UNIVERSITI PUTRA MALAYSIA

A RISK MANAGEMENT EVALUATION FRAMEWORK FOR REVERSE LOGISTICS ORGANIZATIONS USING FAILURE MODE AND EFFECT ANALYSIS AND MULTI CRITERIA DECISION MAKING

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By

HAMID REZA PANJEHFOULADGARAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my father and mother with whom, presence can be defined, love becomes immortal and hopes get renewed everyday

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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HAMID REZA PANJEHFOULADGARAN

January 2016

Chairman : Professor Rosnah Mohd Yusuff, PhD
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Reverse Logistics (RL) is defined as all activities that return used products from the consumers and transform it to usable products to decrease landfill and protect the environment. In RL, the reprocessed used products are competing with new products in terms of quality, quantity and value. The typical processes in designing a RL network includes the collection, inspection, selection and sorting, reprocessing options and redistribution. The complexities of these processes make them vulnerable to risks, which can threaten the performance of RL, and affect investment opportunities. RL is relatively new compared to supply chain management. The risk factors relevant to RL have not been comprehensively identified and consolidated. Since RL risk factors have not been identified, classification and evaluation of these risks are still unexplored. Thus, this study aims to develop a reverse logistics risk management framework including identification, classification and evaluation and monitoring processes. Since there were no previous studies on risks factors for RL, the risks that have been identified in supply chain management and logistics literature were extracted as a basis in determining the RL risk factors. Once the risk factors were identified by RL experts in the field, the risks were classified into homogeneous groups using Self-organizing map (SOM). The number of corrective actions will be lesser and more economical for a cluster of risks than applying corrective action for each risk factor. Fuzzy Failure Mode and Effects Analysis (FMEA) were applied to evaluate RL risks factors. Finally, the clustered risk factors were ranked using the technique for order preference by similarity to ideal solution (TOPSIS) to determine the level of importance among reverse logistics risk factors. The Based on feedbacks from 22 RL experts, 41 risk factors were identified. Self-organizing map (SOM) determined three independent clusters of RL risk factors. The risk priority number (RPN) evaluated by fuzzy FMEA showed customer risk with 761, followed by long distance with 759 and business

disruption with 753 as the most important RL risk factors based on the experts' opinion. The result of risk monitoring via TOPSIS method in ranking of the RL risks within and without clustering showed purchase risk, financial instability and inventory risk are highly ranked among the RL risk factors in the three clusters. Finally, a RL risk management framework was developed to address the risks for RL. The Reverse logistics risk management framework can assist decision makers in RL organizations to identify potential risk factors which threaten their process performance. Moreover, classification of risks in RL and their evaluation based on the proposed framework may be useful for adoption of corrective action and mitigation of the risks and consequently increasing the success of the RL organization.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

RANGKA KERJA PENGURUSAN RISIKO BAGI ORGANISASI LOGISTIK BERBALIK MENGGUNAKAN MOD KEGAGALAN DAN KESAN ANALISIS SERTA KEPELBAGAIAN KRITERIA PEMILIHAN UNTUK MEMBUAT KEPUTUSAN

Oleh

HAMID REZA PANJEHFOULADGARAN

Januari 2016

Pengerusi : Profesor Rosnah Mohd Yusuff, PhD
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Logistik Berbalik (RL) didefinisikan sebagai semua proses yang mengembalikan produk-produk yang telah digunakan dan mengubahnya kepada produk-produk yang boleh dimanfaatkan fungsinya untuk mengurangkan kapasiti tapak pelupusan sampah dan memelihara alam sekitar. Dalam RL, produk yang telah digunakan akan diproses semula dan bersaing dengan produk-produk baru dari segi kualiti, kuantiti dan nilai. Proses tipikal dalam membentuk jaringan rangkaian RL adalah termasuk proses pengumpulan, pemeriksaan, pemilihan, pengasingan, pilihan pemprosesan semula dan pengagihan semula. Kerumitan proses ini menjadikan mereka terdedah kepada risiko yang boleh mengancam prestasi RL, dan dalam masa yang sama boleh menjejaskan peluang pelaburan. RL adalah sistem pengurusan yang terkini berbanding pengurusan rantaian bekalan. Kajian faktor-faktor risiko yang berkaitan dengan RL masih belum dikenal pasti dan belum digabungkan secara menyeluruh. Oleh yang demikian, klasifikasi dan penilaian risiko-risiko ini masih belum diterokai. Justeru, kajian ini dijalankan bertujuan untuk menghasilkan satu rangka kerja yang berkaitan dengan pengurusan risiko logistik berbalik termasuk pengenalan, klasifikasi dan penilaian dan proses pemantauan. Oleh kerana tiada kajian sebelum ini yang berkaitan dengan risiko faktor RL, risiko yang telah dikenal pasti dalam pengurusan rantaian bekalan dan logistik sastera dipetik sebagai asas dalam menentukan faktor-faktor risiko RL. Apabila faktor-faktor risiko telah dikenal pasti oleh pakar-pakar dalam bidang RL, risiko telah dikelaskan ke dalam kumpulan yang sama menggunakan *Self-organizing map* (SOM). Tindakan pembetulan yang perlu diambil untuk satu kelompok faktor risiko memberikan lebih penjimatan dan lebih kurang daripada mengaplikasikan tindakan pembetulan bagi setiap faktor risiko. Mod Kegagalan *Fuzzy* dan Analisis Kesan (FMEA) telah digunakan untuk menilai

kembali faktor-faktor risiko RL. Akhir sekali, faktor-faktor risiko berkelompok telah dikemas kini dan diatur menggunakan teknik keutamaan dari sudut persamaan dengan penyelesaian ideal (TOPSIS) untuk menentukan tahap kepentingan faktor-faktor risiko logistik berbalik. Berdasarkan maklum balas daripada 22 orang pakar RL, 41 faktor risiko telah dikenal pasti. *Self-organizing map* (SOM) telah menentukan tiga kelompok bebas daripada faktor-faktor risiko RL. Bilangan keutamaan risiko (RPN) dinilai oleh FMEA *Fuzzy* menunjukkan risiko pengguna sebanyak 761 unit, diikuti oleh jarak jauh sebanyak 759 unit dan gangguan perniagaan sebanyak 753 unit; dan ia merupakan faktor risiko RL paling penting berdasarkan pendapat pakar-pakar dalam bidang ini. Hasil pemantauan risiko melalui kaedah TOPSIS dalam senarai risiko RL dengan atau tanpa kelompok menunjukkan hasil risiko pembelian, ketidakstabilan kewangan dan risiko inventori; iaitu risiko yang sangat tinggi berbanding dengan tiga kelompok yang lain. Akhir sekali, satu rangka kerja pengurusan risiko RL telah dihasilkan untuk menangani risiko RL. Rangka kerja pengurusan risiko logistik berbalik boleh membantu pembuat keputusan dalam organisasi RL untuk mengenal pasti faktor-faktor risiko yang berpotensi yang boleh mengancam prestasi proses mereka. Lebih-lebih lagi, pengelasan risiko dalam RL dan penilaian mereka berdasarkan rangka kerja yang dicadangkan itu mungkin berguna untuk penggunaan tindakan pembetulan dan pengurangan risiko dan seterusnya meningkatkan kejayaan organisasi RL ini.

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I certify that a Thesis Examination Committee has met on 18 January 2016 to conduct the final examination of Hamidreza Panjehfouladgaran on his thesis entitled "A Risk Management Evaluation Framework for Reverse Logistics Organizations using Failure Mode and Effect Analysis, and Multi Criteria Decision Making" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

RL	Reverse Logistics
SCM	Supply Chain Management
FLC	Fuzzy Logic Controller
FMEA	Failure Mode and Effects Analysis
RPN	Risk Priority Number
SOM	Self-Organizing Map
TOPSIS	Technique for Order Preferences by Similarity to Ideal Solution
GSCM	Green Supply Chain Management
SSCM	Sustainable Supply Chain Management
CLSC	Closed Loop Supply Chain
SCRM	Supply Chain Risk Management
MCDM	Multi Criteria Decision Making

CHAPTER 1

INTRODUCTION

1.1 Reverse Logistics Risk Management

In reverse logistics (RL), product recovery processes like refurbishing; recycling, remanufacturing, repair, redesign and reuse are integrated into manufacturing processes in order to achieve sustainability and decreasing landfills. Product recovery also helps to reduce wastes and raw material extraction and consequently decrease the negative effects on the environment (Barker and Zabinsky, 2011; Lambert et al., 2011; Nikolaou et al., 2013).

The benefits achieved from product recovery are like customer satisfaction, customer value, decreasing resource investments and cost. Thus, product recovery can lead to high revenue and decrease cost (Govindan et al., 2012; Lambert et al., 2011; Turrisi et al., 2013). A good RL can provide competitive advantages for the companies to decrease the customer's risk and increase customer's value. However, recovered products are competing with new products in quality, quantity and value, preventing them in gaining market share (Russo and Cardinali, 2012; Turrisi et al., 2013). These risks might be affecting the success of RL, making risk management an important aspect of any organizations (Cagliano et al., 2012; Gaudenzi and Borghesi, 2006; Khan et al., 2008).

The importance of risk management in RL relied on increasing the value for the supply chain in reverse direction by means of mitigating the risks and decreasing the negative environmental impacts and cost. Researchers have studied supply chain risk management in order to prevent severe negative impacts on the organizations, but there is hardly any research on RL risk management. Hence, RL risk management that is an emerging field with supply chain management (SCM), as well as risk factors is still unexplored (Ageron et al., 2012; Carter and Rogers, 2008; Hall et al., 2013).

A framework on RL risk management may help to mitigate the risks and control the undesirable effects on RL environment. By developing the RL risk management framework, this study hopes to contribute to the lack of knowledge in RL risk management. Organizations will be able to identify clearly the risks faced by their organizations in RL, how to manage them and plan for a successful RL organization.

1.2 Problem Statement

Reverse logistics plays an important role in determining the sustainability of the environment. Since RL compete with new products, investment on product recovery may be risky for the RL organizations. Moreover, RL effects on dynamic of supply chain and it forces organizations to monitor the RL processes. Furthermore, managing the risks and adoption of risk mitigation strategies, increases level of success in the RL organizations (Turrisi et al., 2013). However, risk factors in RL have not been studied as compared to risk factors in SCM. Identifying the risks and their sources will enable RL organizations to reduce the negative effects on RL processes (Huscroft et al., 2013; Turrisi et al., 2013).

The identification of RL risk factors will enable the risk factors to be identified early, gave greater confidence for companies to implement it, and ensure that it contributes to the organizations (Blome and Schoenherr, 2011; Olson and Wu, 2011; Pokharel and Mutha, 2009; Tuncel and Alpan, 2010). The whole risk management process requires risks to be clustered, assessed and monitored. Since risk in RL has not been identified before, the next two steps will be required to be carried out also. Risk clustering decreases the cost of corrective actions for a group of risks factors rather than individual risk (Aqlan and Lam, 2015; Tummala and Schoenherr, 2011). Various methods have been recommended by researchers for risk classification with pros and cons. However, there is no consensus for applying a specific method for clustering of high dimensional input data with large and small dataset. In terms of risk evaluation, FMEA is one of the most prevalent and a powerful tool for risk assessment. Since FMEA works with crisp numbers, its output is not precise to apply in real cases. Combinations of fuzzy set theory and FMEA would give better outcomes as it can be applied to real situations. The lack of research in risk monitoring processes, which is particularly required for the decision makers in RL organizations will also have to be investigated. Risk monitoring determines priority for corrective solutions with minimum cost of actions for individual of a group of similar risk. Therefore, current research will develop a risk management framework to fill the gaps in the literature of RL risk management.

1.3 Objectives

The aim of this research is to develop a framework for risk management in RL. Therefore, the main objectives of the research are as follows:

1) To identify the risk factors in RL.
2) To classify RL risk factors by Self-Organizing Map (SOM).
3) To evaluate risk factors in RL by Fuzzy FMEA and monitoring them by TOPSIS method.

1.4 Significant of Study

A framework for risk management in RL can be used as a basis for decision makers in RL to identify the threats to their organizations. The classification of risk factors may help to reduce the amount of investment for risk mitigation. Corrective actions for a cluster of risks are more cost effective rather than risk mitigation actions for risks individually. Finally, the risk evaluation will help to determine the priority of the risks for the RL organizations to focus and choose corrective actions to mitigate the risks. The risk evaluation increases the level of reliability for the organizations to invest the RL activities.

1.5 Scope of the Work

The study is focused on risk management in RL. Therefore, scope of the work is defined as follows:

1) Since the risk factors for RL have not been identified in previous works, the risk factors of SCM have been used as a basis of risks in RL.

2) The respondents for data collection were chosen among experts in RL, risk management and SCM. Most of the experts were chosen from university academicians, practitioners, and authors of international journal papers in the related fields. Since risks in RL are not widely studied the data collected were also limited.

1.6 Organization of Thesis

The thesis is organized in five chapters. Chapter one is on the introduction of the thesis which is included the problem statement, objectives, scope and limitation of the whole work.

Chapter two is on literature review which is included important aspects of research from previous studies. Topics covered SCM, sustainable supply chain, green SCM and CLSC. RL, risk management are thoroughly studied. Failure mode and effects analysis (FMEA), self-organizing map (SOM), Fuzzy logic controller (FLC) and technique for order preferences by similarity to ideal solution (TOPSIS) are also reviewed in chapter two.

Chapter three of the thesis describes the methodology used in the research. All process of risk management in RL that are used in this research are described in this chapter. Chapter four is shown the results of the risk management in RL. Identified risk factors in RL and its classification are reported in this chapter. The results of risks evaluation and monitoring in RL are also presented in chapter four. Chapter five, is concluded this research and is represented some recommendations for future researches.

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