth, depth, precision and access of information.

The second model is limited at the development of propositions stage. The first and third models are tested by empirical studies conducted in Vietnam. Research methods and strategy would be presented in the next chapter – methodology and empirical study.

CHAPTER 4

RESEARCH METHODOLOGY AND EMPIRICAL STUDY

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Purpose of research is to discover answers to questions through the application of scientific procedure. Pandey and Pandey (2015) outline some most important definitions of research. Of which, research is common parlance that refers to a search for knowledge. Others define research as a scientific and systematic search for pertinent information on a specific topic. In fact, research is the art of scientific investigation. More than a set of skills, research is a way of thinking (Kumar, 2011). Kothari (2004) explains the difference between research methods and research methodology. Accordingly, research methods refer to the methods the researchers use in performing research operations, while research methodology is a way to systematically solve the research problem.

This chapter presents the research methodology and empirical study that drives this thesis. The methodology chapter aims to describe the rationale of specific methods used to identify, select, and analyze information that allows evaluating validity and reliability of the study. Subsequent sections discuss research design and setting, instrument for gathering data and sample, data collection process and analysis methods. The concerns of biodiversity management and transaction governance attributes in the supply chain of shrimp, pangasius and tuna are briefly introduced in the empirical study.

1. Research methodology

This research takes deductive approach with the aim of testing the hypotheses and illustrating how the measurement model operates. The economics of ecosystems and biodiversity (TEEB), corporate biodiversity management, fuzzy set theory, traceability implementation, transaction cost economics and green supply chain management provide fundamental backgrounds to these analyses. Quantitative methods are used for data analysis procedures. Particularly, the first model uses fuzzy logic operations to measure the corporate biodiversity management. The third model uses transaction cost analysis together with statistical descriptive technique. The following figure summarizes research methodology that has been applied in the thesis.

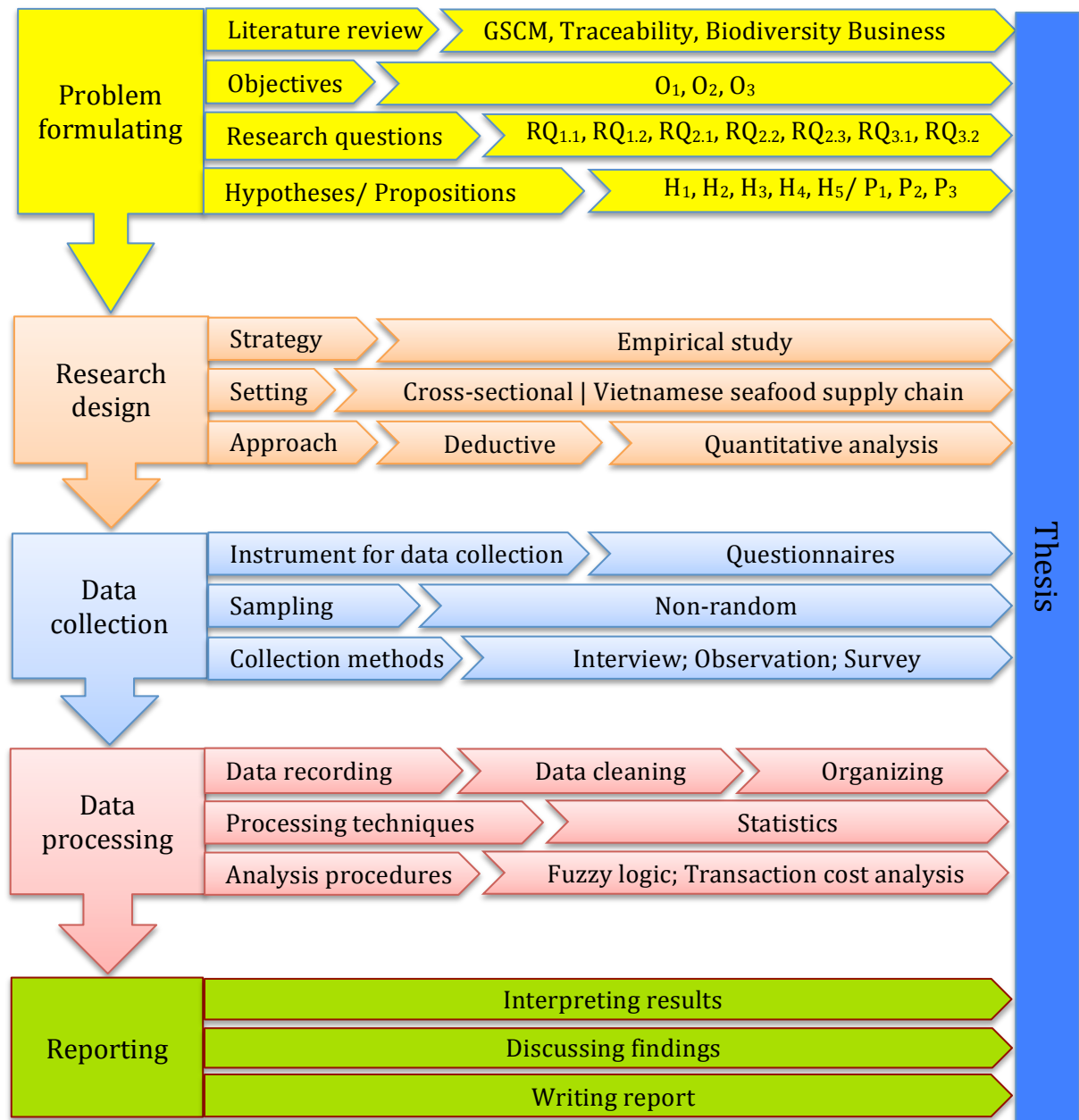


Figure 4.1.1 Research methodology

Research process consists of a series of actions or steps necessary to effectively carry out research. Kumar (2011) presents the research journey that involves three phases with eight steps, i.e. formulating a research problem; conceptualizing a research design, constructing an instrument for data collection, selecting a sample, writing a research proposal, collecting data, processing and displaying data, and writing a research report. Formulation of the research problem is the first and most important step of research

process. A research design is a plan, structure and strategy of investigation to obtain answers to research questions or problems. Construction of a research instrument is the first “practical” step in carrying out a study. The basic objective of any sampling design is to minimize, within the limitation of cost, the gap between values obtained from sample and those prevalent in the study population. Many methods could be used to gather the required information such as observation, interview, survey, etc. Processing of data is the way the information is analyzed. The type of analysis depends upon the type of information and the way the information is communicated to readers. Writing the report is the last step of the research process that informs readers what the researchers have done.

1.1. Research design and setting

As presented, this thesis includes three individual research projects. The objective of the first project is to develop a model for measuring performance of biodiversity management of firms, which focus on the two research questions *RQ 1.1* and *RQ 1.2*. The second project tries to propose a model in order to make a linkage between green supply chain management, implementation of traceability and performance of biodiversity management, which follows the research questions *RQ 2.1*, *RQ 2.2* and *RQ 2.3*. The third project aims to examine variation in the transaction attributes, transaction costs and transaction governance of firms, which address the two other research questions *RQ 3.1* and *RQ 3.2*.

The second project is limited at the development of propositions stage. The cross-sectional design is applied in two other projects. A survey of specialist opinion has been carried out in order to validate Key Performance Indicators in the measurement model. Two company questionnaire surveys are conducted to collect primary data. The empirical studies have been organized in Vietnam with the involvement of enterprises in the aquatic products supply chain.



Figure 4.1.2 Map of Vietnam with difference regions

Source: www.nationsonline.org/oneworld/map/vietnam-administrative-map.htm

Vietnam is one of the leading seafood suppliers in the world. Seafood exports represented approximately \$US 5 billion out of a total export value of USD 71.6 billion in 2010 (CBI, 2012). According to Vietnam Association of Seafood Exporters and Producers (VASEP, 2016), the fishery sector plays an important role in the national economy that accounts for about 4-5 percent of Gross Domestic Product and about 9-10 percent of national export revenue. More than 4 millions of people are involved in the industry. Currently, the fisheries sector ranks third in terms of foreign export earnings after the garment and crude oil industries.

Geographical characteristics constitute important advantages for development of Vietnam's fisheries sector for both fishing and aquaculture operations. The Figure 4.1.2 shows the regions of Vietnam. In terms of geographical location, eastern part of the Vietnam territory is exposed to the South China Sea. The coastal line stretches from the north to the south with a length of about 3,200 kilometers. The sea exclusive economic zone is about of one million square kilometers. The potential of fishery sector is embedded in water bodies of 1.7 million hectares, where 811,700 hectares represent freshwater, 635,400 hectares brackish water and 300,000 – 400,000 hectares wetland areas might be employed for aquaculture development (VASEP, 2016).

Shrimp, pangasius, tuna, and other marine fishes are key seafood products exported to 170 markets in the world. The exports of shrimp contribute up to 46-50% of the total seafood sales of Vietnam. Earnings from pangasius reach \$US 1.7-1.8 billion (25% of the total) and exports of Tuna and Cephalopods represent \$US 450 – 500 million each (VASEP, 2016). The policy of the government of Vietnam aims to guide the seafood sector in order to position it as a global-leading seafood exporter. The focus of policy is on increasing aquaculture production through diversification, of which the protecting fish resources is the priority in the capture fisheries.

Even though the fisheries industry is mainly based on small-scale and fragmented characteristics (Lai et al., 2009). The existing issues related to lack of traceability and sustainability, low vertical integration and weak linkages between operators within the chain represent the most serious bottlenecks for the exports (CBI, 2012). In addition, the cooperation between fishermen and processing factories is not sufficiently strong

within the supply chain due to presence of multilevel middle traders (Hop, 2012). Hence, it is interesting to investigate how the small-scale attributes of the industry affect the way seafood firms implement traceability systems, manage the transaction in material sourcing and perform the environmental management.

1.2. Data collection instrument

Three questionnaires have been developed as instruments for gathering data (*see appendices 3, 4, 5*). The first questionnaire surveys expert's opinion about the relevance of the key performance indicators in the model of measurement of biodiversity management. The second one collects data from enterprises in terms of the importance of indicators and the performance of firms with respect to the selected indicators. The third one gathers information on the impact of traceability implementation to transaction governance structure of firms.

Regarding to the first questionnaire, indicators used to measure the biodiversity management of enterprises have been selected from the literature. Then, the master list of selected indicators was submitted to experts and practitioners for discussion and validation of KPIs relevance. The specialists were asked to assess whether or not an indicator was relevant in the measurement biodiversity management of firms. The results of assessment are presented in the next chapter.

As a next step, the validated indicators were brought into the development of the second questionnaire (*see appendix 4*) that is used in the company survey. Together with general information about the enterprise and respondent, the survey questionnaire consists of two main parts with structured questions. The first part collects the assessments in terms of the performance of biodiversity management of the company with respect to each indicator. The second section asks about the importance of identified indicators. Evaluators were required to express their opinion in the linguistic variables instead of the crisp numbers. Particularly, the importance of each biodiversity performance indicator is evaluated by a question with the answer set in linguistic terms as "Very low", "Low", "Moderate", "High" and "Very High". Similarly, the

performance of a firm with respect to each indicator is evaluated by a question with the answer in linguistic terms as “Excellent”, “Very good”, “Good”, “Fair” and “Poor”.

The third questionnaire includes five major sections (*see appendix 5*). The first part collects general information on firm in terms of turnover, number of employees, legal status, level of vertical integration, certification systems and product price variation. The second part collects features of the current traceability system implemented by the firm. In addition, motivation for the introduction of the traceability system at the firm is also included. For the main three parts of questionnaire, using a five-point Likert scale (*1 = Very Low, 2 = Low, 3 = Medium, 4 = High, and 5 = Very High*), the operation managers were required to evaluate the changes in transaction attributes, transaction costs and transaction governance structure that occurred when their firm implemented a traceability system.

Items were used to assess the variation in the key transaction features that were connected to the introduction of a traceability system based on the literature review (Banterle et al., 2006; Banterle and Stranieri, 2008; Vinholis et al., 2012). Particularly, variations in asset specificity were measured through (1) variation in human asset specificity (long-term business relationships with suppliers, difficulties in substitutions of suppliers, and supplier training); (2) variation in physical asset specificity (processing facilities variations); (3) variation in geographical asset specificity (certified suppliers’ closeness). Variations in uncertainty are measured by the frequency of information flow, especially the variation in the quantity of information flow and the variation in the precision of information flow. Variations in transaction costs are mainly considered by monitoring costs owing to the many organizational costs that are not measureable (Banterle and Stranieri, 2008). Monitoring costs are quantified by means of questions that were related to variation in both supplier activity controls and raw material controls. The proxies that are used to assess governance changes were related to the adoption of price incentives, the introduction of contracts, the application of production rules and the degree of liability enforcement based on the strength of vertical coordination.

1.3. Sample

Up to December 2015, there are 612 plants that meet national standards of hygiene, 100% plants applied HACCP, 461 EU-qualified (EU code) plants and many factories applied GMP, SSOP (VASEP, 2016). These seafood-processing plants are licensed by the National Agro-Forestry-Fisheries Quality Assurance Department (NAFIQAD) and as a result are eligible for exporting. The list of seafood producers in Vietnam qualified to export can be found on the VASEP site.⁸ Regarding to legal type of Vietnamese enterprises, mainly there are state-owned or joined stock companies. The number of private companies has risen in the recent years. The following table provides an overview of the types of companies that were licensed for seafood exports in 2009.

Table 4.1.1 Number and type of companies per region

Region	Type of company					Total
	State owned	Joint stock	Private	Joint venture	100% foreign capital	
Red River Delta	6	9	3	4	4	26
Central Coastal	33	30	71	0	0	134
Southern Delta	30	47	114	4	4	199
Mekong River Delta	22	73	104	1	1	201
Total	91	159	292	9	9	560

Source: CBI (2012)

The Central Coastal area, the Southern Delta and Mekong Delta River are the three most important regions for the seafood processing of Vietnam. Companies locate their processing plants near source of fish materials in order to save on transportation costs

⁸ <http://seafood.vasep.com.vn/657/whybuy/food-safety.html>

and minimize degradation of aquatic materials quality. The companies in the Central Coastal areas mainly source captured products and Pacific white shrimp that is a rapidly developing in this region. The Southern Delta region has advantage to source materials from both the central and southern regions. Moreover, this region has the main harbor from which products can be directly shipped to most export markets. In the Mekong Delta River, the number of processing establishments has increased rapidly since the cultured production of Black Tiger shrimp, *Pangasius* and fish raw materials captured from the Gulf of Thailand and Eastern Archipelagic seas.

Two important criteria for determining sample in this study are (1) location of enterprises and (2) main product of businesses. Regarding the location of the business, the study aims to survey seafood enterprises located in the Central Coastal, Southern Delta and Mekong River Delta areas because these regions represent a major source of fisheries raw material. As regarding the main product, the study wants to learn about supply chain of tuna, shrimp and pangasius products. These are the flagship products in the Vietnamese fisheries sector and the levels of integration in the supply chains as well as the scale development of each subsector are quite different. Based on such criteria, the study applies convenience-sampling method.

Data for this study were collected through two waves of the field trips and surveys via email. The field trips at companies were conducted prior to the electronic surveys in order to pre-test the questionnaire and to observe businesses operations. A total of five seafood businesses involved in the first project that aims to measure the performance of biodiversity management. Of which the three field trips have been carried out at enterprises located at Khanh Hoa (1) to learn their tuna supply chain; Can Tho (1) for pangasius supply chain; and Ca Mau (1) for shrimp supply chain. To increase the sample size, a questionnaire survey was also conducted via email. In this survey, questionnaires were sent to a hundred of seafood businesses in the study area. After two weeks, there were five responses, but three of them lacked information.

Face to face discussion were also organized in the second project. Visits and discussions were held with managers of enterprises from Da Nang (2), Binh Dinh (1), Khanh Hoa (1), and Ninh Thuan (1). In addition, questionnaires had also been delivered to hundreds of firms via email. There were nine of thirteen usable responses from this email survey after a month. Finally, a total of 14 businesses were included in the second project. These businesses were located in different provinces, i.e., Da Nang (6), Binh Dinh (1), Khanh Hoa (5), Ninh Thuan (1), and Vung Tau (1).

Table 4.1.2 Sample in the study

Location	1 st project	2 nd project
Da Nang	-	6
Binh Dinh	-	1
Khanh Hoa	3	5
Ninh Thuan	-	1
Vung Tau	-	1
Can Tho	1	-
Ca Mau	1	-
Total	5	14

Summing up, there are five businesses involved in the first research project. General characteristics of these firms are further described in the empirical data. In the second project, the sample includes five businesses interviews and nine businesses obtained from the email survey. To mention that a firm in Khanh Hoa participated in both projects.

1.4. Analysis methods

Fuzzy logic operations have been applied in the model to measure the performance of corporation biodiversity management. Transaction cost analysis is employed in the

model of assessment the variation of transaction governance structure in the supply chain. The next sub-sections present these procedures.

1.4.1. Fuzzy logic

In several situations, crisp numbered data are insufficient to model real world systems due to vagueness, imprecision, and subjective nature of human thinking, judgment, and preferences. To deal with vagueness, Zadeh (1965) first introduced the fuzzy set theory, which addresses to the rationality of uncertainty due to the ambiguity. In the current project, fuzzy logic methodology was applied in the measurement model of corporate biodiversity management performance. Some related fundamental definitions and operations of fuzzy set theory are adapted from Zadeh (1965; 1975); Kahraman et al. (2003); Awasthi et al. (2010); Junior et al. (2014); Ordoobadi (2009); van Laaehoven and Pedrycz (1983); Kannan et al. (2014) and are further presented below.

1.4.1.1. Fundamental definitions

In traditional set theory, elements have either “complete membership” or “complete non-membership” in a given set. With fuzzy set theory, intermediate degrees of membership are allowed. The coding of membership degree for each element in the set is defined as the membership function of the fuzzy set.

Definition 1: Fuzzy set

Let X be the universe of discourse, $X = \{x_1, x_2, \dots, x_n\}$ and a tilde “ $\sim$ ” will be placed above a symbol if the symbol represents a fuzzy set. A fuzzy set $\tilde{M}$ of X is defined by:

$$\tilde{M} = \{x_i, \mu_{\tilde{M}}(x_i)\}, x_i \in X$$

where, $\mu_{\tilde{M}}(x): X \rightarrow [0, 1]$ is the membership function of $\tilde{M}$ and $\mu_{\tilde{M}}(x_i)$ stands for the membership degree of x_i in $\tilde{M}$.

- If $\mu_{\tilde{M}}(x_i)$ is equals to zero, x_i does not belong to the fuzzy set $\tilde{M}$.
- If $\mu_{\tilde{M}}(x_i)$ is equals to 1, x_i completely belongs to the fuzzy set $\tilde{M}$.
- If $\mu_{\tilde{M}}(x_i)$ has a value between 0 and 1, x_i partially belongs to the fuzzy set $\tilde{M}$.

That is, the pertinence of x_i is true with the degree of membership given by $\mu_{\tilde{M}}(x_i)$.

Definition 2: Fuzzy number

A triangular fuzzy number can be expressed as a triplet (l, u, m) ; the membership function of the fuzzy number $\mu_{\tilde{M}}(x_i)$ is defined as:

$$\mu_{\tilde{M}}(x) = \begin{cases} \frac{x-l}{m-l}, & \text{for } l \leq x \leq m \\ \frac{u-x}{u-m}, & \text{for } m \leq x \leq u \\ 0, & \text{otherwise} \end{cases}$$

in which ***l***, ***m***, and ***u*** are real numbers with $l \leq m \leq u$; ***l*** and ***u*** standing for the lower and upper value for $\tilde{M}$, respectively; and ***m*** for the modal value that represents the point at which the pertinence degree is maximum. Outside interval $[l, u]$, the pertinence degree is null.

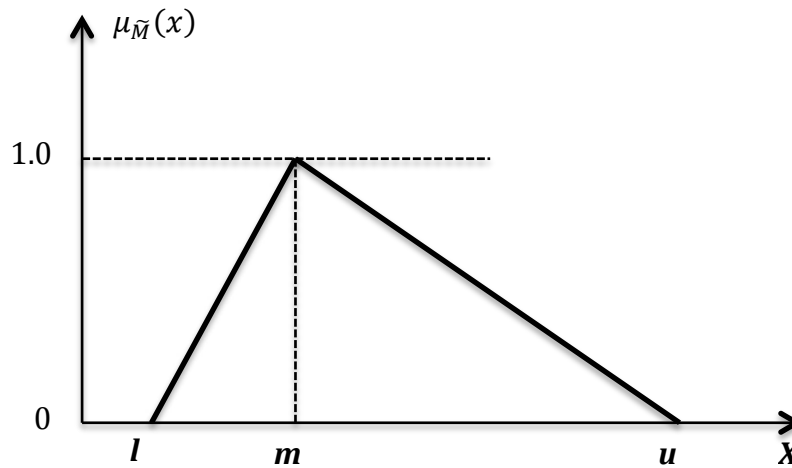


Figure 4.1.3 Membership function of triangular fuzzy number

Definition 3: Operational laws with fuzzy numbers

Given any real number k and two fuzzy triangular numbers $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$, the main algebraic operations are expressed as follows:

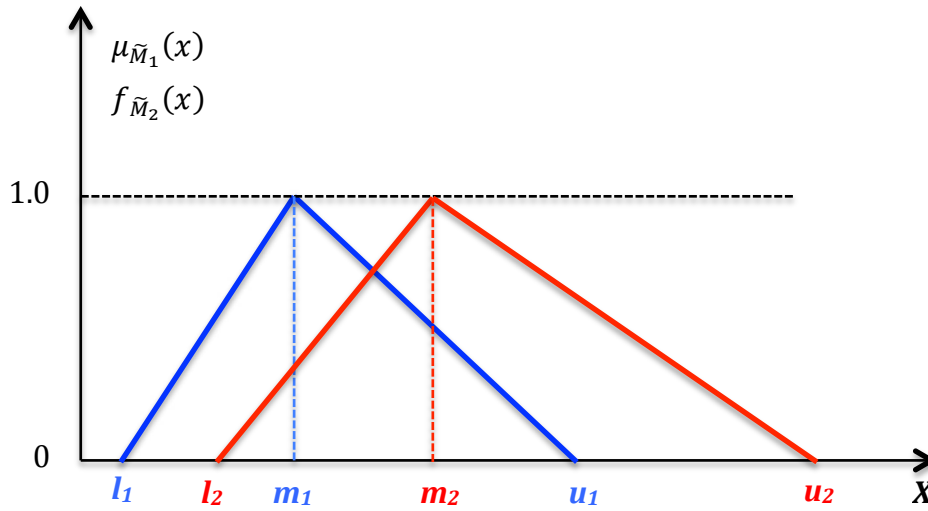


Figure 4.1.4 Two triangular fuzzy numbers

(1) Addition of two triangular fuzzy numbers

$$\tilde{M}_1 + \tilde{M}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2), \quad l_1 \geq 0; l_2 \geq 0$$

(2) Multiplication of two triangular fuzzy numbers

$$\tilde{M}_1 \times \tilde{M}_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2), \quad l_1 \geq 0; l_2 \geq 0$$

(3) Subtraction of two triangular fuzzy numbers

$$\tilde{M}_1 - \tilde{M}_2 = (l_1 - l_2, m_1 - m_2, u_1 - u_2), \quad l_1 \geq 0; l_2 \geq 0$$

(4) Division of two triangular fuzzy numbers

$$\tilde{M}_1 \div \tilde{M}_2 = (l_1 \div l_2, m_1 \div m_2, u_1 \div u_2), \quad l_1 \geq 0; l_2 \geq 0$$

(5) Inverse of a triangular fuzzy number

$$\tilde{M}^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l} \right) \geq 0$$

(6) Multiplication of a triangular fuzzy number by a constant

$$k \times \tilde{M} = (k \times l, \quad k \times m, \quad k \times u), \quad l \geq 0, k \geq 0$$

(7) Division of a triangular fuzzy number by a constant

$$\frac{\tilde{M}}{k} = \left(\frac{l}{k}, \frac{m}{k}, \frac{u}{k} \right), \quad l \geq 0; k \geq 0$$

1.4.1.2. Linguistic variables

A linguistic variable is a variable which values are words or sentences of a natural or artificial language (Zadeh, 1975) that are expressed in linguistic terms, and then converted in fuzzy numbers. Usually, conversion scales are used to transform linguistic terms into fuzzy numbers according to membership function. For each membership function, the average value is the point at which the degree of membership reaches one, or full membership for that set. The upper and lower limits are those points at which the degree of membership reaches zero, or no membership. Other degrees of membership between these two extremes are determined from the membership curve.

Membership functions of importance of indicators

The importance of each biodiversity performance indicator is evaluated by a question to be answered through a closed set of answers in linguistic terms: “Very low: VL”, “Low: L”, “Moderate: M”, “High: H” and “Very High: VH”. These values correspond to fuzzy numbers on the numeric scale 0-1. The following figure illustrates these five membership functions.

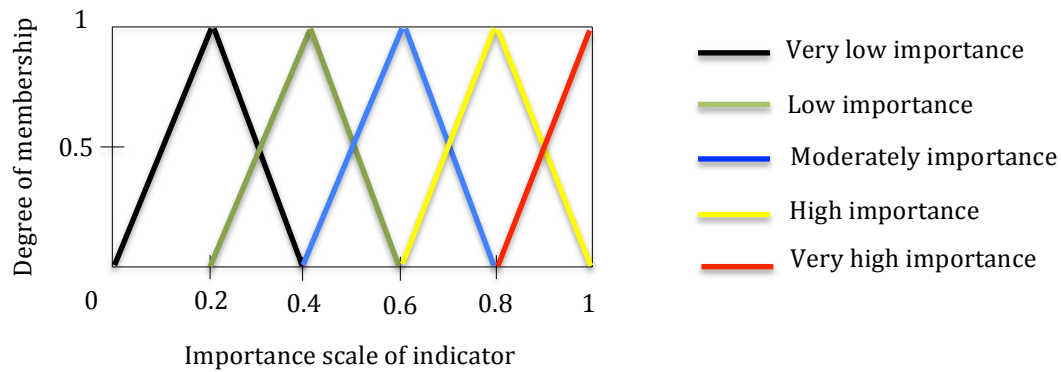


Figure 4.1.5 Membership functions of the linguistic importance weight

Membership functions of corporate performance

Corporate performance against an indicator is evaluated by a question to be answered through a closed set of linguistic terms: “Excellent: EX”, “Very good: VG”, “Good: G”, “Fair: F” and “Poor: P”. These values correspond to fuzzy numbers on the numeric scale 1-9. The membership functions are shown in Figure 4.1.6:

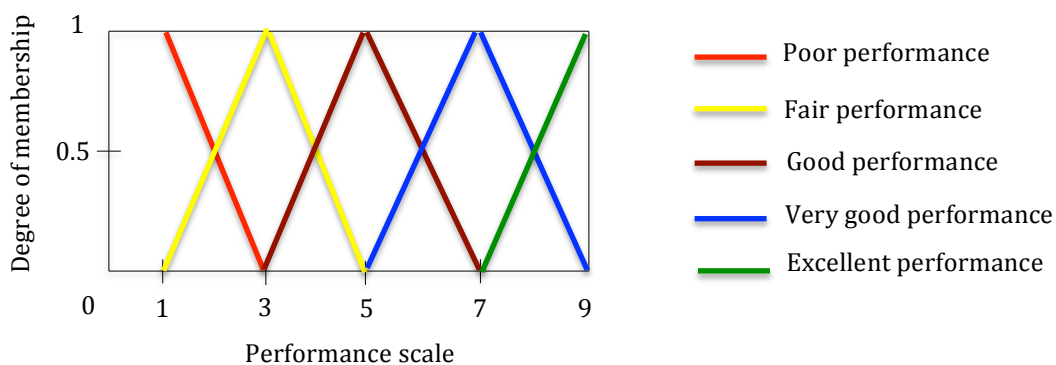


Figure 4.1.6 Membership functions of the linguistic performance rate

The membership function is commonly depicted as a membership curve. The membership curve contains three main components: the horizontal axis that consists from domain elements (usually real numbers) of the fuzzy set, the vertical axis represents the degree of membership scale from 0 to 1, and the surface of the set itself

is related to the degree of membership to the domain element. These membership curves can take several shapes, such as linear representation, S-curve representation, triangular and trapezoidal representations, and “bell” curve representation (Cox, 1994). The triangular is the most frequently used representation since it is better understood by decision makers and is suitable to different real situations.

1.4.1.3. Defuzzification

Ranking may be necessary in order to allow comparison of firms. However, ranking is not an easy task with fuzzy numbers, since the ordering of fuzzy numbers is not as obvious as that of real numbers. Thus, fuzzy numbers shall be converted into real numbers to simplify the task of ranking the firms. Popular defuzzification approaches include the weighted average method, the centroid method, the mean-max membership, the center of sums, the max-membership principle, and the first (or last) of maxima (Cheng and Lin, 2002; Ross, 2004). The most common defuzzification approach is the center of area (COA) or centroid method. For a triangular fuzzy number (l, m, u) , the center of area is calculated as:

$$s_j = \frac{(l_j + m_j + u_j)}{3}$$

Fuzzy logic operations are applied in the model for measuring the performance of corporate biodiversity management. For the model of assessment the variation of transaction governance structure in the supply chain, transaction cost economics provides a framework for that analysis.

1.4.2. Transaction cost analysis

Transaction cost economics poses the problem of economic organization as a problem of contracting that rests on two behavioral assumptions: bounded rationality and opportunism; and three main transaction attributes: asset specificity, uncertainty and frequency. Concerning behavioral assumptions, the cognitive and self-interestedness assumptions from which transaction cost economics works are bounded rationality -

defined as behavior that is “*intendedly* rational, but only *limitedly* so” (Simon, 1961); and opportunism – defined as self-interest seeking with guile, respectively. All complex contracts are unavoidably incomplete because of bounded rationality, and the convenient concept of contract as promise is vitiated by opportunism (Williamson, 1996).

Bounded rationality states that in decision-making rationality of individuals is limited by information they have, the cognitive limitations of their minds, and the finite amount of time they have to make a decision. Simon (1957) coined the phrase ‘*bounded rationality*’ to describe the limited extent in making logical decisions in organizations. This arises because while decision-makers in organizations are intentionally rational, they experience real limits in their cognitive ability in the formulation and solving of problems (receiving, encoding and transmitting) as well as the processing of information.

Opportunism extends the concepts of the normal self-interest of economic actors to allow for their acting in a self-interested way ‘with guile’ in Williamson’s terms. In certain circumstances one party may see an opportunity to exploit a situation at the expense of the other. The problem in managing these phenomena is to understand they occur on occasion and that differing perspectives are to be expected from collaborating parties.

As developed by Williamson (1985), transaction cost analysis was made operational in three steps. First, it takes the transaction to be the basic unit of analysis and names the key features across which transactions differ. Second, it describes the properties of alternative modes of governance. Third, the analysis is completed by applying the “discriminating alignment” hypothesis, which describes how different kinds of transactions are more efficiently governed by different modes of governance. The following sections present the operational framework of transaction cost economics that was adapted from Williamson (1985; 1991; 1996; 2001); Tadelis and Williamson (2012); Banterle and Stranieri, (2008), Hobbs (1996); Vinholis et al. (2012); Klein (2009); Wang and Bravo (2010); Trautman et al. (2008).

1.4.2.1. Unit of analysis

As the first step, the principal dimensions on which transaction cost economics presently rely for the purposes of describing transactions are *(i)* the condition of asset specificity, *(ii)* the frequency with which they recur, and *(iii)* the degree and type of uncertainty to which they are subject. The asset specificity of transaction identifies the bilateral dependency of economic agents arising from the specific investment that is needed to conduct a transaction. It can take a variety of forms: site specificity, physical asset specificity, human asset specificity, dedicated assets, brand name capital and temporal specificity. The level of uncertainty depends on the degree of information asymmetry among economic agents, and it is strictly connected to the probability that subjects will respect contractual obligations. Frequency refers to the occurrence of the economic transaction—whether crudely recurrent or occasional.

a. Asset specificity

Transaction specific assets are means for which a bilateral dependency relationship develops between the parties. Some goods and services can be produced more efficiently if one of the parties invests in transaction specific assets that cannot easily be put to other uses if the buyer-seller relationship breaks down. The asset specificity of transaction identifies the bilateral dependency of economic agents by reason of the specific investment needed to carry out a transaction and it can take a variety of forms:

- (1) Site specificity* – a buyer or seller locates its facilities next to the other to save on inventories or transportation expense;
- (2) Physical asset specificity* – investments are made in specialized equipment or tooling required to produce a component for a particular customer;
- (3) Human asset specificity* – one or both of the parties develop skills or knowledge specific to the buyer-seller relationship that arises in a learning-by-doing fashion;
- (4) Dedicated assets* – capacity is created to serve a customer who is large relative to market size, so that it would be difficult to find alternative customers.

(5) *Brand name capital* – the parties must maintain the reputation of a shared brand name; for example, in franchise relationships the reputation of the franchise depends on the behavior of the individual franchisees.

(6) *Temporal specificity* - has been added by Williamson (1996). An asset is time specific if its value highly dependent in its reaching the user within a specified, relatively limited period of time.

Whatever the form, these assets can sometimes arise spontaneously, without conscious and costly investment, as with knowledge and skills that are incidentally acquired by the parties while working together. Since the value of the transaction-specific assets depends on the continued existence of the buyer-seller relationship, the party that has not invested may expropriate some of the value of the investment by threatening to walk away from the relationship. If the investor cannot be assured of realizing the full value of the transaction-specific investment, efficient investments that reduce the cost of production may not be made, resulting in higher costs to both parties.

b. Uncertainty

Uncertainty is interesting as it is clearly difficult to foresee all the eventualities that might occur over the terms of a contract. Asset specificity, in any of its forms, does not by itself pose contractual hazards that require added governance. In general, a long-term contract can offer the parties adequate compensation for efficient investment in specific assets, and spell out how future contingents decisions that reply on these assets will be made and compensated for. The level of uncertainty depends on the degree of information asymmetry among economic agents and is strictly connected to the probability that subjects will respect contractual obligations. Larger degree of uncertainty can lead to more consequential contractual incompleteness (gaps, errors, omissions, and ambiguities arise) in part due to the contextual influence of bounded rationality and information asymmetries.

c. Frequency

Frequency refers to the occurrence of the economic transaction – whether crudely recurrent or occasionally. In general, when a transaction is frequent and of low specificity then it is likely that the market will offer scale and scope benefits – and outsourcing is favored for example. Williamson (1985) notes that higher levels of transaction frequency provide an incentive for internal organization because “the costs of specialized governance structures will be easier to recover for large transactions of a recurring kind”. If, however, reputation effects work well, increasing transactional frequency will support stronger reputation effects. The level of frequency is related to the lapse of time between one transaction and another.

1.4.2.2. Governance structures

In the second step, transactions can be organized under a range of governance structures—from spot markets to fully integrated firms or organizations. Between the two poles of spot market and vertical integration are contractual forms of increasing duration and complexity, which can include the shared ownership of assets. According to Williamson (1985), there are three basic forms of coordinating transactions, which are also called governance structures: spot markets, hybrid forms and hierarchies.

A spot market is a type of transaction coordination that best approximates the neoclassical theoretical framework of pure competition. The relationships in this format can be repeated without effort and evaluated based on experience. In the hierarchy strategy, transactions are brought into the vertical integration of a firm. Internal organization increases a firm’s power to impose itself on the structure of a production system. Other organizational arrangements, which have been labeled “hybrid” governance structures, occupy a location between the extremes of market exchange and vertical integration. Formal and informal contracts can be established, as the agents are inclined to establish and comply with their clauses.

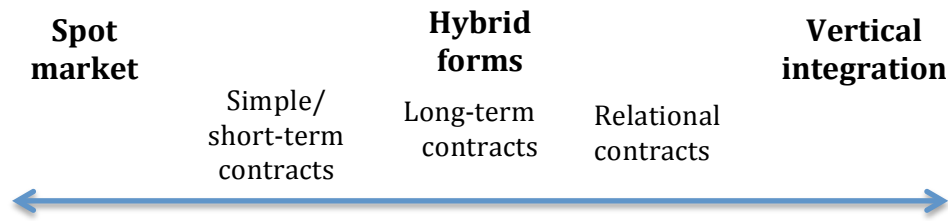


Figure 4.1.7 The basic forms of transaction governance

Spot market: It is the type that best approximates the neoclassical theoretical framework of pure competition. There is no efforts made to repeat the relationship in this format where the goods or services are generic and identifies buyers and sellers as immaterial to the transaction. The evaluation of the relationship by the parties is based on experience.

Hierarchy: The transactions between agents are brought into the vertical integration of the firm. The internal organization increases the firm's power to impose itself on the structure of the production system. The adoption of the hierarchy occurs when the costs of this governance structure are inferior to those obtained via market.

Hybrid: Other organizational arrangements, which have been labeled "hybrid" governance structure, occupy a location between the extremes of market exchange and vertical integration. Given the specificity of the assets and the recurring nature of the transactions, relationships of trust can be built. In this case, incentives sufficient to bring the transaction between the agents into the firm were not found. Formal and informal contracts can be established, since the agents are inclined to establish and comply with their clauses. Simple, short-term contracts involve customization that requires an exchange of information and terms of payment. For more complex customization, longer-term contracts may be required, including adjustment of clauses to respond to contingencies over the life of the contract. When the goods or services cannot be well defined in advance, relational contracts may be used.

When asset specificity, bounded rationality, and opportunism make contracting problems severe, vertical integration may be needed to ensure that the value of transaction-specific assets is internalized. It can also allow for flexible redeployment of assets and personnel when the conditions surrounding the transaction change. However, bounded rationality limits the span of effective managerial control. Lower-level managers and employees may engage in sub-optimizing behavior, or they may have insufficient incentives to minimize production costs.

Each governance structure has strengths and weaknesses. For many types of transactions, markets are the preferred governance structure because they provide “high-powered incentives”. In addition, the supplier obtains the full benefits or bears the full costs of its own activities, and thus has a strong incentive to maximize net value of production costs, and respond quickly to changes in market prices of inputs or outputs. However, transaction cost economics argues that markets have difficulty in dealing with some transactions because of asset specificity, bounded rationality, and opportunistic behavior of the parties to the transaction. Since buyers and sellers can easily walk away from spot market transactions, they have no protection against opportunism when transaction-specific assets are involved.

Table 4.1.3 Strength and weakness of each governance structure

Governance mode	Strengths	Weaknesses
Market	Strong incentives to maximize net value	Cannot protect transaction-specific investments
Contracts	Some protection for investments; market like incentives	Cannot contract for all possible contingencies
Hierarchy	Internalizes value of transaction-specific investments	Cannot control costs as well as markets

Source: https://www.rand.org/content/dam/rand/pubs/monograph_reports/MR865/MR865.chap2.pdf

Contracts offer some protection for transaction-specific assets by keeping the buyer and seller together for a specified period. However, bounded rationality precludes comprehensive *ex ante* contracting that specifies how the parties will behave in all possible circumstances. If contracts are inherently incomplete, parties may perceive potential gains from opportunistic behavior. As a result, attention must be focused on more complex (or internalized) governance mechanisms to fill gaps in the contract, settle disputes, and adapt to new conditions. Contracting parties may also make *ex ante* efforts to screen counterparties in terms of reliability or reputation, and/or design *ex post* safeguards to protect transaction-specific investments.

1.4.2.3. Efficient alignment

A transaction is the basic unit of transaction cost economics analysis, in which a firm serves not only a production function transforming inputs into outputs, but also a governing transactions structure. Given bounded rationality and opportunism, a firm acts on the three transactional dimensions, with an objective to set up order in an exchange relationship, mitigate potential conflict threats, and thus realize mutual gains. This objective is achieved by selecting the appropriate governance mode from discrete structural alternatives – market, hybrid, or hierarchy.

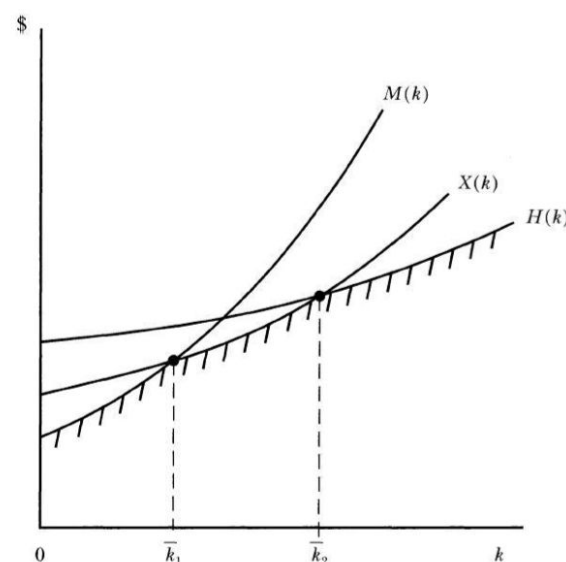


Figure 4.1.8 Governance modes as a function of asset specificity

Source: Klein (2009)

The governance structures are distributed in three different ways, two extreme ones, hierarchy and market, and an intermediary one, the hybrid mode. The higher the asset specificity involved, the higher the cost of its market monitoring. Thus, the governance mode can be altered towards a hybrid mode as the degree of asset specificity is slight $k > \bar{k}_1$, at which monitoring costs by the market are higher than in the hybrid mode. In the mixed or hybrid mode the existence of contracts enabling the system to be “almost verticalised” verified. If the monitoring costs become as high as to make this governance mode inviable, the transaction then forces the system to be managed under the hierarchic mode, as the degree of asset specificity is $k > \bar{k}_2$, necessarily using internal organization to coordinate it.

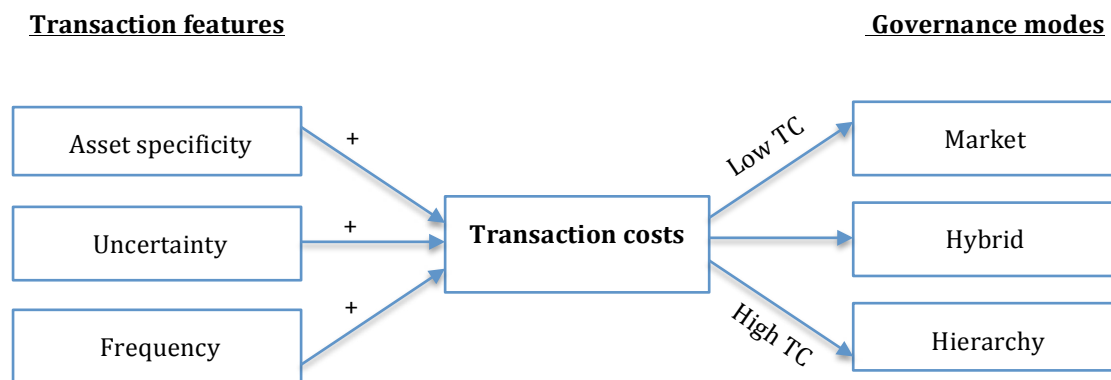


Figure 4.1.9 A transaction cost analytical framework

Source: Wang and Bravo (2010)

The governance structure chosen to conduct specific transactions with specific characteristics affect the organizational efficiency by minimizing the sum of production and transaction costs. In the last step in a transaction cost analysis, organizational efficiency is evaluated based on the alignment between transaction attributes (i.e., asset specificity, uncertainty, and frequency) and forms of governance (i.e., market, hybrid, and hierarchy) under two main behavioral assumptions (i.e., bounded rationality and opportunism). The specificity of the assets is the most important determinant in

choosing more cooperative forms of governance. According to Vinholis et al. (2012), the greater the specificity of the assets involved in production of a product, the stronger the incentive will be to adopt a hybrid form of governance or even vertical integration; a highly uncertain environment will lead a transaction toward the adoption of a hierarchical form of governance; and the more frequently a transaction is repeated, the greater is the possibility of reducing the costs of adopting a complex governance mechanism. Generally, more integrated governance modes are associated with a higher degree of relationship-specific assets, greater uncertainty, more complex transactions, or more frequent exchanges.

2. Empirical study

The questionnaires were carefully prepared prior to make the field trips to enterprises. The purpose of the trips is to pre-test the questionnaires and to collect data for research models. Face to face discussion model was put into practice because of the possibility to explain items in the questionnaire if necessary, and to have a closer look at operations of the business. In addition, desk research has been applied to gather general information about businesses and characteristics of shrimp, pangasius and tuna products supply chain.

Two waves of the field trips were carried out in 2014 and 2016. Seven companies from different provinces, i.e. Da Nang (2), Binh Dinh (1), Khanh Hoa (1), Ninh Thuan (1), Can Tho (1), and Ca Mau (1) had been visited during the field works. Of which a firm in Khanh Hoa had been visited twice. Two other additional site visits were also organized at An Giang province (to learn about pangasius aquaculture farming) and Phu Yen (to learn about tuna supply chain).

The next subsections introduce characteristics of shrimp; pangasius and tuna supply chains. The content is a combination of results from the desk research and field trips. The empirical results would be presented in the next chapter.

2.1. Shrimp supply chain and mangroves forest conservation

According to VASEP (2016), Vietnam is one of the leading suppliers of black tiger shrimp in the world with a production of 300,000 tons per year. This production is a result from more than 600,000 hectares of shrimp farming with two main species black tiger shrimp and white leg shrimp. Shrimp farming areas are concentrated in Mekong Delta provinces. Top 5 provinces having largest shrimp farming area are Ca Mau, Bac Lieu, Soc Trang, Ben Tre and Kien Giang. The shrimp industry is taking its advantages and makes efforts to control the whole production chain from hatcheries - farms – to finished products under global certifications such as ASC, GlobalGAP, BAP.

As the shrimp aquaculture industry has expanded in Vietnam, concerns have been raised about the environmental impacts and the long-term sustainability, particularly the effect to mangrove forest. Healthy mangrove forests are important to support wealth of environmental and economic benefits. Unfortunately, the mangrove forests have been destroyed at alarming rate (McEwin and McNally, 2014). Realizing the potential risks and opportunities that may come to the business activities due to the degradation of mangroves, Minh Phu Seafood Corporation has taken measures to protect mangrove forests. Mangrove conservation has been integrated into the business strategy of the company that developed its own brand “Mangrove Shrimp”.

Minh Phu Seafood Corporation is one of the leading shrimp suppliers worldwide. The corporation is currently producing a large variety of frozen products including Black Tiger and Vannamei shrimp. The company commits to supply good quality and safe products from farms to consumers’ fork. The managers of the company fully understand that appropriate raw material is the most critical point for the operation. At the farming stage, shrimp are cultivated under the application of biotechnology, which minimize the use of chemicals. At the processing step, plants have been equipped with modern equipment that reduces the usage of natural resources and emissions. The company also treats wastewater before disposing it off. Minh Phu’s products meet food safety standards regulated by governmental inspection authorities in consumption markets like US FDA, E.U. Commission, Japanese Ministry of Health Labor and Welfare, AQIS with

certified management programs such as US FDA, HACCP, GMP, SSOP, ISO 22000, BRC Global Standards, Global Trust, ACC (BAP 4 stars), Global GAP, ASC, Naturland Organic.

Table 4.2.1 Business operation performance

	Unit	2011	2012	2013	2014	2015
Production	Tons	30,491	32,487	37,892	54,525	47,750
Export volume	Tons	27,178	32,049	38,799	47,570	44,165
Export value	\$US million	334.39	369.40	519.53	729.06	526.25

Source: Minh Phu Seafood Corporation Annual Report (2015)

Sustainable development policy has clearly been declared to all stakeholders including internal employees. *“Good and sustainable quality – Friendly environment – Responsibility to community”* is the motto of Minh Phu Seafood Corporation. The company has established a responsible value chain for shrimp products, with the participation of actors in the chain from brood stock, post-larvae, feed, processing and export, import and logistics, distribution and retail. Their own brand “Mangrove Shrimp” and “Selva Shrimp” certification promote the effort of the company to be biodiversity friendly.

In addition to the measures taken for conservation of mangroves being environmentally responsible enterprise, Minh Phu Seafood Corporation is also involved in the project named Mangroves and Markets (MAM). The project is focused on enhancement aquaculture sustainability and improving access to organic certification by encouraging local shrimp farmers to plant mangroves in their aquaculture areas (SNV, 2016). In addition, the MAM project promotes ecosystem-based adaption by providing incentives for mangrove conservation with the implementation of Payment for Ecosystem Services systems (PES) (IUCN, 2015). Accordingly, key actors in the Mangrove Shrimp supply chain from farmers, through to processing companies, importers to traders those who work together to introduce ecologically shrimp from areas of high deforestation and

degradation to consumers. The consumers of organic shrimp are mostly from Europe, US, Japan, and South Korea.

Under the agreement, Minh Phu Seafood Corporation has signed contracts with 1,150 farmers managing 4,700 hectares of mangrove forests (IUCN, 2016). These contracts offer a price premium for compliance with the Naturland organic standard. In specific, the company guarantees to pay an additional VND 3,000 (equivalent \$US 0.13) per kilogram of certified organic shrimp compared to market price and amount of VND 500,000 (\$US 22) per hectare per year for the mangrove areas. The premium payments are incentives for farmers to comply with Naturland standard and compensate for mangrove ecosystem services. The Black Tiger shrimp are grown in established mangrove forests using the natural productivity of the surrounding forest habitat with no feed, fertilizers or chemicals.

According to SNV report (SNV, 2016), the productivity of Black Tiger shrimp in the integrated shrimp-mangrove farmed model is about 150 kg/hectare/year. The optimal density is from 8 to 14 post-larvae in the water square meter. In fact, farmers can stock 20 or more post-larvae (PL) per m² to reach the possible maximum yield 250 kg per hectare. In order to get such high yield, high quality of post-larvae is the critical requirement. To support increased productivity, MPC has transported the organic post-larvae from their own hatchery in Ninh Thuan to the Mekong Delta, where it sells to farmers at a loss. Increasing yield through the use of healthier and higher survival rate post-larvae is important because a small increase in productivity would increase farmers' incomes.

Mr. Nguyen Tan Ngoan, quality manager of MPC, who has 15 years of work experience in the company and 8 years of experience in the position, said that a farmer could get about 5-7 kg of shrimp in average in each time of harvesting. Depending on the tide, farmers can harvest two or three times per month. The price of mangroves shrimp is around VND 250,000 per kilogram. So the minimum monthly income of households in the mangrove protected areas is VND 5 million (\$US 240). This amount is not high but the net income from selected integrated mangrove-shrimp farming has increased 1.5

times by comparison with traditional shrimp aquaculture or rice-shrimp without mangroves (SNV, 2016).

Mr Ngoan also added that the ecological shrimp accounts about 4-5% from the total volume exported by the company. Customer demand for ecological shrimp is growing in the developed markets. “The deployment model shrimp-mangrove has not only sustainable benefit for the company but also for all parties in the supply chain”, he concludes. The founder of Minh Phu Corporation, Mr Le Van Quang also said “With certified shrimp from the farmers in the area, we oversee the shrimp farming process and protection of the forest. We have a responsibility to protect the forest, and at the same time ensure that the shrimp industry here will develop enough to supply our factory and global market demand”.

The shrimp-mangrove forest area scheme managed by Minh Phu Seafood Corporation has achieved the world’s first "Selva Shrimp" certification. Based in Zurich, Blueyou Consulting has established a strategic partnership with Minh Phu to distribute the Black Tiger prawns raised in the integrated shrimp-mangroves model. Selva Shrimp is the first and only Black Tiger shrimp product to be recommended as the “Best Choice” by the Monterey Bay Aquarium’s Seafood Watch program. So far, Selva shrimp has been mainly sold to foodservice. As the Asia Pacific region has become more concerned with sustainability, hotel chains such as the Marriott, Hilton and Grand Hyatt have declared themselves committed to responsibly-sourced seafood (Under Current News, 2015).

2.2. Pangasius supply chain

Vietnamese production of pangasius for export has developed at an incomparable rate with any other food crops in any other location (Belton et al., 2011). Nowadays, Vietnam is well known as the biggest pangasius supplier with a contribution of 80% (FAO, 2012) or even 90% according to Seafish (2011) of the total world production. Pangasius have been farming mostly within ten provinces in the Mekong Delta River including An Giang, Dong Thap, Tien Giang, Can Tho, Vinh Long, Ben Tre, Hau Gian, Soc Trang, Tra Vinh, Kien Giang. The production of Vietnamese pangasius is approximately estimated at 1.1 million metric tons (mt) in 2015 (Ragnar and Tverates, 2013), a slightly decrease from

its peak of 1.4 mt in 2012. This volume is produced at the considerably most intensity on farming area 5,623 hectares in 2015 (VASEP, 2016). An approximately 300 mt volume in production per hectare is more typical, although a very high yield figure of up to 600 mt per hectare with extremely high stocking densities possible with this species (Seafood Watch, 2014). Rapid growth in production of the farmed Vietnamese whitefish pangasius and massive export to the European Union has provoked criticism of the fish's environmental, social and safety credentials by actors including WWF, Members of the European Parliament and had a negative media coverage (Little et al., 2012).

2.2.1. Input-output structure

Pangasius catfish (*Pangasius hypophthalmus*) have been cultured in the Mekong Delta since 1960s. The fish was originally farmed for local domestic consumption that relied on wild fry, and virtually unknown as a food fish outside Asia. From the late of 1980s, market liberalization in Vietnam together with the development of artificial propagation techniques in the late 1990s resulted in expansion of the production. Initially, the exports of pangasius were focused on the U.S. market, but protectionist trade measures imposed in 2002 led the Vietnamese industry to seek more diversified global markets. Consequently, the exports have grown almost exponentially since that time (Belton et al., 2011) with the export value increasing several times since 2000. In particular, farming area reached 6,000 hectares in 2011 with a value of around USD 2 billion.

According to the Seafood Watch (2014) the industry's development has been characterized by periods of rapid growth and dramatic shifts in production practices from small-scale in the 1990s to net pen culture in the early 2000s. Commercial output of Vietnamese Pangasius catfish increased from 22,500 tons to more than 1 million tons and export values rose from \$19.7 million to \$0.98 billion between 1998 and 2007. The peak of Pangasius production (all of which originated from just nine Mekong Delta provinces) was registered in 2012 with 1.4 million tons produced with an export value of approximately \$1.45 billion. The next years' production slightly declined, representing approximately 920,000 tons in 2014 and 1.1 million tons in 2015 (Ragnar and Tverates, 2013).

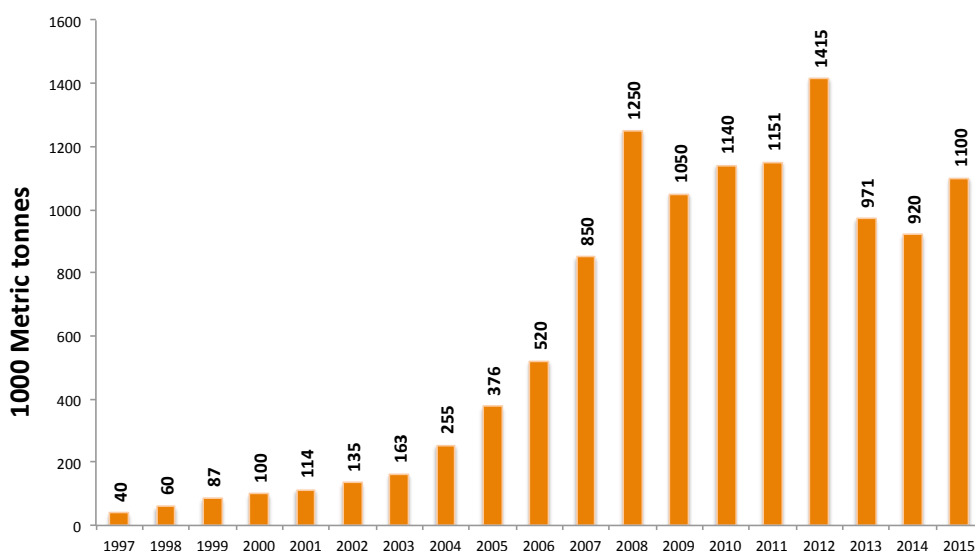


Figure 4.2.1 Vietnamese Pangasius production

Source: Ragnar and Tveretas (2013)

The pre-export segment of the pangasius supply chain is described by four main functions: seed production at hatcheries, fingerling production at nurseries, grow-out of market-sized fish in ponds and processing of raw fish into various products in processing plants. However, the supply chain can be more complex in reality with the participation of thousands operators those who work together to supply pangasius fish to the end-consumer. In general, the key agents in the pangasius supply chain may include inputs suppliers, aquaculture farmers, collectors, processors, wholesalers/retailers/ food services, and consumers as depicted in the following figure.

Farmer directly supply to processors over 90% of the raw pangasius fish. Processors exports about 98% of their production to foreign markets and the remaining 2% is distributed on local market. A share of 10% from total production volume of fish that is marketed through intermediaries is mostly (80%) supplied to wholesalers and retailers. The rest is supplied to processing companies (CBI, 2012). Approximately, one-third of the fish sold in domestic markets is processed, made up of both filleted fish as well as waste material from processing companies (Loc et al., 2010).

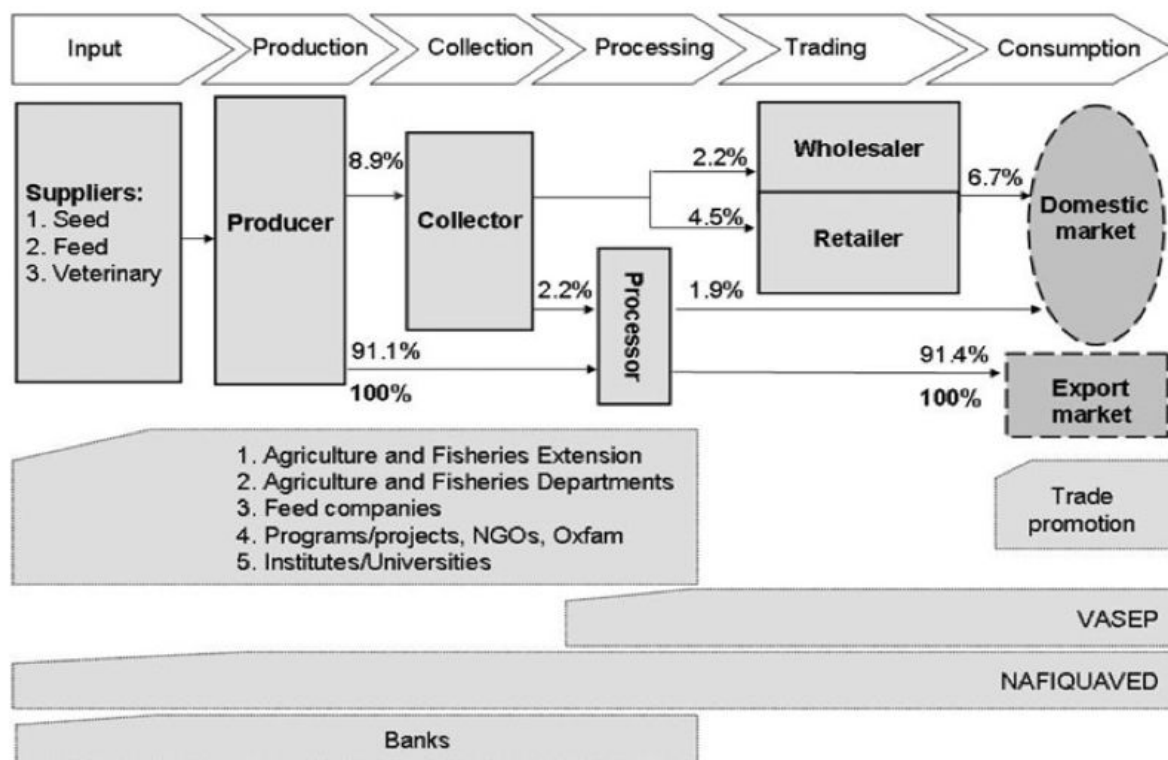


Figure 4.2.2 Vietnamese Pangasius value chain

Source: Adapted from Loc et al. (2010)

In supporting activities, a number of state and private organisations facilitate pangasius production and trade. Ministry of Agriculture and Rural Development (MARD) manages and enforces regulation on the quality of pangasius production; National Agro-Forestry-Fisheries Quality Assurance Department (NAFIQAD) controls the quality and safety of fishery products intended for export through inspections and Vietnam Association of Seafood Exporters and Producers (VASEP) supports businesses in terms of trainings, market access, information sharing, production and legal advice. The local offices of the MARD have organized a series of trainings about standards for farmers (Trifkovic, 2014).

2.2.2. Pangasius supply chain ⁹

With an average of one million mt of pangasius produced annually, the Food and Agriculture Organisation (FAO) has categorized Vietnamese pangasius production as hyper-intensive. Due to intensive and high-density culture, the production figures can be reached of over 200-300 mt per ha per crop; and with around 1.45 crops per year, as much as 400-600 mt per ha per year. Belton et al. (2011) describe pangasius as the most intensive and productive food production system on earth. Intensive aquaculture of pangasius has a highly integrated supply chain, which can be divided into four main categories of operators including input suppliers, farmers, middlemen and processors/exporters.

2.2.2.1. Input suppliers

There are four main inputs being supplied to the pangasius farmers: seed, feed, chemicals and medicines, and equipment. In general, these inputs are sold through two marketing channels: 1) directly from the producers to large-scale farmers or 2) through local distributors who are often middlemen or export companies that also provide working capital and (post) harvest services. The way in which farmers purchase their inputs depends on their financial situation. Farmers with sufficient financial resources buy directly from the producers for a slightly better price while those with a lack of financial resources buy through traders and pay a slightly higher price. Equipment for pangasius farming is mostly sold through local warehouses that sell inputs for the agricultural sector.

Initially, fingerlings were caught in nature and sold to fish farmers. Now, in order to respond to increasing production, hundreds of hatcheries in the Mekong River Delta to produce pangasius fingerlings resulted from successful of the artificial propagation of Vietnamese pangasius since 1995. In a hatchery, fish fingerlings are produced under controlled conditions. Types of hatcheries range from state owned firms, to large and small-scale private businesses (CBI, 2012). Private small-scale hatcheries smaller than 1

⁹ This description is general based on the report of CBI (2012)

hectare are very common. These are often family businesses producing large quantities of fingerlings. The number of large-scale private hatcheries that are well equipped and managed is much smaller than the small-scaled ones. State-owned hatcheries are larger and better equipped than private ones. State owned hatcheries have a large influence on the pangasius sector, e.g., they conduct research on indigenous species, improve aquaculture techniques and maintain the quality of brood-stock. However, the state-owned hatcheries supply only 20% of the fingerlings for the Mekong River Delta (Khoi, 2010). Therefore, especially small-scaled farmers rely on the private hatcheries. The quality of seed produced by small-scaled private hatcheries is often very low. The low quality of seeds is one of the main cause of high mortality rates at pangasius farms.

In the initial development phase of the Vietnamese pangasius industry, grow-out farmers prepared their own feed using a range of locally available ingredients. In 2000 almost 90% of pangasius were still using home-made feeds (CBI, 2012). In 2005, more than 50% of the farmers shifted to commercial feeds and by 2011 it is estimated that even over 90% of the pangasius farmers use commercial feeds. Today, over thirty companies produce pangasius feed in the Mekong Delta, producing around 1.95 million tons in 2012 (Seafish, 2015). Commercial feeds have low fishmeal inclusion (5%-10%) and a high vegetable ingredient content (90%+) (Seafish, 2015).

The use of commercial feeds increases the productivity of pangasius farms, but also makes pangasius farming a more cost intensive business. In November 2011, 1 kg of pangasius feed costs approximately USD 0.55 while a farmer needs 1.6 kg of feed to produce 1 kg of pangasius (FCR = 1.6). The cost of commercial feed accounts for 60-80% of total production costs or approximately USD 0.85 of a total cost of USD 1.15. Large-scale commercial pangasius producers mostly buy the feed directly from the feed companies while small-scale producers often buy feed on a credit basis from local distributors. More than 70% of the pangasius feed production is estimated to be in the hands of foreign companies (CBI, 2012).

Although exact figures are not available, it is known that many farmers use additional medicines to reduce mortality rate of fish. Vitamin C supplements and Vitamin mixes that prevent diseases are the most used supplements; other used medicines are

antibiotics, probiotics. In addition, some chemicals are used to maintain water quality. These inputs are regularly supplied by feed distributors and aquaculture shops in the provinces. Although some of these inputs are legal, it is argued that many farmers also use illegal substances that they can easily buy from local pharmacies and distributors (CBI, 2012).

2.2.2.2. Pangasius farmers

According to MARD, more than 15,000 households raised pangasius in Vietnam in 2004 (Khoi, 2010). The major provinces of pangasius farms are An Giang, Dong Thap and Vinh Long, these provinces counted about 3,900 farms in 2008. In Can Tho, about 1,600 hectares were allocated to farming of pangasius, still the exact number of farmers in region is unknown (CBI, 2012).

During the last few years, the development of the pangasius sector resulted in appearance of more large-scale producers and disappearance of several small-scale producers. Although the number of commercial large-scale pangasius farms is increasing the vast majority of pangasius farms are still smaller than one hectare, especially in provinces that have a long-standing fish farming tradition such as An Giang where more than 70% of pangasius production originates from small-scale producers (CBI, 2012). Provinces that are located more downstream in the Mekong River Delta where pangasius farming only arose when it became clear that it had a great export potential have more large-scale commercial farms. These are often directly owned and managed by export companies.

The productivity of pangasius farms is very high. Depending on the price that exporters pay from the product, farmers harvest their ponds ideally after 6 months when they can harvest fishes of 700 grams that is the preferred size by exporters. If the price is low, farmers can decide to grow their fishes to 1 kg with the hope that prices will improve. If a farmer harvest after 6 months, it is obvious that the farm can harvest approximately 1.8 times per year, representing about 250 tons of fish per harvest of 1 ha pond. In

November 2011, the farm gate price of pangasius was approximately between 25,500 – 27,000 VND or USD 1.2-1.3/kg (CBI, 2012).

It is important to realize that export companies own and operate the most of the large-scale commercial farms and individual households operate most at small-scale level. International markets put a lot of pressure on pangasius farmers to move towards more sustainable production methods. The large-scale commercial farms are therefore quickly moving towards more sustainable production and certification of the pangasius farms. For household farms that lack sufficient investment capital, this process is going slower. However, the Vietnamese government and NGOs are helping farmers to organize themselves and to develop infrastructure through which small-scale farmers can also proceed towards certification (CBI, 2012).

The high productivity, and the relatively low risk of crop failure of pangasius farms result in a more vertically integrated value chain. Only a small share of production is marketed through middlemen or traders. FAO estimated that more than 84% of the small-scale farmers sell their product directly to processing companies while this is the case for 100% of the farms that are larger than 0.5 hectares (CBI, 2012).

2.2.2.3. Middlemen and transporters

The role of middlemen is not very significant in Vietnamese pangasius supply chain. Most of farmers directly sell their product to processors with the help of companies specialized in harvesting and transporting. Most of the time these transporters are directly affiliated with processing companies. The large scale production and high level of vertical integration in pangasius sector have generated high production volumes. Only about 10% of total production is traded through middlemen and of this 10%, approximately 80% is sold as whole fish on the local market, while 20% is sold to processing companies (CBI, 2012).

The transporters mostly use special boats with a huge capacity and facilities to keep the fish alive during transportation from farm to processing factories. However, upstream the Mekong River Delta transporters use trucks, as large boats cannot reach many of the farms. The average capacity of the boat is 20 to 40 tons of pangasius. Skippers try to transport the fish to the processing companies on the same day, because the longer the transport takes, the more weight the fish will lose. The transporters cooperate with a technician from the buying division of the export companies to check the quality of fish and presence of malachite green, chloramphenicol and nitrofurantoin. In some cases, large export companies use their own trucks and boats to collect the pangasius from the farms from which they buy directly. The main difference with the middlemen is that these transporters never buy or sell the product, but get paid per ton of material they transport (CBI, 2012; Khoi, 2010).

2.2.2.4. Processors and exporters

The final process before being transported to the export harbors involves the preparation of fillets by the processing factory. The average capacity of a firm is roughly 40-50 tons of fresh fish per day. All raw materials are inspected upon arrival and approved by the quality inspection team before being allowed into processing areas. After purchasing live pangasius, the fish are washed, beheaded, gutted, filleted, skinned, trimmed, sized and classified, inspected on quality, frozen, and packed for export or the local market. Fish waste from fillet production such as the head, tail, skin and viscera is processed into fishmeal or fish oil (Khoi, 2010). On average, fillets accounted for 30-40% of the weight of a whole fish (the dress out ratio). More specifically, 3.2 kg of live pangasius are required to produce 1 kg of fillet. Frozen fish is the most common product, followed by dried products and fish sauce or paste. In supermarkets in the EU, pangasius is also sold as fresh fillets. These products, however, are not imported as fresh fish but refer to frozen fillets that are refreshed and sold as fresh pangasius fillets. Moreover, high-value added products such as ready to cook or surimi are also produced by various processors (CBI, 2012).

In Vietnam, more than 140 processing establishments for fish are certified for exports. In 2010, there were 291 pangasius exporters. About two-thirds of these exporters can be considered small exporters with an export volume of less than 1,000 tons in 2010. The one-third of large exporters has a share of almost 75% of the total export volume. The vast majority of these processing establishments are located in the provinces in Mekong River Delta (CBI, 2012).

The Table 4.2.2 below shows the number of pangasius exporters according to export value and volume based on the most recent VASEP data. It is obvious that there are a couple of extremely large export companies, but in the most part there are companies that export between 1,000 and 5,000 tons per year equal to USD 2-12 million. Therefore, it can be expected that especially the medium, large, and very large companies have their own farms and are most like to engage soon in sustainable certified pangasius exports.

Table 4.2.2 Number of pangasius processors per province

Province	Processing unit	Export volume (1000 tonnes)	Value (\$ million)
An Giang	15	159	342
Dong Thap	12	115	277
Can Tho	22	166	350
Tien Giang	13	97	202
Hau Giang	1	6	14
Ben Tre	3	14	32
Vinh Long	2	11	19
Ho Chi Minh	19	37	78
Tra Vinh	2	6	16
Kien Giang	1	3	6
Vung Tau	1	1	2
Da Nang	2	3	4
Others	>47	42	87
Total	>140	660	1,429

Source: CBI (2012)

The total export volume of pangasius amounts to 659,400 tons representing a value of almost USD 1.5 billion. Most of the medium and large size exporters have their own farms, therefore are able to ensure a minimal supply volume to keep their factories running. Many of the large companies also engage in contract farming agreements with farmers cooperatives in order to supplement their integrated production. The remaining capacity of their factories is only used if the market situation allows it and the required supply is sourced through spot market relationships with farmers.

2.2.3. Markets

Likely production, the export of pangasius also increased significantly during 2000-2010 years. In 2000, the volume of the export was 700 tons, while ten years later this volume has increased to 660,000 tons with a value of USD 1.4bn (CBI, 2012). The EU and US are considered the most important destination markets for pangasius. In 2012, 24.4% of Vietnamese pangasius volume was exported to the EU and 20.8 % was exported to the US. The remaining 50% is exported to countries in Asia, Mexico, Brazil, China and other (SFP, 2015), the structure of export per countries is shown in the figure below.

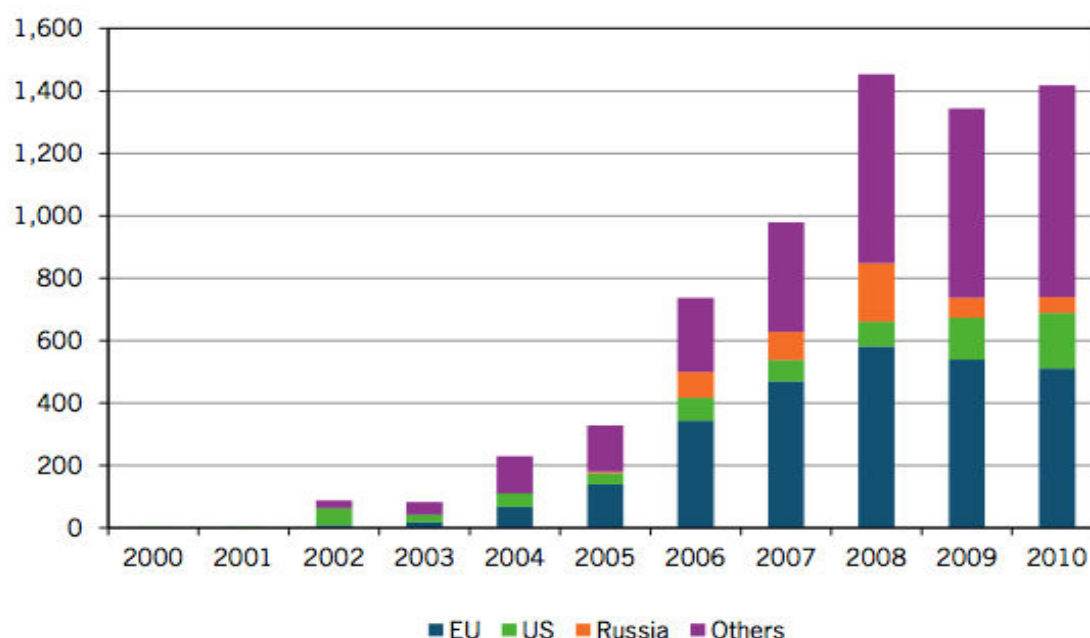


Figure 4.2.3 Export value of pangasius in 2000 - 2010 (million USD)

Source: CBI (2012)

Europe is the largest seafood market and importer in the world with a share of 20% - 25% of the global seafood market. Pangasius is one of the most important fish products imported by the EU markets. Although a few more countries produce pangasius nowadays, more than 99% of frozen pangasius imported into Europe comes from Vietnam (CBI, 2015). Until the year of 2012, Europe was a booming market for Vietnamese Pangasius, with imports growing every year. However, the largest markets for pangasius in Europe, i.e. Spain, the Netherlands and Germany, all saw their import value go down during 2012 – 2014. The import value of frozen pangasius fillets into Europe decreased from 342 million euros in 2012 to 275 million in 2014 (CBI, 2015).

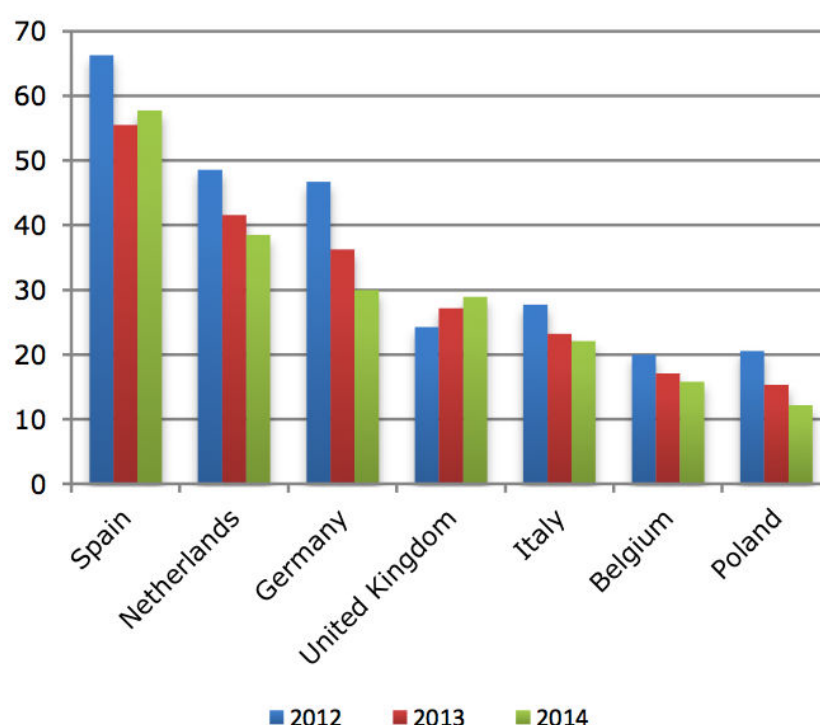


Figure 4.2.4 EU imports of frozen pangasius fillets in 2012-2014 (million Euro)

Source: CBI (2015)

Although the value of pangasius imports is decreasing, the demand still remains strong because pangasius remains positioned as a low-value white fish across Europe. The Netherlands leads in terms of pangasius consumption per capita. In fact, the pangasius export value to Europe has decreased since 2008. This might be the result of the strong

competitiveness in the European whitefish market during the past few years that has put downward pressure on the export prices of pangasius. Particularly, the two most important reasons for the general decline are the competition with other white fish species, most importantly Alaska Pollack and cod in some markets; and the negative perception of the product among certain buyers and consumers (CBI, 2015).

2.3. Tuna supply chain: traceability and transaction

With approximately 2,000 vessels, an estimated 14,000 metric tons of annual catch, and a total export value of nearly \$US 370 million, Vietnam's yellowfin tuna fisheries is an important player in the raising global demand of tuna (WWF, 2016). The tuna suppliers are mostly located in Binh Dinh, Phu Yen and Khanh Hoa provinces. Yet, the sector faces challenges, as there is a weak harvest strategy, inadequate data on marine ecosystem impacts, and insufficient management applied to reduce bycatch such as sharks and turtles (Seafood Sustainability, 2016).

The World Wildlife Fund and a number of partners have been working together to help build a steadily improving fishery of Vietnam Yellowfin Tuna by launching the Vietnam Yellowfin Tuna Fisheries Improvement Project (FIP). The FIP efforts address governance, fishing practice, and environmental impacts of the fishery so that they can ultimately achieve Marine Stewardship Council (MSC) certification. The core objective of FIP is prototyping the application of Fit as FIP traceability in order to ensure that Vietnam Yellowfin tuna is differentiated in the marketplace. Particularly, Fit as FIP traceability system ensures differentiation of yellowfin tuna harvested by Vietnamese hand-line or long-line vessels from those products derived from "re-exported" raw materials (WWF, 2016).

Yellowfin tuna is mainly harvested in the offshore zone of provinces Binh Dinh, Phu Yen, and Khanh Hoa in the South China Sea. Long-line and hand-line are traditional methods for fishing tuna. A typically fishing trip usually lasts about 20-30 days with 8-10 employees on a vessel. After landing, the fish are sold to the middlemen (about 50%) or

directly to processing companies (50%). Quantity and quality of fish is often determined at the harbor, and then fish is transported to the processing plant. As the last step in the supply chain, yellowfin tuna entirely is exported to the international market. In fact, the harvested production of Vietnamese yellowfin tuna does not fulfill the demand of processing companies.

Regarding the traceability, the boats are required to record fishing trip as fishing days, fishing areas, quantity and fish species harvested in their logbooks. In addition, fishers are demanded to provide the boat registration number, fishing license and other safety certifications. In fact, both the seller and the buyer just care about quantity and quality of fish. Fishermen do often not share information related to fishing ground excluding fishers in the group.

A fisher usually contacts the buyer by notifying the time for unloading fish and estimated production before landing. Price is determined at the time of unloading. Purchasing transaction is often based on (1) long-term established business relationship and (2) financial ties between parties. At the port, fish are unloaded from vessel and transported to purchasing camp where buyer cleans the fish and grade its quality. Both buyer and seller then record the quantity and quality of traded fish. These data are documented in the manual of each party. Lastly, the fish is put on refrigerator truck for transportation to processing plants.

3. Conclusion to the chapter

The chapter has introduced the choice of deductive approach with quantitative methods as a suitable research methodology for this study. Three questionnaires have been developed as a data collection instrument. In addition, the study incorporates desk research method, focus group discussion with experts and face-to-face interviews with practitioners during the field trips. Participants in the study were enterprises from the Vietnamese seafood products supply chain - one of the leading seafood exporters in the

world. Fuzzy logic operations have been applied to measure the performance of corporate biodiversity management. Transaction cost analysis is employed to evaluate the variation of transaction governance structure. The empirical study section presents characteristics of supply chain for some key seafood products such as pangasius, shrimp and tuna. Also, the chapter considers biodiversity conservation and traceability issues in the seafood supply chain. The next chapter – results and discussions – presents in detail the findings from the empirical research.

CHAPTER 5

RESULTS AND DISCUSSIONS

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This chapter presents results from the empirical studies that have been conducted based on methods described in the previous chapter. Data obtained throughout the surveys are analyzed and interpreted. The survey of specialists' opinion confirms the key performance indicators in the measurement model. The first wave of company survey provides cases to illustrate how the measurement model works. The impact of the implementation of traceability on transaction governance structure is empirically examined by data from the second wave of company survey. Findings of the study are discussed afterward.

1. Measuring the performance of biodiversity management

The model for measuring the biodiversity management performance consists of two components. The first component is identification of Key Performance Indicators to be used in the assessment process. The second component describes how the model operates at a step-by-step procedure. The KPIs are validated through a specialist opinion survey. The questionnaire is used to gather empirical data during the company survey. The data is cleaned and processed applying procedures of assessment model. The next sections present the results from the specialist survey; general characteristics of enterprises in the sample and performance of corporate biodiversity management in the Vietnamese seafood supply chain.

1.1. Key Performance Indicators

A master list of potential indicators is submitted to academic experts and industry practitioners for discussion and validation. The specialists assessed the relevance of each indicator in measuring corporate biodiversity management. The results of the survey based on the responses provided by seven specialists are presented in the following table.

Table 5.1.1 Relevant of performance indicators

Indicators/Sub-indicators	Relevant	
	Yes	No
Company assesses interactions between its activities and biodiversity	7	0
Company evaluates its impacts on biodiversity	7	0
Company evaluates its dependence on biodiversity	7	0
Company assesses risks associated with biodiversity	7	0
Company assesses opportunities associated with biodiversity	6	1
Company states biodiversity management policy in its activities	7	0
Company integrates biodiversity consideration into its strategies	7	0
Biodiversity management plays a role in its environmental management system	6	1
Company develops policy/ project/ action plan for biodiversity conservation	5	2
Company commits to biodiversity conservation	7	0
Company's senior management commits to biodiversity conservation	6	1
Company allocates resources to ensure biodiversity management implementation	6	1
Company guarantees the fair and equitable sharing of benefits from the genetic used resources	7	0
Company commits to voluntary compensate its impact on biodiversity	4	3
Company implements biodiversity management in the practices of operations	7	0
Biodiversity issues are managed at site-level, being included in the design of company's facilities: offices, production site, storage, showroom, etc.	5	2
Company ensures sustainable sourcing of raw materials	6	1
Suppliers are engaged in the company's biodiversity policy	5	2
Product design aims to reduce consumption of natural resources and carbon footprint	7	0
Manufacturing processes aim to reduce emissions, water and energy consumption	6	1
Staff undergoes trainings and participates in saving energy, water, etc.	5	2
Company makes public the report about biodiversity management	7	0
Company develops collaborations with external stakeholders including the local community in biodiversity conservation	6	1
Company analyzes feedback on biodiversity received from customers, stakeholders, suppliers, etc.	6	1
Company publications for stakeholders, including shareholders, customers, suppliers, NGOs improve in terms of biodiversity management, public reporting	6	1

Although there are a few diverging opinions, almost all specialists confirmed the relevance of the listed indicators in measuring corporate biodiversity management performance. The specialists are also encouraged to consider the indicators and/or sub-indicators that they believe to be relevant in assessing the performance of biodiversity management. Some experts propose biodiversity indicators to be integrated in the decision process at strategic/political level, such as: the share of biodiversity in the calculation of value creation (not just from an economic valuation point of view) and amount earmarked for biodiversity-related R&D. Finally, five Key Performance Indicators were constructed, i.e. Biodiversity Business Assessment, Biodiversity Management Policy; Biodiversity Conservation Commitment, Biodiversity Stewardship Practices, and Biodiversity Performance Reporting that complement a total of twenty sub-indicators.

1.2. Empirical data

In the next step, the validated indicators are included in the questionnaire used in the company survey. Five seafood businesses (Minh Phu Seafood, NTSF Seafood, Nha Trang Seafood – F17, Hai Vuong Group, Cafico Vietnam) are involved in the project. General characteristics of these firms are described in the subsequent sections.

1.2.1. Minh Phu Seafood Corporation

Minh Phu Seafood Corporation is a private enterprise established in 1992. After 20 years of experience, Minh Phu has become the leading seafood corporation in Vietnam, and one of the largest seafood exporters in the world. In 2006, the company has developed a full process circle from producing shrimp feed to biological products, commercial shrimps and processing for export. This is the remarkable step in strictly competitive and stern requirements of markets. With its quality policy *“Good and sustainable quality – Friendly environment – Responsibility to community”*, the company commits to supply good quality and safe products to consumers; ensure customer’s standards and other requirements of product safety to local and international markets.

The company's main target is production of disease-free and clean baby shrimp, expansion of areas for raising commercial shrimp, production of biological products for the aquaculture industry, production and processing of shrimp for export. The company also focuses on continuously expansion of areas for disease-free and industrial shrimp association with forestry and fishery farms to raise shrimp on large scale and providing raw materials of clean shrimp to processing factories. Minh Phu commits to develop and support a responsible value chain of shrimp, where each member in the production chain: from broodstock, post-larvae, feed, processing and export, import and logistics, distribution and retail, understands his/her responsibility in creating greater value. The company's certifications such as BAP, ASC, Global GAP, Naturland, Bio Suisse, EU BIO for the value chain brings competitive advantage and opportunity to assess markets.

With respect to the sustainable development practices, Minh Phu is aware of the business responsibility on the environment, society and employees. The company is also aware of the responsibility to offer qualitative and safe food products to consumers. That is why the company develops the responsible value chain for shrimp product lines, for instance, mangrove – shrimp responsible value chain; rice – shrimp responsible value chain.

All the farms comply with the provisions and requirements for assessing the environmental impact at the beginning of project. Shrimp are cultivated under the application of biotechnology measures that minimizes the use of chemicals. In addition, the application of advanced farming technology minimizes water changes and treatment. About 40% of the farming area uses water treatment systems. Shrimp farming is sustainable and environment friendly.

The company aims to use less natural resources and to reduce pollution. Thus, Minh Phu has improved the manufacturing process that enhanced productivity and created better working conditions for employees. The company's factories are equipped with modern technological lines with low energy consumption. Consequently, it succeeded to reduce water consumption by 60-70%.

The processing plant is equipped with sewage treatment systems based on UASB and MBBR technologies to recover biogas. The recovery and reuse of biogas contributes to fuel saving, reduction of the greenhouse emissions as CH₄, CO₂. Lamps in the fish processing plants are equipped with LEDs instead of neon lights. With LED lights, the company has cut its power consumption costs by approximately 65%. In addition, usage of LED lamps reduces harm to the environment. Besides that, Minh Phu also uses lightweight packaging, which can be recycled or can self-destruct and therefore protect the environment.

The environmental protection policy of the company mainly focuses on:

- Commitment to develop and carry out solutions for protection of environment; usage of biological products during feeding commercial shrimp period, exclusion from the production processes of chemical and anti-biotic products, which may cause damage to ecological system.
- Treatment of wastewater before disposing it off, simultaneously, collecting and reusing exhausted gas after treatment.

Community and social responsibilities of the company are mainly represented by:

- Caring about the spiritual and physical livings of its workers and ensuring compliance with government's and export markets' policies and regulations.
- Creation of long-term solidarity with all members of the corporation.
- Supporting regional and local community, creating and developing environment friendly concept within the corporation and surrounding households.

More detail about company, please visit the site: <http://www.minhphu.com/trang-chu>

1.2.2. NTSF Seafoods Joint Stock Company

NTSF Seafoods joint Stock Company was established in 2006 and officially gained EU approval DL 461 in 2008. NTSF SEAFOODS inherits good experience, technology from other companies in the industry, as a result becoming one of the prestigious companies in Vietnam, with a large range of fields: catching, cultivating, processing aquatic

products, dealing in machinery and materials. Taking actions in order to ensure quality and safe products for its customers, the company succeeded to meet international standards such as HACCP, BRC, IFS, ISO 22000, ISO 14000, ACC. General characteristics of the company are:

- Aqua-product export turnover: Over USD 30 million/year
- Production: Over 10,000 MTS of final products/year
- Production lines: 2 lines
- Freezing capacity: 100 MTS/day
- IQF machines: 14 machines + 9 refreezing machines
- Cold storage: 10,000 MTS
- Workers: over 2,000 workers

Product quality is the decisive element that decides all the activities of NTSF SEAFOODS. Company guarantees to follow strictly all regulations of BRC, IFS and constantly improves Quality Management System; especially takes a better care of preventive actions, than providing a solution for happenings. As well, the company provides appropriate working conditions for its employees and commits to continuously improve them. The company also guarantees to strictly implement all Vietnam's environmental regulations and apply all Food Safety Regulation of Vietnam, import market and customers, and to supply safe foods for consumption. The company is responsible for making customers satisfied with a better level of quality, quantity, price and time of delivery as well as increase effect of production and trading of company. Quality is specific targeted as:

- Gaining IFS certification
- Loading for shipment 100% is in accordance with contracts conditions
- No claims received from customer
- Inspection of Safe Production Condition and Quality Management System conducted by NAFIQAVED: A level and Customer's auditors are always meeting requirements, no serious issues.
- Implementing strictly Vietnam's environmental regulation
- Providing fully working conditions to the employees

Further info, please visit the site: <http://www.ntsfafoods.com.vn/index.php>

1.2.3. Hai Vuong Group

Hai Vuong Group is currently Vietnam's largest processor and exporter of tuna and pelagic fish products. The Group's main activities include processing, trading, marketing, and exporting of tuna and pelagic products. The group's products are exported to more than 50 countries and territories worldwide, registering annual sales of around US dollar 150 million. In terms of capacity, the group can process nearly 40,000MT of seafood, including almost 30,000MT of tuna and pelagic fish a year. Hai Vuong Group has a total staff of around 3,000 loyal and dedicated people, including 2,500 factory workers.

The group imports almost 90% of the raw materials from various sources globally, from both long line vessels and purse seine vessels in Taiwan, Korea, Japan, Fiji, Spain, etc. The group makes sure all raw materials purchases are made from reliable sources, taking into consideration the need for processing raw material in a safe manner. These materials are then treated and processed through to finished products with high added value. The management commits to supply frozen fish products of highest quality to all international customers. This commitment is accomplished by using raw materials directly frozen on fishing vessels equipped with deep-freezing facilities, thus eliminating any possible decomposition.

Hai Vuong Group possesses state-of-the-art manufacturing facilities to ensure good quality of the products and meet customers' expectations. The Group includes three processing factories named Hai Vuong, Dragon Waves, Nha Trang Bay and an aquaculture farm. With more than 17 years of experience in the tuna/seafood industry, Hai Vuong Group has successfully built good reputation in both international and local business areas. To that aim, the group has established and implemented various food safety management systems including HACCP, BRC, IFS, USDC, HALAL, GLOBAL G.A.P.... for each of the factories. Below are the key milestones:

- "Certificate of compliance with food safety regulation on fisheries business operation" for HaiVuong, Dragonwaves, Nha Trang Bay, annually audited and renewed.

- "HACCP Certificate" for Hai Vuong (1997), Dragonwaves (2004).
- EU Code: Hai Vuong (DL318), Dragonwaves (DL314), Nha Trang Bay (DL 620).
- "BRC Certificate" for Dragonwaves (from 2006), renewed annually.
- "ISO 17025:2005" for Dragonwaves Laboratory (from 2008), renewed annually.
- "Dolphin safe" accredited by Earth Island Institute for Dragonwaves (2008), renewed annually.
- "USDC Certificate" for HaiVuong, Dragonwaves (from 2010), renewed annually.
- "IFS Certificate" for Nha Trang Bay.
- "Halal Certificate" for Dragonwaves (2014).
- "Global G.A.P Certificate" for Hoa Son Tilapia Farm - Dragonwaves (2014).

More detail about company, please visit the site: <http://www.haivuong.com>

1.2.4. Nha Trang Seafood Company

The Nha Trang Seafood - F17 Company is located in the Nha Trang city with three factories granted code for exports to markets such as the US, EU, Japan, Australia, South Korea, Canada (DL17, DL 90 and DL 394). The company's main activities comprise fishing, aquaculture, processing of aquatic food products. The export products include shrimps, fish, squid, crab, frozen, and dried seafood. The production capacity demands about 12000 tons of raw materials per year. The number of employees is around 1700 people. Annual export sales of the company reached US dollars 50 million.

Delivering qualitative products is the main company's mission, in which respect, the company strictly complies with Vietnam's regulations on food safety and applies quality management systems recognized worldwide. The quality management system is certified:

- The system of hazard analysis and critical control points - HACCP
- British Retail Consortium - BRC Global Standard
- International standards ISO 9001-2000
- International Food Standard - IFS
- Aquaculture Certification Council - ACC

In order to achieve its objectives of a sustainable development, the company has adopted domestic and international standards in production and business activities. Currently the company is implementing the standard ASC (Aquaculture Stewardship Council) for shrimp farms. Specifically, shrimp farms meet the requirements such as:

- Shrimp farms are located in the area of local planning
- Farms comply with environmental law and do not affect the surrounding environment.
- Farms are not in the national and international protected areas and do not damage the wild animals in the Red Book.

In addition, the company uses contracted suppliers for shrimp material. Accordingly, the company supports the farmers in terms of technical monitoring during shrimp farming. The company commits to purchase the entire shrimp material that met quality and safety requirements. Price is determined at the time of harvest. Farmers commit to supply all of raw shrimp to the company. Absolutely, farmers are not allowed to use banned chemical or antibiotics in the breeding operation. In addition, farmers must make a full record of information related to the pond as: pond area, stocking density, the amount of feed, chemical used during the feeding process.

More detail about company, please visit the site: <http://nhatrangseafoods.vn>

1.2.5. Cafico Vietnam Corporation

The business activities of Cafico Vietnam focus on producing and trading marine products. Main export products include squid, cuttlefish, octopus, shrimp (black tiger, vannamei) that are oriented to major markets such as Japan, Taiwan, Hong Kong, South Korea, and China. Sushi and sashimi products are well appreciated in the Japanese market. Qualitative and safe food is always the top concern of the company. The statement “Each worker is a quality controller, taking responsibility for the product made by him/herself” is the philosophy that represents the basic factor to maintain the trader’s name reputation and product quality.

HACCP program (Hazard Analysis and Critic Control Point) has been applied to the production in order to ensure the best quality for products. HACCP program includes Sanitation Standard Operating Procedures (SSOP) and Good Manufacturing Practice Regulations (GMP), which help producers reject hazards out of their products. The company has its own laboratory for regular bacterial inspection that supports the product quality management at the factory. HACCP and QC provisions represent the core forces of the company, which enable it to control product quality, production regulations, and specifications and check bacterial conditions during production. Each year, the company organizes training courses to upgrade worker's skill, to educate workers to obey discipline in processing steps, production and sanitation regulations.

Environmental risk assessment is an important activity and frequently considered subject within the company. The company may face environmental risks associated with water, soil and ecosystems and biodiversity loss. The regulations on environmental protection are strictly followed. Environmental annual report presents the quantity of materials used in production, the amount of packaging and discarded materials. In addition, the company reports on power consumption for the year and electricity savings. The power-saving initiatives are always encouraged. The company also announces the indicators related to usage of water such as total water consumption, wastewater, and reused sewage rate.

Emissions from the company's operations include solid waste, wastewater and NH₃ gas. For the solid and hazardous wastes, the company signs the destruction contracts with specialized agencies for environmental remediation. The wastewater is drained into the treatment system before being discharged into the natural environment. NH₃ gas emissions are measured by specialized agencies, identified and assessed satisfactory.

More detail about company, please visit the site: <http://www.cafico.vn/vn/default.aspx>

1.3. Performance of corporate biodiversity management

The measuring procedure starts by submitting a list of indicators to each corporate evaluator. The evaluators are required to express their opinion on the importance of each indicator and to rate the firm in terms of performance towards the indicators. Their choices then become inputs for the measuring model. The above-described corporate participants are anonymity guaranteed through a coding system. Accordingly, the five seafood companies are referred as Firm_1, Firm_2, Firm_3, Firm_4, and Firm_5, in a sequence that does not match the above order of description.

Table 5.1.2 Evaluator's ratings for the importance of indicators and sub-indicators

Indicators	Sub-indicators	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5
Biodiversity	Business Assessment	M	H	VH	L	H
	Impact evaluation	L	H	VH	L	H
	Dependence evaluation	L	H	VH	L	L
	Risk assessment	L	H	VH	M	M
	Opportunity perception	M	H	VH	L	M
Biodiversity	Management Policy	H	H	H	VL	M
	Integrating into strategy	L	VH	H	VL	M
	Part of EMS	M	VH	H	VL	M
	Biodiversity action plans	M	H	H	VL	M
Biodiversity	Conservation Commitment	VH	M	H	VL	M
	Commitment from senior management	VH	H	H	VL	M
	Allocation of resources	H	M	H	VL	L
	Sharing benefits	M	H	H	VL	L
	Voluntary compensation of the impacts	M	H	M	VL	H
Biodiversity	Stewardship Practices	M	VH	H	L	H
	Site-level impact management	M	VH	H	VL	L
	Green purchasing	H	VH	H	VL	H
	Supplier engagement	M	H	H	H	H
	Product design	H	VH	H	M	H
	Emissions, water, energy reduction	H	VH	H	VL	H
	Employee training and participation	H	VH	H	VL	H
Biodiversity	Performance Reporting	L	H	M	L	H
	Collaboration with stakeholders	M	H	M	L	H
	Feedback analysis	L	VH	M	L	H
	Public reporting	M	H	M	VL	H

The elicitation process for importance ratings is completed as shown in *Table 5.1.2*. For instance, the evaluators at Firm_2 and Firm_5 consider that the importance of indicator “*Biodiversity Business Assessment*” is “High” while the opinion of the evaluators at Firm_1, Firm_3, and Firm_4 for this indicator are “Moderate”, “Very High” and “Low”, respectively.

The importance weightings in linguistic terms are be converted into fuzzy numbers. For instance, the importance of the “*Biodiversity Business Assessment*” indicator to the evaluator at the Firm_1 is “Moderate”, and then the corresponding fuzzy number is (0.4, 0.6, 0.8) according to the linguistic scales of *Table 3.1.1*. The importance of the “Impact evaluation” sub-indicator to the evaluator at the Firm_1 is “Low”, and then the corresponding fuzzy number is (0.2, 0.4, 0.6).

Then the fuzzy importance weight for each indicator is calculated. The fuzzy importance weights at the end nodes of each branch are determined by tracing down all the nodes on that branch (see *Figure 3.1.5*). Let’s take an illustration from the Firm_1, the importance of the end node of the first branch “*Impact evaluation*”, denoted w_{11} , is computed by multiplying the importance rating of “*Biodiversity Business Assessment (M)*” by the importance rating of “*Impact evaluation (L)*”. Thus according to Firm_1, the fuzzy importance weight of criterion “*Impact evaluation*” is:

$$w_{11} = (M) \times (L) \sim (0.4, 0.6, 0.8) \times (0.2, 0.4, 0.6) = (0.08, 0.24, 0.48)$$

The importance weights of the other indicators presented in *Table 5.1.3* are calculated in the same manner.

Table 5.1.3 Fuzzification and calculating importance weights for indicators

Indicators	Sub-indicators	ID	Firm_1	Fuzzification	Importance weight
Biodiversity	Business Assessment		M	(0.4, 0.6, 0.8)	
	Impact evaluation	C1	L	(0.2, 0.4, 0.6)	(0.08, 0.24, 0.48)
	Dependence evaluation	C2	L	(0.2, 0.4, 0.6)	(0.08, 0.24, 0.48)
	Risk assessment	C3	L	(0.2, 0.4, 0.6)	(0.08, 0.24, 0.48)
	Opportunity perception	C4	M	(0.4, 0.6, 0.8)	(0.16, 0.36, 0.64)
Biodiversity	Management Policy		H	(0.6, 0.8, 1.0)	
	Integrating into strategy	C5	L	(0.2, 0.4, 0.6)	(0.12, 0.32, 0.6)
	Part of EMS	C6	M	(0.4, 0.6, 0.8)	(0.24, 0.48, 0.8)
	Biodiversity action plans	C7	M	(0.4, 0.6, 0.8)	(0.24, 0.48, 0.8)
Biodiversity	Conservation Commitment		VH	(0.8, 1.0, 1.0)	
	Senior commitment	C8	VH	(0.8, 1.0, 1.0)	(0.64, 1.0, 1.0)
	Allocation of resources	C9	H	(0.6, 0.8, 1.0)	(0.48, 0.8, 1.0)
	Sharing benefits	C10	M	(0.4, 0.6, 0.8)	(0.32, 0.6, 0.8)
	Voluntary compensation	C11	M	(0.4, 0.6, 0.8)	(0.32, 0.6, 0.8)
Biodiversity	Stewardship Practices		M	(0.4, 0.6, 0.8)	
	Site-level impact management	C12	M	(0.4, 0.6, 0.8)	(0.16, 0.36, 0.64)
	Green purchasing	C13	H	(0.6, 0.8, 1.0)	(0.24, 0.48, 0.8)
	Supplier engagement	C14	M	(0.4, 0.6, 0.8)	(0.16, 0.36, 0.64)
	Product design	C15	H	(0.6, 0.8, 1.0)	(0.24, 0.48, 0.8)
	Emission, water, energy reduction	C16	H	(0.6, 0.8, 1.0)	(0.24, 0.48, 0.8)
	Staff training and participation	C17	H	(0.6, 0.8, 1.0)	(0.24, 0.48, 0.8)
Biodiversity	Performance Reporting		L	(0.2, 0.4, 0.6)	
	Collaboration with stakeholder	C18	M	(0.4, 0.6, 0.8)	(0.08, 0.24, 0.48)
	Feedback analysis	C19	L	(0.2, 0.4, 0.6)	(0.04, 0.16, 0.36)
	Public reporting	C20	M	(0.4, 0.6, 0.8)	(0.08, 0.24, 0.48)

Likewise, the importance weightings are converted from linguistic terms into fuzzy numbers and calculate the fuzzy importance weights of each indicator for the remaining firms. The results are presented from the second column to the fifth column in the *Table 5.1.4* under header “Fuzzy importance weights according to firms’ perception”.

Table 5.1.4 Aggregate fuzzy indicators weights

Id.	Fuzzy importance weights according to firm's perception - $\tilde{w}_{jk}$					Aggregated fuzzy importance weights $\tilde{w}_j$
	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	
C1	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.64, 1.0, 1.0)	(0.04, 0.16, 0.36)	(0.36, 0.64, 1.0)	(0.04, 0.536, 1.0)
C2	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.64, 1.0, 1.0)	(0.04, 0.16, 0.36)	(0.12, 0.32, 0.6)	(0.04, 0.472, 1.0)
C3	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.64, 1.0, 1.0)	(0.08, 0.24, 0.48)	(0.24, 0.48, 0.8)	(0.08, 0.52, 1.0)
C4	(0.16, 0.36, 0.64)	(0.36, 0.64, 1.0)	(0.64, 1.0, 1.0)	(0.04, 0.16, 0.36)	(0.24, 0.48, 0.8)	(0.04, 0.528, 1.0)
C5	(0.12, 0.32, 0.6)	(0.48, 0.8, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.16, 0.36, 0.64)	(0.0, 0.432, 1.0)
C6	(0.24, 0.48, 0.8)	(0.48, 0.8, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.16, 0.36, 0.64)	(0.0, 0.464, 1.0)
C7	(0.24, 0.48, 0.8)	(0.36, 0.64, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.16, 0.36, 0.64)	(0.0, 0.432, 1.0)
C8	(0.64, 1.0, 1.0)	(0.24, 0.48, 0.8)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.16, 0.36, 0.64)	(0.0, 0.504, 1.0)
C9	(0.48, 0.8, 1.0)	(0.16, 0.36, 0.64)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.08, 0.24, 0.48)	(0.0, 0.416, 1.0)
C10	(0.32, 0.6, 0.8)	(0.24, 0.48, 0.8)	(0.36, 0.64, 1.0)	(0.0, 0.04, 0.16)	(0.08, 0.24, 0.48)	(0.0, 0.4, 1.0)
C11	(0.32, 0.6, 0.8)	(0.24, 0.48, 0.8)	(0.24, 0.48, 0.8)	(0.0, 0.04, 0.16)	(0.24, 0.48, 0.8)	(0.0, 0.416, 0.8)
C12	(0.16, 0.36, 0.64)	(0.64, 1.0, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.08, 0.24)	(0.12, 0.32, 0.6)	(0.0, 0.48, 1.0)
C13	(0.24, 0.48, 0.8)	(0.64, 1.0, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.08, 0.24)	(0.36, 0.64, 1.0)	(0.0, 0.568, 1.0)
C14	(0.16, 0.36, 0.64)	(0.48, 0.8, 1.0)	(0.36, 0.64, 1.0)	(0.12, 0.32, 0.6)	(0.36, 0.64, 1.0)	(0.12, 0.552, 1.0)
C15	(0.24, 0.48, 0.8)	(0.64, 1.0, 1.0)	(0.36, 0.64, 1.0)	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.08, 0.6, 1.0)
C16	(0.24, 0.48, 0.8)	(0.64, 1.0, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.08, 0.24)	(0.36, 0.64, 1.0)	(0.0, 0.568, 1.0)
C17	(0.24, 0.48, 0.8)	(0.64, 1.0, 1.0)	(0.36, 0.64, 1.0)	(0.0, 0.08, 0.24)	(0.36, 0.64, 1.0)	(0.0, 0.568, 1.0)
C18	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.16, 0.36, 0.64)	(0.04, 0.16, 0.36)	(0.36, 0.64, 1.0)	(0.04, 0.408, 1.0)
C19	(0.04, 0.16, 0.36)	(0.48, 0.8, 1.0)	(0.16, 0.36, 0.64)	(0.04, 0.16, 0.36)	(0.36, 0.64, 1.0)	(0.04, 0.424, 1.0)
C20	(0.08, 0.24, 0.48)	(0.36, 0.64, 1.0)	(0.16, 0.36, 0.64)	(0.0, 0.08, 0.24)	(0.36, 0.64, 1.0)	(0.0, 0.392, 1.0)

In the next step, the aggregated fuzzy importance weight of each indicator ($\tilde{w}_j$) is computed using equations in the *step 4*. For example, the aggregate fuzzy importance weight of the “*Impact evaluation*” indicator is given by $\tilde{w}_1 = (w_{1l}, w_{1m}, w_{1u})$, where:

$$w_{1l} = \text{Min} (0.08, 0.36, 0.64, 0.04, 0.36) = 0.04$$

$$w_{1m} = 1/5*(0.24 + 0.64 + 1.0 + 0.16 + 0.64) = 0.536$$

$$w_{1u} = \text{Max} (0.48, 1.0, 1.0, 0.36, 1.0) = 1.0$$

Thus, $\tilde{w}_1 = (0.04, 0.536, 1.0)$

Likewise, $\tilde{w}_2 = (0.04, 0.472, 1.0)$

Similarly, we compute the aggregate fuzzy importance weights for the remaining indicators. The aggregated weights of all twenty indicators are illustrated in *Table 5.1.4*.

Now, the performance ratings are converted from linguistic terms into fuzzy numbers. For example, if the evaluator at Firm_1 believe that the performance of his/her firm with respect to indicator “*Public reporting*”, denoted C20, is “Excellent” then the corresponding fuzzy number is (7, 9, 9) according to the scale of *Table 3.1.2*.

Table 5.1.5 Fuzzification for performance ratings

Id.	Performance in linguistic terms					Performance in fuzzy number - $\tilde{r}_{ij}$				
	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5
C1	G	EX	G	P	VG	(3, 5, 7)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)
C2	G	EX	G	VG	VG	(3, 5, 7)	(7, 9, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)
C3	VG	VG	G	VG	G	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)
C4	VG	G	G	F	G	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)
C5	P	VG	G	F	F	(1, 2, 3)	(5, 7, 9)	(3, 5, 7)	(1, 3, 5)	(1, 3, 5)
C6	G	VG	P	G	G	(3, 5, 7)	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)	(3, 5, 7)
C7	VG	P	G	P	P	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)	(1, 1, 3)	(1, 1, 3)
C8	EX	VG	G	P	F	(7, 9, 9)	(5, 7, 9)	(3, 5, 7)	(1, 1, 3)	(1, 3, 5)
C9	VG	G	G	P	P	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(1, 1, 3)	(1, 1, 3)
C10	VG	G	F	P	P	(5, 7, 9)	(3, 5, 7)	(1, 3, 5)	(1, 1, 3)	(1, 1, 3)
C11	G	VG	F	F	P	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)	(1, 1, 3)
C12	G	VG	VG	F	F	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)
C13	VG	EX	G	P	VG	(5, 7, 9)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)
C14	G	EX	G	G	VG	(3, 5, 7)	(7, 9, 9)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
C15	G	P	G	G	VG	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
C16	VG	EX	VG	P	EX	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)	(1, 1, 3)	(7, 9, 9)
C17	VG	EX	VG	P	VG	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)	(1, 1, 3)	(5, 7, 9)
C18	G	P	G	P	VG	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)
C19	F	EX	G	P	VG	(1, 3, 5)	(7, 9, 9)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)
C20	EX	VG	G	P	G	(7, 9, 9)	(5, 7, 9)	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)

Under step 6, we calculate the aggregated fuzzy scores for firms. The aggregate fuzzy score for each of firm is calculated by multiplying the fuzzy performance ratings matrix from *Table 5.1.5* by the aggregated fuzzy importance weights from *Table 5.1.4*.

$\tilde{R}$	C1	C2	...	C20		$\tilde{W}$		$\tilde{S}$
Firm_1	(3, 5, 7)	(3, 5, 7)	...	(7, 9, 9)	$\otimes$	(0.04, 0.536, 1.0)	$=$	(1.6, 57.4, 152.6)
Firm_2	(7, 9, 9)	(7, 9, 9)	...	(5, 7, 9)		(0.04, 0.472, 1.0)		(2.3, 63.8, 154.2)
Firm_3	(3, 5, 7)	(3, 5, 7)	...	(3, 5, 7)		...		(1.4, 48.1, 137.0)
Firm_4	(1, 1, 3)	(5, 7, 9)	...	(1, 1, 3)		...		(1.4, 25.8, 91.0)
Firm_5	(5, 7, 9)	(5, 7, 9)	...	(3, 5, 7)		(0.04, 0.424, 1.0)		(2.2, 49.4, 135.4)
						(0.0, 0.392, 1.0)		

Under the final step, the aggregate fuzzy scores were defuzzified and converted into crisp scores using the centroid method. Firms were then ranked according to their crisp scores. The firm with the highest score emerged as the best biodiversity management performer. The result is summarized in *Table 5.1.6*.

Table 5.1.6 Defuzzification and performance ranking

	Aggregated fuzzy score	Crisp score	Rank
Firm_1	(1.6, 57.4, 152.6)	70.54	2
Firm_2	(2.3, 63.8, 154.2)	73.44	1
Firm_3	(1.4, 48.1, 137.0)	62.19	4
Firm_4	(1.4, 25.8, 91.0)	39.39	5
Firm_5	(2.2, 49.4, 135.4)	62.33	3

Firm_2 has the highest score in terms of the performance of biodiversity management in the study sample. The following ranks are the Firm_1, Firm_5, Firm_3 and Firm_4, respectively (*see Table 5.1.6*). Fuzzy score with respect to individual indicator can also be converted into a crisp score to see how each firm performs on the subject of single indicator, as drawn in the following figure.

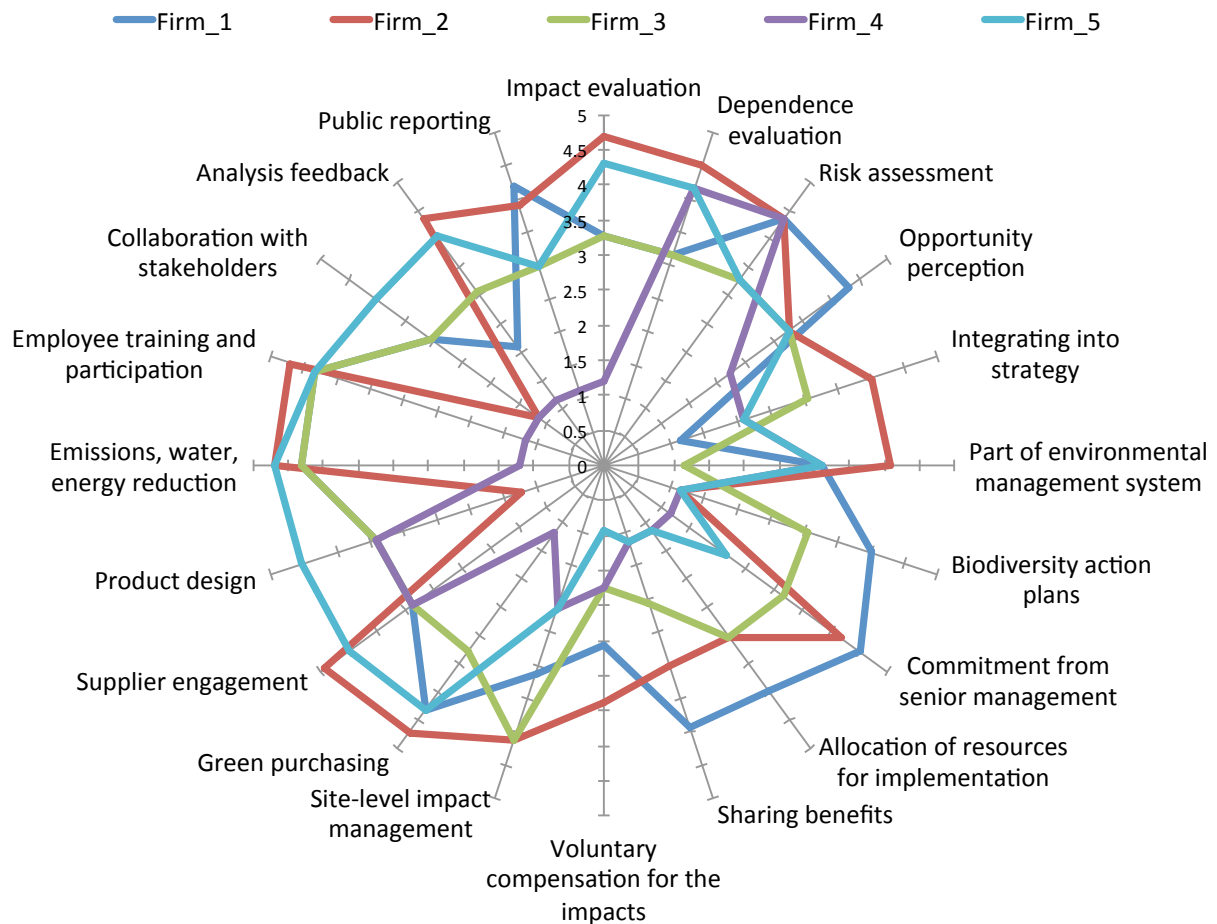


Figure 5.1.1 Performance of firms with respect to single indicator

On overall, businesses achieve the higher score on the Biodiversity Business Assessment key indicator (impact evaluation, dependence evaluation, risk assessment, opportunity perception) and on the Biodiversity Stewardship Practices key indicator (site-level impact management, green purchasing, supplier engagement, product design, reduction of emissions, water, energy consumption). The corporate performance scores are lower on the Biodiversity Conservation Commitment indicator (senior commitment, allocation of resources, voluntary compensation of the impact) and on the Biodiversity Management Policy indicator (integration into strategy, integration into the environmental management systems, biodiversity action plans). Similarly, companies do not post very high scores in public reporting of their biodiversity management efforts to the local communities, customers, suppliers, stakeholders, and other non-government organizations (*see Figure 5.1.2*).

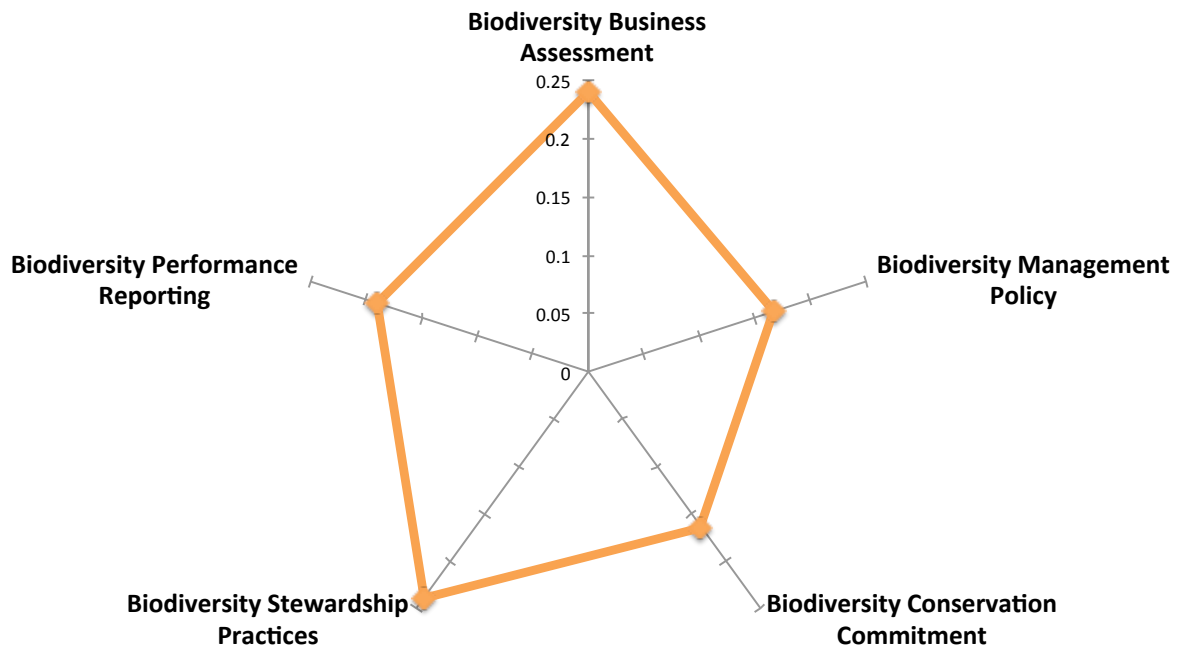


Figure 5.1.2 Overall performance with regard to KPIs

1.4. Sensitivity analysis

Sensitivity analysis addresses the question how sensitive is the overall performance score to small changes in the individual weights assigned by evaluators during preferences process. This question can be answered by varying slightly the values of the weights and observing the effects on the performance scores. This is useful in situations where uncertainties exist in the definition of the importance of different factors.

In this case, sensitivity analysis is to investigate the impact of the important weights of indicators (denoted by w_j for indicator C_j , where $j = 1, 2, \dots, n$) on the overall performance score of corporate biodiversity management. In order perform the sensitivity analysis, 25 experiments have been conducted. In experiments 1st - 20th, the weight of each indicator is set as highest value (0.8, 1, 1) one by one and the important weights of remaining indicators are set to the lowest value (0, 0.2, 0.4). In the last five experiments (21st - 25th), weights of all indicators are set equal to (0.8, 1, 1); (0.6, 0.8, 1); (0.4, 0.6,

0.8), (0.2, 0.4, 0.6) and (0, 0.2, 0.4), respectively. The details of 25 experiments are presented in the following table.

Table 5.2.7 Experiments for sensitivity analysis

Expt.	Setting	Aggregate performance scores					Ranking
		Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	
1	$\tilde{w}_1 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 1\}} = (0, 0.2, 0.4)$	31.93	35.53	28.46	16.86	29.66	F2 > F1 > F5 > F3 > F4
2	$\tilde{w}_2 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 2\}} = (0, 0.2, 0.4)$	31.93	35.53	28.46	20.73	29.66	F2 > F1 > F5 > F3 > F4
3	$\tilde{w}_3 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 3\}} = (0, 0.2, 0.4)$	33.4	34.46	28.46	20.73	28.2	F2 > F1 > F3 > F5 > F4
4	$\tilde{w}_4 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 4\}} = (0, 0.2, 0.4)$	33.4	33	28.46	17.8	28.2	F1 > F2 > F3 > F5 > F4
5	$\tilde{w}_5 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 5\}} = (0, 0.2, 0.4)$	29.53	34.46	28.46	17.8	26.73	F2 > F1 > F3 > F5 > F4
6	$\tilde{w}_4 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 4\}} = (0, 0.2, 0.4)$	31.93	34.46	26.06	19.26	28.2	F2 > F1 > F5 > F3 > F4
7	$\tilde{w}_7 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 7\}} = (0, 0.2, 0.4)$	33.4	30.6	28.46	16.86	25.8	F1 > F2 > F3 > F5 > F4
8	$\tilde{w}_8 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 8\}} = (0, 0.2, 0.4)$	34.46	34.46	28.46	16.86	26.73	F1 = F2 > F3 > F5 > F4
9	$\tilde{w}_9 = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 9\}} = (0, 0.2, 0.4)$	33.4	33	28.46	16.86	25.8	F1 > F2 > F3 > F5 > F4
10	$\tilde{w}_{10} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 10\}} = (0, 0.2, 0.4)$	33.4	33	27	16.86	25.8	F2 > F1 > F3 > F5 > F4
11	$\tilde{w}_{11} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 11\}} = (0, 0.2, 0.4)$	31.93	34.46	27	17.8	25.8	F2 > F1 > F3 > F5 > F4
12	$\tilde{w}_{12} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 12\}} = (0, 0.2, 0.4)$	31.93	34.46	29.93	17.8	26.73	F2 > F1 > F3 > F5 > F4
13	$\tilde{w}_{13} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 13\}} = (0, 0.2, 0.4)$	33.4	35.53	28.46	16.86	29.66	F2 > F1 > F5 > F3 > F4
14	$\tilde{w}_{14} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 14\}} = (0, 0.2, 0.4)$	31.93	35.53	28.46	19.26	29.66	F2 > F1 > F5 > F3 > F4
15	$\tilde{w}_{15} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 15\}} = (0, 0.2, 0.4)$	31.93	30.6	28.46	19.26	29.66	F1 > F2 > F5 > F3 > F4
16	$\tilde{w}_{14} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 14\}} = (0, 0.2, 0.4)$	33.4	35.53	29.93	16.86	30.73	F2 > F1 > F5 > F3 > F4
17	$\tilde{w}_{17} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 17\}} = (0, 0.2, 0.4)$	33.4	35.53	29.93	16.86	29.66	F2 > F1 > F3 > F5 > F4
18	$\tilde{w}_{18} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 18\}} = (0, 0.2, 0.4)$	31.93	30.6	28.46	16.86	29.66	F1 > F2 > F5 > F3 > F4
19	$\tilde{w}_{19} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 19\}} = (0, 0.2, 0.4)$	30.46	35.53	28.46	16.86	29.66	F2 > F1 > F5 > F3 > F4
20	$\tilde{w}_{20} = (0.8, 1, 1) \mid \tilde{w}_{\{i \setminus 20\}} = (0, 0.2, 0.4)$	34.46	34.46	28.46	16.86	28.2	F1 = F2 > F3 > F5 > F4
21	$\tilde{w}_i = (0.8, 1, 1)$	112	120.93	94.66	57.06	95.6	F2 > F1 > F5 > F3 > F4
22	$\tilde{w}_i = (0.6, 0.8, 1)$	98.8	105.86	84.13	51.33	84.66	F2 > F1 > F5 > F3 > F4
23	$\tilde{w}_i = (0.4, 0.6, 0.8)$	97.8	104.2	83.13	51	83.26	F2 > F1 > F5 > F3 > F4
24	$\tilde{w}_i = (0.2, 0.4, 0.6)$	51.86	54.93	44.66	27.6	44.66	F2 > F1 > F3 = F5 > F4
25	$\tilde{w}_i = (0, 0.2, 0.4)$	28.4	29.46	24.93	15.73	24.66	F2 > F1 > F3 > F5 > F4

Based on the sensitivity analysis, firms can be categorized into three groups according to their performance scores. The highest score group consists of Firm_2 and Firm_1; the middle group includes of Firm_3 and Firm_5; and the lowest class is Firm_4. It can be seen from Table 5.1.7 that Firm_2 has the highest score in 19 experiments (Expt. No. 1-3, 5-6, 8, 11-14, 16-17, 19-25) out of 25 experiments. Firm_1 has the highest score in 8

experiments (Expt. No. 4, 7-10, 15, 18, 20). Both Firm_1 and Firm_2 have the same score in two experiments (Expt. No. 8 and 20). Firm_3 and Firm_5 have the same grade when both of them are classified in the 3rd rank in 13 experiments and 4th rank in 12 experiments, in which they have the same score in the experiment No. 24. Firm_4 has lowest score in all of experiments.

We can conclude that the preferences process is relatively insensitive to the important weights of indicators. Firm_2 is clearly the best performance one in corporation biodiversity management with the highest score in 76% of total experiments. Follow ranks are Firm_1, Firm_5 or Firm_3 and Firm_4. It is interesting to recognize that Firm_5 is ranked higher than Firm_3 in the premier analysis. From Table 5.1.6, the performance score of Firm_5 is 62.33 while the score of Firm_3 is 62.19. The different in the performance scores between two these firms (0.2%) may be insignificant. Moreover, the sensitivity analysis shows that two of businesses have the same ranking.

In order to determine the ranking of businesses, we can run sensitivity analysis again by adding more experiments. Another solution is to conduct further investigation by applying other method. One of the most suitable methods in this case is fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS). Next section presents the preliminaries of fuzzy TOPSIS model and its application in measuring the performance of corporate biodiversity management.

1.5. Ranking with Fuzzy TOPSIS

Originally, Hwang and Yoon (1981) developed a technique to order preference by similarity to ideal solution, which is known as TOPSIS model, for solving the multiple attribute decision-making (MADM) problems. The vital idea of the TOPSIS is to define positive and negative ideal solutions and then to measure the distance of the alternatives from the ideal solutions based on which the rankings of the alternatives are determined (Kannan et al., 2014). The positive ideal solution (PIS) is the solution that maximizes the benefits criteria and minimizes the cost criteria, whereas the negative ideal solution (NIS) maximizes the cost criteria and minimizes the benefit criteria (Chen

and Hwang, 1992). Accordingly, the selected alternative should be closest to the PIS and farthest away from NIS.

Fuzzy logic can be incorporated with TOPSIS, called fuzzy TOPSIS model, to generate an overall performance score that allows making a straightforward rank. In fuzzy TOPSIS, the ratings and weights are defined by the linguistic variable, which are then converted to fuzzy numbers. Similar to conventional TOPSIS model, fuzzy TOPSIS also identifies an index called closeness coefficient (similarity) to the PIS and remoteness to the NIS. Then, the method selects an alternative whose closeness coefficient to the PIS is maximized. As a hybrid approach, fuzzy TOPSIS can combine the advantages of fuzzy logic and conventional TOPSIS that allow some degree of subjectivity in the measurement model. The advantages of fuzzy TOPSIS are simple computation process, systematic procedure, a sound logic (Govindan et al., 2013; Shen et al., 2013) and distinguishability between benefit and the cost category criteria (Awasthi et al., 2010).

The preliminaries of fuzzy TOPSIS model and its applications have been successfully used in the various performance measurement models. For instance, Chen et al. (2006) present a fuzzy TOPSIS approach for suppliers evaluation and selection in supply chain management. Buyukozkan et al. (2008) conduct the fuzzy TOPSIS to achieve the final partner as the strategic alliance partner in logistics value chain based on ranking results. Awasthi et al. (2010) use fuzzy TOPSIS for measuring environmental performance of suppliers. Ayag and Ozdemir (2012) show a performance analysis on machine tool selection problem through modified TOPSIS and alpha-cut based fuzzy Analytical Network Process (ANP). Wanke et al. (2015) report on the performance assessment of the Asian airlines using TOPSIS as the cornerstone method to compute efficiency scores. The combination between fuzzy TOPSIS and supply chain operations reference (SCOR®) model brings several benefits to evaluate the performance of suppliers in the dimensions cost and delivery performance and to categorize the suppliers according to their performance (Lima-Junior and Carpinetti, 2016). In general, the fuzzy TOPSIS method is summarized as follows:

Step 1: Constructing the decision matrix

Step 2: Aggregate the evaluation of decision makers

- Step 3: Construct the normalized decision matrix
- Step 4: Construct the weighted normalized decision matrix
- Step 5: Determine the positive ideal and negative ideal solutions
- Step 6: Calculate the distance of each alternative from PIS and NIS
- Step 7: Calculate the closeness coefficient
- Step 8: Find the ranks

Here, it is not needed to repeat the procedure of fuzzy TOPSIS, but some operations in the model are basically derived from Hwang and Yoon (1981); Awasthi et al. (2010; 2011); Kannan et al. (2014; 2009). Next section presents results by applying the fuzzy TOPSIS model in measuring the performance of corporate biodiversity management.

1.5.1. Results by using fuzzy TOPSIS

In this work, step 1 and step 2 have been done from the previous model. In particular, the aggregated fuzzy weightings for the indicators are presented in Table 5.1.4; and the performance ratings for firms are presented in Table 5.1.5. The application of fuzzy TOPSIS model for ordering the performance of corporate biodiversity management is presented as follows.

First, it is constructed the normalized decision matrix. The raw data are normalized using linear scale transformation to bring the various criteria scales into a comparable scale. The normalized fuzzy decision matrix $\tilde{R}$ is given by:

$$\tilde{R} = [\tilde{r}_{ij}]_{m \otimes n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

where,

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+} \right); \text{ and } u_j^+ = \max_i u_{ij} \text{ for benefit criteria}$$

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}} \right); \text{ and } l_j^- = \min_i l_{ij} \text{ for cost criteria}$$

It is important to recognize that all of 20 indicators in the model are in benefit category that means the higher performance is better. Thus, the fuzzy decision matrix is

normalized according to transformation formula for benefit criteria. For example, the normalized rating for Firm_1 with respect to indicator C1 is given by:

$$u_j^+ = \max_1(7, 9, 7, 3, 9) = 9$$

thus,

$$\tilde{r}_{11} = \left(\frac{3}{9}, \frac{5}{9}, \frac{7}{9}\right) = (0.33, 0.56, 0.78)$$

Likewise, the normalized values for the remaining indicators of firms are computed. The normalized fuzzy decision matrix for the five firms is presented in Table 5.1.8.

Table 5.1.8 Normalized fuzzy decision matrix

Indicator	Normalized performance ratings - $\tilde{r}_{ij}$				
	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5
C1	(0.33, 0.56, 0.78)	(0.78, 1, 1)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
C2	(0.33, 0.56, 0.78)	(0.78, 1, 1)	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)	(0.56, 0.78, 1)
C3	(0.56, 0.78, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
C4	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.11, 0.33, 0.56)	(0.33, 0.56, 0.78)
C5	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.11, 0.33, 0.56)	(0.11, 0.33, 0.56)
C6	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)	(0.11, 0.11, 0.33)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)
C7	(0.56, 0.78, 1)	(0.11, 0.33, 0.56)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.11, 0.11, 0.33)
C8	(0.78, 1, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.11, 0.33, 0.56)
C9	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.11, 0.11, 0.33)
C10	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.11, 0.33, 0.56)	(0.11, 0.11, 0.33)	(0.11, 0.11, 0.33)
C11	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)	(0.11, 0.33, 0.56)	(0.11, 0.33, 0.56)	(0.11, 0.11, 0.33)
C12	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)	(0.56, 0.78, 1)	(0.11, 0.33, 0.56)	(0.11, 0.33, 0.56)
C13	(0.56, 0.78, 1)	(0.78, 1, 1)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
C14	(0.33, 0.56, 0.78)	(0.78, 1, 1)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)
C15	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.56, 0.78, 1)
C16	(0.56, 0.78, 1)	(0.78, 1, 1)	(0.56, 0.78, 1)	(0.11, 0.11, 0.33)	(0.78, 1, 1)
C17	(0.56, 0.78, 1)	(0.78, 1, 1)	(0.56, 0.78, 1)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
C18	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
C19	(0.11, 0.33, 0.56)	(0.78, 1, 1)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
C20	(0.78, 1, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)	(0.11, 0.11, 0.33)	(0.33, 0.56, 0.78)

Next step is to construct the weighted normalized decision matrix. The weighted normalized matrix $\tilde{V}$ for indicators is computed by multiplying the weights ($\tilde{w}_j$) of evaluation indicators with the normalized fuzzy decision matrix $\tilde{r}_{ij}$.

$$\tilde{V} = [\tilde{v}_{ij}]_{m \otimes n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

where,

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$$

The $\tilde{r}_{ij}$ values from Table 5.1.8 and $\tilde{w}_j$ values from Table 5.1.4 are used to compute the fuzzy weighted decision matrix for the firms. For example, the fuzzy weight for indicator C1 regarding to Firm_1 is given by:

$$\tilde{v}_{11} = (0.33, 0.56, 0.78) \otimes (0.04, 0.536, 1) = (0.01, 0.29, 0.78)$$

Likewise, the fuzzy weights of the firms for the remaining indicators are computed (Table 5.1.9).

Then, the fuzzy negative ideal solution and the fuzzy positive ideal solution are computed. The fuzzy negative ideal solution (FNIS) of indicator j computed as follows:

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-)$$

where,

$$\tilde{v}_j^- = \min_i \{v_{ij}\}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

The fuzzy positive ideal solution (FPIS) of indicator i is computed as follows:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots, \tilde{v}_n^+)$$

where,

$$\tilde{v}_j^+ = \max_i \{v_{ij}\}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

For example, the FNIS and FPIS for indicator C1 is determined by

$$A_1^-$$

$$= \min[(0.01, 0.29, 0.77), (0.03, 0.53, 1), (0.01, 0.29, 0.77), (0.00, 0.24, 1), (0.00, 0.05, 0.33)] \\ = (0.004, 0.05, 0.33)$$

and,

$$A_1^+$$

$$= \max[(0.01, 0.29, 0.77), (0.03, 0.53, 1), (0.01, 0.29, 0.77), (0.00, 0.24, 1), (0.00, 0.05, 0.33)]$$

$$= (0.03, 0.53, 1)$$

Similar computations are performed for the remaining indicators. The results are presented in last two columns of Table 5.1.9.

Table 5.1.9 Weighted normalized fuzzy decision matrix, FPIS and FNIS

Ind.	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	FNIS (A^-)	FPIS (A^+)
C1	(0.01, 0.29, 0.77)	(0.03, 0.53, 1)	(0.01, 0.29, 0.77)	(0.00, 0.05, 0.33)	(0.02, 0.41, 1)	(0.00, 0.05, 0.33)	(0.03, 0.53, 1)
C2	(0.01, 0.26, 0.77)	(0.03, 0.47, 1)	(0.01, 0.26, 0.77)	(0.02, 0.36, 1)	(0.02, 0.36, 1)	(0.01, 0.26, 0.77)	(0.03, 0.47, 1)
C3	(0.04, 0.40, 1)	(0.04, 0.40, 1)	(0.02, 0.28, 0.77)	(0.04, 0.40, 1)	(0.02, 0.28, 0.77)	(0.02, 0.28, 0.77)	(0.04, 0.40, 1)
C4	(0.02, 0.41, 1)	(0.01, 0.29, 0.77)	(0.01, 0.29, 0.77)	(0.00, 0.17, 0.55)	(0.01, 0.29, 0.77)	(0.00, 0.17, 0.55)	(0.02, 0.41, 1)
C5	(0, 0.04, 0.33)	(0, 0.33, 1)	(0, 0.24, 0.77)	(0, 0.14, 0.55)	(0, 0.14, 0.55)	(0, 0.04, 0.33)	(0, 0.33, 1)
C6	(0, 0.25, 0.77)	(0, 0.36, 1)	(0, 0.05, 0.33)	(0, 0.25, 0.77)	(0, 0.25, 0.77)	(0, 0.05, 0.33)	(0, 0.36, 1)
C7	(0, 0.33, 1)	(0, 0.04, 0.33)	(0, 0.24, 0.77)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.33, 1)
C8	(0, 0.50, 1)	(0, 0.39, 1)	(0, 0.28, 0.77)	(0, 0.05, 0.33)	(0, 0.16, 0.55)	(0, 0.05, 0.33)	(0, 0.50, 1)
C9	(0, 0.32, 1)	(0, 0.23, 0.77)	(0, 0.23, 0.77)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.32, 1)
C10	(0, 0.31, 1)	(0, 0.22, 0.77)	(0, 0.13, 0.55)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.04, 0.33)	(0, 0.31, 1)
C11	(0, 0.23, 0.62)	(0, 0.32, 0.8)	(0, 0.13, 0.44)	(0, 0.13, 0.44)	(0, 0.04, 0.26)	(0, 0.04, 0.26)	(0, 0.32, 0.8)
C12	(0, 0.26, 0.77)	(0, 0.37, 1)	(0, 0.37, 1)	(0, 0.16, 0.55)	(0, 0.16, 0.55)	(0, 0.16, 0.55)	(0, 0.37, 1)
C13	(0, 0.44, 1)	(0, 0.56, 1)	(0, 0.31, 0.77)	(0, 0.06, 0.33)	(0, 0.44, 1)	(0, 0.06, 0.33)	(0, 0.56, 1)
C14	(0.04, 0.30, 0.77)	(0.09, 0.55, 1)	(0.04, 0.30, 0.77)	(0.04, 0.30, 0.77)	(0.06, 0.42, 1)	(0.04, 0.30, 0.77)	(0.09, 0.55, 1)
C15	(0.02, 0.33, 0.77)	(0.00, 0.06, 0.33)	(0.02, 0.33, 0.77)	(0.02, 0.33, 0.77)	(0.04, 0.46, 1)	(0.00, 0.06, 0.33)	(0.04, 0.46, 1)
C16	(0, 0.44, 1)	(0, 0.56, 1)	(0, 0.44, 1)	(0, 0.06, 0.33)	(0, 0.56, 1)	(0, 0.06, 0.33)	(0, 0.56, 1)
C17	(0, 0.44, 1)	(0, 0.56, 1)	(0, 0.44, 1)	(0, 0.06, 0.33)	(0, 0.44, 1)	(0, 0.06, 0.33)	(0, 0.56, 1)
C18	(0.01, 0.22, 0.77)	(0.00, 0.04, 0.33)	(0.01, 0.22, 0.77)	(0.00, 0.04, 0.33)	(0.02, 0.31, 1)	(0.00, 0.04, 0.33)	(0.02, 0.31, 1)
C19	(0.00, 0.14, 0.55)	(0.03, 0.42, 1)	(0.01, 0.23, 0.77)	(0.00, 0.04, 0.33)	(0.02, 0.32, 1)	(0.00, 0.04, 0.33)	(0.03, 0.42, 1)
C20	(0, 0.39, 1)	(0, 0.30, 1)	(0, 0.21, 0.77)	(0, 0.04, 0.33)	(0, 0.21, 0.77)	(0, 0.04, 0.33)	(0, 0.39, 1)

As a next step, the distance of each firm from FPIS and FNIS is computed. Given two fuzzy triangular numbers $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$, the distance between the two fuzzy numbers $d(\tilde{M}_1 | \tilde{M}_2)$ is calculated using the vertex method by:

$$d(\tilde{M}_1 | \tilde{M}_2) = \sqrt{\frac{1}{3} * [(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]}$$

For example, for Firm_1 and indicator C1, the distance $d_v(\tilde{v}_{11} | \tilde{v}_1^-)$ and $d_v(\tilde{v}_{11} | \tilde{v}_1^+)$ are computed as follows:

$$d_v(\tilde{v}_{11} | \tilde{v}_1^-) = \sqrt{\frac{1}{3} * [(0.01 - 0.00)^2 + (0.29 - 0.05)^2 + (0.77 - 0.33)^2]} = 0.291$$

$$d_v(\tilde{v}_{11} | \tilde{v}_1^+) = \sqrt{\frac{1}{3} * [(0.01 - 0.03)^2 + (0.29 - 0.53)^2 + (0.77 - 1)^2]} = 0.188$$

Likewise, the distance for the remaining indicators is computed for the five firms. The results are shown in Table 5.1.10.

Table 5.1.10 Distance from negative and positive ideal solutions

Ind.	$d_v(\tilde{v}_{ij} \tilde{v}_j^-)$					$d_v(\tilde{v}_{ij} \tilde{v}_j^+)$				
	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5
C1	0.291	0.473	0.291	0	0.436	0.188	0	0.188	0.473	0.068
C2	0	0.176	0	0.141	0.141	0.176	0	0.176	0.060	0.060
C3	0.144	0.144	0	0.144	0	0	0	0.144	0	0.144
C4	0.290	0.145	0.145	0	0.145	0	0.145	0.145	0.290	0.145
C5	0	0.419	0.279	0.139	0.139	0.419	0	0.139	0.279	0.279
C6	0.282	0.424	0	0.282	0.282	0.141	0	0.424	0.141	0.141
C7	0.419	0	0.279	0	0	0	0.419	0.139	0.419	0.419
C8	0.463	0.431	0.287	0	0.143	0	0.064	0.182	0.463	0.321
C9	0.416	0.277	0.277	0	0	0	0.138	0.138	0.416	0.416
C10	0.414	0.276	0.138	0	0	0	0.138	0.276	0.414	0.414
C11	0.231	0.347	0.115	0.115	0	0.115	0	0.231	0.231	0.347
C12	0.142	0.284	0.284	0	0	0.142	0	0	0.284	0.284
C13	0.442	0.482	0.295	0	0.442	0.072	0	0.194	0.482	0.072
C14	0	0.193	0	0	0.147	0.193	0	0.193	0.193	0.072
C15	0.299	0	0.299	0.299	0.449	0.149	0.449	0.149	0.149	0
C16	0.442	0.482	0.442	0	0.482	0.072	0	0.072	0.482	0
C17	0.442	0.482	0.442	0	0.442	0.072	0	0.072	0.482	0.072
C18	0.277	0	0.277	0	0.415	0.138	0.415	0.138	0.415	0
C19	0.139	0.442	0.278	0	0.418	0.304	0	0.168	0.442	0.054
C20	0.434	0.413	0.275	0	0.275	0	0.050	0.163	0.434	0.163
$\sum d_v$	5.575	5.898	4.410	1.124	4.364	2.189	1.821	3.341	6.560	3.480

Then, it is computed the distance d_v of each firm from the fuzzy positive ideal matrix A^+ and fuzzy negative ideal matrix A^- . The distance (d_i^+, d_i^-) of firm_i, $i = 1, 2, \dots, m$ from the FPIS and the FNIS is computed as follows:

$$d_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij} | \tilde{v}_j^+), i = 1, 2, \dots, m$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij} | \tilde{v}_j^-), i = 1, 2, \dots, m$$

where $d_v(\tilde{v}_{ij} | \tilde{v}_j^{(\cdot)})$ is the distance measurement which has been determined in the Table 5.1.10.

Finally, it is computed the closeness coefficient (CC_i) of each alternative. The closeness coefficient CC_i represents the distance to the fuzzy positive ideal solution A^+ and the fuzzy negative ideal solution A^- simultaneously. The closeness coefficient of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}, i = 1, 2, \dots, m$$

Using distance d_i^+ and d_i^- , it is computed the closeness coefficient CC_i of the five firms. For example, for Firm_1, the closeness coefficient is given by:

$$CC_1 = \frac{d_1^-}{d_1^- + d_1^+} = \frac{5.575}{5.575 + 2.189} = 0.718$$

Table 5.1.11 **Closeness Coefficients**

	Firm_1	Firm_2	Firm_3	Firm_4	Firm_5
d_i^-	5.575	5.898	4.410	1.124	4.364
d_i^+	2.189	1.821	3.341	6.560	3.480
CC_i	0.718	0.764	0.568	0.146	0.556
Rank	2	1	3	5	4

Likewise, CC_i for other firms are computed and the final results are shown in Table 5.1.11. By comparing the CC_i values of the five firms in Table 5.1.11, it can be found that Firm_2 has the best biodiversity performance according to the closeness coefficient. The following ranks Firm_1, Firm_3, Firm_5, and Firm_4. It is needed to conduct sensitivity analysis in order to determine the order between businesses.

1.5.2. Sensitivity analysis

The sensitivity analysis is performed to examine the influence of the preferences given by the evaluators for the performance scores of corporate biodiversity management. In order to perform the sensitivity analysis, 25 experiments were conducted. In experiments 1st - 20th, the weight of each indicator is set as highest value (0.8, 1, 1) one by one and the important weights of remaining indicators are set to the lowest value (0, 0.2, 0.4). In the last five experiments (21st – 25th), weights of all indicators are set equal to (0.8, 1, 1); (0.6, 0.8, 1); (0.4, 0.6, 0.8), (0.2, 0.4, 0.6) and (0, 0.2, 0.4), respectively. The result of sensitivity can also be illustrated in the following figure.

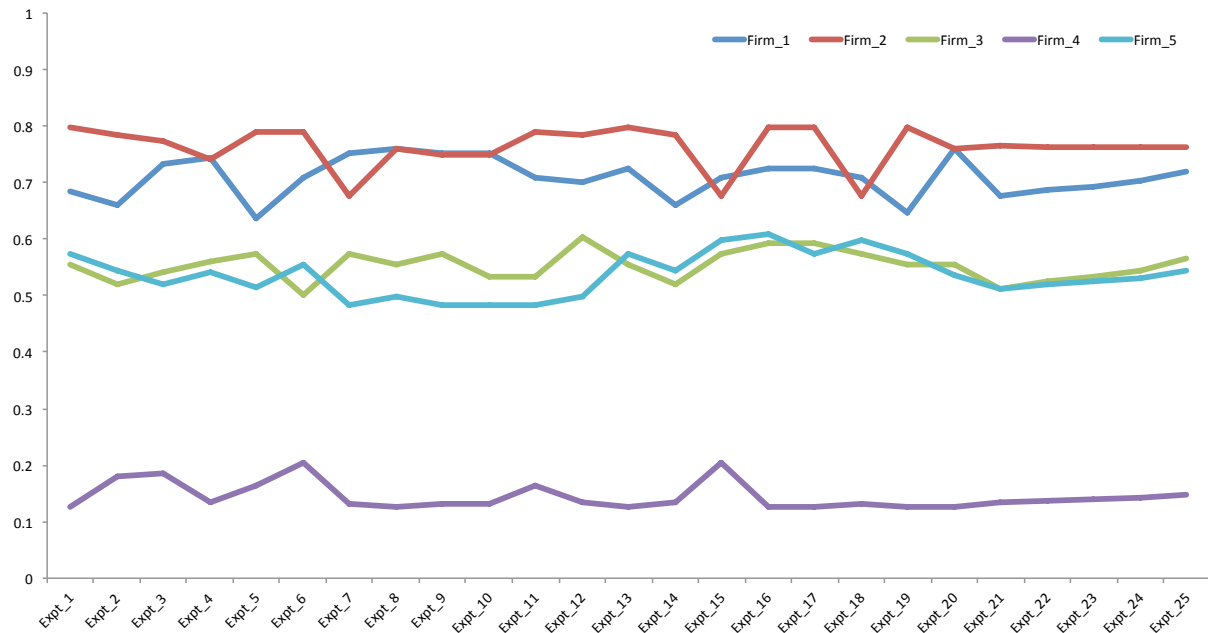


Figure 5.4.3 Results of sensitivity analysis

The details of 25 experiments are designed as presented in the following table. It can be seen from Table 5.1.12 that Firm_2 has the highest score in 19 experiments (Expt. No. 1-3, 5-6, 8, 11-14, 16-17, 19-25) out of 25 experiments. Firm_1 has the highest score in 6 experiments (Expt. No. 4, 7, 9-10, 15, 18,). Firm_3 is classified at the 3rd rank in 15 experiments. Firm_5 is graded at the 4th rank in 15 experiments. Firm_4 has lowest score in all of experiments.

Table 5.1.12 Result of sensitivity analysis

Expt.	Setting	Closeness Coefficient					Rank
		Firm_1	Firm_2	Firm_3	Firm_4	Firm_5	
1	$\tilde{w}_1 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 1\}} = (0, 0.2, 0.4)$	0.684	0.797	0.554	0.126	0.575	F2 > F1 > F5 > F3 > F4
2	$\tilde{w}_2 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 2\}} = (0, 0.2, 0.4)$	0.660	0.783	0.519	0.179	0.543	F2 > F1 > F5 > F3 > F4
3	$\tilde{w}_3 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 3\}} = (0, 0.2, 0.4)$	0.732	0.774	0.540	0.186	0.520	F2 > F1 > F3 > F5 > F4
4	$\tilde{w}_4 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 4\}} = (0, 0.2, 0.4)$	0.744	0.740	0.560	0.134	0.541	F1 > F2 > F3 > F5 > F4
5	$\tilde{w}_5 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 5\}} = (0, 0.2, 0.4)$	0.636	0.790	0.574	0.164	0.515	F2 > F1 > F3 > F5 > F4
6	$\tilde{w}_4 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 4\}} = (0, 0.2, 0.4)$	0.709	0.790	0.500	0.204	0.555	F2 > F1 > F5 > F3 > F4
7	$\tilde{w}_7 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 7\}} = (0, 0.2, 0.4)$	0.751	0.675	0.574	0.130	0.483	F1 > F2 > F3 > F5 > F4
8	$\tilde{w}_8 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 8\}} = (0, 0.2, 0.4)$	0.759	0.761	0.554	0.126	0.498	F2 > F1 > F3 > F5 > F4
9	$\tilde{w}_9 = (0.8, 1, 1); \tilde{w}_{\{i \setminus 9\}} = (0, 0.2, 0.4)$	0.751	0.748	0.574	0.130	0.483	F1 > F2 > F3 > F5 > F4
10	$\tilde{w}_{10} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 10\}} = (0, 0.2, 0.4)$	0.751	0.748	0.533	0.130	0.483	F1 > F2 > F3 > F5 > F4
11	$\tilde{w}_{11} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 11\}} = (0, 0.2, 0.4)$	0.709	0.790	0.533	0.164	0.483	F2 > F1 > F3 > F5 > F4
12	$\tilde{w}_{12} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 12\}} = (0, 0.2, 0.4)$	0.700	0.784	0.604	0.134	0.498	F2 > F1 > F3 > F5 > F4
13	$\tilde{w}_{13} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 13\}} = (0, 0.2, 0.4)$	0.723	0.797	0.554	0.126	0.575	F2 > F1 > F5 > F3 > F4
14	$\tilde{w}_{14} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 14\}} = (0, 0.2, 0.4)$	0.660	0.783	0.519	0.135	0.543	F2 > F1 > F5 > F3 > F4
15	$\tilde{w}_{15} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 15\}} = (0, 0.2, 0.4)$	0.709	0.675	0.574	0.204	0.597	F1 > F2 > F5 > F3 > F4
16	$\tilde{w}_{14} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 14\}} = (0, 0.2, 0.4)$	0.723	0.797	0.593	0.126	0.610	F2 > F1 > F5 > F3 > F4
17	$\tilde{w}_{17} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 17\}} = (0, 0.2, 0.4)$	0.723	0.797	0.593	0.126	0.575	F2 > F1 > F3 > F5 > F4
18	$\tilde{w}_{18} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 18\}} = (0, 0.2, 0.4)$	0.709	0.675	0.574	0.130	0.597	F1 > F2 > F5 > F3 > F4
19	$\tilde{w}_{19} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 19\}} = (0, 0.2, 0.4)$	0.645	0.797	0.554	0.126	0.575	F2 > F1 > F5 > F3 > F4
20	$\tilde{w}_{20} = (0.8, 1, 1); \tilde{w}_{\{i \setminus 20\}} = (0, 0.2, 0.4)$	0.759	0.761	0.554	0.126	0.536	F2 > F1 > F3 > F5 > F4
21	$\tilde{w}_i = (0.8, 1, 1)$	0.676	0.764	0.510	0.134	0.511	F2 > F1 > F5 > F3 > F4
22	$\tilde{w}_i = (0.6, 0.8, 1)$	0.687	0.763	0.525	0.137	0.519	F2 > F1 > F3 > F5 > F4
23	$\tilde{w}_i = (0.4, 0.6, 0.8)$	0.693	0.763	0.532	0.139	0.524	F2 > F1 > F3 > F5 > F4
24	$\tilde{w}_i = (0.2, 0.4, 0.6)$	0.703	0.763	0.545	0.142	0.532	F2 > F1 > F3 > F5 > F4
25	$\tilde{w}_i = (0, 0.2, 0.4)$	0.719	0.763	0.566	0.147	0.545	F2 > F1 > F3 > F5 > F4

It can be concluded that the preferences of evaluators are relatively insensitive to the important weights of indicators. Firm_2 is clearly best performance. Following ranks Firm_1, Firm_3, Firm_5 and Firm_4, orderly.

1.6. Discussion

The measurement of biodiversity management performance remains controversial. The publication of initial reports suggested that a major difficulty for the measurement of biodiversity businesses interactions is to transform theory into practice (GRI, 2007). The challenge consists in finding a set of corporate performance indicators to measure impact, dependence, risks and opportunities associated with biodiversity (Bishop et al., 2008; ISIS and F&C, 2004). Another concern is the subjectivity due to insufficient quantitative data during the evaluation process. For instance, although the reviewers gathered quantitative data where possible, not all companies were able to provide sufficient data; and it is inevitable that some subjectivity is inherent when qualitative data are used (Globalbalance, 2014).

This study confirms that measuring biodiversity management performance is an extremely difficult work due to the complex nature of the relationship between businesses activities and biodiversity (Hanson et al., 2012; Houdet, 2008; EBBC, 2013; TEEB, 2010). This is the fact why many previous conservation performance systems focus on indirect measures of achievement and on different aspects of the problem such as the business and biodiversity interdependence indicators (Houdet, 2008), set of corporate biodiversity indicators (EBBC, 2013), the Normative Biodiversity Metric (Jarrett 2011; 2012) and the implementation of biodiversity management systems (Globalbalance, 2014). The proposed model with five Keys Performance Indicators including twenty sub-indicators may help achieve a comprehensive assessment of the interaction between businesses activities and biodiversity. They can also guide a company to implement the biodiversity management strategy designed to mitigate business risks and leverage opportunities.

Measurements of performance of corporate biodiversity management typically face challenges of incomplete information and unobtainable information. The ambiguity and uncertainty situation stems from the complexity of interrelations between biodiversity (genetic diversity, species, habitats, etc.) and businesses activities (procurement, manufacturing, transportation, sales, etc.) in nature. Given the bounded of human thought for the complexity of things, one usually cannot give the accurate judgments for

the things. One may feel more confident to give interval judgments rather than expressing his/her preferences in the form of single numerical values. Obviously, fuzzy logic is not fuzzy (Zadeh, 2008). The various successful applications of this theory can be found in artificial intelligence, computer science, medicine, control engineering, decision theory, expert systems, logic, management science, operation research, pattern recognition and robotics (Zimmermann, 2010) with a huge literature, several dedicated journals, and many conferences each year for 50 years since its inception (Dubois and Prade, 2015). Based upon the advantages of fuzzy logic, linguistic variables are suitable for measures the performance of corporate biodiversity management.

2. Traceability and transaction governance in the seafood supply chain

This model is constructed to determine whether the implementation of traceability leads to changes in the transaction governance structure within the supply chain. The questionnaire survey has been conducted to collect the primary data from firms in the Vietnamese seafood supply chain. The following sections present an overview of physical flows of fisheries' raw materials in the chain; transaction modes; empirical data of the research and variations in transaction characteristics and transaction governance when firms implement traceability systems.

2.1. Transaction models in the Vietnamese seafood supply chain

Vietnam is one of the largest seafood suppliers worldwide. In fact, the Vietnamese fisheries industry is characterized as being small scaled and fragmented (Lai et al., 2009). Low vertical integration and weak linkages between operators in the seafood chain are the most important bottlenecks for exports (CBI, 2012). Moreover, the cooperation between fishermen and processing factories is not sufficiently strong in the supply chain, which is due in part to the presence of multilevel middle traders (Hop, 2012). These fragmented attributes have affected seafood firms' management and structure of their transactions in the materials purchasing processes.

The figure 5.2.1 shows the physical flows of fish raw materials in the supply chain. Fishers (including fishermen and aquaculture farmers) mostly sell their seafood

products to middle traders (collectors and/or middlemen) and processing plants. Meanwhile, a very small proportion (approximately 1%) is supplied to the domestic market. The percentage of production volume to parties in the chain varies in different types of materials and the vertical integration levels in each sector. In particular, farmers supply about 72 -75% of shrimp to collectors and 25-28% to processing plants. Similarly, middle traders collect about 99% of hard clams and then they re-sell to factories. In the tuna sector, fishermen sell about 50% of their products to collectors, and the rest are sold to processing factories. Almost 90% of pangasius products are provided directly to processors because of the presence of large-scale farms and high levels of vertical integration in the industry.

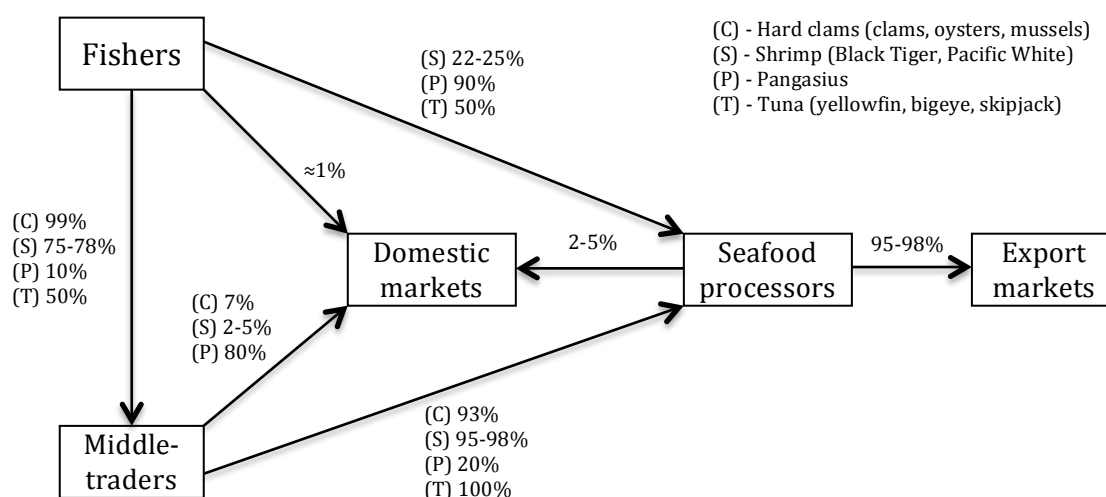


Figure 5.2.1 Product flows in the Vietnamese seafood supply chain

Notably, middle traders establish their link in the seafood supply chain by collecting fisheries' raw materials and reselling them to processing plants. Middle trader supply more than half (about 50 to 99%) of the material delivered to seafood processing plants. After material collection, middle traders resell about 93-100% of the products, which they obtain primarily from seafood processing companies, while a small share of the products is obtained from the domestic market (2-7%). As the last step, export companies supply almost the entirely processed seafood to international markets (95-98%) and only a small proportion of products (2-5%) is oriented to domestic consumers through supermarkets and food services, such as seafood stores and restaurants.

Table 5.2.1 Transaction governance modes in the Vietnamese seafood supply chain

Governance structure		Description
Market	Spot market	- Fisheries' raw materials are traded for immediate delivery in which there is no interdependence between the parties. - Negotiation of the price and volume of fisheries' materials occurs near the delivery date. - There is no commitment to continue the relationship with any particular seafood processor and supplier. - Seafood processors, middlemen and fishers are separate legal entities.
Hybrid form	Relational contract	- Relational contracts can be established based on the trust between seafood processing plants and suppliers. - An informal (oral) agreement can be negotiated between these separate legal entities, but agreements mostly concern purchasing. - Market quotation on the delivery date will determine the price of the materials. - Economic incentives as premium payment for quality and traceability can be agreed upon for responsible and mitigating opportunistic actions. - The volume of materials and delivery date can be pre-estimated for aquaculture fishery materials.
	Simple contract	- This is a formal contract between the seafood processing company and both farmers and middle traders who maintain their status as separate legal entities. - The volume, quality, future delivery date of materials and, in some cases, terms of payment are pre-established in the contract. - The premium price can be determined depending on the demand and supply for quality and traceable materials.
	Long-term contract	- The processing company commits to purchasing the aquaculture fisheries' raw materials and to supporting production through the supply of farm inputs, farm preparation, the provision of technical advice and, in some cases, financial capital. - The farmer agrees to provide an agreed-upon volume and the quality standards of the aquaculture materials to the seafood processor at a predetermined time. - Both are separate legal entities.
Hierarchy	Vertical integration	- Both the seafood processing plants and the farmers are part of the same legal entity. - The transaction is internalized in the company. - The seafood processing firms have their own confinement farms for the production of aquaculture materials that meet the specific characteristics required by certain market segments.

Regarding the material purchasing by seafood firms, transactions can vary, and they include spot markets, contract forms and vertical integration, in which the relational contract is considered the most popular mode. The table 5.2.1 summarizes different types of transactions in the Vietnamese seafood supply chain.

2.2. Empirical data

Field trips and questionnaire survey had been conducted for gathering empirical data. A total of 14 firms are involved in the project. These firms are located in different provinces, i.e., Da Nang (6), Binh Dinh (1), Khanh Hoa (5), Ninh Thuan (1), and Vung Tau (1).

At the first stage, face-to-face discussion had been organized to pre-test the questionnaire. Five enterprises were involved at this stage. At each firm, the discussion often began with a briefly introduction to the project objectives and the commitment in terms of ethical research. The questionnaire was presented to ensure that respondents clearly understand the subjects. Then, the respondent filled information on the questionnaire and, in some cases, were held discussed. The field trip ended by a tour to get knowledge about the firm's operations.

Questionnaires survey was carried out at the second stage of data collection process. The questionnaire was delivered to firms via email and nine responses were received.

Mainly the respondents are purchasing managers, sales managers and (vice) general directors with an average of five years' experience in the position. The firms that provide the feedback are mostly small and medium sized with an average annual turnover of \$25 million primarily from their seafood products export business.

Table 5.2.2 General characteristics of firms

Firm	Respondent	Number of Employees	Year of Operation	Main product	Turnover (\$1000)	Export (%)
F1	Operation manager	400	15	Seafood	12,300	100
F2	Marketing staff	9	7	Seafood	500	100
F3	Exporting manager	600	18	Fish	10,000	90
F4	Purchasing manager	1,000	31	Shrimp	80,000	60
F5	Marketing manager	50	10	Seafood	7,000	10
F6	Operation manager	150	2	Tuna	-	-
F7	Marketing manager	700	-	Tuna	35,000	100
F8	Vice director	1,000	5	Shrimp	20,000	100
F9	Director	819	9	Tuna	36,000	90
F10	Director	694	4	Tuna	30,000	90
F11	Vice director	408	17	Tuna	-	-
F12	Exporting staff	120	4	Canned tuna	60,000	25
F13	Exporting staff	320	7	Seafood	4,700	55
F14	Director	150	7	Shrimp	7,000	100

2.3. Implementation of traceability systems

As described above, export represents an average revenue of 77% of seafood companies. Vietnamese seafood products have recently appeared in major markets, such as the USA, the EU, Japan, Canada, South Korea and Russia, where traceability implementation is mandatory. The European Union has mandatory traceability requirements for all seafood products in its General Food Law (Regulation EC-178/2002). In addition, regulation EC-1005/2008 imposes requirements for traceability for seafood products in order to prevent illegal, unreported and unregulated fishing (IUU). In America, the U.S. Country of Origin Legislation of 2002 (or COOL) calls for seafood products to carry labels that identify both the country of origin and the method of production. Moreover, the U.S. Bioterrorism Act has generated regulations that require establishment and maintenance of a chain of custody records by persons who manufacture, process, pack, transport, distribute, receive, hold or

import food into the United States (Magera and Beaton, 2009). “One up, one down” is the simplest model of external traceability, and it is the minimum requirement of traceability regulations in the mentioned markets.

In the research, only six enterprises implemented the "one step up, one step down" traceability procedure. Seven of the respondents indicated that they use internal traceability, and one firm does not apply any traceability systems. Almost all of the companies (12 answers) use a paper-based method for their traceability system, and only one employs an electronic barcode-based model (Table 5.2.3).

Table 5.2.3 The implementation of traceability systems

	Number of firm
Type of traceability system	
No traceability	1
Paper based	12
Barcode based	1
Radio frequency identification	0
Level of traceability	
No traceability	1
Internal	7
One up - one down	6
Supply chain	0

The enterprises implemented traceability systems for different reasons (Table 5.2.4). The primary motivation is improvement of safety and quality of food and compliance with customers’ requirements within the supply chain. Notably, the companies confirm the implementation of traceability as being an important measure for sustainable development.

Table 5.2.4 Motivation for the implementation of traceability systems

	Total	Number of firms				
		Very low	Low	Medium	High	Very high
Improve food safety	14	0	0	0	9	5
Improve quality of product	14	0	0	1	9	4
Higher price for final product	13	1	1	5	4	2
Improve competitive advantage	13	0	1	3	7	2
Customer's request	14	0	0	3	8	3
Market requirement	13	0	2	0	6	5
Stakeholders' request	13	0	2	6	3	2
Legislation	13	0	1	5	6	1
Pressures from NGOs	12	0	2	4	5	1
Liability of firm in the supply chain	14	0	1	6	5	2
Efficiency of supply chain management	14	0	2	6	4	2
Sustainable concerns	14	1	0	2	9	2

2.4. Variations in transaction characteristics and transaction governance

The results of the survey underscored an increase in asset specificity, i.e., in human assets, physical assets, and intangible assets. The degree of transaction uncertainty decreased when the time, quantity and precision of exchanged information increase. The frequency of transactions did not considerably vary. The respondents also mentioned that implementation of traceability systems increased transaction costs (information costs, negotiating costs, system management costs, control supplier activity costs and raw material costs). Specifically, the proxies of vertical relationships increased in variation, with the exclusion of contractual formalization.

Regarding variations in transaction characteristics, the seafood companies stated that a long-term business relationship with suppliers was an important factor in decision about what suppliers can be included in a traced supply chain (10/14 respondents). The implementation of traceability requires an investment not only related to physical asset specificity (10/14 answers), but also in intangible assets associated with certification (11/14 respondents) and system planning (10/14 respondents). The augmentation of such asset investment supports the hypothesis that (*h1*) the implementation of traceability leads to an increase in investment specificity between agents in the seafood supply chain.

A decrease in the degree of uncertainty throughout the supply chain was also observed as 50% of the answers indicated an increase in the timing of exchange information and as 9/14 respondents described growth in the quantity and accuracy of the information that is exchanged in transactions. These improvements support the hypothesis that (*h2*) the implementation of traceability leads to more transparency in the supply chain. The third hypothesis (*h3*) was not supported because of little variation in the lapse time between transactions.

Regarding to transaction costs, the businesses report an increase in monitoring costs to supplier activity controls (10/14 answers at the high and very high levels) and raw materials controls (13/14 answers). Cost of managing the system registers a small variation with 8/14 respondents. These variations support the hypothesis (*h4*) to indicate that the implementation of traceability systems results in the changes in transactions costs. A little variation in information cost and negotiation cost are also observed in the survey.

Table 5.2.5 Variations of transaction characteristics

	Total	Number of firms				
		Very low	Low	Medium	High	Very high
Variation in transaction characteristics						
<i>Variation in asset specificity</i>						
<i>(1) Human asset specificity</i>						
Long business relationships with suppliers	14	0	2	2	8	2
Difficulty in substitution of certified suppliers	13	0	2	6	4	1
Training of suppliers for certification	14	2	3	5	1	3
<i>(2) Physical asset specificity</i>						
Variation in processing facilities	14	2	2	3	6	1
Traceability system implementation	14	0	1	3	6	4
<i>(3) The intangible asset specificity</i>						
Certification	14	0	1	2	8	3
Planning of the system	14	0	1	3	8	2
<i>(4) Geographical asset specificity</i>						
Certified supplier's closeness	14	0	2	7	4	1
<i>Variation in uncertainty</i>						
Timing of exchanged information	14	0	1	6	7	0
Quantity of exchanged information	14	0	1	4	9	0
Precision of exchanged information	14	0	4	1	9	0
<i>Variation in frequency</i>						
Lapse time between transactions	13	1	4	7	1	0
Variation in transaction costs						
Information cost	14	0	2	1	10	1
Negotiating cost	13	0	1	5	7	0
Cost of managing the system	14	0	0	6	5	3
Supplier activity controls	14	0	1	3	8	2
Raw materials controls	14	0	0	1	9	4
Proxies of variation in vertical relationships						
Variation in the raw material price	14	0	2	0	9	3
Price incentives	14	0	1	3	10	0
Enforcement of purchasing and production rules	14	1	1	3	9	0
Variation in the degree of liability	14	0	1	4	9	0
Contract formalization	14	0	2	6	6	0

The section of the survey about governance reveals a growth in raw material prices (12/14 respondents) and liability among the agents of the supply chain (9/14 answers). Nine of the interviewed firms also reported an increased application of price incentives and purchasing, and production rules enforcement in raw material purchasing transactions. Thus, the hypothesis (*h5*) regarding the reorganization of transactions is supported that the implementation of a traceability system leads to the introduction of economic incentives in the supply chain through an increase in the price of raw materials and/or the provision of additional contractual support.

2.5. Discussion

Although Vietnam is one of the leading seafood exporters in the world, the issues of food safety, sustainability and traceability are serious bottlenecks of the industry. The small-scale characteristics of fisheries, a lack of close links between agents in the supply chain and limited awareness of traceability by fisheries and collectors create challenges in ensuring proper information about seafood products. The cooperation between fishermen and processing factories is not sufficiently strong within the supply chain, being weakened by multilevel of middle traders that have a strong present in the chain. The mentioned fragmentation attributes of the industry have affected the way in which seafood firms manage transactions of purchasing materials. Traceability systems have been implemented in Vietnam seafood export firms to fulfill the international standards in terms of food quality and safety requirements.

The implementation of traceability in the Vietnamese seafood supply chain requires additional investment in human assets, especially in developing long-term relationships with suppliers. The increase in dedicated investment assets leads to an increase in monitoring costs related to the controls of suppliers' activities and raw materials. Consequently, the level of transaction uncertainty decreased owing to an increase in the timing, quantity and accuracy of exchanged information. These findings are fairly consistent with other outcomes in the literature. Indeed, in the study on the effects of voluntary traceability on vertical relationships within the Italian food supply chain, Banterle and Stranieri (2008) find that a long-term business relationship is an important factor for 87% of respondents. An increase in monitoring costs is also

reported, which is associated with control of supplier activities (84% of answers) and raw materials (69%). There was a decrease in the degree of uncertainty throughout the supply chain, with an increase in the timing (83%), quantity (84%) and precision (86%) of exchanged information.

Notably, the findings in this study also featured certain differences as compared to previous studies. Especially, Banterle and Stranieri (2008) find low variation in physical assets investments such as processing equipment (62.3% of answers) and system implementation (81.5%) with the introduction of traceability systems. The intangible assets in terms of certification (69.9%) and planning (81.5%) also showed low variation. The cost of managing the system (83.6%) and the price of raw materials (71.9%) do not show significant variation. In contrast, such variations in the Vietnamese seafood supply chain are quite high according to the empirical results. These inconsistencies in variation can be explained by different level of integration in the supply chain and in the implementation of the traceability system. In the Italian food supply chain, 40% of firms are vertically integrated, and 18% of firms own some of the agricultural suppliers (Banterle and Stranieri, 2008).

3. Conclusion to the chapter

The present thesis addresses a small part of the problem in terms of how to measure the performance of biodiversity management of firms. To allow some degree of subjectivity related to evaluator's preferences, the fuzzy set theory is applied in the methodology development of the proposed model. A total of twenties indicators is identified and classified into five categories of Key Performance Indicators, named Biodiversity Business Assessment, Biodiversity Management Policy; Biodiversity Conservation Commitment, Biodiversity Stewardship Practices, and Biodiversity Performance Reporting. Fuzzy logic operations are applied to calculate scores with a step-by-step procedure and define ranking of firms. In order to demonstrate how the model works, an empirical examination has been conducted with a case of five Vietnamese companies in the “red-zone” of biodiversity business risk – seafood sector.

In terms of the implementation of traceability, almost all Vietnamese seafood companies use paper-based traceability systems. The implementation of traceability systems leads to an increase in asset specificity, a decrease in transaction uncertainty and low variation in the frequency of transactions. Other consequences of traceability systems implementation represent increased transaction costs (information costs, negotiating costs, system management costs, and control supplier activity costs). Price incentives, purchasing and production rule enforcement and liability serve as proxies for the vertical relationship, which has shown an increase in variation. Small-scale characteristics of the fisheries industry affect the way in which seafood firms manage transactions within their supply chains.

The importance of the finding is presented in the conclusion chapter that also includes the potential implications in terms of managerial practices and scientific contribution aspects. Further research directions are also suggested in the next section.

CONCLUSIONS

This section concludes the thesis and intends to restate purpose, consolidate research domain, recommend future research and cover implications. The chapter begins with a summary of projects presented in the thesis. The main findings of the research questions are summarized. The importance of this research in terms managerial and theoretical aspects is stated. Strengths and limitations of this thesis are discussed. The thesis ends with a suggestion for further research and a general conclusion.

1. Summary of projects

In parallel with climate change, the loss of biodiversity is a frequently discussed topic at political, economic, social and environmental forums. Most of biodiversity and ecosystem benefits are public goods that have no price (TEEB, 2008). Since the biodiversity has public goods characteristics, i.e. non-excludability and non-rivalry, companies often see biodiversity conservation as a purely government responsibility, therefore their motivation in adopting environmentally responsible behavior is weak (TEEB, 2010). Most of private investors and managers consider biodiversity as a resource to be exploited or an environmental liability, rather than an asset to be conserved and managed in its own right (Bishop et al., 2008). The survey performed by the PricewaterhouseCoopers released that almost 27% global CEOs expressed concerns about the impacts of biodiversity loss on their business growth prospects (PwC, 2010).

The commons is tragedy (Hardin, 1968). Habitat loss and degradation, climate change, pollution, over-exploitation and the spread of invasive species are only some of the evidences of the global decline in biological diversity (TEEB, 2010a). Companies' activity is considered the major factor that causes biodiversity loss (Houdet et al., 2012). In fact, companies have two-way interactions with biodiversity and ecosystem services at the same time. These inter-relationships can occur either directly from the operations of a company or indirectly through company's partners within the supply chain.

The loss of biological diversity is a serious issue of the seafood sector, exposing it to several potential risks as ensuring continuous supply of raw material and satisfy customers' expectations on sustainable sourcing (Jenning et al., 2014). Overfishing is the most significant immediate threat to marine biodiversity (TEEB, 2010; Hiddink et al., 2008; MEA, 2005). According to FAO (2004), almost 10 percent of global fish stocks or species groups are significant depleted; nearly 25 percent are overexploited, depleted or recovering from depletion; and 52 percent are fully exploited. Lack of transparency is another weak aspect of seafood supply chain that affects marine ecosystem due to opened possibilities to launder easily illegal and unreported catches (Pramod et al., 2014). The oceans will be very different from today (Jenkins, 2003). Consequently, seafood businesses are more and more facing challenges in security fish material sourcing as well as fulfillment the demand of consumers in terms of sustainability.

This study observes the biodiversity management, the effect of the implementation of traceability systems and the role of green supply chain management in achieving a sustainable seafood supply chain. Green supply chain management is considered as an innovative model that can contribute to reduce the rate of biodiversity loss and increase traceability of products by providing tools to manage the risks and improve coordination between partners within chain (Guang Shi et al., 2012). The literature review is focused on tracking the fundamental background of the disciplines on which is based the development of research models.

Concerning research strategy, this thesis includes three individual projects, each addressing a particular objective. The first project attempts to develop a model for measuring the performance of corporate biodiversity management. The second one investigates the relationships between green supply chain management, traceability and biodiversity management. The third project aims to assess variations in the transaction characteristics and transaction costs of firms in the supply chain when the firms implement traceability systems.

The first and the third models have been empirical examined in the Vietnamese seafood supply chain. Face-to-face discussion during field trips and questionnaire surveys are used to gather primary data. The second model is limited at the development of propositions phase.

2. Findings of the study

The present study is mainly focused on assessing the measurement of corporate biodiversity management performance. Measuring performance of biodiversity management is an extremely challenging task due to complex relationship between businesses activities and biodiversity. Lack of sufficient data and subjectivity of human thought in evaluation process are the major limitations of existing measurement methods. To allow some degree of subjectivity from evaluator's preferences, the fuzzy set theory has been applied in developing the model methodology. The model consists of two main tasks: first to identify Key Performance Indicators; second to evaluate firms' performance with respect to the identified indicators and to form the ranking of firms.

The first task is to submit a master list of performance indicators on biodiversity management for evaluation to specialists (including academic experts and practitioners). The specialists are asked to validate the relevance of each indicator from the list. As a result, the KPIs for measuring the performance of biodiversity management include five indicators, i.e. (1) Biodiversity Business Assessment; (2) Biodiversity Management Policy; (3) Biodiversity Conservation Commitment; (4) Biodiversity Stewardship Practices; (5) Biodiversity Performance Reporting, and twenty sub-indicators.

Once the performance indicators have been validated, the second task is to realize a step-by-step measurement process. The evaluators from firms are required to express their preferences in linguistic terms for both importance of the indicators and

performance of the firm against the indicators, a process that allows room for subjectivity. These preferences are then used as inputs for performance evaluation process. The task is accomplished by applying fuzzy set theory. Fuzzy operators are used to calculate fuzzy scores for each firm. These scores are then converted into crisp values in order to rank firms according to their performance. The firm with the highest score is the one with the best performance in biodiversity management. The evaluating procedure consists of seven following steps:

Step 1: Assessing the importance of indicators and corporate performance

Step 2: Fuzzification the importance weights and performance ratings

Step 3: Determining fuzzy importance weights

Step 4: Calculating aggregate fuzzy weights

Step 5: Setting up the fuzzy performance matrix

Step 6: Computing the aggregate fuzzy scores

Step 7: Defuzzification and ranking

In order to illustrate how the model works, an empirical examination has been conducted with a case of five companies from the Vietnamese seafood supply chain. The results indicate that seafood companies perform better on indicators as Biodiversity Stewardship Practices (site-level impact management, green purchasing, supplier engagement, product design, reduction of emissions, water, energy consumption) and on the indicator Biodiversity Business Assessment (impact evaluation, dependence evaluation, risk assessment, opportunity perception). Indicators as Biodiversity Conservation Commitment (senior commitment, allocation resources, voluntary compensation of impacts) and Biodiversity Management Policy (integrating into strategy, parts of environmental management systems, biodiversity action plans) are less considered by interviewed companies. In addition, the interviewed companies are observed to take poor actions to announce their efforts in the biodiversity management to the local communities, customers, suppliers, stakeholders, and other non-government organizations.

Table 6.0.0 Summary of results

Research question	Model/ Hypothesis	Empirical result
RQ1.1: What are key performance indicators for measuring biodiversity management of firms? RQ1.2: What is procedure for the measurement of biodiversity management of firms?	The model consists of two components: - Identification of KPIs - Suggestion of a procedure for measuring the performance of corporate biodiversity management	- Five Key Performance Indicators - A seven steps measurement procedure based on fuzzy logic - An empirical examination from a case of five companies from the Vietnamese seafood supplies chain.
RQ2.1: How do GSCM practices improve the performance of biodiversity management? RQ2.2: How does the implementation of traceability system improve the biodiversity management performance? RQ2.3: How do GSCM practices enhance product traceability in the supply chain?	A theoretical model links GSCM, traceability and biodiversity management	Propositions: P1: GSCM practices implementation increases the performance of biodiversity management of firms. P2: There is a positive effect of the implementation of traceability on the performance of biodiversity management. P3: GSCM practices implementation improves traceability in the supply chain.
RQ3.1: How do the transaction features, transaction costs and transaction organization of firms change as they implement traceability systems? RQ3.2. Does the implementation of traceability systems increase the level of vertical integration among the economic agents in the supply chain?	The implementation of traceability systems leads to: - H1: An augmentation in transaction asset specificity among the agents that determine an increase in monitoring costs; - H2: A higher level of transaction transparency that decreases the level of transaction uncertainty; - H3: An increase in transaction frequency; - H4: An increase in monitoring costs; - H5: Shift transactions from market to hybrid forms, and transactions that are organized through hybrid forms should engender enforcement of such forms by introducing economic incentives through an increase in the price of raw materials and/or provide more contractual support.	H1: Supported H2: Supported H3: Not supported H4: Supported H5: Supported

Fuzzy logic is also incorporated with TOPSIS model to generate an overall performance score that allows ranking of firms as a straightforward task. The advantages of fuzzy TOPSIS are simple computation process, systematic procedure, a sound logic and distinguishability between benefit and the cost category criteria (Awasthi et al., 2010). Sensitivity analysis is designed to examine the influence of the judgments given by the evaluators for the performance scores of firms. The result of the sensitivity analysis indicates that the preferences of evaluators are relatively insensitive to the important weights of indicators.

The second model integrates biodiversity management, traceability and green supply chain management into a theoretical framework. Generally, GSCM practices implementation is proposed to have positive effects on the performance of biodiversity management and traceability. In turn, a better traceability can contribute to increase biodiversity performance. GSCM practices include five dimensions: internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery (Zhu et al., 2008a; Zhu and Sakis, 2004). The performance of food traceability system can be evaluated by its ability to improve the breadth, depth, precision and access of information (Golan et al., 2004; Bosona and Gebresenbet, 2013). The five KPIs are suggested within the first model to measure biodiversity management performance.

The implementation of traceability systems leads to variations in the transaction characteristics of the Vietnamese seafood supply chain. These variations in turn cause changes in the transaction costs and transaction governance structure of seafood export firms. The results indicate that the implementation of traceability systems leads to an increase in asset specificity (71%), a decrease in transaction uncertainty (60%) and low variation in the frequency of transactions (7%). The introduction of traceability also increases transaction costs (information costs, negotiating costs, system management costs, and control supplier activity costs). Price incentives, purchasing and production rule enforcement and liability serve as proxies for the vertical relationship, which show an increase in variation.

The survey also shows that almost all Vietnamese seafood companies use paper-based traceability systems. Small-scale characteristics of the fisheries industry impact the way in which seafood firms manage transactions in their supply chains. Complex supply chains in fisheries and trust-based transactions may affect application of suitable transaction governance structures within the chain. Seafood processors can purchase required raw materials from hundreds of small-scale fishers and middlemen on the spot market. This approach is time consuming and implies significant human effort and increase costs of transaction. Relational contract with oral agreements is the most popular transaction mode in the Vietnamese seafood supply chain.

3. Significance of results

The findings of this study should be of interest to readers both practitioners and academics in the domain of sustainable operations. This thesis may contribute to operational management discipline in three aspects, i.e. managerial implication, practical implication and theoretical implication. The following paragraphs present these implications, respectively.

The managerial implication of the thesis results is considerable. Businesses often face a challenge to find a set of performance indicators to measure the impact, dependence, risk and opportunity related to biodiversity. The presented five KPIs with twenty sub-indicators may contribute to realize a comprehensive assessment of interactions between businesses activities and biodiversity. There are also implications to put the measurement procedure in practice and implement the biodiversity management strategy with the aim to mitigate business risks and to gain opportunities. In addition, organizations can integrate this study to develop audit schemes and rank businesses in terms of the performance of biodiversity management. The strength of the present approach with fuzzy logic application is its ability to measure performance of corporate biodiversity management in the circumstance of lack of quantitative data as well as capturing the subjectivity of human preferences.

At the practical implication, the discussions on the potential risks and opportunities related to biodiversity loss rise attention of stakeholders on the biodiversity issues. Biodiversity is absolutely necessary for present and future operations of all types of

businesses regardless of their size, sector, or location. Companies themselves depend on biodiversity as input sources for production processes, while they simultaneously influence biodiversity through output elements. The interactions between biodiversity and businesses may be large or small, negative or positive, direct or indirect, but they are inevitable. It is hence becoming increasingly difficult to ignore the consequences of biodiversity loss on business operations. The improvement in corporate performance in terms of biodiversity conservation may help firms avoid business risks and gain business opportunities.

For the assessing the impact of traceability implementation on transaction governance structure, this study provides the empirical data from a developing country, particularly from the seafood supply chain. The results show that vertical integration in the supply chain is probably the best way to ensure the traceability of seafood products. However, to internalize transactions within a business entity requires additional capital and human resource, and significant investments in assets (tangible and intangible, as well as human). Only a few of the Vietnamese seafood companies are able to own their agricultural supplier. The purchasing model directly from fishermen helps businesses to clearly identify the origin of the products, but this purchasing model has disadvantages being time consuming and requiring increased cost and manpower. Raw material bought from commercial intermediaries can save capital, however traceability of purchased material may not be fully ensured.

Regarding to theoretical implication, this study can be considered as the first attempt to integrate biodiversity concerns in the framework of green supply chain management. The scope of GSCM has ranged from green purchasing to integrated supply chains flowing from supplier to manufactures to customer, and reverse logistics (Zhu and Sarkis, 2004). As an innovation of organizational philosophy, GSCM contributes to improve environmental performance of a company based on reduced pollution and less energy and resource consumption (Zhu et al., 2011). Even though, some aspects of biodiversity management such as habitat change and/or invasive alien species are rarely addressed in GSCM analyses. This research tries to integrate the core components of biodiversity, i.e. species, population, ecosystems, genes into the scope of GSCM as an extension.

4. Limitations

The findings from the measurement model of biodiversity management must be interpreted in the context of a number of potential limitations. The proposed model consists of two main tasks: first is to identify Key Performance Indicators; second is to evaluate firms' performance with respect to identified indicators and their ranking. The possible limitation can occur at the first task, the Key Performance Indicators may not reflect all aspects of businesses' biodiversity management activity. For example, the loss of biological diversity is generally addressed at local scale, while local threats to species may be driven by economic activities in somewhere else in the world (GRI, 2007). Even if a species is shown to decline at a site, this does not necessarily mean that it results from a company's activities (ISIS and F&C, 2004).

During the second task, the evaluator at firm is asked to express his/her preferences in linguistic terms for both importance of selected indicators and company's performance in respect of each indicators. These preferences are used as inputs for performance evaluation process. The aggregated fuzzy importance weight of each indicator is then determined as presented in the method section. These weightings become the measurement scales for all businesses. The potential drawback that may occur at this task is related to performance assessment if the evaluators tend to make the unfairness judgment about the performance of their firm. The firms' performance score essentially depends on how well the evaluators think their firm is doing with respect to the indicators. Although the model allows some degree of subjectivity in the choices, it is limited in adjusting the possible biases in the self-assessment.

Although this research provides empirical data on the impact of traceability implementation on transaction reorganization in the seafood supply chain, it has several limitations. First, the analyses are limited to the statistical description of the evaluation of seafood companies in terms of the variation in transaction attributes, transaction costs and transaction governance structure. Because of a small sample size, any statistical models to test the hypotheses are not be applied. Second, the considered in the research Vietnamese seafood companies are assumed to be leaders within the supply chain. In fact, Vietnamese exporters are suppliers in the globalized seafood supply chain. Further research is suggested to investigate transaction governance in

connection with partners in the downstream of the global supply chain, i.e., overseas importers, distributors and retailers.

For the second model, the study attempts to integrate biodiversity and traceability concerns into the framework of green supply chain management. In fact, the quantitative analysis has been set at the beginning of the project, but this objective was not reached in this thesis. Therefore, the study is limited from the building model stage. In the further research, the application of confirmatory factor analysis (CFA) and structural equation modeling (SEM) seem to be suitable methods for testing the model.

5. Suggestions for further research

Several works indicate that businesses may get new opportunities if they develop strategies to reduce potential risks related to biodiversity loss, otherwise they can failure to seize these opportunities (van den Burg and Bogaardt, 2014, GRI, 2007, MEA, 2005, WEF, 2010). Doing nothing for biodiversity means that companies do not gain competitive advantage associated with biodiversity conservation. If that is the case, the question is how the biodiversity management performance can be a source of sustained competitive advantage of firms.

According to the resource-based view (RBV) theory, a firm is said to have a sustained competitive advantage when it implements a value creating strategy that cannot be simultaneously implemented by any current or potential competitors, and when these other firms are unable to duplicate the benefits of this strategy. Built on two primary assumptions in terms of heterogeneity and immobility of strategic resources, the RBV model offers a framework for examination of the link between firm resources and sustained competitive advantage. Although a firm can control several resources in terms of physical capital, organizational capital and human capital, in order for a resource or capability of a sustained competitive advantage, a resource must possess four attributes, i.e. (1) it must be value; (2) it must be rare among a firm's current and potential entrant; (3) it must be imperfectly imitable; and (4) it must be non-substitutable (Barney, 1991). A recommendation for future research is to examine whether the biodiversity management performance meet these four must-have criteria for a source of competitive advantage.

In addition, Hart (1995) argues that the RBV still contains one serious omission: it systematically ignores the constraints and challenges imposed by the biophysical (natural) environment, which is one of the most important drivers of new resource and capability development for firms. To insert the natural environment aspect into the RBV, Hart proposes a natural-resource-based view of the firm (NRBV) – a theory of competitive advantage. Based on the NRBV theory, firms can gain competitive advantages in terms of lower costs; preempt competitors and future position when they implement three interconnection strategies, i.e. pollution prevention, product stewardship and sustainable development (Hart, 1995).

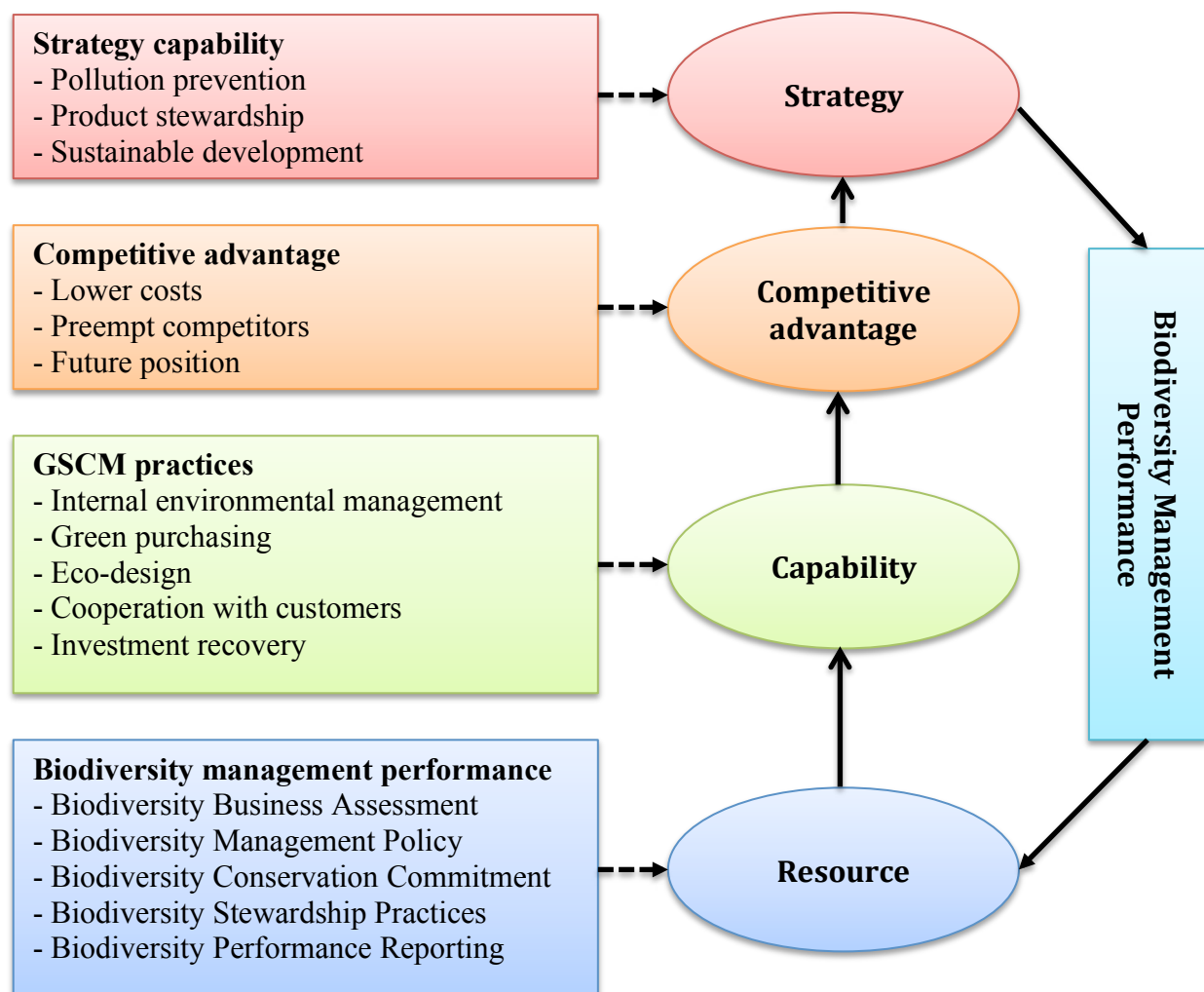


Figure 6.0.0 From biodiversity management to strategy formulation

Thus, it is very interesting to investigate how biodiversity management performance; green supply chain management, competitive advantage; and strategy capability are connected. That is an additional suggestion for the next step of further research. In this model, the performance of biodiversity management can be considered as a source of competitive advantage. GSCM practices can be firm's capabilities in terms of what the firm can do because of teams resources working together. Identified competitive advantages and strategy formulation can be applied the NRBV model (Hart, 1995) and the framework to form a strategy (Grant, 1991).

6. General conclusion

Measures the performance of corporate biodiversity management typically face the challenge of incomplete information because of the complexity of interrelations between biodiversity (genetic diversity, species, habitats, etc.) and businesses activities (procurement, manufacturing, transportation, sales, etc.) in nature. As a result, subjectivity in the judgments of evaluators is unavoidable. Without any doubt, most of information required for the measurement is very difficult to quantify. In such an unquantifiable information circumstance, it is forced for evaluators to provide the precise assessment in pure numerical values. Given the bounded of human thought for the complexity of things, one usually cannot give the accurate judgments for the things. One may feel more confident to give interval judgments rather than expressing his/her preferences in the form of single numeric. Accordingly, linguistic terms such as "low importance" or "excellent performance" can be better to capture some degree of subjectivity during the judgment process. Therefore, linguistic variables are suitable for measures the performance of corporate biodiversity management based upon the advantages of fuzzy set theory.

The interactions between biodiversity and businesses are perhaps small or large, negative or positive, direct or indirect, but they are inevitable. Biodiversity business interactions occur at all levels of a supply chain. Therefore, biodiversity management needs to be implemented at all chain levels. The core components of biodiversity, i.e. species, population, ecosystems, genes can be integrated into the framework of green

supply chain management in order to reduce habitat change, pollution, climate change, overexploitation of resources, and invasive alien species. GSCM is considered as an innovation of organizational philosophy that may have positive effects on the performance of corporate biodiversity management by reducing pollution, consuming less energy and resources through eco-design, green purchasing, internal environmental management, cooperation with customers and investment recovery.

Traceability system is an important component of supply chain management that makes strong linkages between upstream and downstream actors in the chain, which is crucial required to get deeper and to share information through the flows of a product including biodiversity attributes. The implementation of traceability systems results in the reorganization of transaction governance between firms in the supply chain. Specifically, the traceability systems implementation leads to an increase in asset specificity, a decrease in transaction uncertainty and low variation in the frequency of transactions. Moreover, the introduction of traceability has also increased transaction costs that include information costs, negotiating costs, system management costs, and control supplier activity costs.

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<http://www.ntsseafoods.com.vn/index.php>

<http://www.haivuong.com>

<http://nhatrangseafoods.vn>

<http://www.cafico.vn/vn/default.aspx>

APPENDICES

Appendix 1 Drivers of biodiversity loss in marine ecosystems

Problem	Reason	Description
Unsustainable fishing: - 53% of the world's fisheries are fully exploited, and 32% are overexploited, depleted, or recovering from depletion. - Most of the top ten marine fisheries, accounting for about 30% of all capture fisheries production, are fully exploited or overexploited. - Several important commercial fish populations have declined to the point where their survival is threatened. - Unless the current situation improves, stocks of all species currently fished for food are predicted to collapse by 2048.	Poor fisheries management	- In many cases, fisheries rules, regulations and enforcement measures are not efficient; fishing capacity and efforts are not sufficiently limited or controlled. - Another important issue is that today's fishing activities often occur far from the eye of regulators and consumers.
	Pirate fishing	Illegal, Unreported and Unregulated fishing (IUU) fishing is a serious global problem that contributes to overfishing, creates unfair competition, and impedes sustainable fisheries.
	Massive bycatch	- Large industrial vessels, small artisanal boats, coastal fisheries, high seas fisheries... all around the world, fishing catches far more than is needed or wanted. - The main reason that bycatch occurs is because modern fishing gear is very strong, often covers an extensive area and can be highly unselective - meaning it catches not only the target species but also many other creatures as well.
	Destructive fishing practices	Many fishing practices are extremely destructive to delicate habitats - particularly vital fish breeding grounds like coral reefs seagrass meadows, for examples bottom trawling, cyanide fishing, dynamite fishing, and ghost fishing.
Aquaculture: Poorly managed aquaculture can lead to a string of unintended impacts that place humans and wildlife in harm's way.	Chemical inputs	Excessive use of chemicals—such as antibiotics, antifoulants and pesticides—or the use of banned chemicals can have unintended consequences for marine organisms and human health.
	Disease and parasites	Viruses and parasites that transfer between farmed and wild species as well as among farmed species present a risk to wild populations or other farms.
	Escapes	Escaped farmed species can compete with wild fish and interbreed with local wild stocks of the same population, altering the overall pool of genetic diversity.
	Feed	Aquaculture must responsibly source and reduce its dependency upon fishmeal and fish oil—a primary

		ingredient in feed—so as not to put additional pressure on the world's fisheries. Fish caught to make fishmeal and fish oil currently represent one-third of the global fish harvest.
	Nutrient pollution and carrying capacity	Excess food and fish waste increase the levels of nutrients in the water and have the potential to lead to oxygen-deprived waters that stress aquatic life.
	Social issues	Seafood farming often employs a large number of workers on farms and in processing plants, potentially placing labor practices and worker rights under public scrutiny. Additionally, conflicts can arise among users of the shared coastal environment.
	Land conversion and degradation	Clearing of land for agriculture feed sources affects high conservation value areas.
Inadequate protection: Only 3.4% of the world's oceans have been designated as protected - compared to almost 16% of our planet's land area.	Not enough protection and lack of proper management	- Marine species and habitats do not exist in isolation. They are part of an intricate web of ocean life where the health of one species is dependent on the health of the entire system. Therefore it makes sense to protect the system as a whole rather than looking solely at single species or one patch of reef. Yet, of the small number of marine protected areas that have been established, most exist in isolation. - Worse, the vast majority suffers from little or no management at all. Fewer than 10% achieving their management goals and objectives, almost all are open to tourism and recreation, and 90% are open to fishing.
	Conflicting priorities	- Marine park managers - and the governments and non-profit organizations that support them - must often juggle conflicting national and local priorities coming from a variety of sectors, such as industry, artisanal fishers, commercial fishers, tour operators, local town councils, farmers, and scientific researchers. - In addition, park managers often have extremely limited budgets and staff, and frequently rely on community participation and volunteers to carry out much of the essential work. - This means that in most cases, park staff cannot adequately patrol marine reserves, carry out essential research, or implement effective conservation strategies.
	Sensitive habitats at risk	Of particular concern is the current lack of protection for a number of sensitive habitats and areas. These include coral reefs, mangroves forests, deep seas, the high seas, particularly sensitive areas at risk from shipping activities, breeding grounds for commercially important fish.
Pollution: Over 80% of marine pollution comes from	Oil	Oil spills cause huge damage to the marine environment - but in fact are responsible for only around 12% of the oil entering the seas each year. According to a study by the US National Research Council, 36% comes down drains and

land-based activities. From plastic bags to pesticides - most of the waste we produce on land eventually reaches the oceans, either through deliberate dumping or from run-off through drains and rivers.		rivers as waste and runoff from cities and industry.
	Fertilizers	Fertilizer runoff from farms and lawns is a huge problem for coastal areas. The extra nutrients cause eutrophication - flourishing of algal blooms that deplete the water's dissolved oxygen and suffocate other marine life.
	Seas of garbage	- Solid garbage also makes its way to the ocean. Plastic bags, balloons, glass bottles, shoes, packaging material – if not disposed of correctly, almost everything we throw away can reach the sea. - Plastic garbage, which decomposes very slowly, is often mistaken for food by marine animals. High concentrations of plastic material, particularly plastic bags, have been found blocking the breathing passages and stomachs of many marine species, including whales, dolphins, seals, puffins, and turtles. Plastic six-pack rings for drink bottles can also choke marine animals. - This garbage can also come back to shore, where it pollutes beaches and other coastal habitats.
	Sewage disposal	In many parts of the world, sewage flows untreated, or under-treated, into the ocean. For example, 80% of urban sewage discharged into the Mediterranean Sea is untreated. This sewage can also lead to eutrophication. In addition, it can cause human disease and lead to beach closures.
	Toxic chemicals	- Almost every marine organism, from the tiniest plankton to whales and polar bears, is contaminated with man-made chemicals, such as pesticides and chemicals used in common consumer products. - Some of these chemicals enter the sea through deliberate dumping. For centuries, the oceans have been a convenient dumping ground for waste generated on land. This continued until the 1970s, with dumping at sea the accepted practice for disposal of nearly everything, including toxic material such as pesticides, chemical weapons, and radioactive waste.
Climate change: Marine species affected by climate change include plankton - which forms the basis of marine food chains - corals, fish, polar bears, walruses, seals, sea lions, penguins, and seabirds. The Intergovernmental Panel on Climate Change predicts a further rise of between 1.4°C and 5.8°C by the end of the century. Climate change	Coral bleaching	One of the most visually dramatic effects of climate change is coral bleaching, a stress response caused by high water temperatures that can lead to coral death. Recent years have seen widespread and severe coral bleaching episodes around the world, with coral mortality reaching 70% in some regions.
	Stormy weather	Tropical storms and heavier rainfall may increase and so too would the consequent physical damage to coral reefs, other coastal ecosystems, and coastal communities.
	Moving homes	As the oceans warm, the location of the ideal water temperature may shift for many species.
	Altered lifestyles	- Rising temperatures can directly affect the metabolism, life cycle, and behavior of marine species. For many species, temperature serves as a cue for reproduction. Clearly, changes in sea temperature could affect their successful breeding.

could therefore well be the knock-out punch for many species which are already under stress from overfishing and habitat loss.		- The number of male and female offspring is determined by temperature for marine turtles, as well as some fish and copepods (tiny shrimp-like animals on which many other marine animals feed). Changing climate could therefore skew sex ratios and threaten population survival.
	Rising sea levels	- Global sea levels may rise by as much as 69cm during the next 100 years due to melting of glaciers and polar ice, and thermal expansion of warmer water. - Rising water levels will have serious impacts on marine ecosystems. The amount of light reaching offshore plants and algae dependent on photosynthesis could be reduced, while coastal habitats are already being flooded. - Rapid sea level rise will likely be the greatest climate change challenge to mangrove ecosystems, which require stable sea levels for long-term survival.
	Decreased mixing	Vertical mixing in the ocean is important for many reasons, including transporting nutrients from deep to shallow waters, and surface water rich in oxygen into deeper waters. In some areas, changes to ocean temperature profiles induced by climate change are causing a reduction in the amount of mixing, and for example, reducing oxygen levels at depth.
	Acidic oceans	- After absorbing a large proportion of the carbon dioxide released by human activities, the oceans are becoming acidic. If it weren't for the oceans, the level of carbon dioxide in the atmosphere would be much higher. - The effect could be that fish, squid, and other gilled marine animals may find it harder to "breathe", as the dissolved oxygen essential for their life becomes difficult to extract as water becomes more acidic. And shellfish, crabs, lobsters, and corals may find it more difficult to build their calcium carbonate shells. In some areas, calcium carbonate shells may even start to dissolve.

Source: World Wildlife Fund - WWF (2015)

Appendix 2 Example of biodiversity management from RICOH GROUP

Ricoh is a global technology company that has been transforming the way people work for more than 80 years. Under its corporate tagline – *imagine. change.* – Ricoh continues to empower companies and individuals with services and technologies that inspire innovation, enhance sustainability and boost business growth. These include document management systems, IT services, production print solutions, digital cameras, and industrial systems. Headquartered in Tokyo, Ricoh Group operates in over 190 countries. In the financial year ending March 2015, Ricoh Group had worldwide sales of 2,231 billion yen (approx. 18.5 billion USD).

Ricoh preserves biodiversity by maintaining and improving the self-recovery capabilities of the global environment through their business activities as well as their social contribution activities.

Ricoh Group Biodiversity Policy

Society has developed thanks to the earth's abundant natural resources. However, we recognize that the very diversity of life that has supported our environment is in decline; so, in response, we have formulated this biodiversity policy.

Basic Policy

Given that we gain a lot of benefit from living things and pursue business activities that have an impact on biodiversity, we will reduce the impact of our activities on biodiversity and engage proactively in its protection.

1. Management tasks

Treat biodiversity protection as essential for ensuring the sustainable growth of the company, and implement sustainable environmental management.

2. Understanding and reducing impact

Assess, grasp, analyze, and set numerical targets for the impact on biodiversity of all our business activities, including raw materials procurement, and work continuously to reduce this impact.

3. Implementation

Give priority to measures with a high degree of impact and effectiveness from a biodiversity and business perspective.

4. Developing new technologies

Aim to realize a sustainable society, develop technologies that make use of biological resources, learn from the mechanisms of ecosystems and the nature of living things, and employ the knowledge gained to develop technologies and sustainable production processes.

5. Working with local communities

From the perspective of sustainable development, work not only with government organizations, but also with local residents, NGOs, and other stakeholders to promote the protection of the precious global ecosystems and of the biodiversity of countries and regions where we conduct business.

6. Involving each person

By getting executives to take the lead and implementing Group-wide educational initiatives, enhance recognition of the importance of biodiversity among all employees to enable them to act independently.

7. Expanding the scope of our activities

By collaborating with customers, suppliers, other companies, NGOs, international organisations, and so on, share information, knowledge and experience concerning biodiversity, and expand the scope of our protection activities.

8. Communication

Contribute to raising awareness of biodiversity protection among people at large by sharing the experience of our activities and achievements proactively.

Biodiversity conservation

As indicated in Ricoh's Environmental Principles, introduced in 1992, the Ricoh Group does not see environmental conservation activities and business management as two incompatible issues. Instead, we see conservation of the global environment as a natural responsibility as a global citizen. Conservation of the global environment impact of our business operations and products on the environment but also to maintain and improve the self-recovery capabilities of the global environment. Recognizing that our businesses depend on the global ecosystem and that biodiversity plays an indispensable role in the health of the ecosystem, the Ricoh Group laid down the Ricoh Group Biodiversity Guidelines. This is to further develop the various conservation measures we have been taking, such as ecosystem conservation activities, promotion of voluntary activities by employees, and "social contribution in environmental conservation" (e.g., awareness-raising programs to encourage other community members), and ecosystem preservation through CDM projects. To these measures, we have added measures to reduce the impact of our business activities on biodiversity by using the new policy as our basic guideline on biodiversity preservation.

Ricoh Group Biodiversity Guidelines

Human society largely depends on the ecosystem. But our society has had a tremendous impact on the ecosystem, placing a wide-scale burden upon it. In the past 50 years, the biodiversity has been badly degraded due to human activities. If we do not act now to start conserving the biodiversity and change our way of using natural resources to a more sustainable approach, the survival of human society may even be at risk. To articulate this idea in a concrete form, the Ricoh Group laid down the Ricoh Group Biodiversity Guidelines in March 2009. The Guidelines combined the existing measures of the Group toward global environmental conservation and new measures for biodiversity conservation to help develop and promote specific activities. With these

Guidelines, the Ricoh Group will continue our effort to realize an affluent society built on a sustainable global environment.

Development of biodiversity conservation activities

Biodiversity conservation activities at the Ricoh Group first started in 1999, when we started the Forest Ecosystem Conservation Project with environmental NGOs and local communities throughout the world. This was to recognize our responsibility as a manufacturer of products that uses a good amount of paper to engage in the conservation of forest resources. Also in 1999, we started the Environmental Volunteer Leader Development Program to encourage employees to take initiative in environmental conservation activities. In 2003, we laid down the Environmental Standards for Paper Product Procurement as a measure for conservation of precious natural forest throughout the world. Since 2006, the Ricoh Global Environment Month Symposium has been help with biodiversity as the theme to promote understanding and cooperation in biodiversity conservation activities among different corporations. In 2008, when the Japan Business Initiative for Conservation and Sustainable Use of Biodiversity (JBIB) was established, we helped the organisation as one of the founding members with the goal of promoting cooperation and active involvement of various companies in biodiversity conservation.

Declaration on Business

Ricoh signed the Leadership Declaration on the “ Business and Biodiversity Initiative” at the ninth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP9), held in Germany in May 2008. This initiative led by German Government calls on businesses to take leading action to reduce degradation of biodiversity. The signatory corporations set voluntary goals, carry out assessment of the impact of their business activities on biodiversity, and incorporate countermeasures into environmental management systems.

Raising the awareness of employees of the relationships humans share with nature

The survival of human society is possible only due to biodiversity. If we are to realize a sustainable society, therefore, it is essential that each and every one of us gets actively involved in the conservation of biodiversity, the basis of the global environment's self-recovery capabilities. Based on the Ricoh Group Biodiversity Guidelines created in March 2009, we published the Biodiversity Conservation Activity Handbook to teach our employees the values of biodiversity and show them what each of them can do to conserve biodiversity. In April 2009, we started a website for environmental information called "Gaiaia", to encourage employees to take an interest in biodiversity conservation. In addition to these programs, we are planning to offer study sessions and fieldwork sessions to learn and understand the mechanisms of the global environment from the perspective of other life forms on Earth. We will continue to provide opportunities for employees to raise their awareness and take good actions to conserve biodiversity in the course of their daily work and private life.

Mapping of relationship between business activities and biodiversity

The Ricoh Group created a map to show the exact relationship between our business activities and biodiversity. The "Map of Corporate Activities and Biodiversity" follows the JBIB format to show the relationship between corporate activities, such as product lifecycle and land use, and biodiversity at a glance. From the map, we learned that the copier industry has a large impact on the ecosystem during procurement of raw materials (e.g., paper pulp and metals) and during manufacturing (particularly in regard to water resources). We will use the information from the map in our conservation activities in close cooperation with each business division.

Source: Adapted from RICOH (2009)

Appendix 3 Questionnaire for Specialist survey

Question 1: Please identify indicators/ sub-indicators that are relevant to measure performance of biodiversity management of firm.

Indicator 1. Company analyzes the interaction between business activities and biodiversity.

☐ Relevant

☐ Non-relevant

Sub-indicators	Relevant	
	Yes	No
Company evaluates its impacts of business activities on biodiversity		
Company evaluates its dependence of business activities on biodiversity		
Company assesses business risks associated with biodiversity		
Company assesses business opportunity associated with biodiversity		

Indicator 2. Company states biodiversity management policy in business activities.

☐ Relevant

☐ Non-relevant

Sub-indicators	Relevant	
	Yes	No
Company integrates biodiversity consideration into business strategies		
Biodiversity management plays a role in the environmental management system		
Company develops policy/ project/ plan for conservation biodiversity		

Indicator 3. Company commits to conserve biodiversity in business activities.☐ Relevant☐ Non-relevant

Sub-indicators	Relevant	
	Yes	No
Company has biodiversity management commitments in place and approved by senior management		
Company allocates resources to ensure biodiversity management implementation		
Company guarantees the fair and equitable sharing benefits from the used of genetic resources		
Company commits the voluntarily compensation to the impacts of the activities		

Indicator 4. Company implements biodiversity management in the practice of operations.☐ Relevant☐ Non-relevant

Sub-indicators	Relevant	
	Yes	No
Biodiversity issues are managed at site-level and/or company-level through inclusion space required for buildings: offices, production site, storage, showroom, and other facilities		
Company ensures for sustainable sourcing of raw materials		
Suppliers are engaged into the company's biodiversity policy		
Product design considers reduction demand on natural resources and carbon footprint		
Manufacturing processes aim to reduce of emissions, water and energy consumption		

The staffs are trained for saving energy, water		

Indicator 5. Company makes publicly report in terms of biodiversity management.

☐ Relevant

☐ Non-relevant

Sub-indicators	Relevant	
	Yes	No
Company develops collaborations with external stakeholders including local community in conservation biodiversity		
Company analyzes feedback related to biodiversity from customers, stakeholders, suppliers		
Company deliveries improvements in terms of biodiversity management on stakeholders including shareholders, customers, suppliers, NGOs, publicly reporting		

Question 2: Please add any other indicators/ sub-indicators that you believe are relevant but not listed.

PART I: GENERAL FEATURES OF THE FIRM

Please provide some following general features of the firm

1. Name of firm:
2. Address:
3. Legal configuration of firm:
4. Number of employees:
5. Year of operation:
6. Approximation yearly turnover:
7. Main products:

PART II: ASSESSMENT OF PERFORMANCE

This is a list of indicators and sub-indicators to be considered for measuring performance of biodiversity management of firm. Please specify your opinion of how each of indicator performs at your company as:

- P ~ Poor performance
 F ~ Fair Performance
 G ~ Good performance
 VG ~ Very good performance
 EX ~ Excellent performance

ID	Indicator	Performance				
		P	F	G	VG	EX
I.1	Company evaluates the impacts of business activities on biodiversity					
I.2	Company evaluates the dependence of business activities on biodiversity					
I.3	Company assesses business risks associated with					

	biodiversity					
I.4	Company assesses business opportunity associated with biodiversity					
II.1	Company integrates biodiversity consideration into the strategies					
II.2	Biodiversity management plays a role in the environmental management system					
II.3	Company develops policy/ project/ plan for conservation biodiversity					
III.1	Company has biodiversity management commitments in place and approved by senior management					
III.2	Company allocates resources to ensure biodiversity management implementation					
III.3	Company guarantees the fair and equitable sharing benefits from the used of genetic resources					
III.4	Company commits the voluntarily compensation to the impacts of the activities					
IV.1	Biodiversity issues are managed at site-level and/or company-level through inclusion space required for buildings: offices, production site, storage, showroom, and other facilities					
IV.2	Company ensures for sustainable sourcing of raw materials					
IV.3	Suppliers are engaged into the company's biodiversity policy					
IV.4	Product design considers reduction demand on natural resources and carbon footprint					
IV.5	Manufacturing processes aim to reduce of emissions, water and energy consumption					
IV.6	The staffs are trained for saving energy, water					
V.1	Company develops collaborations with external stakeholders including local community in					

	conservation biodiversity					
V.2	Company analyzes feedback related to biodiversity from customer, stakeholder, suppliers					
V.3	Company deliveries improvements in terms of biodiversity management on stakeholders including shareholders, customers, suppliers, NGOs, publicly reporting					

PART III: ASSESSMENT OF IMPORTANCE

This is a list of indicators and sub-indicators to be considered for measuring performance of biodiversity management of firm. Please specify the importance of each indicator and sub-indicator as:

- VH ~ Very High Importance
- H ~ High Importance
- M ~ Moderate Importance
- L ~ Low Importance
- VL ~ Very Low Importance

Indicator I: Biodiversity Business Assessment

ID	Description	Important				
		VL	L	M	H	VH
I	Company analyzes the interaction between business activities and biodiversity					
I.1	Company evaluates the impacts of business activities on biodiversity					
I.2	Company evaluates the dependence of business activities on biodiversity					
I.3	Company assesses business risks associated with biodiversity					

I.4	Company assesses business opportunity associated with biodiversity					

Indicator II: Biodiversity Management Policy

ID	Description	Important				
		VL	L	M	H	VH
II	Company develops biodiversity management policy in business activities					
II.1	Company integrates biodiversity consideration into the strategies					
II.2	Biodiversity management plays a role in the environmental management system					
II.3	Company develops policy/ project/ plan for conservation biodiversity					

Indicator III: Biodiversity Conservation Commitment

ID	Description	Important				
		VL	L	M	H	VH
III	Company commits to conserve biodiversity in business activities					
III.1	Company has biodiversity management commitments in place and approved by senior management					
III.2	Company allocates resources to ensure biodiversity management implementation					
III.3	Company guarantees the fair and equitable sharing benefits from the used of genetic resources					
III.4	Company commits the voluntarily compensation to the impacts of the activities					

Indicator IV: Biodiversity Stewardship Practices

ID	Description	Important				
		VL	L	M	H	VH
IV	Company implements biodiversity management in the practices of operations					
IV.1	Biodiversity issues are managed at site-level and/or company-level through inclusion space required for buildings: offices, production site, storage, showroom, and other facilities					
IV.2	Company ensures for sustainable sourcing of raw materials					
IV.3	Suppliers are engaged into the company's biodiversity policy					
IV.4	Product design considers reduction demand on natural resources and carbon footprint					
IV.5	Manufacturing processes aim to reduce of emissions, water and energy consumption					
IV.6	The staffs are trained for saving energy, water					

Indicator V: Biodiversity Performance Reporting

ID	Description	Important				
		VL	L	M	H	VH
V	Company makes publicly report in terms of biodiversity management					
V.1	Company develops collaborations with external stakeholders including local community in conservation biodiversity					
V.2	Company analyzes feedback related to biodiversity					

	from customer, stakeholder, suppliers					
V.3	Company deliveries improvements in terms of biodiversity management on stakeholders including shareholders, customers, suppliers, NGOs, publicly reporting					

PART IV: INFORMATION OF RESPONDENT

1. Name:
2. Year of working:
3. Position:
4. Experience at the position:
5. Email:
6. Phone number:

Appendix 5 Questionnaire survey for traceability and transaction governance

PART I GENERAL FEATURES OF THE FIRM

Please provide some following general features of the firm

1. Name of firm:

Address:

2. Legal configuration of firm:

☐ Private

☐ Limited

☐ Foreign investment

☐ Joint-stock

☐ State

☐ Other

3. Number of employees:

4. Year of operation:

5. Main products:

6. Approximation yearly turnover (in USD):

in which, percentage of export: %

7. Which certification does the firm have?

☐ HACCP

☐ ISO 9001: 2000

☐ ISO 14000

☐ ISO 22000

☐ Global GAP

☐ HALAL

☐ MSC

☐ Other ...

☐ BAP

☐ BRC

☐ IFS

8. Which source of raw material does the firm collect from?

☐ Directly from fishers and/or aquaculture farmers: %

☐ Middlemen: %

☐ Agent: %

☐ Import: %

☐ Other: %

PART II THE FEATURES OF TRACEABILITY SYSTEM

1. Please specify the currently traceability system which the firm is implementing?

☐ No traceability

☐ Paper based

☐ Radio Frequency Identification based

☐ Barcode based

☐ GPS based

☐ Other

2. Please give the score of the motivation of implementing traceability system at the firm?

	Very low	Low	Medium	High	Very high
Improve food safety					
Improve quality of product					
Higher price for final product					
Improve competitiveness					
Customer request					
Market requirement					
Investor requirement					
Legal requirement					
Pressure from social and environmental organizations					
Liability of firm in the supply chain					
Efficiency of supply chain management					
Sustainable concerns					
Biodiversity concerns					
Other					

3. Please indicate the scope of traceability implementation at the firm:

- ☐ Not implementing traceability
- ☐ Internal of the firm
- ☐ One step up – one step down
- ☐ Whole supply chain

PART III THE VARIATION OF TRANSACTION CHARACTERISTICS

Please rate the variation of the following factors when the firm implements traceability system:

	Very low	Low	Medium	High	Very high
Long business relationships with suppliers					
Difficulty in substitution of certified suppliers					
Training of suppliers for certification					
The variation in processing facilities					
Traceability system implementation					
Certification					
The planning of the system					
The certified suppliers closeness					
Timing of exchanged information					
Quantity of exchanged information					
Precision of exchanged information					
Lapse time between transactions					

PART IV THE VARIATION OF TRANSACTION COSTS

Please rate the variation of the following factors when the firm implements traceability system:

	Very low	Low	Medium	High	Very high
Information cost					
Negotiating cost					
Cost of managing the system					
Supplier activity controls					
Raw materials controls					

PART V THE VARIATION OF PROXIES OF VERTICAL COORDINATION

1. Please rate the variation of the following factors when the firm implements traceability system:

	Very low	Low	Medium	High	Very high
Raw material price variation					
Price incentives					
Purchasing and production rules enforcement					
Liability degree variation					
Contracts formalization					

2. Please indicate the ability to supply of raw materials

- ☐ Completely purchasing from the market
- ☐ Completely self-sufficient
- ☐ Partly self-sufficient

2.1. In the case partly self-sufficient of raw materials, please indicate the percentage of self-sufficiency: (%)

3. Which contract mode is the firm applying to purchase raw material?

- ☐ Short-term contract %
- ☐ Long-term contract %
- ☐ Verbal agreement %
- ☐ No commitment %

PART VI INFORMATION OF RESPONDENT

1. Name:
2. Age:
3. Year of working:
4. Position:
5. Experience:
6. Email:
7. Phone number: