A Risk Management Tool for the Reverse Supply Chain Network

A Thesis Presented to

The Faculty of California Polytechnic State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science in Engineering

With Specialization in

Integrated Technology Management

By

Sheeva Banisalam

June 2008

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APPROVAL PAGE

TITLE: A Risk Management Tool for the Reverse Supply Chain Network

AUTHOR Sheeva Banisalam

DATE

SUBMITTED: June 6, 2008

Dr. Roya Javadpour

Advisor or Committee Chair

Signature

Dr. Unny Menon

Committee Member

Signature

Dr. Liz Schlemer

Committee Member

Signature

ABSTRACT

A Risk Management Tool for the Reverse Supply Chain Network

Sheeva Banisalam

The forward and reverse supply chains have unique characteristics that vary among different organizations. Most organizations manage and quantify risks in the forward supply chain by utilizing various available risk management tools. These risk management tools have been developed solely for the forward supply chain. This research presents the development and implementation of a risk management tool to be used to manage and quantify risks specifically in the reverse supply chain.

Implementation of this tool at Company ABC demonstrates how the risk management tool is used in order to be beneficial to the organization. The tool is designed to be easily implemented at minimal cost and serves as a valuable tool for personnel faced with important and costly decisions regarding risk occurrence in the reverse supply chain network.

ACKNOWLEDGEMENTS

I would like to thank my thesis advisor Dr. Roya Javadpour at Cal Poly for her time and effort to help me complete this thesis. I am extremely grateful for her guidance and support. I would also like to thank Dr. Unny Menon and Dr. Liz Schlemer for their inputs, comments and suggestions to improve this thesis.

Finally, I am forever grateful for the unconditional support from my family and friends, especially my mother and father, who have been there for me during every step of my journey.

TABLE OF CONTENTS

LIST OF FIGURES	viii
LIST OF TABLES	ix
CHAPTER 1: INTRODUCTION.....	1
1.1 Overview.....	1
1.2 Supply Chain Overview.....	1
1.3 Reverse Supply Chain.....	2
1.4 Risk Management	4
1.5 Supply Chain Risk Management	6
1.6 Reverse Supply Chain Risk Management	8
1.7 Problem Statement.....	8
1.8 Objectives	9
CHAPTER 2: LITERATURE REVIEW	10
2.1 Risks in Supply Networks.....	10
2.2 Risk Management Tools and Models	12
2.3 Risk Quantification in Supply Chains	15
2.5 Risk Minimization	16
2.7 Risk Assessment in Various Decision Making.....	18
2.6 Risk Uncertainty in Supply Networks	19
CHAPTER 3: METHODOLOGY	23
3.1 Introduction.....	23
3.2 Purpose of Risk Management.....	23
3.3 Assumptions.....	24
3.4 Steps for Risk Management in the Reverse Supply Chain	25
3.4.1 <i>First Step: Map Reverse Supply Chain Network</i>	26
3.4.2 <i>Second Step: Identification of Risks</i>	27
3.4.3 <i>Third Step: Map Risk Impact</i>	30
3.4.4 <i>Fourth Step: Assess and Quantify Risks</i>	31
3.4.5 <i>Fifth Step: Assess and Quantify Loss</i>	33
3.4.6 <i>Sixth Step: Managing Risk</i>	36
CHAPTER 4: IMPLEMENTATION	38
4.1 Introduction.....	38
4.2 Map Reverse Supply Chain Network	39
4.3 Identification of Risks.....	40
4.4 Map Risk Impact.....	41
4.5 Assess and Quantify Risk	42
4.6 Asses and Quantify Loss.....	43
4.7 Manage Risk	47
4.8 Conclusion	48
CHAPTER 5: CONCLUSION.....	50

5.1 Risk Management Framework.....	50
5.2 Contributions	51
CHAPTER 6: FUTURE RESEARCH.....	53
WORKS CITED.....	54
APPENDIX A: SENSITIVITY ANALYSIS.....	546

LIST OF FIGURES

CHAPTER 1

Figure 1.1: Supply Chain Process.....	2
Figure 1.2: Reverse Supply Chain Process	3
Figure 1.3: Risk Management Process.....	4

CHAPTER 2

Figure 2.1: Risk in Global Supply Chain.....	11
Figure 2.2: Supply Network Risk Tool.....	12
Figure 2.3: Interpretive Structural Modeling for Risk Mitigation in Supply Chain	13
Figure 2.4: Summary of Reverse Supply Chain Investment.....	20

CHAPTER 3

Figure 3.1: Risk Management Tool	25
Figure 3.2: Step 1 of Mapping Risk Impact.....	30
Figure 3.3: Step 2 of Mapping Risk Impact.....	31
Figure 3.4: Step 3 of Mapping Risk Impact.....	31

CHAPTER 4

Figure 4.1: Map of Reverse Supply Chain Network.....	39
Figure 4.2: Map of Risk Impact.....	42
Figure 4.3: Risk Management Model	49

LIST OF TABLES

CHAPTER 2

Table 2.1: Types of Risks and Descriptions	11
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CHAPTER 3

Table 3.1: Impact of Risk Scoring Table	32
Table 3.2: Probability of Risk Scoring Table	32
Table 3.3: Total Risk Score	33
Table 3.4: Impact of Loss Scoring Table.....	34

CHAPTER 4

Table 4.1: Types of Risk and Descriptions.....	40
Table 4.2: Types of Loss and Descriptions.....	41
Table 4.3: Risk Quantification.....	43
Table 4.4: Loss Quantification.....	43
Table 4.5: Risk Variables.....	44
Table 4.6: Loss Variables	45
Table 4.7: Risk Equations.....	45
Table 4.8: Risk Score in Descending Order.....	46
Table 4.9: Score 3-2-1.....	47
Table 4.10: Score 9-3-1.....	47
Table 4.11: Sensitivity Analysis	47

CHAPTER 1

Introduction

1.1 Overview

Once lightly regarded, the flow of product returns is becoming a significant concern for many manufacturers. The total value of products returned by consumers in the U.S. is enormous - estimated at \$100 billion annually (Blackburn et al. 2004). When products are returned by the customers, the manufacturer must decide how to most profitably dispose of the product: reuse as-is, refurbish, salvage, or recycle. There are many risks involved in the process of returned materials. Risk management in the reverse supply chain is relatively unexplored and underdeveloped. A major component in any effort to increase the efficiency and effectiveness of the flow of products back to the manufacturer must be the concurrent development of risk management system to control risk in the reverse supply chain.

This research is directed at the creation of a new risk management tool to help industries improve their material flow efficiency within their reverse supply chain. The remainder of this chapter covers some background information relevant to the work, and further defining and justifying the problem to be dealt with.

1.2 Supply Chain Overview

The supply chain is defined as an integrated manufacturing process wherein raw materials are manufactured into final products, then delivered to customers. This chain is

traditionally characterized by a forward flow of materials (Beamon 1999). Figure 1.1 illustrates the structure of the traditional supply chain (Blackburn et al. 2004).

Figure 1.1 Supply Chain Process

The supply chain concept arose from a number of changes in the manufacturing environment, including the rising costs of manufacturing, the shrinking resources of manufacturing bases, shortened product life cycles, and the globalization of market economies (Beamon 1998). The primary objective of supply chain management is to improve performance in areas such as procurement and to fulfill customer demands through the most efficient use of resources, including distribution capacity, inventory and labor (Kocabasoglu et al. 2007).

1.3 Reverse Supply Chain

The reverse supply chain refers to the series of activities necessary to remove new or used products from a customer for the purpose of recycling, remanufacturing, and re-using the product (Kocabasoglu et al. 2007). This chain is traditionally characterized by a backward flow of materials. Figure 1.3 illustrates the structure of the reverse supply chain (Blackburn et al. 2004).

Figure 1.2 Reverse Supply Chain Process

The reverse supply chain entails five sequential steps (Blackburn et al. 2004):

1. *Product Acquisition* - obtaining the used product from the user;
2. *Reverse Logistics* - transporting the products to a facility for inspecting, sorting and disposition;
3. *Inspection and Disposition* - assessing the condition of the return and making the most profitable decision for reuse;
4. *Remanufacturing* - returning the product to original specifications, also known as refurbishing;
5. *Marketing and Distribution* - creating secondary markets for the recovered products

Customers return products to the reseller (product acquisition), from where they are shipped to the returns evaluation location (reverse logistics) for credit issuance and product disposition (inspection and disposition). Diagnostic tests are performed to determine what disposal action recovers the most value from the returned product.

Products are remanufactured if considered cost effective, and sold in secondary markets for additional revenue. Some customers return products that are new and never used, therefore these products are returned to the forward distribution center. Products not reused or remanufactured are recycled or thrown out as waste (Blackburn et al. 2004).

The reverse supply chain has a positive impact on the environment by minimizing waste and maximizing resources (Beamon 1999). A well developed reverse supply chain systems offers the potential to make significant gains in environmental performance, while minimizing customer retention and maximizing product feedback.

1.4 Risk Management

Risk management is the structured approach of identifying risk, quantifying the likelihood of its occurrence, and measuring its potential effect on the business (Tohamy 2008). Risk management encompasses three processes: risk assessment, risk mitigation, and evaluation and assessment (Stoneburner et al. 2002). Figure 1.4 illustrates the steps required in the risk management process.

Figure 1.3 Risk Management Process

Risk assessment is the first process in the risk management methodology. Organizations use risk assessment to determine the extent of the potential threat and the risk associated with the system. The risk assessment methodology encompasses nine primary steps (Stoneburner et al. 2002).

Risk Assessment Activities

1. System Characterization
2. Threat Identification
3. Vulnerability Identification
4. Control Analysis
5. Likelihood Determination
6. Impact Analysis
7. Risk Determination
8. Control Recommendations
9. Results Documentation

Risk mitigation is the second process in the risk management methodology. It involves prioritizing, evaluating, and implementing the appropriate risk-reducing controls recommended from the risk assessment process. The risk mitigation methodology encompasses seven primary steps (Stoneburner et al. 2002).

Risk Mitigation Activities

1. Prioritize Actions
2. Evaluate Recommended Control Options
3. Conduct Cost-Benefit Analysis
4. Select Control
5. Assign Responsibility
6. Develop Safeguard Implementation Plan
7. Implement Selected Controls

Most organizations continue to develop and expand, which means that new risks will surface and risks previously mitigated may be a concern. Thus the risk management process is ongoing and evolving. Risk management teams must evaluate whether the previously selected controls are still applicable and effective. In addition they must evaluate the possible risk level changes in the business environment.

In ideal risk management, a prioritization process is followed whereby the risks with the greatest loss and the greatest probability of occurring are handled first, and risks with lower probability of occurrence and lower loss are handled in descending order. In practice the process can be very difficult, and balancing between risks with a high probability of occurrence but lower loss versus a risk with high loss but lower probability of occurrence can often be mishandled.

A successful risk management program relies on senior management commitment and the competence of the risk assessment team, which must have the expertise to apply the risk assessment methodology to a specific system. The ability to identify risks and providing cost-effective safeguards that meet the needs of the organization are essential in risk management.

1.5 Supply Chain Risk Management

For many global supply chain networks that consist of hundreds of companies with over several tiers of suppliers and customers, there are numerous risks to consider. The majority of these risks fall into two categories: internal risks and external risks (Goh et al. 2007). Internal risks arise from within the supply chain network and can include risks such as supply risk, demand risk, operation risk, and exchange risk. External risks

arise from the interactions between the supply chain network and its environment, such as natural disasters or terrorism.

An important component in supply chain design and risk analysis is the establishment of appropriate performance measures, which are used to determine the efficiency and effectiveness of the supply chain system. These measures are typically concerned with customer satisfaction, service, responsiveness, and cost (Beamon 1999). A number of performance measures appropriate for the traditional supply chain have been developed in order to assess risk in the supply chain network. Harland et al. (2003) identified six sequential steps in analyzing risk:

1. Map supply network
2. Identify Risk, its current location and potential loss
3. Assess risk
4. Manage risk
5. Form collaborative supply network risk strategy
6. Implement supply network risk strategy

The purpose was to increase visibility of risk that spectators in a network are exposed to or might potentially become exposed to, and to help in the assessment and management of that risk. Supply chain risk management is defined as the identification and management of risk within the supply networks and externally through a co-ordinated approach among supply chain members to reduce supply chain vulnerability as a whole (Goh et al. 2007).

1.6 Reverse Supply Chain Risk Management

There are a number of risks and uncertainties associated with the reverse supply chain and recovering used material from consumers. These risks are related to timing, quality of returned products, quantity of returned products, and variety of returns (Srivastava 2008). There are also risks involved with consumer behavior and preferences. Additional risks include estimating asset value, cost of operations, and decision making for product returns along the reverse supply chain. The number of existing risks makes forecasting and planning returned products a challenge (M.V. de la Fuente et al 2008.).

1.7 Problem Statement

Although a number of performance measures appropriate for traditional supply chains have been developed, and a supply network risk tool has been developed, these existing measures and tools are inadequate for use in the reverse supply chain (Beamon 1999). Risk analysis in the reverse supply chain has not been measured and there has been no previous research done regarding management of such.

One of the greatest challenges of reverse supply chain is the uncertainty associated with product returns. This uncertainty allows room for numerous risks in the reverse supply chain which makes forecasting and planning returned products a challenge. There is room for improvement to minimize cost and create an efficient reverse network. In order to improve the reverse supply chain and minimize costs, a thorough analysis of risk minimization must be performed. The reverse supply chain requires the establishment and implementation of new performance measurement systems and risk analysis model.

1.8 Objectives

This research aims at developing a model that will quantify all risks in the reverse supply chain and analyze the probability of each risk taking place. The model will also include the impact each risk has on the following two elements:

- Financial
- Customer Satisfaction

The specific objectives of this research may be summarized as follows:

- Provide a network diagram of all potential risks
- Develop a reverse supply chain network risk tool
- Develop, test, and validate a working model for Company ABC
- Integrate the working model with Company ABC's current model

CHAPTER 2

Literature Review

2.1 Risks in Supply Networks

A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformations of these materials into intermediate and finished product and the distribution of these finishes products to customers (Chopra and Meindl 2002). The network consists of many internal and external risks that have recently been analyzed by many authors. Risk can be divided into different types according to how its realization impacts on a business and its environment. Table 2.1 summarizes and combines various authors' work of the types of risks in the supply chain (Harland et al. 2003).

Table 2.1: Types of Risks and Description

Type of Risk	Description
Strategic risk	Affects business strategy implementation
Operations risk	Affect's a firm's internal ability to products and supply goods/services
Supply risk	Adversely affects inward flow of any type of resources to enable operations to take place; also termed 'input risk'
Customer risk	Affects likelihood of customers placing orders; grouped with factors such as product obsolescence in 'product/market risk'
Asset impairment risk	Reduces utilization of an asset and can arise when the ability of the asset to generate income is reduced
Competitive risk	Affects a firm's ability to differentiate its products/services from its competitors
Reputation risk	Erodes value of whole business due to loss of confidence
Financial risk	Erodes a firm to potential loss through changes in financial markets; can also occur when specific debtors default
Fiscal risk	Arises through changes in taxation
Legal risk	Exposes the firm to litigation with action arising from customer, suppliers, shareholders or employees

Manuj and Mentzer (2008) explored the interaction of different risks in the global supply chain. Figure 2.1 graphically shows the interactions between different types of risks, along with risk event examples. Supply, operation and demand risks affect each other and are embedded in the context of “other risks” The risk event listed under each heading are not exhaustive but only representative of each category. “Other” risks are beyond the direct control of any entity in the supply chain, aggravate the impact of other risk event, and include events that compromise the security of the supply chain. It is also important to note that an outcome for one firm in the supply chain may be a “risk event” for another firm. For example, a supplier going out of business is an outcome for the supplier and a risk event for the customer firm.

Figure 2.1: Risk in Global Supply Chains

2.2 Risk Management Tools and Models

Harland et al. (2003) provided a brief review of risk, supply networks, and risk in supply networks as mentioned earlier in Chapter 1. Their research described the development and testing of a supply network risk tool. The aim of the tool was to increase visibility of risk that workers in a network are exposed to, or might potentially become exposed to, and to help the assessment and management of that risk. Particularly, it helped categorize the types of risk and losses.

The tool was also developed in an action research based way, and briefly reviewed the feedback from those involved in using the tool. While substantial research was done on risk in supply networks, the supply risk tool was developed for the forward supply chain. Therefore, the supply risk tool needs further development in order to be used in the reverse supply chain network. The tool developed for helping to identify, assess and manage risk is provided in Figure 2.2 (Harland et al. 2003).

Figure 2.2: Supply Network Risk Tool

variables that are most important for effective risk minimization in a supply chain. The next step would be developing a tool with the relationships of risk enablers in the reverse supply chain, which would allow managers to view the risks that have the most impact in the network.

Goh et al. (2007) presented a stochastic model of the multi-stage global supply chain network problem by incorporating a set of related risks, namely, supply, demand, exchange, and disruption. By integrating properties of well developed techniques found in previous two-stage stochastic programming, they provided a new solution methodology using the Moreau-Yoshida regularization, and designed an algorithm for treating the multi-stage global supply chain network problem with profit maximization and risk minimization objectives. This algorithm can be used to solve some practical supply chain network problems, but did not focus on the risk and problems within the reverse supply chain.

The research done by Manuj and Mentzer (2008) provides direction to managers for choosing risk management strategies in global supply chains. Their research provided three major contributions. A definition of supply chain risk was developed and four types of global supply chains risks were defined. In addition, the interaction of different risks in the global environment is explored. Second, a definition of risk management in a global supply chain context was developed. Risk descriptions of risk management strategies were provided and important antecedents to strategy selection were discussed. Third, three moderators in the process of risk management were explored, namely team composition, supply chain complexity management, and inter-organizational learning.

2.3 Risk Quantification in Supply Chains

Quantifying risks, such as measuring the probability and impact of the each risk, is an important method of analyzing risks in the forward and reverse supply networks. Mitchell (1995) defined risk as “...the probability of loss and the significant of that loss to the organization or individual”. Mitchell (1995) expressed this as a formula to assess the probability of loss ‘ P ’ ($loss_n$) and the significance of the loss ‘ I ’ ($loss_n$) for an event n :

$$\mathbf{Risk}_n = P(loss_n) * I(loss_n) \quad (2.1)$$

Choi et al. (2008) investigated the issues of channel coordination in a supply chain when the individual supply chain decision makers take mean-variance (MV) objectives. They proposed an MV formulation to quantify difference risk concerns of the retailer and the supply chain coordinator in a vertically integrated two-echelon supply chain under a stochastic demand environment. Optimization models under MV objectives were formulated for the retailer and the supply chain coordinator. From their analytical and numerical analyses, they found that the incorporation of risk concerns into the setting of supply chain coordinating policy is very important because different risk preferences of the individual agents can substantially affect the achievability of channel coordination.

Ahluwalia and Nema (2006) created a multi-objective, multi-step reverse logistics formulation for integrated solid waste management for computer waste management. The model is based on an integer linear programming method with the objectives of minimizing environmental risk as well as minimizing cost. The model can be used a decision-support tool for selecting overall configuration of waste reuse, recycle, treatment and disposal facilities, and transportation routes based on cost and risk parameters. The

model can guide managers in the planning of new facilities at appropriate locations and select the routes depending on their priority of objective. This model addresses risk in the reverse supply chain, but only takes into account transportation risk and risk at various facilities. It does not take into account the many other risks such as supply risk, demand risk, trade credit risk and many other risks that are encountered in the reverse supply chain.

Horvath et al. (2007) offer a Markov chain approach to modeling the expectations, risks, and potential shocks associated with cash flows stemming from retail reverse logistics activities. The Markov chain allowed the retailer to assess liquidity issues as a unit of product moves from one return state to another. A decision heuristic is offered including definitions, possible sources of change in liquidity position, and suggested managerial responses to each category of illiquidity. The general model serves as a starting point in understanding the financial issues surrounding reverse logistics in the retail supply chain, but it does not accurately depict reverse flows with the goal of minimizing and managing organizational risk.

2.5 Risk Minimization

Sheu (2007) presented a coordinated reverse logistics management system for the treatment of multi-source hazardous wastes in a give region, in this case, a specific high-technology manufacturing zone. A linear multi-objective analytics model was formulated that systematically minimizes both the total reverse logistics operating costs and corresponding risks. By identifying the critical activities and related operational requirement, a composite multi-objective function and ten groups of constraints were

formulates. The proposed multi-objective functions were written as a composite form (U) given by

$$U = w_C \check{C} * w_R \check{R} \quad (2.2)$$

where the sum of the weights given to the cost and risk terms, i.e. w_C and w_R , should be equal to 1. The symbols $\check{C}$ and $\check{R}$ in equation 2.2 represent the normalized forms for the corresponding aggregate operational costs and risks, respectively and are given by

$$\check{C} = \frac{C - C_{\min}}{C_{\max} - C_{\min}} \quad (2.3)$$

$$\check{R} = \frac{R - R_{\min}}{R_{\max} - R_{\min}} \quad (2.4)$$

The symbols $C_{\min}$ and $R_{\max}$ in equation 2.3 and 2.4 represent the estimates of aggregate operational costs and risks measured, in the case that only cost minimization problem is considered (i.e., w_C is set to be 1); and, in contrast, $C_{\max}$ and $R_{\min}$ represent the corresponding estimates measures, in the case that only the risk minimization problem is involved (i.e., w_R is set to be 1.) Using the proposed model, results of numerical studies indicated that when the aspect of risk-induced penalties was not considered, the operational costs of region hazardous-waste management could be efficiently reduced by 58%, compared to the existing operations costs at the study site in the case where the goal of risk-minimization was not involved.

2.7 Risk Assessment in Various Decision Making

Risk assessment is the first process in the risk management methodology.

Organizations use risk assessment to determine the extent of the potential threat and the risk associated with the system. Wang et al. (2007) proposed a new integrated AHP-DEA methodology to evaluate the risks of hundreds or thousands of bridge structures. The proposed methodology uses analytic hierarchy process (AHP) to determine the weights of criteria linguistic terms such as *High*, *Medium*, *Low*, and *None* to assess bridge risks under each criterion, the data envelopment analysis (DEA) method to determine the values of the linguistic terms, and the simple additive weighting (SAW) method to aggregate bridge risks under different criteria into an overall risk score for each bridge structure. The integrated AHP-DEA methodology is applicable to any number of decision alternatives and particularly useful to complex multiple criterion decision making (MCDM) problems with a large number of decision alternatives, where pair wise comparisons are difficult to make. A numerical example was investigated to illustrate the application of the methodology.

Shyur (2008) proposed a new quantitative methodology for the assessment of risk in civil aviation. The *spline method* is used to present the baseline hazard function. This approach allows finding fundamental cause of human error related accidents through the analysis of operational safety data. The model takes into account the relationships among relevant aviation risk factors such as human, technical, environmental, and organization factors that affect safety and system performance. The results of this case study demonstrate that the proposed model is a more promising regression model with the

potential of becoming very useful in practice and leading to further generalization of aviation risk analysis.

Kunene and Weistroffer (2008) have developed an approach that seeks to incorporate prior knowledge about broader decision objectives into the data mining process using multicriteria decision analysis. Their approach has the desirable effect of letting decision objectives drive data reductions. They applied decision tree induction from data mining analysis, to a knowledge-enhanced database and employed a multicriteria decision analysis method as well as rule-based systems, to analyze and structure the prior knowledge about the patients in definitive care. The research performed can be further developed with the intention of expanding the decision structure and collecting data that is currently unavailable electronically or data that is recorded in other areas and departments of the organization.

2.6 Risk Uncertainty in Supply Networks

Kocabasoglu et al. (2007) explored managerial efforts in reverse supply chains, where the focus is on the capture and exploitation of used products and materials. They believed investment in the reverse supply chain should not be made in isolation, but instead must be integrated with investments selected to improve the forward supply chain. After defining a series of hypotheses, a survey of plant managers was used to empirically assess the linkages between supply chain investments, organization risk propensity, and recycling and waste management. Organizational risk propensity is defined as the likelihood of a firm's acceptance of less or more risky behavior over time.

They found that ongoing investment in the forward supply chain was significantly related to investment in recycling and waste management, but not to investment in reconditioning. Risk propensity was found to mediate the relationship between the external business uncertainty and investment in the forward and reverse supply chain. A model was developed showing the effects of business uncertainty on forward and reverse supply chain investments, however the proposed model does not quantify the types of risks involved in both process, and uses the general term “risk” when conducting surveys. The results of the analysis performed are presented in Figure 2.4.

Figure 2.4: Summary of Reverse Supply Chain Investment: recycling and waste management. (--->) No pathways were statistically significant; (→) All pathways were statistically significant; (⇒) Mixed results -some pathways were statistically significant.

Risks and uncertainties are factored heavily in decision making, and those stemming from supply chains are prominent in the competitiveness and viability of companies and organizations. The idea that every supply chain is made up of five internal

chain/network constructs is presented by Cavinato (2004). Further, four categorizations of relevant product/supply costs are presented as are four types of supply risks. A categorization for identifying risks and uncertainties in supply chains is shown as the five sub-chains /networks to every supply chain:

1. *Physical* - the actual movements and flows within and between firms, transportation, service mobilization, delivery movement, storage, and inventories.
2. *Financial* - the flows of cash between organizations, incurrence of expenses, and use of investments for the entire chain/network, settlements, processes and systems.
3. *Informational* - the processes and electronic systems, data movement triggers, access to key information, capture and use of data, enabling processes, market intelligence.
4. *Relational* - the appropriate linkage between a supply, the organization and its customers for maximum benefit; includes internal supply matter relationship throughout the organization.
5. *Innovational* - the processes and linkages across the firm, its customers, suppliers, and resource parties for the purpose of discovering and bringing to market product, service, and process opportunities.

The topic of supply chain logistics risk and uncertainty uncovers the many new pointes of intersection the field has with others throughout the corporation and supply

and distribution systems. Risk and uncertainty are evidence that the field is broadening and the practices, processes, concepts, theories must expand with it. By identifying risks and uncertainties, chapter 3 will introduce the structure and framework of developing a risk management tool for the reverse supply chain.

CHAPTER 3

Methodology

3.1 Introduction

Previous research has shown a number of various models that have the ability to manage risks in different situations, as well as in forward supply chain networks.

However, a framework does not exist to implement risk management in the reverse supply chain. Therefore, this research aims at developing a framework that will identify, quantify, and manage potential risks in the reverse supply chain. In addition, the intention of the framework is to implement the model at a high-tech company.

There were different approaches taken, before the methodology was developed. The reasoning behind for the proposed methodology was to develop a simple, quick, and efficient way to manage risk, with minimal training, time, and cost. Previous risk management models involved numerous multi-variable functions, stochastic models, and other methodologies, which were very analytical and time consuming. The objective of this tool was for user to be able to follow the framework, and develop it further, without previous risk management experience.

3.2 Purpose of Risk Management

Today the key issues in both forward and reverse supply chain are the formation of an effective supply network to ensure customer satisfaction and sustain capability. This requires the coordination of information, materials, and funds across multiple functional areas both within and among companies. To achieve this, companies must

identify, evaluate, rank, and manage its supply chain risks. As supply chains become more complex, the uncertainties and risks affecting the other links in the chain increase.

Risk management process is focused on understanding the various threats minimizing their impact by addressing probability and direct impact. Generally, organizations plan to protect against recurrent, low-impact risks in their supply chains but ignore high-impact low likelihood risks. The sources of supply chain risks are many, as different links of a supply chain are exposed to different types of risk. Although it is impossible to completely eliminate risks from a supply chain it can be reduced by organizations better preparing themselves. The purpose of the proposed risk management tool is to assist organizations in better preparing themselves in case that certain risks occur.

The proposed risk tool consists of six main components which will be discussed in more detail later in this chapter:

- Map the reverse network
- Identification of risks
- Map impact of risks
- Assess and quantify risk
- Assess and quantify loss
- Manage risk

3.3 Assumptions

There are several assumptions made in the development of the framework for the risk management tool to be used in the reverse supply chain of an organization. The risk

management tool described in this chapter is developed for a company with the following characteristics:

- High-tech industry sector
- Domestic returns (U.S. and Canada)
- Returned products sent to one location

3.4 Steps for Risk Management in the Reverse Supply Chain

The framework to identify, assess, quantify, and manage risk in the reverse supply chain is provided in Figure 3.1. The information needed to efficiently implement this framework will be covered in this chapter.

Figure 3.1: Risk Management Framework

3.4.1 First Step: Map Reverse Supply Chain Network

A diagrammatical representation of the supply network helps the user understand the process and is beneficial in mapping the flow of all returned materials from one or several locations. Mapping this reverse supply network involves the understanding of key roles and responsibility in the various steps of the network. There are three primary steps in creating an effective and accurate reverse supply network diagram:

1. *Identify departments:* The processes in the reverse supply chain usually involve more than one organization or department. Such departments include sales, customer service, and manufacturing. Identifying the departments involved in the process of returned materials, it will create an organized layout of the reverse network, which will also clarify the responsibilities in the occurrence of certain events.

2. *Identify locations and processes:* Once the departments are identified, the next step is to identify all the locations and processes within each department specifically involved in the flow of returned materials. Locations such as different warehouses, distribution centers, and service centers may be involved in the flow of returned materials. Each location has specific systems and procedures that help facilitate the process of returned products as well as the outcome of each product. By identifying the specific location and process, management will be able to identify the responsibilities and tasks at each location and create an organized layout of the reverse network.

3. *Map returned material process flow:* More often than not, when materials are returned to the manufacturer, there are many input and output streams involved in the process. Products may be returned for several different reasons; all which can be placed in certain categories such as “*good returns*” where the product is new and may be resold,

or “*bad returns*”, where the product is used and the value of the product is questionable. It is important to layout the process of returned materials and the outcome of each product, which typically includes the product being re-used, refurbished, resold, or recycled. The multiple streams in a reverse supply chain network make it difficult to isolate different risks that may occur in the network. Therefore, mapping the entire reverse supply chain process, including all the internal and external locations, will assist organizations in managing the different streams and the risks that may associate with the flow of materials being returned.

3.4.2 Second Step: Identification of Risks

After establishing the context, the next step in the process of managing risk is to identify potential risks. After establishing the network and processes of the reverse supply chain, the next step in the process of managing risk is to identify potential risks and the location of each risk. Risks are events that when triggered, cause problems. Hence, risk identification can start with the source of problems, or with the problem itself. The type of risks, location and definition may vary in different organizations. Therefore it is important for each organization to identify the significant risks and locate each risk in order to understand the impact a risk can have on the reverse network as a whole. This process encompasses three primary steps:

1. Identify types of risks: The first step in identification of risks is to recognize which risks are internal, external, or fall into both categories. There are a number of internal and external risks that may interfere with the network and cause delays and disruptions. Internal risks arise from within the organization where the organization has

direct control over. Examples of internal risks include supply risks, demand risks, and system risks. External risks arise from the interactions between the organization and its environment, where the organization has no direct control over. Examples of external risks include environmental risk, transportation risks, and economic risks.

The number of internal and external risks may vary in the reverse supply chain of different organizations; however a majority of them consist of the same three core risk elements:

- Strategic Uncertainty
- Operational Catastrophes
- Operational Accidents

Strategic uncertainty includes risks with a source of uncertainty such a supply side, demand-side, and asset value uncertainty. Operational catastrophes consist of risks that stem from sources such as terrorism, natural disasters, or bankruptcies. Operational accidents such as delays, disruptions, and accidents include everything from minor everyday occurrences to major malfunctions such as the breakdown of a computer system. By identifying all the major and minor risks, as well as the internal and external risks, organizations are able to identify the variety of potential threats before they occur, minimizing the element of surprise.

2. Define each risk: Once a list of all risks has been created, the next step is to examine each risk and define what each specific risk signifies in the organization.

Incorporated in the definition of each risk should be the following:

- Risk Driver
- Risk Location
- Risk Effect

The risk driver is the force or instigator that drives the risk occurrence. It is imperative to recognize the possible sources that cause the risk to take place in order to minimize the potential threats of each risk, and well as managing the reverberations of each risk. Defining the driver or multiple drivers allows the user the capability of risk avoidance as well. Once the driver is defined, assessing the location of the risk is crucial. An effective method of approach is locating risks on the reverse network diagram discussed earlier. This gives management the opportunity to target all risks in the reverse supply chain using a visual approach.

However, locating risks is a complicated process since many risks may occur in multiple locations, or may even affect the entire network as a whole. The intricacy continues if a risk is both internal and external, which can affect both input and output streams. Identifying locations of each risk is complex, however the user must make the best assumptions for the reason that this process will assist the user in assessing risks further on this chapter.

3. *Identify potential loss:* The occurrence of a risk generally leads to some sort of problem. The problem often leads to some type of loss affecting the organization. After the effect of each risk identified as previously discuss, the potential loss becomes comprehensible to the organization. Losses can be quantified and related to resulting damages caused by a variety of risks. Situations can give rise to different types of loss. Some losses are relatively minor and others can be catastrophic in their level. The following are categories of losses organizations may experience due to risk occurrence in the reverse supply chain:

- Customer satisfaction loss
- Financial loss
- Time loss

Having categorized the types of risk and the types of losses that can arise in the reverse supply chain network, these can be combined to help management assess risk and manage risk efficiently.

3.4.3 Third Step: Map Risk Impact

Risk can impact an organization in many different ways which we will further discuss in this chapter. However, the largest impact a risk can have is the potential chain reaction of other risks that may follow. This occurs in supply networks for the reason that there are multiple links and processes connecting different locations in the network. As a result, multiple risks are connected and linked together as well.

Before assessing risks, the user should use a flowchart tool such as VISIO to create a network diagram of all the risks in the organization, in order to link the affects of each risk. There are three primary steps in doing this. First, create a process box for each risk in the organization. Next, link each risk to other risks it may affect. Lastly, organize risks in hierarchy order to visualize impact of each risk. Refer to Figure 3.1, 3.2, and 3.3 to observe the three steps.

Figure 3.2: Step 1 of Mapping Risk Impact - Create a process box for each risk

Figure 3.3: Step 2 of Mapping Risk Impact: Link each risk to other risks it may affect

Figure 3.4: Step 3 of Mapping Risk Impact: Organize risks in hierarchy order to identify impact of risks

Creating a risk impact diagram of all the risks in the organization allows management to visualize the potential chain reaction of risks. In addition, the risk impact diagram illustrates how an individual risk or event is capable of affecting several other risks. However, it can also display several risks and events influencing only one individual risk. Risks can also be grouped together if they are all in the same location or have similar affects. The process of creating this diagram will also help assess and quantify risk impact further on in this chapter.

3.4.4 Fourth Step: Assess and Quantify Risks

Once risks have been identified and located, they must then be assessed as to their potential severity of loss and to the probability of occurrence. These quantities can be

either simple to measure, in the case of the value of a lost building, or difficult to know for sure in the case of the probability of an unlikely event occurring. Therefore, in the assessment process it is critical to make the best educated guesses possible in order to properly prioritize the implementation of the risk management plan.

The fundamental difficulty in risk assessment is determining the rate of occurrence since statistical information is not available on all kinds of past incidents. Furthermore, evaluating the severity of the risk impact is often quite difficult for immaterial assets. Assuming statistics are not available, best educated opinions are the primary source of information.

A scoring system is proposed in this model to measure impact and probability of risk. Using levels of *High*, *Medium*, and *Low*, each risk will be given an impact score and a probability score based on the following table:

Table 3.1: Impact of Risk Scoring Table

Impact of Risk	
Level	Score
High	3
Medium	2
Low	1

Table 3.2: Probability of Risk Scoring Table

Probability of Risk	
Level	Score
High	3
Medium	2
Low	1

Using the given impact score of risk r , probability score of risk r , and impact score of loss l , the following formula is used for risk quantification of individual risk n :

$$R_r = I_r * P_r \quad (3.1)$$

where R_r = Total risk of risk r

I_r = Impact score of risk r

P_r = Probability score of risk r

Using the scoring tables and the risk quantification formula, we can conclude the following for an individual risk:

Table 3.3: Total Risk Score

Range of R_r	1-9
Maximum R_r	9
Minimum R_r	1

3.4.5 Fifth Step: Assess and Quantify Loss

Once the individual score of each risk is determined, the next step is to analyze what the company has to lose if a certain risk occurs. In addition, analyze what other risks the company may suffer from due to a particular risk occurring. The true impact of an individual risk may be determined by incorporating the following in our previous risk quantification formula:

- Impact of losses
- Impact of risks affected

Once risks and losses are analyzed, the corresponding loss must be incorporated to achieve the true impact of each risk. . Using levels of *High*, *Medium*, and *Low*, each loss will be given an impact score based on the following table:

Table 3.4: Impact of Loss Scoring Table

Impact of Loss	
Level	Score
High	3
Medium	2
Low	1

In addition, the total impact of each risk can not be determined unless all other risks affected are incorporated. Using the risk impact diagram created earlier in the chapter, the chain reaction of risks and losses for each specific risk needs to be identified. In order to accurately quantify each risk, a sensitivity analysis was performed on four different possible equations, in order to determine which formulation had the most accurate risk impact score. The results can be seen in the appendix. After thorough analysis, the following formula is used to quantify each risk by multiplying all the correlating risks by all the correlating losses:

$$R_x = \forall I_r * \forall I_l * P_x \quad (3.2)$$

where

R_x = Total score of risk x

I_r = Impact score of risk r

I_l = Impact score of loss l

P_x = Probability score of risk x

In order to validate the formulation, a sensitivity analysis was performed using a different equation quantifying the total risk. The following formula was used in order to analyze the risks and compare the results to equation 3.2. In equation 3.3, the risk score of risk x is quantified by adding the sum of the impacts of correlating risks and the sum of the impacts of correlating losses. This value is then multiplied by the probability of risk x in order to get the total risk score.

$$R_x = \left[\sum_{i=m}^m I_{ri} + \sum_{j=n}^n I_{lj} \right] * P_x \quad (3.3)$$

where R_x = Total risk of risk x
 I_r = Impact score of risk r
 I_l = Impact score of risk l
 P_x = Probability score of risk x

and $i = 1, 2, \dots, m$ where m = number of possible risks
 $j = 1, 2, \dots, n$ where n = number of possible losses

The formulation seemed reasonable; however it wasn't definite whether the addition of risks and losses would have the same effectiveness as multiplication has in equation 3.2. Therefore both equations are used to compare the results of the significance of each risk in the reverse supply chain.

In order to validate the scoring system of 3-2-1, a comparative analysis was done using the scoring system of 9-3-1. The purpose of using scores 9-3-1 was to create a

significant difference between the *High*, *Medium*, and *Low* values. Both scoring systems are used in order to compare the significance of the risk in the reverse supply chain.

The general equations developed allow the user to include the variety of risks and losses specific to the reverse network of the company. Once the risks are quantified, comparing the scores of each risk will determine the high impact risks that may concern the company, as well as the low impact risks with minimal consequences resulting from the risk occurrence.

3.4.6 Sixth Step: Managing Risk

Once the risks are identified and quantified, the process of managing risk begins. In order to manage risks, assessment information is analyzed and alternative interventions are proposed. Depending upon the risk position, scenarios of alternative network structures and relationship strategies can be developed to realign risk, exposure to it, likely losses and location of those losses. The network is managed simply by creating a visual model of all risks, losses, impacts, and drivers. When new risks are established, they can be placed in the model with the chosen redesign of the network and relationships within it. This strategy of managing old risks and new risks is implemented and gives rise to a remapping of the network.

What-if analysis: One of the most important functions of the risk management tool is for management to be able to test different scenarios and make educated decisions of risk effects. As previously mentioned, the most basic goal of the tool is to verify the impact of each risk by quantifying it. If the user wants to increase risk effects or losses, they need to recalculate the risk formulas provided in the previous chapter. Since new

risks do not have certain probabilities or precise impacts, management may need to may the best educated estimates when accumulating more risks to the model.

Cost analysis: The framework developed allows an organization to create the tools needed to manage risks in the reverse supply chain using minimal time and cost. Creating this tool should not cost an organization more money than it already spends on the salary of its current employers. Therefore, the time saved by referencing the tool in the future offsets the amount of time and cost of having employers creating the tool. Once the tool is available, management can save time determining where the risk took place, or why it happened, simply by referencing the tool.

CHAPTER 4

Implementation

4.1 Introduction

The reverse supply chain of Company ABC will be used to demonstrate how the proposed risk management tool can be effective in the process of returned products. The identity of Company ABC has been concealed in order to protect intellectual property agreements. The risk management tool developed is to be used by management and other employers in the Reverse Logistics group. Management for this group and all of the receiving facilities involved in the reverse supply chain is located mainly in California. The Reverse Logistics group at Company ABC is responsible for all products being returned to the company in the United State and Canada. Various teleconferences are held daily to keep the team up to date with the latest information regarding returned materials.

Currently the Reverse Logistics group does not acquire any sort of tool to help evaluate, assess, or manage risks in the process of returned material. Management has asked that a model or tool be developed in order to assist them in quantifying risks in the return stream of products. In order to do so, both the sales and return programs needed to be analyzed to understand where the returns were coming from. After carefully analyzing the people, locations, and processes affecting the returns stream, the implementation of the risk management tool seemed necessary for Company ABC.

The risk management tool developed for the Reverse Logistics group is intended to be reviewed on a daily basis to check risks that may have occurred. The tool will assist in identifying where each risk takes place as well as the cause and effect of each risk. The reverse supply chain of Company ABC will be used in the demonstration of this risk tool.

4.2 Map Reverse Supply Chain Network

As discussed in chapter 3, the first step is to map the reverse supply chain network in order to help the user understand the process flow of all returned materials. There are three primary steps in creating an effective and accurate reverse supply network diagram; identifying departments, identifying locations, and identifying the flow of materials.

Figure 4.1 shows the layout of the reverse supply chain for Company ABC.

Figure 4.1: Map of Reverse Supply Chain Network

The layout is divided into three segments, each segment representing a department that is involved in the flow of returned materials. This layout will allow management to see who owns what in each department. Within each department are

several locations involved in the flow of returned materials. It is important to understand the process at each location to identify who owns what at each location. Due to intellectual property agreements, the processes at each location are to be concealed for Company ABC.

4.3 Identification of Risks

The second step involves identifying the risks in the reverse supply chain. This can be done by following three primary steps: identifying the type of risk, defining each risk, and identifying the potential loss. Table 4.1 shows the risks identified in the reverse supply chain of Company ABC. It includes the type of risk, as well as the description:

Table 4.1: Types of Risks and Descriptions

Type of Risk	Description
External Risks	
Environmental	Natural disasters, earthquake, flood, storm, or fire
Forecast	Receive inaccurate forecast of returned products
Geo-Political	Taxation increase and/or SOX compliance
Intellectual Property	Proprietary material leaks to open market
Macro-Economic	Rise of gas prices and/or Nation in recession.
Transportation	Shipping co. out of business and/or shipment delayed
Vendor	Increase of cost and/or goes out of business
Internal Risks	
Asset Value	Product resold not usable
Capacity	Throughput is inadequate
Data	Inaccurate data entered into system
Demand	Uncertainty of product demand
Financial	Insufficient funding for initiatives
Inventory	Inaccurate inventory count
Operations	Unusable product re-enters reverse logistics loop
Overstock	Overstock of items in warehouse
Receivables	Products received do not contain authorization no.
Resource	Strike and/or layoff occurs
System	System breakdown/malfunction
Supply	Insufficient supply for customers

After identifying all of the risks, it is important to identify the different losses a company might experience due to the impact of risks. Table 4.2 shows the loss identified in the reverse supply chain of Company ABC. It includes the type of loss, as well as the description.

Table 4.2: Types of Loss and Description

Type of Loss	Description
Customer Sat Loss	Customer Satisfaction rating falls due to poor service
Financial Loss	Loss of monetary funds due to variety of risks
Time Loss/Delay Risk	Loss of time caused by delays of different risks

4.4 Map Risk Impact

The third step involves mapping the impact of risks which requires linking each risk to other risks it may affect. Organizing the risks in hierarchy order and/or by type of risk helps visualize the impact the risk has on the entire network. Figure 4.2 is the layout of risks impacting one another, specifically in the reverse supply chain of Company ABC. As seen in the layout, the risks above the center line are external risks, and the risks below the center line are internal risk. The purpose of having Delay Risk in the center is the fact that both internal and external risks may cause delays in the return flow of materials. In addition, the purpose of grouping Receivables, Inventory, Supply, Demand, and Overstock together is for the reason that all five risks take place within the

warehouse, and more often than not will somehow affect one other, creating a chain reaction.

Figure 4.2 Map of Risk Impact

4.5 Assess and Quantify Risk

The fourth step is assessing the risks identified earlier. Using the 3-2-1 scoring system with levels of *High*, *Medium*, and *Low*, each risk was assessed and given an impact score and a probability score based on the scoring tables mentioned in chapter 3. After assessing each risk, the risk was quantified using equation 3.1. The data is shown in Table 4.3

$R_r = I_r * P_r \tag{3.1}$

Table 4.3 Risks Quantification

	Impact (I_r)	Probability (P_r)	Total Risk (R_r)
External Risks			
Environmental	High	Low	3
Forecast	Medium	Medium	4
Geo-Political	High	Low	3
Intellectual Property	Medium	Low	2
Macro-Economic	High	High	9
Transportation	High	Medium	6
Vendor	High	Low	3
Internal Risks			
Asset Value	Medium	High	6
Capacity	Low	Low	1
Data	High	High	9
Demand	Low	High	3
Financial	High	Low	3
Inventory	High	Low	3
Operations	High	Low	3
Overstock	Low	High	3
Receivables	Low	High	3
Resource	High	Medium	6
System	High	Medium	6
Supply	Low	High	3

4.6 Asses and Quantify Loss

The fifth step takes into account the effect of each risk, including the loss and the chain reaction of other risks taking place due to the initial risk. Using the 3-2-1 scoring system with levels of *High*, *Medium*, and *Low*, each loss was assessed and given an impact score based on the scoring tables mentioned in chapter 3. The data is shown in Table 4.4.

Table 4.4: Loss Quantification

	Impact
Types of Loss	
Customer Sat Loss	Medium
Financial Loss	High
Time Loss/Delay Risk	High

After assessing all of the risks, the impact of each risk, and the loss generated by each risk, the true impact of each risk x was quantified using equation 3.2.

$$R_x = \forall I_r * \forall I_l * P_x \quad (3.2)$$

In order to simplify the quantification, Table 4.5 and Table 4.6 were created to display the variables of each risk and loss, as well as the associated scores mentioned earlier in this chapter.

Table 4.5: Risk Variables

Type of Risk	Total Risk	Impact Score	Probability Score
External Risks			
Environmental	R_{EN}	$I_{EN} = 3$	$P_{EN} = 1$
Forecast	R_{FO}	$I_{FO} = 2$	$P_{FO} = 2$
Geo-Political	R_{GP}	$I_{GP} = 3$	$P_{GP} = 1$
Intellectual Property	R_{IP}	$I_{IP} = 2$	$P_{IP} = 1$
Macro-Economic	R_{ME}	$I_{ME} = 3$	$P_{ME} = 3$
Transportation	R_{TR}	$I_{TR} = 3$	$P_{TR} = 2$
Vendor	R_{VE}	$I_{VE} = 3$	$P_{VE} = 1$
Internal Risks			
Asset Value	R_{AV}	$I_{AV} = 2$	$P_{AV} = 3$
Capacity	R_{CA}	$I_{CA} = 1$	$P_{CA} = 1$
Data	R_{DA}	$I_{DA} = 3$	$P_{DA} = 3$
Demand	R_{DE}	$I_{DE} = 1$	$P_{DE} = 3$
Financial	R_{FI}	$I_{FI} = 3$	$P_{FI} = 1$
Inventory	R_{IN}	$I_{IN} = 3$	$P_{IN} = 1$
Operations	R_{OP}	$I_{OP} = 3$	$P_{OP} = 1$
Overstock	R_{OV}	$I_{OV} = 1$	$P_{OV} = 3$
Receivables	R_{RC}	$I_{RC} = 1$	$P_{RC} = 3$
Resource	R_{RS}	$I_{RS} = 3$	$P_{RS} = 2$
System	R_{SY}	$I_{SY} = 3$	$P_{SY} = 2$
Supply	R_{SU}	$I_{SU} = 1$	$P_{SU} = 1$

Table 4.6: Loss Variables

Type of Loss	Impact Score
Customer Sat Loss	$I_{CL} = 2$
Financial Loss	$I_{FL} = 3$
Time Loss/Delay Risk	$I_{TL} = 3$

Using the Risk Impact diagram created earlier in this chapter, the affect of each risk was identified and incorporated in the risk quantification equation. Table 4.7 lists the corresponding equations in order to quantify each risk defined for Company ABC, as well as the total risk score for each quantified risk.

Table 4.7: Risk Equations

R_{EN}	$= (I_{EN}) (I_{TL} * I_{FL}) (P_{EN})$	
R_{FO}	$= (I_{FO} * I_{CA} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{FO})$	
R_{GP}	$= (I_{GP}) (I_{FL}) (P_{GP})$	27
R_{IP}	$= (I_{IP}) (I_{TL} * I_{FL}) (P_{IP})$	48
R_{ME}	$= (I_{ME}) (I_{FL}) (P_{ME})$	9
R_{TR}	$= (I_{TR}) (I_{CL} * I_{FL} * I_{TL}) (P_{TR})$	18
R_{VE}	$= (I_{VE}) (I_{CL} * I_{FL}) (P_{VE})$	27
R_{AV}	$= (I_{AV}) (I_{CL} * I_{FL}) (P_{AV})$	108
R_{CA}	$= (I_{CA} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{CA})$	18
R_{DA}	$= (I_{DA} * I_{SY} * I_{CA} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{DA})$	36
R_{DE}	$= (I_{DE} * I_{OV}) (I_{CL}) (P_{DE})$	12
R_{FI}	$= (I_{FI}) (I_{CL} * I_{FL} * I_{TL}) (P_{FI})$	324
R_{IN}	$= (I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{IN})$	6
R_{OP}	$= (I_{OP} * I_{RS} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{OP})$	54
R_{OV}	$= (I_{OV} * I_{AV}) (I_{CL}) (P_{OV})$	12
R_{RC}	$= (I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{RC})$	108
R_{RS}	$= (I_{RS} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL}) (P_{RS})$	12
R_{SY}	$= (I_{SY} * I_{CA} * I_{RC} * I_{IN} * I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL} * I_{FL} * I_{TL}) (P_{SY})$	36
R_{SU}	$= (I_{SU} * I_{DE} * I_{OV} * I_{AV}) (I_{CL} * I_{FL}) (P_{SU})$	72
		610

The significance of each risk can be seen in Table 4.8, with the list of risks and their corresponding scores in descending order. The score of each risk is directly correlated with the effect of each risk. Here the scores of the risks can be compared, and as seen in the table, the higher the score, the greater the effect the risk has on the entire network. By using the risk tool, we were able to quantify each risk in the reverse supply chain of Company ABC.

According to our analysis, System, Data, Transportation, and Operations risks have the highest influence on the flow of returned materials. In addition, Supply, Geo-Political, and Demand risks have the lowest significance on the reverse supply chain of Company ABC.

Table 4.8: Risk Score in Descending Order

Score	Risk
648	System
324	Data
108	Transportation
108	Operations
72	Resource
54	Financial
48	Forecast
36	Asset Value
36	Receivables
27	Enviornmental
27	Macro-Economic
18	IP
18	Vendor
12	Capacity
12	Inventory
12	Overstock
12	Supply
9	Geo-Political
6	Demand

In order to compare results, a sensitivity analysis was done comparing equation 3.2 and equation 3.3. In addition, both formulations were analyzed using two different scoring systems, 3-2-1 and 9-3-1. Therefore, four separate analyses were conducted. The results of sensitivity analysis are shown in Table 4.11 with the risks listed in descending order of their scores.

$$R_x = \forall I_r * \forall I_l * P_x \quad (3.2)$$

$$R_x = \left[\sum_{i=m}^m I_{ri} + \sum_{j=n}^n I_{lj} \right] * P_x \quad (3.3)$$

Table 4.9 Score 3-2-1

Impact/Probability	
Level	Score
High	3
Medium	2
Low	1

Table 4.10 Score 9-3-1

Impact/Probability	
Level	Score
High	9
Medium	3
Low	1

Table 4.11: Sensitivity Analysis

Eq. 3.3 Score 3-2-1		Eq. 3.3 Score 9-3-1		Eq. 3.2 Score 3-2-1		Eq. 3.2 Score 9-3-1	
Score	Risk	Score	Risk	Score	Risk	Score	Risk
54	Data	342	Data	648	System	2E+05	System
42	System	171	Receivables	324	Data	59049	Data
33	Receivables	162	Macro-Economic	108	Transportation	6561	Transportation
28	Forecast	141	System	108	Operations	6561	Operations
28	Resource	135	Asset Value	72	Resource	2187	Financial
22	Transportation	90	Transportation	54	Financial	2187	Resource
21	Asset Value	84	Resource	48	Forecast	729	Enviornmental
18	Macro-Economic	69	Forecast	36	Asset Value	729	Forecast
17	Operations	63	Overstock	36	Receivables	729	Macro-Economic
15	Overstock	45	Demand	27	Enviornmental	729	Asset Value
12	Capacity	37	Operations	27	Macro-Economic	729	Receivables
12	Demand	30	Financial	18	IP	243	IP
11	Financial	27	Enviornmental	18	Vendor	243	Vendor
10	Inventory	21	IP	12	Capacity	81	Geo-Political
10	Supply	21	Vendor	12	Inventory	81	Capacity
9	Enviornmental	20	Capacity	12	Overstock	81	Inventory
8	IP	18	Geo-Political	12	Supply	81	Overstock
8	Vendor	18	Inventory	9	Geo-Political	81	Supply
6	Geo-Political	18	Supply	6	Demand	27	Demand

It is reasonable to say that the significance of each risk differs applying each equation. When analyzing the risks, equation 3.2 showed to be more effective, creating significant differences between the risks, therefore equation 3.2 was used. However, by comparing the results of both scoring systems in the implementation, there was not a significant difference in the ranking of the scores. Therefore scoring system of 3-2-1 was continued to be used.

4.7 Manage Risk

The sixth and final step is to create a visual model to help management view all risks, losses, and impacts in the reverse network. This is similar to the Risk Impact diagram created earlier in the chapter, however all the risk-drivers have been added in order to reference the source of each risk. In addition, each risk correlates with a color based on the score it received in Table 4.8. Figure 4.3 shows the layout of the Risk Management Model for Company ABC.

4.8 Conclusion

The implementation of the risk tool at Company ABC demonstrates how the tool can assist the user in managing risks in the reverse supply chain of the company. The company had a fairly complicated return of materials process and was comprised of a variety of risks, locations, and departments. Once the user follows the steps in the tool by identifying, assessing, quantifying, and managing all the risks, the user can create a model which will further assist the risk management needed in the Reverse Logistics group.

Figure 4.3: Risk Management Model

CHAPTER 5

Conclusion

5.1 Summary

Customer satisfaction and sustainability hold a high priority in the eyes of organizations today. For most companies, as product sales increase, so do product returns, which in turn has companies' eager to maintain their customer satisfaction ratings. The forward and reverse supply chains have unique characteristics that vary among different organizations. Most organizations manage and quantify risks in the forward supply chain by utilizing various available risk management tools. These risk management tools have been developed solely for the forward supply chain. Currently, a framework does not exist to implement risk management in the reverse supply chain. This research presents the development and implementation of a risk management tool to be used to manage and quantify risks specifically in the reverse supply chain.

Implementation of this tool at Company ABC demonstrates how the risk management tool is used in order to be beneficial to the organization. The tool is designed to be easily implemented at minimal cost and serves as a valuable tool for personnel faced with important and costly decisions regarding risk occurrence in the reverse supply chain network.

The framework proposed will assist the user such that they have the ability to identify, quantify, and manage risks in the reverse supply chain, without previous risk management experience. By analyzing several formulation methods, the concluding method of multiplying the risks affected by the losses affected will identify the

significance of each risk. Creating visual models of the reverse supply chain, risks, and risk drivers, is vital tool that will help the user effectively manage risks.

In order to validate the effectiveness of the tool, measures need to be made to check the benefits the tool has on the organization. The most significant measure to be made is time. By using the framework developed, and referencing the risk management visual model, the user should save a lot of time finding the source, cause, and affect of the risk of the reverse supply chain. By saving time, the organization is avoiding costs, which is the main purpose of the tool. Cost avoidance is important in any organization, and by implementing the framework, the value of employee time correlates with cost savings. In the near future, the user implementing the risk management framework should measure the time saved in order to validate the benefits of the tool.

5.2 Contributions

The proposed risk management tool uses existing principles of risk management in supply chain; however, it is unique because the characteristics of the new tool are solely developed for the reverse supply chain. Risk management methods in the past have been designed for familiar forward supply networks where materials are sent from the manufacturer to the customer. In the flow of returned products, several customers return new or used products to the manufacturer, which then are sent to specific locations based on the quality and usability of the product.

The proposed risk management tool allows the user to quantify and locate all risks in the reverse network at the time of risk occurrence. These features allow the user to achieve the overlying goal of managing risks and developing alternatives quickly and

efficiently in the least amount of time. Since the tool may be used for different organizations, many different factors effect the identification and quantification of risks that lie in the reverse network of the organization. Therefore, the effectiveness of this tool will vary among different companies.

CHAPTER 6

Future Research

In this research, the variety of different risks in the reverse supply chain were analyzed, quantified, and managed by the user. The calculated risk scores are indications of the likelihood and probability of each risk taking risk, which in turn assists the user in preparing for risk occurrence. The framework developed helps monitor the reverse supply chain, specifically identifying and managing potential risks.

The framework may be further developed and tested among many organizations in the high-tech industry sector, in order to validate the effectiveness. In addition, the risk management tool may be generalized and expanded for the utilization of different industries. Overtime, the framework may be continuously improved by the progression of future developments such as advanced formulations, computer-aided models, or user-based software.

Once the risk management tool has been implemented, the next step that should be taken is developing alternatives for the individual risk occurrences. Creating a decision tool would help the user choose the alternative needed to be taken when a certain risk occurs. This would be a very high level analytical process that may be time consuming, costly, and company specific. It may be beneficial in situations to have a model that more accurately reflects the decisions needed to be made in time of risk emergency.

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APPENDIX A

Sensitivity Analysis

Risk Quantification

Risk Addition Model

$$R_r = \left[\sum_{i=1}^m I_{ri} + \sum_{j=1}^n I_{lj} \right] * P_r$$

Level	Impact	Probability
High	3	3
Medium	2	2
Low	1	1

Risk	Impact	Probability	Risk Sum	Score
Loss				
Customer Sat	2	-	-	
Financial	3	-	-	
Time	3	-	-	
External				
Environmental	3	1	9	9
Forecast	2	2	14	28
Geo-Political	3	1	6	6
IP	2	1	8	8
Macro-Economic	3	3	6	18
Transportation	3	2	11	22
Vendor	3	1	8	8
Internal				
Asset Value	2	3	7	21
Capacity	1	1	12	12
Data	3	3	18	54
Demand	1	3	4	12
Financial	3	1	11	11
Inventory	3	1	10	10
Operations	3	1	17	17
Overstock	1	3	5	15
Receivables	1	3	11	33
Resource	3	2	14	28
System	3	2	21	42
Supply	1	1	10	10

Score	Risk
54	Data
42	System
33	Receivables
28	Forecast
28	Resource
22	Transportation
21	Asset Value
18	Macro-Economic
17	Operations
15	Overstock
12	Capacity
12	Demand
11	Financial
10	Inventory
10	Supply
9	Environmental
8	IP
8	Vendor
6	Geo-Political

Risk Quantification

Risk Addition Model

$$R_r = \left[\sum_{i=1}^m I_{ri} + \sum_{j=1}^n I_{lj} \right] * P_r$$

Level	Impact	Probability
High	9	9
Medium	3	3
Low	1	1

Risk	Impact	Probability	Risk Sum	Score
Loss				
Customer Sat	3	-	-	
Financial	9	-	-	
Time	9	-	-	
External				
Environmental	9	1	27	27
Forecast	3	3	23	69
Geo-Political	9	1	18	18
IP	3	1	21	21
Macro-Economic	9	9	18	162
Transportation	9	3	30	90
Vendor	9	1	21	21
Internal				
Asset Value	3	9	15	135
Capacity	1	1	20	20
Data	9	9	38	342
Demand	1	9	5	45
Financial	9	1	30	30
Inventory	9	1	18	18
Operations	9	1	37	37
Overstock	1	9	7	63
Receivables	1	9	19	171
Resource	9	3	28	84
System	9	3	47	141
Supply	1	1	18	18

Score	Risk
342	Data
171	Receivables
162	Macro-Economic
141	System
135	Asset Value
90	Transportation
84	Resource
69	Forecast
63	Overstock
45	Demand
37	Operations
30	Financial
27	Environmental
21	IP
21	Vendor
20	Capacity
18	Geo-Political
18	Inventory
18	Supply

Risk Quantification
Risk Multiplication Model

$$R_x = \forall I_r * \forall I_l * P_x$$

Level	Impact	Probability
High	3	3
Medium	2	2
Low	1	1

Risk	Impact	Probability	Risk Sum	Score
Loss				
Customer Sat	2	-	-	
Financial	3	-	-	
Time	3	-	-	
External				
Environmental	3	1	27	27
Forecast	2	2	24	48
Geo-Political	3	1	9	9
IP	2	1	18	18
Macro-Economic	3	3	9	27
Transportation	3	2	54	108
Vendor	3	1	18	18
Internal				
Asset Value	2	3	12	36
Capacity	1	1	12	12
Data	3	3	108	324
Demand	1	3	2	6
Financial	3	1	54	54
Inventory	3	1	12	12
Operations	3	1	108	108
Overstock	1	3	4	12
Receivables	1	3	12	36
Resource	3	2	36	72
System	3	2	324	648
Supply	1	1	12	12

Score	Risk
648	System
324	Data
108	Transportation
108	Operations
72	Resource
54	Financial
48	Forecast
36	Asset Value
36	Receivables
27	Environmental
27	Macro-Economic
18	IP
18	Vendor
12	Capacity
12	Inventory
12	Overstock
12	Supply
9	Geo-Political
6	Demand

Risk Quantification

Risk Multiplication Model

$$R_x = \forall I_r * \forall I_l * P_x$$

Level	Impact	Probability
High	9	9
Medium	3	3
Low	1	1

Risk	Impact	Probability	Risk Sum	Score
Loss				
Customer Sat	3	-	-	
Financial	9	-	-	
Time	9	-	-	
External				
Environmental	9	1	729	729
Forecast	3	3	243	729
Geo-Political	9	1	81	81
IP	3	1	243	243
Macro-Economic	9	9	81	729
Transportation	9	3	2187	6561
Vendor	9	1	243	243
Internal				
Asset Value	3	9	81	729
Capacity	1	1	81	81
Data	9	9	6561	59049
Demand	1	9	3	27
Financial	9	1	2187	2187
Inventory	9	1	81	81
Operations	9	1	6561	6561
Overstock	1	9	9	81
Receivables	1	9	81	729
Resource	9	3	729	2187
System	9	3	59049	177147
Supply	1	1	81	81

Score	Risk
177147	System
59049	Data
6561	Transportation
6561	Operations
2187	Financial
2187	Resource
729	Environmental
729	Forecast
729	Macro-Economic
729	Asset Value
729	Receivables
243	IP
243	Vendor
81	Geo-Political
81	Capacity
81	Inventory
81	Overstock
81	Supply
27	Demand