Robustifying Supply Chains against Corruption Risk: A New Zealand Dairy Industry Study Using System Dynamics

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Abstract

Studies on dairy supply chain risk management (SCRM) primarily cope with specific risks or partial supply chains. Little research focuses on risk management from a comprehensive perspective. Risk interactions lead to ultimate supply chain performance (SCP). Thus, a systemic study on dairy SCRM contributes to exploring the complexity of this supply chain. Corruption in supply chains would negatively affect businesses, and has attracted increasing concerns. However, research on corruption within supply chains is largely overlooked. Corruption risk in supply chains is identified as a research gap. This research explores how corruption modifies the effects of supply chain risks (SCRs) and thereby SCP in the dairy sector, and develops mitigation strategies to robustify supply chains against corruption risk.

This research critically reviewed literature on corruption, SCRM, corruption as a risk factor in the supply chain, supply chain robustness against corruption, and corruption risk in the context of dairy supply chains. Accordingly, research gaps and research questions were formed. A conceptual framework was developed to exhibit the research process and research methods. This research adopted in-depth case studies in New Zealand dairy companies, substantially covering the entire dairy industry in this country. Thematic analysis was performed on interview data primarily collected from high level managers. Case studies identified risk factors for primary risk events in New Zealand dairy supply chains, as well as the impacts of corruption. Examining the interactions amongst SCR variables and corruption contributes to a high level picture. System dynamics (SD) modelling was consequently employed to explore underlying dynamic relationships among variables. Both direct and indirect impact of corruption on the supply chain can be expected to be investigated through simulation. By integrating corruption's impact with supply chain operations, this research is unique in applying the concept of robustness to mitigate corruption risk. This study defines and manages leverage risks, which minimise the impact of corruption on SCP and thereby enhance supply chain robustness against corruption effectively.

Keywords: Corruption, SCRM, Dairy SCRs, Supply chain robustness, Case study research, SD modelling

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Glossary

CLD	*Causal Loop Diagram*
CPI	*Corruption Perceptions Index*
IP	*Independent Processor*
NZ	*New Zealand*
SCP	*Supply Chain Performance*
SCR	*Supply Chain Risk*
SCRM	*Supply Chain Risk Management*
SD	*System Dynamics*
SFD	*Stock and Flow Diagram*

1 Introduction

1.1 Research background

There have been a number of studies on corruption from various perspectives such as economy, politics, and culture. Corruption is an intricate system and widespread in our society. It is associated with various dimensions in both public and private sectors, and negatively impacts overall development. Businesses are exposed to corruption risk in the supply chain with unchecked momentum. According to PwC's 2018 Global Economic Crime and Fraud Survey (PwC, 2018), bribery and corruption was ranked among the top five in industries such as consumer, professional services and industrial products. UN Secretary-General Ban Ki-moon indicated that "businesses must also prevent corruption within their ranks, and keep bribery out of tendering and procurement processes" and urged the private sector to "adopt anti-corruption measures in line with the UN Convention" (United Nations, 2009).

Although New Zealand (NZ) is consistently among the least corrupt nations, NZ businesses cannot be complacent (Ministry of Justice, 2013). According to a report (Paredes, 2014), one-third of NZ businesses have experienced fraud during the last two years. Among NZ's "Big Five Frauds", bribery and corruption rank the third (15%), but economic crime figures of NZ are below the global average. To help NZ businesses fight against corruption, an integrity group was formed including organisations such as Transparency International, the Serious Fraud Office, Deloitte, Chapman Trip, BusinessNZ, and ExportNZ (SFO, 2014).

Corruption in supply chains is able to penetrate every aspect of business operations (Transparency International, 2009), for example, Volkswagen's emission scandal in 2015 and the China Shandong illegal vaccine scandal in 2016. Rolls-Royce, an engineering giant, bribed middlemen for orders in six countries (Watt, Pegg, & Evans, 2017). Odebrecht, Brazil's biggest engineering conglomerate, bribed officials for contracts in 12 countries (Pereira, 2017). Besides this, there were increasing cases of corruption in multinational corporations in China. As stated by People's Daily Online (2009), 64% of the investigated 500,000, or more, corruption cases over the last decade in China were related to international trade and foreign businesses. The well-known corporations such as Walmart, IBM, Carrefour, and Siemens were involved in commercial bribery. However, in both developed and developing territories, only around one third organisations conduct risk assessment pertaining to anti-bribery and corruption (PwC, 2018).

1.2 Research focus

In the global economy, competition between businesses has migrated to the supply chains. It has been suggested that the drive towards more efficient supply chains has caused them to be more vulnerable to disruption (Christopher & Lee, 2004; Engardio, 2001; Jüttner, 2005). Terms such as disruption and disturbance are generally used to describe triggering events (Radhakrishnan, Harris, & Kamarthi, 2018). Risk is concerned by the likelihood and impact of events, and ISO (2018) defines risk as "effect of uncertainty on objectives" which is observed from dimensions such as risk sources, potential events, their consequences and their likelihood. Of them, risk source is "element which alone or in combination has the potential to give rise to risk"; event is "occurrence or change of a particular set of circumstances"; consequence is "outcome of an event affecting objectives"; and likelihood is "chance of something happening" (ISO, 2018). As expressed by Radhakrishnan et al. (2018), supply chain vulnerability is normally linked with risk since supply chain vulnerability is a supply chain's susceptibility to the likelihood and impact of disruption. In Asbjørnslett (2009)'s view, vulnerability could be employed to illustrate the lack of supply chain robustness or resilience in facing threats that emerge within and out of the supply chain system boundaries. Further, robustness is defined as "a system's ability to resist an accidental event and return to do its intended mission and retain the same stable situation as it had before the accidental event" (Asbjørnslett, 2009). It has been demonstrated by Wieland and Wallenburg (2012) that SCRM is significant for supply chain robustness. Considering the characteristics of complex supply chains, numerous risks accompanying efficiency and effectiveness can be uncovered. Studies show that proper management of SCRs can significantly affect corporate profits (Cousins, Lamming, & Bowen, 2004; Hendricks & Singhal, 2005). SCRM has become a strong focus of both academics and practitioners (Ghadge, Dani, & Kalawsky, 2012; C. Tang, 2006; Dexiang Wu, Wu, Zhang, & Olson, 2013). Wieland and Wallenburg (2012) indicated that SCRM contributes to reducing supply chain vulnerability through proactive (robust) and reactive (agile) strategies. Besides, they called for more studies to focus on supply chain robustness, considering its importance to customer value as well as business performance.

As various types of SCRs would emerge, Wieland and Wallenburg (2013) suggested that the impact of risk types (e.g., everyday vs exceptional risks) deserves reflections with regard to supply chain robustness studies. One special risk factor, corruption, could even bring disastrous impact to a supply chain. Corruption was listed among triggers of widespread and systemic supply chain disruptions (World Economic Forum, 2012). As a widespread and persistent problem, corruption has undergone plentiful researches from various perspectives. In recent years, there has been a transfer in corruption studies from country-level to firm-level data (Jensen, Li, & Rahman, 2010), from macro-level to micro-level (C. Hauser & Hogenacker, 2014), and from public sector to private sector (Sööt, Johannsen, Pedersen, Vadi, & Reino, 2016).

Corruption in supply chains has both private-to-private corruption and private-to-public corruption, where private-to-public corruption (companies bribe government officials for public contracts or government services) only occupies a minor proportion (Transparency International, 2009). The threat of corruption to the private sector and supply chains has been demonstrated by Webb (2016), who stressed that the Global Declaration against Corruption which was held in May 2016 tackled very little business activity. Argandoña (2003) appealed that private-to-private corruption is worth more concern since it is a serious issue and would lead to high financial, legal, social and ethical costs. Considering the complexity of supply chains, corruption in a small scale in a company would impair reputation of the whole supply chain (CREM, 2011). Arnold, Neubauer, and Schoenherr (2012) indicated that little research can be found studying corruption from the perspective of operations and supply chain management. They investigated factors that facilitate companies' inclination towards corruption in operations and supply chain management. However, no research focuses on minimising corruption's impact in presence of corruption.

As such, this research identifies corruption risk in the supply chain as a research gap. As indicated in the preceding description: 1) supply chain vulnerability is associated with SCRs; 2) supply chains would be threatened by corruption, leading to high costs; 3) SCRM facilitates the reduction of supply chain vulnerability through proactive (robust) and reactive (agile) strategies. Regarding the proactive (robust) strategies, measures are taken to prevent the risk from occurrence or minimise its impact when it occurs (Wieland & Wallenburg, 2012). Hence, this research aims at robustifying supply chains against corruption risk. SCRs and corruption's moderated impact on SCRs are explored through case study research. The interactions among risk variables are explicated by constructing SD models. Leverage risks (discussed in later chapters) are identified and mitigated to enhance supply chain robustness in the presence of corruption. To further explore this research topic, NZ dairy industry is selected for case studies.

Dairy products are crucial components of the Western and Asian style diet. Milk is an important source of essential nutrients (Tsuda et al., 2000). Particularly, it forms a large part of young children's diet. The dairy industry would be vulnerable to scare of contamination. A typical example is the incident of 2008 melamine contamination of infant formula in China. Additionally, an occurrence of contamination in the botulism scare of 2013 risks not only Fonterra's reputation (a leading global dairy firm in NZ), but also the country's reputation as an exporter.

SCRs and corruption in the dairy industry have become a serious concern. A risk in a node propagates to other nodes within a supply chain. A minor risk in a supply chain could produce a disastrous effect (Waters, 2011). This can be illustrated by the product recall crises. Steves (2016) summarised historically significant recall events from 1982 to 2015. Some of the recall events are caused by the problems of suppliers. For example, in 2007, because of the ingredient contamination by a supplier, the company Menu Foods recalled large quantities of containers of pet food. Product recalls bring about company losses and customer confidence declined. Consecutive crises in the dairy sector results in the increased concerns of firms and individuals regarding product quality and safety. Corruption, as a risk variable (Nasir, Quaddus, & Shamsuddoha, 2014), is one of causes of possible quality deterioration (Enderwick, 2009). It is challenge for NZ dairy firms to operate a business in an offshore market since they are unable to effectively manage the entire global supply chain. Because of this, more dairy firms actively seek effective and flexible supply chain management to be more robust in order to mitigate the negative effects of SCRs and corruption.

NZ is an international leader to produce and export dairy products. The dairy industry consists of a large portion of the country's exports, which occupies 3.5 percent of the national GDP (Ballingall & Pambudi, 2017). However, in NZ dairy industry, little research can be found on risks and corruption from the perspective of supply chain management, so this research will explore strategies to robustify supply chains against corruption risk in the NZ dairy industry.

1.3 Research objective

This research critically reviews relevant literature, and identifies corruption risk in the supply chain as a research gap. To bridge this research gap, this research focuses on how corruption modifies SCR effects, as well as on management strategies of SCRs to enhance robustness in the presence of corruption. The impact of corruption is included in the study of dairy SCRs and their mitigations. There are three primary research objectives in this research project.

(1) To examine dairy SCRs from a systemic perspective

Dairy risks propagate throughout supply chains. A systemic and dynamic view in dairy SCRs would complement current studies on dairy risk management.

(2) To understand corruption from the perspective of supply chains

Research on corruption generally concerns the economy, politics, culture and other factors from a specific or systemic perspective. This research studies corruption as a risk factor for the supply chain, and aims to extend the body of knowledge in supply chain corruption.

(3) To explore how corruption modifies SCR effect and SCP, and develop management strategies to robustify supply chains against corruption

Corruption would modify the effect of SCRs as well as SCP, which has not been well studied in academic research. This research could incorporate corruption's impact into the study of dairy SCRM, and develop corresponding management strategies.

1.4 Thesis structure

This section puts forward the thesis structure, by using a flowchart in Figure 1.1 to exhibit the research process.

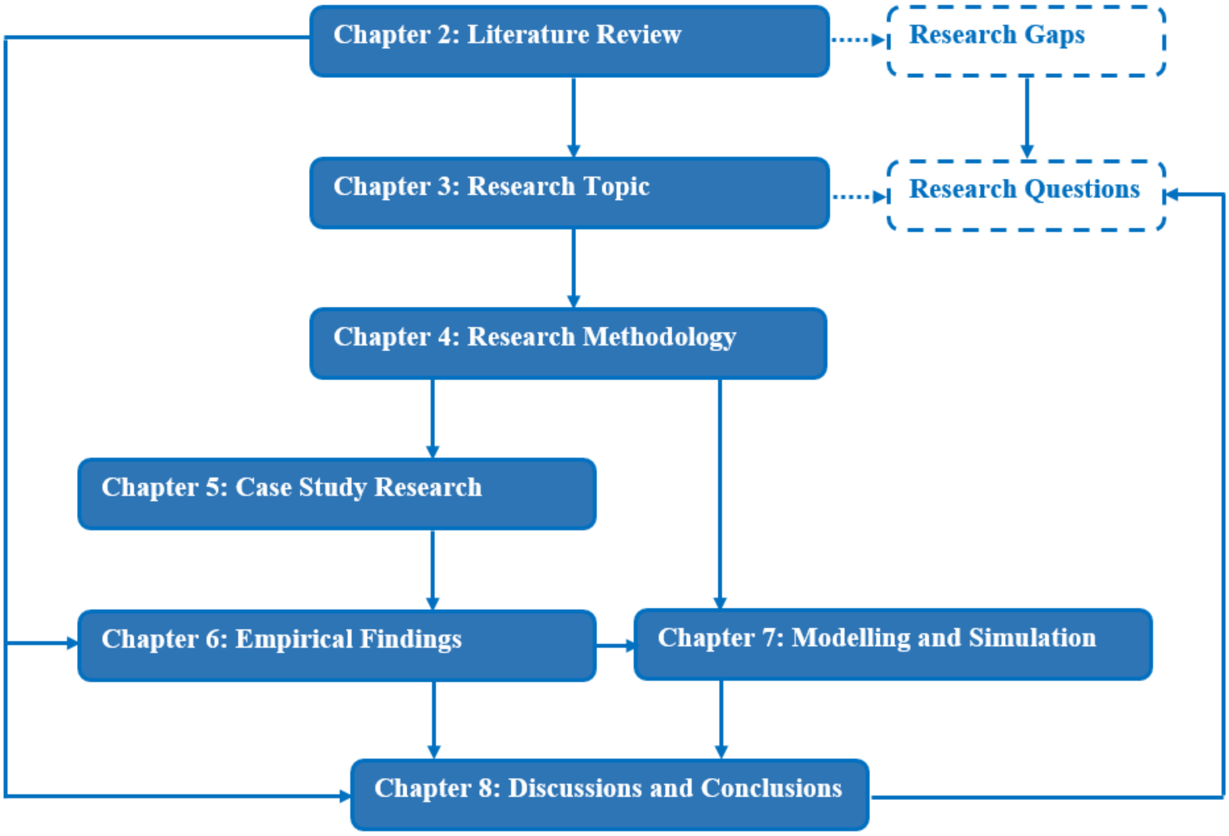


Figure 1. 1 Flowchart of this Thesis

Chapter 2 critically reviews literature on corruption, SCRM, corruption as a risk factor in the supply chain, supply chain robustness against corruption, and corruption risk in the context of dairy supply chains. This chapter contributes to understanding the state of art in pertinent fields, and identifies the research gap in this study.

Chapter 3 proposes the research topic and elaborates the formation of research questions. The research topic is clearly illustrated through a figure, which shows the interactions between corruption and the supply chain system. Thereafter, research rationale is presented to lay a foundation for conducting subsequent research.

Chapter 4 explicates the research methodology in this project. This chapter displays the research framework which shows the process of filling the research gap. Two research methods are also introduced - case study research and SD modelling.

Chapter 5 presents the process of conducting case study research. In this chapter, the NZ dairy industry is selected for exploring this research topic. Case organisations, techniques used to collect data, and the method to perform data analysis are illustrated, which are the premises for the next chapter.

Chapter 6 summarises the empirical findings by analysing the collected data. Dairy SCRs and the impact of corruption are explored respectively. The derived risk indicators are compared with extant literature.

Chapter 7 builds SD models based on the empirical findings. A complex system is constructed concerning dairy SCRs in the presence of corruption. With the simulation results, management strategies are developed on how to enhance supply chain robustness against corruption.

Chapter 8 rounds off the thesis by summarising empirical and modelling findings, comparing with extant literature to discuss systemic analysis of dairy SCRM and supply chain robustness against corruption, putting forward the contributions made in this research, highlighting research implications and limitations, and pointing out possible future research avenues.

2 Literature Review

2.1 Corruption

Corruption is a pervasive problem in the world. It is a misuse of power aimed at gaining private benefits; all countries can be affected in some way. Many studies have struggled with the definition of corruption and most of the definitions are associated with public officials. Shleifer and Vishny (1993) regarded government corruption as "the sale by government officials of government property for personal gain". The World Bank (1997) defined corruption as "the abuse of public office for private gain". This definition covers major kinds of corruption confronted by the World Bank itself.

However, corruption is not confined to public officials; the private sector also needs consideration. Heidenheimer, Johnston, and LeVine (1989) thought corruption is a transaction between the public and private sectors, and thus public goods are transformed into private gains illegitimately. Rose-Ackerman (1978) considered that corruption is at the intersection of these two sectors. Roy (2005) gave a new definition of corruption for 21st century business managers. He regarded it as "a phenomenon that involves illegal, immoral gratification in cash or kind in exchange for securing an unethical advantage over others in business and/or in society", thus differing from existing definitions, it considers stakeholder issues.

According to a report commissioned by NORAD (Andvig, Fjeldstad, Amundsen, Sissener, & Søreide, 2000), corruption exists in organisations without state agencies or state officials, such as private businesses, non-governmental organisations and associations. Corruption presents in the form of bribing, swindling or mafia-methods. It is also a moral and cultural problem and some illegal habits are accepted and expected, causing hidden costs and confusing the distinction between the public and private sectors.

2.1.1 Corruption in a broad category

Many studies have analysed the relationship between widespread corruption and slow growth. As UN Secretary-General Ban Ki-moon said on 2012's International Anti-Corruption Day, the cost of corruption contains not only the apparent loss of numerous stolen or squandered government resources, but also the recessive loss of schools, hospitals, clean water, roads or bridges built with that money, therefore changing fate of families and communities (United Nations, 2012). However, corruption still prevails, and it seems that people do not have many incentives to fight against it. Mauro (2004) built two models to achieve multiple equilibria in corruption by using strategic complementarities. Only outside bodies or non-governmental organisations may help the government break the vicious corruption cycle. A. Mishra (2006) emphasised that we should pay attention to the persistence of corruption, instead of the practice itself. A static framework was applied to reveal how widespread corruption becomes a social norm.

A norm, independent of government, is an attractive way of social control. Any deviation from the norm will be disapproved and refused (Elster, 1989; Posner & Rasmusen, 1999). According to repeated experiments by Barr and Serra (2010), the engagement in corruption of some individuals shows their values and social norms which indicates that corruption is partly a cultural phenomenon. Historical precedents and customs may influence a nation in its institutions and contractual norms (Knack & Keefer, 1995; Lambsdorff, 2006; Paldam, 2002). The degree of historical influence on corruption is determined by how history shapes cultural norms of the society because the cultural norms dominate corrupt acts (Goel & Nelson, 2010).

After research by Olken (2007) and Blume and Voigt (2011) on the link between corruption and government auditing, J. Liu and Lin (2012) explored how to curb corruption from the perspective of government auditing via an empirical study. They argued that rectification activities after audits are helpful in government transparency and relieve the corruption problem.

Treisman (2000) surveyed corruption's victims by analysing six variables: British heritage, Protestant tradition, log per capita GDP, openness to imports, federal structure, and uninterrupted democracy. He claimed that the former four indexes can reduce corruption. A federal structure is associated with a more corrupt status than a unitary one. Democracy reduces corruption only after it has been in effect for decades. The aspect of democracy was agreed by Lambsdorff (2005), who proposed that democracy produces an effect of reducing corruption in the long run. He also emphasised that it does not include the medium type of democracy which may even increase corruption.

Serra (2006) proposed economic development levels, democratic institutions and political stability when analysing corruption. She indicated that richer countries are likely to have less corruption (seen also in Billger and Goel (2009)). Schumacher (2013) identified that a higher income tends to lower the politician's intention to corrupt. Besides this, strong social capital helps to decrease bribe-taking. Fan, Lin, and Treisman (2009) conducted an experience-based survey of firm managers in eighty countries and found that more governmental or administrative tiers in a country correlated with more frequent corruption in public affairs, especially in developing countries.

A broad and rapidly growing literature can be found regarding the influence of corruption on economic development. Many researchers like Leff (1964), Huntington (1968), Friedrich (1972), Summers and Heston (1988), Nye (1989) and Acemoglu and Verdier (1998) considered that corruption can be beneficial for the development of an economy. They suggested that when government regulations are strict, dilatory and inefficient, corruption may act as a hedge against bad regulations. Entrepreneurs can avoid inefficient regulations at a low cost. Thus, corruption can raise the operating efficiency of the economic system.

However, various studies are critical about the effect of corruption on an economy. Early researchers such as Krueger (1974), Gould and Amaro-Reyes (1983), and Myrdal (1968) strongly argued that corruption impedes economic development. This is also confirmed by many empirical research studies. Mauro (1995) analysed the relationship between corruption and investment of 58 countries. His research showed that corruption is negatively correlated with the ratio of investment to GDP, and that corruption is detrimental for economic growth. He also found that growth is negatively correlated with the level of corruption in sub-samples of those countries full of strict bureaucratic regulations, which contests the idea that corruption may act as a hedge against bad regulations and promote economic growth. In addition, Knack and Keefer (1995), Gyimah-Brempong (2002), H. Li, Xu, and Zou (2000) and other researchers achieved similar results from an empirical approach. Kaufmann and Wei (2000) supported this view by studying at the firm level. They found evidence showing that paying bribes brings the business sector more costs than benefits. This view is backed up by some recent literature. Aidt (2009) held the opinion that corruption is more sand than grease for the wheels. Likewise, scholars such as Dissou and Yakautsava (2012), and Egharevba and Chiazor (2013) also demonstrated this negative relationship. In the movement of curbing corruption to promote economic growth, persistence was emphasised by Swaleheen (2012). He presented evidence to prove that only when corruption decreases persistently can the economy grow.

Through analysing panel data on 71 developed and developing countries, Ullah and Ahmad (2011) argued that an inverted, U-shaped relationship exists between the corruption index and economic growth (shown in Figure 2.1) by using the Generalized Method of Moment. They found that weakness in institutions, political stability and bureaucratic efficiency are detrimental to economic growth, but corruption is found to be both growth favourable (with low incidence) and growth detrimental (with high incidence).

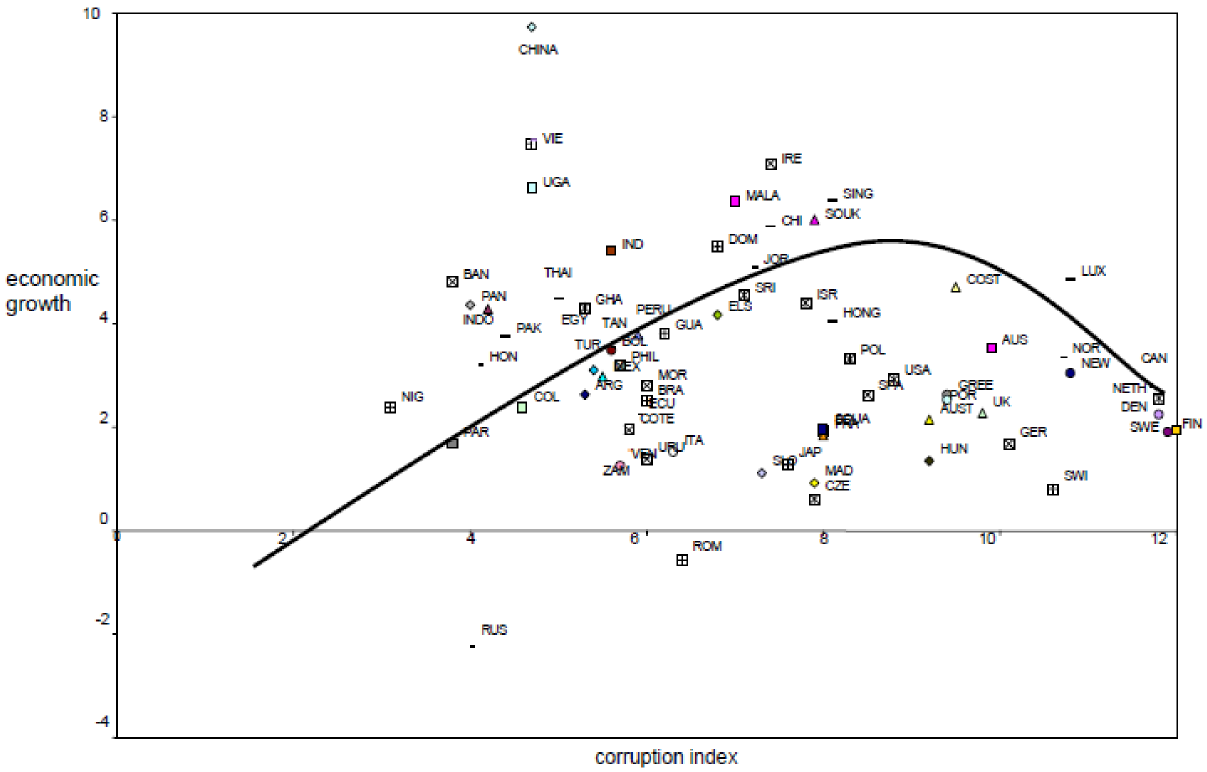


Figure 2. 1 Relationship between Corruption and Economic Growth (Ullah & Ahmad, 2011)

In addition to economic development, corruption also impacts other areas. Johnston (2000) suggested that severe corruption threatens democracy by negatively impacting political institutions and mass participation, and economic development which is needed to sustain democracy. Gupta, Davoodi, and Alonso-Terme (1998) claimed that corruption increases income inequality and poverty through the following paths: 1) reduction of economic growth; 2) decreasing progressivity of the tax system; 3) ineffectiveness of social spending; 4) impact on formation of human capital; 5) impact on asset ownership; and 6) inequality of education. According to evidence from surveying high-level officials of fast growing economies, corruption in the public sector is regarded as the most severe obstacle to national development, with no significant regional differences (Kaufmann, 1997).

The causes and consequences of corruption sometimes interweave with each other. Many studies researched the relationship between corruption and the effectiveness of the legal system (Herzfeld & Weiss, 2003; Jain, 2001; Levin & Satarov, 2000). A significant inter-relationship has been found between them. Corruption leads to the decreasing of a legal system’s effectiveness and vice versa.

Truex (2011) utilised a survey in Nepal to show differences in attitudes toward various corrupt behaviours and found a significant impact of education on these behaviours by a standard OLS regression method. He indicated that increasing education levels may decrease the presence of corruption norms and corruption in developing countries. de Figueiredo (2013) suggested that it is not so accurate to evaluate the corruption level within countries by using measures such as public official convictions per capita. A measurement model which regards an institution as a system with corruption as a failure is proposed and applied to the United States. It is an effective tool for policymakers to identify and reduce corruption levels.

A range of studies focus on corruption from a specific area. Recognizing the lack of systemic research on corruption, Ullah and Arthanari (2011), and Ullah, Arthanari, and Li (2012), integrated corruption-related variables in cultural, economic, political and other realms into a holistic system, and accordingly formed a high-level model to present the complex interactions among those variables. They demonstrated how SD modelling can explore the underlying dynamics of the complex corruption phenomenon.

2.1.2 Corruption in supply chains

According to the CBI Market Information Database (CREM, 2011), corruption causes economic, social, environmental and political damage. Although only economic damage seems directly related to companies, the other three factors also affect the economy in the long term. Social, environmental and political factors can ultimately cause economic damage in some way. Thus, companies are affected by corruption in a broad category. Corruption in one company in the supply chain could influence the whole supply chain's reputation. This means corruption can be propagated among the supply chain system.

Apart from direct cost, corruption in the supply chain also brings indirect costs including management time, relevant resources and so forth (United Nations Global Compact, 2010). With regard to the business case, corporate activities and corresponding corruption are divided into the following spheres (Figure 2.2). Corruption in the domain regarded as relevant for supply chains is shown as commercial bribery, or more broadly called private-to-private corruption. The private-to-public corruption is only a small part of corruption that companies face in the supply chain (Transparency International, 2009).

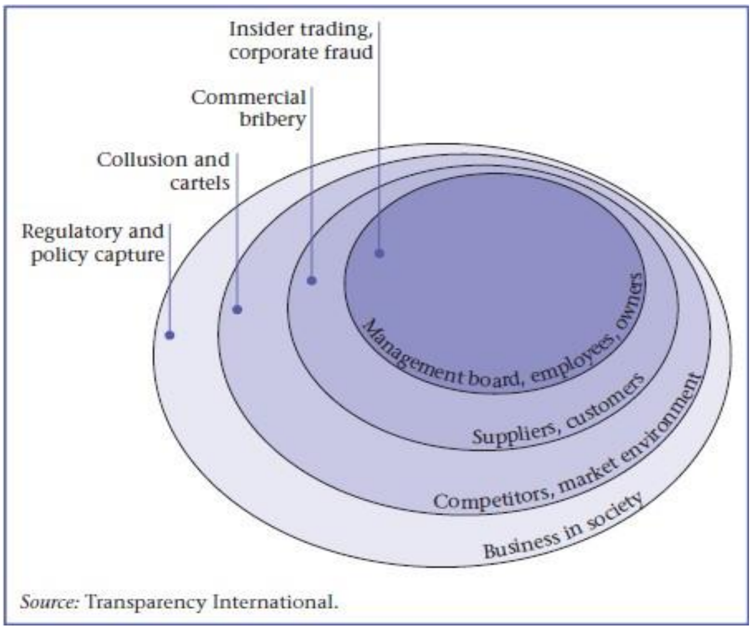


Figure 2. 2 Corporate Activities and Corruption (Transparency International, 2009)

Howard, Krause, and Gibson (2010) mentioned the global trend of commercial bribery prohibition. Such prohibition can even be found in countries known to be infested with corruption. Heine, Huber, and Rose (2003) focused on the study of anti-bribery laws in the private sector among 13 OECD countries. International Chamber of Commerce (2002) suggested that claiming damages from the private-to-private corruption is rare because of difficult procedures, difficulty of providing evidence for the act, criminal and civil measures separation, high costs and the reluctance of victims. Argandoña (2003) pointed out that private-to-public corruption attracts primary concerns because of its impact on economics, society, politics, and ethics. He argued that private-to-private corruption is also important, widespread, harmful, and worth combating. However, he realised that the number of studies on private-to-private corruption is much less than that on public sector corruption. Argandoña (2003) pointed out that private-to-private corruption has started to attract particular concerns since around 2000. Transparency International (2009) emphasised the importance of fighting corruption in the private sector. Although there is growing interest on private sector corruption, systematic research is still minimal. Therefore, Sööt et al. (2016) conducted a baseline study and solved problems such as managers' perceptions on risks related to private sector corruption, and the relationships between managers' perceptions on corruption risks and strategies for preventing corruption.

Fighting corruption is not only a task for governments, but also for organisations. Achilles (2015) discussed the reasons why companies should also fight against corruption: (1) Corrupt companies within the supply chain can make related companies spend both money and time dealing with the complications; (2) Supplier corruption may affect customers legally and bring serious damage to their reputations; and (3) If companies check the supply chain against corruption actions together with customers, product quality and company growth can be achieved. Concerning the public sector corruption, Roy (2005) underlined anti-corruption from the perspective of decision-making managers. He asserted that external control is not enough to fight against corruption. Internal self-restraint models for making decisions should be concerned in anti-corruption activities. A corruption-related decision-making model was proposed in his research to assist decision-making managers when facing corruption-related situations.

One significant category of supply chain corruption is procurement fraud committed by suppliers, often in league with their customers' own employees (United Nations Global Compact, 2010). Arnold et al. (2012) asserted that no research focuses on corruptive behaviour in the field of operations and supply chain management. They identified factors influencing the inclination of a company toward corruption, which are organisational complexity, corporate culture, internationality, and functional complexity. Supply chain corruption is still at a nascent stage, and this research attempts to extend knowledge in this field by defining its concept, as Wacker (2004) suggested that vague definitions can result in confusion and inhibit theory development. Hence, based on the corruption's definition given by Roy (2005), the researcher defines supply chain corruption as *an activity within a supply chain, that involves illegal or immoral behaviour to obtain illegal or unethical rewards over others by abuse of power, and is conducted by person(s) in:*

(a) government agency; or

(b) private sectors; or

(c) other stakeholders.

2.2 SCRM

2.2.1 Definition of relevant terminologies

Risk is always connected with uncertainty and surprise. It is often hard to differentiate risk and uncertainty. P. K. Mishra and Raja Shekhar (2012) defined risk as "an event with known probability, which brings out an unpleasant result", and considered uncertainty as "an event with unknown probability necessitates the same". Risk is most commonly regarded as "the variation in the distribution of possible outcomes, their likelihoods, and their subjective values" in the classical decision theory (March & Shapira, 1987). J. Vilko, Ritala, and Edelmann (2014) underlined the importance of considering the levels and nature of uncertainty for risk management in supply chains. In their study, J. Vilko, Ritala, and Edelmann proposed a conceptual framework about different types of uncertainty in the context of supply chains, and contribute to the development of better risk management strategies by understanding uncertainty types. Risks and hazards were distinguished by Sadgrove (2005), who stated that a hazard is a source of potential harm, while risk is the possibility that a hazard will cause damage. O. Tang and Musa (2011) pointed out two important dimensions of risk, which are the outcome of risk impact, and the expectation of risk sources. This is essentially similar to the formula proposed by Mitchell (1995): $Risk_n = P (Loss_n) * I (Loss_n)$, ('n' stands for different events). This formula considers both the probability and impact of a risk event.

A supply chain is a complex network with various connected organisations. Supply chain vulnerability is exposure to serious disturbance, caused by risks that are both within and external to the supply chain (Christopher & Peck, 2004). Risk and supply chain vulnerability are related in that "at risk" means being vulnerable and likely to be lost or damaged (Christopher & Peck, 2004). A supply chain disruption may cause a deviation from the expected performance, and the deviation leading to adverse consequences for the focal company is regarded as a SCR (Wagner & Bode, 2008). Jüttner, Peck, and Christopher (2003) considered SCR as "the possibility and effect of a mismatch between supply and demand" in a simple term in their research. Jüttner (2005) emphasised that SCR exists not only in the boundaries of the firm itself, but also the boundary spanning flows. Various researchers present their perceptions about defining SCRs. However, there is still no unified definition (Diehl & Spinler, 2013; Sodhi, Son, & Tang, 2012). O. Tang and Musa (2011) defined SCR from two aspects: (1) "events with small probability but may occur abruptly"; and (2) "these events bring substantial negative consequences to the system". They defined SCR from a broad perspective, and did not elaborate it in terms of supply chains. Heckmann, Comes, and Nickel (2015) regarded SCR as "the potential loss for a supply chain in terms of its target values of efficiency and effectiveness evoked by uncertain developments of supply chain characteristics whose changes were caused by the occurrence of triggering-events". Accordingly, I follow the definition given by Ho, Zheng, Yildiz, and Talluri (2015), which is "the likelihood and impact of unexpected macro and/or micro level events or conditions that adversely influence any part of a supply chain leading to operational, tactical, or strategic level failures or irregularities".

Risk management has been increasingly realised by many companies. However, research results are scattered in different fields, such as marketing (Cox, 1967), economics (Kahneman

& Tversky, 1979), strategic management (Simons, 1999), finance (Prechel & Boies, 1998), and international management (Ting, 1988). Many researchers have contributed to the development of risk management from a logistics perspective, for example, Zsidisin and Ellram (1999), Svensson (2002), and Johnson (2001). However, Jüttner (2005) felt that risk management should be studied from a systemic supply chain aspect instead of a single company, and a practitioner perspective is needed to discover the real requirements for SCRM. SCRM is a term coined by L. M. Hauser (2003), and Atkinson (2003), because of growing interest in risks to the supply chain.

Breaking through the limitations in the definition proposed by Norrman and Lindroth (2002), Jüttner (2005) focused on the whole supply chain instead of logistics only and defined SCRM as "the identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole". Managing risks in any supply chain is a significant task for its smooth functioning (P. K. Mishra & Raja Shekhar, 2012). Similar to SCR, scholars have proposed various definitions of SCRM. Pursuing collaborative and integral SCRM strategies is effective in minimizing supply chain disruptions (Revilla & Saenz, 2017). C. Tang (2006) combined some definitions and considered SCRM as "the management of SCRs through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity". According to Goh, Lim, and Meng (2007), SCRM means "the identification and management of risks within the supply network and externally through a co-ordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole". Lavastre, Gunasekaran, and Spalanzani (2012) took both intra-company and inter-company into account and defined SCRM as "the management of risk that implies both strategic and operational horizons for long-term and short-term assessment". While various definitions have been proposed, there is no consensus. Ho et al. (2015) realised that current definitions are not comprehensive in either elements, processes, methods, or events. Thus, they defined SCRM as "an inter-organisational collaborative endeavour utilising quantitative and qualitative risk management methodologies to identify, evaluate, mitigate and monitor unexpected macro and micro level events or conditions, which might adversely impact any part of a supply chain".

2.2.2 Classification of SCRs

Many literature analyses SCRs, and classifies them from different perspectives. Table 2.1 lists the categorisations of risk sources in chronological order.

Table 2. 1 Categorisations of Risk Sources

Year	Categorisations of risk sources	Literature sources
1993	Environmental, industry, organisational, problem specific, and decision-maker related variables	Ritchie and Marshall (1993)
2000	Externally-driven (environmental), internally-driven (process), and decision-driven (information)	DeLoach (2000)
	Exogenous, and endogenous	Ritchie and Brindley (2000)
2002	External to the supply chain, internal to the supply chain, and network related	Jüttner, Peck, and Christopher (2002)
2003	Operational disturbance, tactical disruption, and strategic uncertainty	Paulsson and Norrman (2003)
	Supply-demand co-ordination, and disruption	Kleindorfer and Wassenhove (2003)
	Environmental, network-related, and organisational	Jüttner et al. (2003)
2004	Operational accidents, operational catastrophes, and strategic uncertainty	Norrman and Lindroth (2004)
	Process, control, demand, supply, and environmental	Christopher and Peck (2004)
	Disruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory, and capacity	Chopra and Sodhi (2004)
	Material flow risk, information flow risk, cash flow risk, security risk, opportunistic behaviour risk, and corporate social responsibility risk	Spekman and Davis (2004)
2005	Coordinating supply and demand, and disruptions to normal activities	Kleindorfer and Saad (2005)
	Supply, demand, and environmental	Jüttner (2005)
2006	Internal controllable, internal partially controllable, internal uncontrollable, external controllable, external partially controllable, and external uncontrollable	T. Wu, Blackhurst, and Chidambaram (2006)
	Demand-side, supply-side, and catastrophic	Wagner and Bode (2006)
	Operational, and disruption	C. Tang (2006)

Table 2.1 (*Continued*)

Year	Categorisations of risk sources	Literature sources
2007	Strategic, tactical, and operational	Ritchie and Brindley (2007)
	Organisational, network level, industry level, and environmental level	Gaonkar and Viswanadham (2007)
2008	Supply, operational, demand, security, macroeconomic, policy, competitive, and resource	Manuj and Mentzer (2008)
	Demand side, supply side, regulatory, legal and bureaucratic, infrastructure, and catastrophic	Wagner and Bode (2008)
	Supply, process, demand, intellectual property, behavioural, and political/social	C. Tang and Tomlin (2008)
2009	Supply, process, demand, rare-but-severe disruption, and other (intellectual property, behavioural , political and social)	C. Tang and Tomlin (2009)
2011	Demand, delay, disruption, inventory, manufacturing (process) breakdown, physical plant (capacity), supply (procurement), system, sovereign, and transportation	Tummala and Schoenherr (2011)
	Material flow risk (source, make, deliver, supply chain scope), financial flow risk, and information flow risk (information flow risk, intellectual property)	O. Tang and Musa (2011)
2013	Supply side, manufacturing side, demand side, logistics side, information, and environment	Punniyamoorthy, Thamaraiselvan, and Manikandan (2013)
2015	Macro-risks (natural, man-made), and micro-risks (demand, manufacturing, supply, infrastructural)	Ho et al. (2015)
2016	Operational, infrastructure, legal, cultural and social, economic, supplier, forecasting, warehouse, transportation, labour, and natural disaster	Rogers, Srivastava, Pawar, and Shah (2016)

In addition to the above classifications, there are studies classifying risks from internal and external views. However, they used different boundaries to distinguish between internal and external risks.

Cucchiella and Gastaldi (2006) distinguished internal and external risks by considering the firm as the boundary. They considered that internal sources include available capacity, customs regulations, information delays and internal organisation. And external sources contain competitor action, manufacturing yield, political environment, price fluctuations, stochastic cost and supplier quality. Christopher and Peck (2004) considered two boundaries in dividing risks: the firm and the supply chain network. Based on four main parts (supply side, control systems, manufacturing process and demand side) of the product delivery process (Mason-Jones & Towill, 1998), Christopher and Peck (2004) listed the categories as internal to the firm (process and control), external to the firm but internal to the supply chain network (demand and supply), and external to the network (environmental). Klassen and Vereecke (2012) used a similar method in classifying the levels (based on stakeholder theory, (Freeman, 1984)) of interested individuals and groups for the social issues in the supply chain. The levels are internal (within a firm), inter-firm (interactions with strong economic ties) and external (interactions with weak economic ties). Goh et al. (2007) identified internal and external risks by considering global supply chain networks as the boundary. Risks from interactions between companies within the supply chain network such as supply, demand, and trade credit risks, are classified as internal risks. Risks from interactions between supply chain networks and the environment are regarded as external risks.

Categorisations of risk sources classify risks according to their different sources. Various risks exist within each type of risk source. There are different ways of categorising from diversified perspectives. By using the risk source proposed by Jüttner et al. (2003), Table 2.2 lists SCRs within three types of risk sources: organisational, network-related, and environmental risks.

Table 2. 2 Risks within Each Type of Risk Source

Risk sources	Risks	Literature sources
Organisational	Quality of internal financial control systems	Ritchie and Brindley (2000)
	Lack of effective management structures	Ritchie and Brindley (2000)
	Unclear future rules and regulations	Norrman and Lindroth (2004)
	Operational uncertainty	Kleindorfer and Saad (2005), Manuj and Mentzer (2008), Gaonkar and Viswanadham (2007), Jüttner et al. (2003), C. Tang and Tomlin (2008)
	Manufacturing capacity	Johnson (2001), Manuj and Mentzer (2008)
	Information system uncertainty	Chopra and Sodhi (2004), Manuj and Mentzer (2008), Jüttner et al. (2003)
	High levels of process variations	Manuj and Mentzer (2008)
	Research-and-development activities	Gaonkar and Viswanadham (2007)
	Opportunistic behaviour	Gaonkar and Viswanadham (2007)
	Labour dispute	Chopra and Sodhi (2004), Jüttner et al. (2003)
	Supplier bankruptcy	Chopra and Sodhi (2004)
	Poor quality or yield at supply source	Chopra and Sodhi (2004), Zsidisin, Panelli, and Upton (2000), Tummala and Schoenherr (2011)
	Bottlenecks in supply	Norrman and Lindroth (2004)
	Supplier business risk	Zsidisin et al. (2000)
	Variations in demand (seasonal imbalances, fad volatility, etc.)	Johnson (2001), Manuj and Mentzer (2008)
	New product adoption	Johnson (2001), Manuj and Mentzer (2008)
	Short product life	Johnson (2001)
	Financial strength of customers	Chopra and Sodhi (2004)
	Uncertainty surrounding the random demands, volatile demand	Nagurney, Cruz, Dong, and Zhang (2005), Ritchie and Brindley (2000), Norrman and Lindroth (2004)
	Demand volume uncertainty, demand mix uncertainty	C. Tang and Tomlin (2008)

Table 2.2 (*Continued*)

Network-related	Logistics capacity	Johnson (2001), C. Tang and Tomlin (2008), Wagner and Bode (2006)
	Single source of supply, capacity and responsiveness of alternative suppliers	Chopra and Sodhi (2004), Tummala and Schoenherr (2011)
	Inflexibility of supply source	Chopra and Sodhi (2004)
	Bullwhip effect	Chopra and Sodhi (2004), Wagner and Bode (2006), Lee, Padmanabhan, and Whang (1997), Manuj and Mentzer (2008)
	Attacks on entities in the firm's ecosystem	Gaonkar and Viswanadham (2007)
	Irregular behaviour of their network partners	Gaonkar and Viswanadham (2007)
Environmental	Technology developments	Ritchie and Brindley (2000), Zsidisin et al. (2000), Manuj and Mentzer (2008)
	Natural hazards	Kleindorfer and Saad (2005), Chopra and Sodhi (2004), Gaonkar and Viswanadham (2007), Jüttner (2005), Jüttner et al. (2003)
	Terrorism	Kleindorfer and Saad (2005), Chopra and Sodhi (2004), Gaonkar and Viswanadham (2007)
	Socio-political uncertainties	Jüttner (2005), Jüttner et al. (2003), Christopher and Peck (2004)
	Accidents	Jüttner et al. (2003), Christopher and Peck (2004)
	Currency fluctuations	Johnson (2001)
	Exchange rates	Chopra and Sodhi (2004), Manuj and Mentzer (2008)
	Economic shifts in wage rates	Manuj and Mentzer (2008)
	Interest rates	Manuj and Mentzer (2008)
	Administrative barriers	Wagner and Bode (2008)
	Legal changes	Wagner and Bode (2008), Gaonkar and Viswanadham (2007)
	Environmental legislation	Wagner and Bode (2008)
	A new entrant with a sell direct kind of business model	Gaonkar and Viswanadham (2007)
	Financial barriers	Gaonkar and Viswanadham (2007)

Various SCRs have been identified by different researchers. All of these risks were divided into the three categories (organisational, network-related, and environmental). This does not contain all the risks within supply chains. An elaborated summary can be referred to Ho et al. (2015).

2.2.3 Risk management

Not all risks exist within one company. Different companies may face different SCRs with different weights. It is important to study SCRM from a systematic perspective. This section explores the process and approaches of risk management in supply chains. The SCRM framework presents procedures of the risk management process and has been discussed by many researchers. Adhitya, Srinivasan, and Karimi (2008) put forward a framework for SCRM including risk identification, consequence analysis, risk estimation, risk assessment, risk mitigation, and risk monitoring. Blome and Schoenherr (2011) highlighted four steps (risk identification, risk analysis, risk mitigation and risk monitoring) in the SCRM process. Mullai (2009) proposed a risk management system, constituted with risk assessment (risk analysis and risk evaluation), risk management and risk communication. Jüttner et al. (2003) suggested four steps in SCRM: 1) Assessing risk sources; 2) Identifying risk concept by defining its consequences; 3) Tracking risk drivers from the strategies; and 4) Mitigating risks (avoidance, control, cooperation and flexibility). Bandaly, Satir, Kahyaoglu, and Shanker (2012) raised an SCRM framework containing risk taxonomy (risk domain, source of risk, adverse event), risk assessment and measurement, risk prioritisation, risk sharing or transfer, risk management approaches (mitigation, prevention and avoidance), and finally, risk management performance evaluation. Based on the framework, the planning process can be built to form a complete risk management strategy.

Risk management frameworks are also discussed in terms of supply networks. Hallikas, Karvonen, Pulkkinen, Virolainen, and Tuominen (2004) introduced a general risk management process in supplier networks, which include: 1) Risk identification; 2) Risk assessment; 3) Decision and implementation of risk management actions (generally used strategies: risk transfer, risk taking, risk elimination, risk reduction, and further analysis of individual risks); and 4) Risk monitoring. Harland, Brenchley, and Walker (2003) proposed a tool for managing supply network risks, including six steps: 1) Map supply network; 2) Identify risk and its current location; 3) Assess risk; 4) Manage risk; 5) Form collaborative supply network risk strategy; and 6) Implement supply network risk strategy. Cucchiella and Gastaldi (2006) stood in line with Harland et al. (2003) and applied similar steps to risk management in the supply chain network. Kern, Moser, Hartmann, and Moder (2012) developed a conceptual model for supply risk management, which consists of five linking constructs: risk identification, risk assessment, risk mitigation, risk performance and continuous improvement process. Through partial least squares analyses, they found that risk identification assists risk assessment and then supports risk mitigation.

Although the suggested procedures are not unified and have different focuses, components that are frequently mentioned are risk identification, risk assessment, risk mitigation, and risk monitoring. In the following review of methods, the SCRM process is classified into two main components (Musa, 2012): risk analysis (risk identification, risk estimation and risk evaluation) and risk control (risk mitigation and risk monitoring). As suggested by Ho et al. (2015), quantitative methods have been increasing since 2004, and the number of articles applying quantitative methods is three times more than that of qualitative methods in 2013. However, they claimed that qualitative approaches are mainly employed in risk categorisation, risk identification, and SCRM framework development, while quantitative methods are primarily applied for risk assessment and risk evaluation. Generally, the qualitative approach is dominant in SCRM studies (Ghadge et al., 2012; Kilubi, 2016).

2.2.3.1 Risk analysis approach

Risk identification is critical for risk analysis (T. Wu et al., 2006). However, research on SCR identification is found to be limited (Rao & Goldsby, 2009). Bandaly et al. (2012) mentioned the same problem that risk identification and assessment methods are insufficient. They underlined the importance of risk classification for risk identification. Risk classification provides a systematic way to find potential risks. However, risk identification is regarded as depending on both managers' perceptions and industry characteristics (Jüttner et al., 2003; K. D. Miller, 1992).

Several recent research papers address risk identification issues. Neiger, Rotaru, and Churilov (2009) proposed a value-focused process engineering based on a risk identification method consisting of five steps and aiming at increasing supply chain values. Kayis and Karningsih (2012) developed a knowledge-based system approach based SCR identification tool - SCR Identification System - for manufacturing organisations. In using this tool, both potential risks and relationships between SCRs can be detected since it considers risks deriving from different process strategies. Huo and Zhang (2011) identified retail enterprise SCRs in the process of planning, purchasing, sales, delivery and returns via the diagnostic tool - the Supply Chain

Operations Reference model. Cagliano, De Marco, Grimaldi, and Rafele (2012) presented a structured methodology for SCR identification and analysis. Risk identification was achieved by the Activity Breakdown Structure on the basis of process breakdown according to the Supply Chain Operations Reference model; and the Risk Breakdown Structure tool was applied to depict the different impact of risks on activities, forming the Risk Breakdown Matrix. Besides these, they chose key performance indicators based on the specific risk events. The indicators are used to measure effects brought by risky events, rather than to measure the overall SCP. However, this method cannot illustrate risk propagation across supply chains. Adhitya et al. (2008) used a HAZard and OPerability analysis method to identify deviations among all the supply chain parameters, and applied a dynamic simulation method - Integrated Refinery In-Silico - for consequence analysis.

After identifying risks, risk assessment becomes the next challenge for the development of risk management strategies (Bandaly et al., 2012). Literature on risk assessment was reviewed according to the methods that were utilised. In addition, this research classified semi-quantitative methods (such as Analytical Hierarchy Process) into the qualitative category.

(1) Qualitative methods of risk assessment

Many research articles assess or manage SCRs via empirical studies. After conducting case study research in multimodal maritime supply chains, J. P. Vilko and Hallikas (2012) presented a risk analysis framework to identify SCR drivers and risk impacts. Tuncel and Alpan (2010) aimed at using a Petri net-based model through an industrial case study for risk management and real-time decision making in supply chain networks. The risk analysis method, called the Failure Mode, Effects and Criticality Analysis, is combined with the model to be used in the paper for risk identification and assessment. Scholars such as S. Kumar, Boice, and Shepherd (2013), and Chaudhuri, Mohanty, and Singh (2013), applied similar approaches in risk analysis. Considering the lack of synthesis of many existing risk management tools, S. Kumar et al. (2013) depicted a risk management system for global supply chains, with the Process Flow Chart tool and supply chain Failure Modes and Effects Analysis for risk identification and root cause determination, and the tool scorecard for risk assessment. Chaudhuri et al. (2013) developed a step-by-step method and modified Failure Modes and Effects Analysis for SCR assessment and alleviation in the phase of new product development.

Sofyalıoğlu and Kartal (2012) used the method of Fuzzy Analytical Hierarchy Process to determine SCRs and their management strategies in a company in the iron and steel industry.

Likewise, B. Liu (2010) employed the method of AHP and Fuzzy Comprehensive Evaluation to quantify the categorised SCRs, in building the risk assessment model. In many cases, managers analyse risks via experience. T. Wu et al. (2006) proposed a systematic methodology aimed at assessing and managing the inbound supply risks. This risk analysis approach classifies risk factors in a new hierarchical classification system and adopts an enhanced AHP technique for risk weight calculation of different suppliers. The AHP method was also adopted by Gaudenzi and Borghesi (2006) for SCR evaluation. Jiang, Chen, and Wang (2007) examined risks (organisational, cooperative relationships between organisations and outer environment risks) in the supply chain network. By using the fuzzy evaluation method, risk probability and impact can be calculated. The supply chain network reliability is determined by the risk value of these three aspects.

Jüttner (2005) carried out a survey on organisation respondents (137 managers out of 1,700 Institute of Logistics members responded) about risk analysis tools. Four tools specifically come from the context of a supply chain (Scott & Westbrook, 1991), that is, assessing the importance of your business to your customers' business, critical path analysis, supply chain mapping, and assessing the importance of your business to your suppliers' business. Five traditional tools are developed in the context of an organisation (Goldberg, Davis, & Pegalis, 1999), which are brain storming, process mapping, risk likelihood/impact analysis, scenario planning, and the six sigma method. From the analysis results, Jüttner found that most of the traditional tools are more commonly applied than those focusing on the context of a supply chain.

(2) Quantitative methods of risk assessment

According to Ho et al. (2015), studies on SCR assessment extensively adopt quantitative methods. However, Heckmann et al. (2015) implied that the challenge in SCRM is the SCR quantification and modelling. In their paper, literature about SCR classification, definition and quantitative modelling were critically reviewed. They suggested that most research regards SCR objectives as efficiency optimisation such as inventory, cost and profit, while the effectiveness aspect such as a service level is not considered as much. Y. Wang and Huang (2009) presented a SCR assessment model using a neural network to avoid subjectivity. Schmitt and Singh (2012) constructed a simulation model based on a consumer-packaged goods company. Risks in the supply chain network are mainly focused on supply disruptions and demand uncertainties. They worked out different mitigation test results with conclusions that generalise all firms with similar concerns. A systematic approach is needed because improvement of the weakest links helps enhance its overall strength. Since the supply chain structure is hard to identify, Takata and Yamanaka (2013) proposed a method to measure potential risks related to the parts of products based on the bill of material (BOM). This BOM-based SCRM method consists of three steps to balance costs and benefits of different countermeasures. Desheng Wu and Olson (2008) adopted three risk evaluation models: chance constrained programming, data envelopment analysis, and multi-objective programming, to model a supply chain of three levels by using simulated data. The results provide decision makers with evaluation tools to select suppliers. Pai, Kallepalli, Caudill, and Zhou (2003) reviewed some inferencing tools (Bayesian Networks, Fuzzy Logic and Hybrid Networks) for risk analysis and found that the appropriate tool is selected according to the data type.

To analyse SCRs in similar industries, Punniyamoorthy et al. (2013) provided an instrument for the heavy engineering industry. SCR sources were summarised in six risk constructs by using group judgment and a survey. Then they proposed a higher order structural model for risk construct prioritisation. Squire and Chu (2011) worked out a Delphi report, showing probability, impact and mitigation levels of the top risk factors in firms with different operating environments. They found that most firms are not equipped with formal risk identification tools. Markmann, Darkow, and von der Gracht (2013) also applied the Delphi expert survey method to risk identification and assessment, and even considered the possibility of the construction of a Delphi-based SCRM framework.

2.2.3.2 Risk control approach

In terms of risk control in supply chains, various models and techniques have been proposed. Qualitative and quantitative methods are utilised to analyse SCRs. Likewise, risk mitigation and management can also be achieved through these two methods.

(1) Qualitative methods of risk control

By using an empirical case study method, Oke and Gopalakrishnan (2009) investigated risk types and mitigation strategies (generic and specific) through different kinds of interviews. Blome and Schoenherr (2011) conducted eight in-depth case studies, and found that the SCRM approaches and capabilities needed in financial crises are different between manufacturing and service firms. They also proposed that dynamically adapted capabilities are more crucial than tools and resources for a proficient SCRM. Fitrianto and Hadi (2012) recognised that there is a lack of SCRM on the shrimp industry, thus they formed an initial concept on the application of SCRM in this industry in Sidoarjo (Indonesia). After proposing the research framework, they suggested that case study research would be conducted in future research. Y.-C. Yang (2011) utilised a bowtie diagram to explore appropriate risk management strategies. This method is useful for risk assessment where a quantitative method is inappropriate. Faisal, Banwet, and Shankar (2006) applied Interpretive Structural Modelling to depict the interrelationships between the selected 11 enablers of SCR mitigation, thus helping to find the key enablers that are important for risk mitigation. Diabat, Govindan, and Panicker (2012) classified risks and relevant mitigation strategies. The method of Interpretive Structural Modelling is used to distinguish autonomous risks from linkage risks. Lavastre et al. (2012) employed both qualitative and quantitative methods to study SCRM. Through empirical research, they ranked the tools applied in SCRM (shown in Table 2.3).

Table 2. 3 Rank of Tools Applied in SCRM (Lavastre et al., 2012)

Rank	Tools
1	PDCA cycle, Deming cycle, six-sigma, and permanent improvement
2	Mapping internal and external processes (Value Stream Mapping)
3	Question positioning approach (“What if?”)
4	Ishikawa diagram, and brainstorming
5	Pareto diagram, and ABC ranking
6	Failure Mode, Effects and Criticality Analysis
7	Scores method (measure of intensity by aggregation)

(2) Quantitative methods of risk control

Strategies for risk mitigation need to be quantified to prove their effectiveness and efficiency, which leads to extensive use of quantitative methods in risk mitigation (Ho et al., 2015). C. Tang (2006) categorised SCRM articles into four aspects: supply management, demand management, product management, and information management. He reviewed various quantitative models and strategies combined with practices from these four aspects.

From an empirical perspective, Thun and Hoenig (2011) analysed SCRM by conducting a survey in the German automotive industry. The probability-impact-matrix was developed after analysing the identified SCRs. Two instruments of SCRM are proposed: preventive and reactive. Besides this, they found that the group using preventive instruments performed better in flexibility or the reduction of safety stocks, and the other group performed better in disruptions resilience or bullwhip effect reduction. Apart from investigation, surveys were also conducted for model testing. Dekker, Sakaguchi, and Kawai (2013) established a structural model made up of three parts: transaction characteristics, SCM practices and supplier trust. They examined the use of control practices (such as contractual contingency planning, performance target setting and so on) that cope with buyer-supplier transaction risks. To test the four proposed hypotheses, they performed an empirical analysis on Japanese manufacturing firms. The results show the importance of transaction characteristics (which define transaction risks) for the selection of trusted supply chain partners and the use of control practices. Cheng, Yip, and Yeung (2012) studied supply risk management by examining a theoretical model based on the social capital theory. After testing the model by collected data, they suggested that when the buying firms perceive supply risks, they develop *guanxi* (relationship) networks with key suppliers to mitigate these risks.

Blos, Wee, and Yang (2010) created a disruption risk mitigation framework, combining the Business Continuity Planning process life cycle with operational constructs. Hahn and Kuhn (2012) developed an optimisation-based framework and a decision model for value-based performance management, including risk management in supply chains. They adopted the metric Economic Value Added to manage SCRs by value creation. Based on both qualitative and quantitative metrics of Supply Chain Operations Reference, Abolghasemi, Khodakarami, and Tehranifard (2015) recognised the key factors of SCP and managed SCRs, by using the Supply Chain Operations Reference model and Bayesian Networks. Aqlan and Lam (2015) put forward a methodology to quantify and mitigate SCRs. Bow-Tie analysis was utilised to calculate SCR parameters. On the one hand, the fault-tree analysis identifies the probability of occurrence of different risk factors, which trigger the occurrence of the risk event. On the other hand, the event-tree analysis shows the impact of the risk event. In their research, the risk mitigation matrix was used to present the scores and costs of different mitigation strategies. In this matrix, risk interconnections were considered, which solve the dilemma that mitigating one risk intensifies another. Among the different mitigation strategies, the optimisation technique was then utilised to identify the best strategy combination.

A new association rule-hiding algorithm was proposed by Le, Arch-Int, Nguyen, and Arch-Int (2013) for risk management in retail supply chains, where data sharing increased the probability of sensitive knowledge leakage. Goh et al. (2007) presented a stochastic model of the multi-stage supply chain networks with a set of risks. Then they applied the methodology of Moreau-Yosida regularisation and an algorithm for the objective of maximum profit and minimum risk. This solution was expected to be used in a large scale supply chain network problem. With regard to supply chain outsourcing risks, Dexiang Wu et al. (2013) adopted an integrated stochastic-fuzzy multi-objective model and a proposed algorithm for risk management. Under various scenarios composed of different risk aversion and uncertainty levels, the computational results arrive at conclusions that are helpful for decision makers.

SD modelling takes into consideration the various interactions among variables and the dynamic feedback structure. By utilising this method, different policies can be simulated to identify the most suitable risk mitigation method without changing the real system. Peng, Peng, and Chen (2014) applied an SD model to managing post-seismic SCRs. The affected supply chain was built by imitating the situation of a road network and information delay. The authors proposed a decision tree (on the basis of simulation results of experiments) for the selection of suitable stocking strategies. Chaoyu Li, Ren, and Wang (2016) also used SD method for risk management. Risks are illustrated from four aspects: probability of a hazardous event, probability of a given variable affected by the event occurrence, consequence probability of a given variable, and consequence severity for a given variable. Risk impact can be analysed by various variables instead of being translated to one attribute. On this basis, the SD method was employed to integrate all the relevant variables in the system. Through scenario analysis, the researchers explored the impact of different risks on the system’s performance, and identified the most effective risk mitigation approach. Giannakis and Louis (2011) formulated a multi-agent based framework. The generic multi-agent SCRM-based model helps manage operational and tactical risks proactively and also proposes mitigation strategies for disruption risks in the manufacturing supply chains. The agent-based simulation of the proposed framework was expected in the future. Xia and Chen (2011) proposed a strategic decision-making model based on dual cycles (the operational process cycle and the product life cycle). They discovered the unilateral, bilateral and internally circulatory relationships among the different SCRM elements and clusters, and designed a methodology to select the best SCRM tools.

Research on risk management is categorised by qualitative and quantitative methods as above. Moreover, research on a particular strategy for risk management can be analysed. Table 2.4 provides some of the strategies illustrated in various studies. An overview of SCRM strategies was performed by Kilubi (2016), who conducted a systematic literature review on this topic.

Table 2. 4 Strategies for Risk Management

Strategies	Literature details
Supply chain visibility	Christopher and Lee (2004) emphasised the importance of supply chain confidence, i.e. the visibility inside the whole supply chain, for risk mitigation. Nooraie and Parast (2015) constructed a multi-objective decision model to examine the interaction among supply chain visibility, SCR, and supply chain cost. The analysis results demonstrated that supply chain visibility contributes to SCR mitigation and supply chain cost reduction. However, Nooraie and Parast also underlined the importance of balance among these factors because supply chain visibility is at the expense of investment.
Supply chain collaboration	J. Chen, Sohal, and Prajogo (2013) conducted a survey to examine the impact of supply chain collaboration on risk mitigation and Structural Equation Modelling is used for analysis. Supplier, customer and internal collaboration are found useful for the corresponding supply, demand and process risks, and only the latter two mitigations directly affect SCP. Lavastre et al. (2012) indicated that SCRM is both an operational management tool and a strategic tool which regards collaboration as a key factor (in line with C. Tang (2006)) for SCP.
Flexibility	From a systematic perspective, Fayezi, Zutshi, and O'Loughlin (2014) proposed an analytical framework to assess the mismatches between uncertainty and flexibility in supply chains. Flexibility requirements were assessed in different parts of the supply chain and then decision making can be facilitated to improve the performance in uncertain situations, but the flexibility gaps were only measured in a qualitative way. Quantitative description was not utilised in this paper. A framework of flexible product quality risk management in supply chains was proposed by Tse and Tan (2012), showing the multi-sourcing decision pathway. They used a marginal, incremental analysis approach for product quality risk management and supply chain visibility evaluation. Flexibility was stressed by C. Tang and Tomlin (2008) in mitigating SCRs. After presenting five different flexibility strategies and five stylised models, they illustrated analytically that low levels of flexibility could already achieve the desired effect.
Agility and its antecedents	Braunscheidel and Suresh (2009) regarded agility and its antecedents as a mitigation strategy for disruption risks in the supply chain. A theoretical framework and the method of Structural Equation Modelling were adopted for analysis.

Table 2.4 (*Continued*)

Inventory management	Son and Orchard (2013) compared two different inventory-based policies for supply-side disruption mitigation through an analytical model and simulations. They concluded that an R-policy (strategic inventory reserves) is more effective than a Q-policy (larger orders) considering product availability measures. Xanthopoulos, Vlachos, and Iakovou (2012) developed stochastic inventory models suitable for different kinds of disruption risks in dual-sourcing supply chains, which can help both risk-neutral and risk-averse decision makers.
Supply chain design	The aforementioned SD method was employed by Sidola, Kumar, and Kumar (2011) in their research for SCR analysis and design. Garcia-Herreros, Grossmann, and Wassick (2013) aimed at reducing the risks of facility disruptions by supply chain design. They put forward a formulation on the basis of a stochastic programming framework, considering distribution centre location, storage capacity and customer demand. Speier, Whipple, Closs, and Voss (2011) focused on designing supply chains to mitigate risks in product safety and security. In their research, a supply chain security framework and a multi-method approach were developed. Tabrizi and Razmi (2013) also integrated risk management in the step of supply chain design. They developed a mixed-integer fuzzy model, depicting uncertainties by the theory of fuzzy sets, and applied a fuzzy interactive resolution method to provide different decision plans. To minimise risks, Cardoso, Barbosa-Póvoa, and Relvas (2013) focused on supply chain design and planning by using a multi-objective model. They measured risks by four indices (variance, variability index, downside risk, and conditional value-at-risk) preferred by different decision makers.

2.2.4 Summary

In a global survey conducted by PwC (2013) and the MIT Forum for Supply Chain Innovation, five key principles are verified for companies to better manage risk challenges in supply chains. It also identifies the priority of seven capability enablers including risk governance in Figure 2.3.

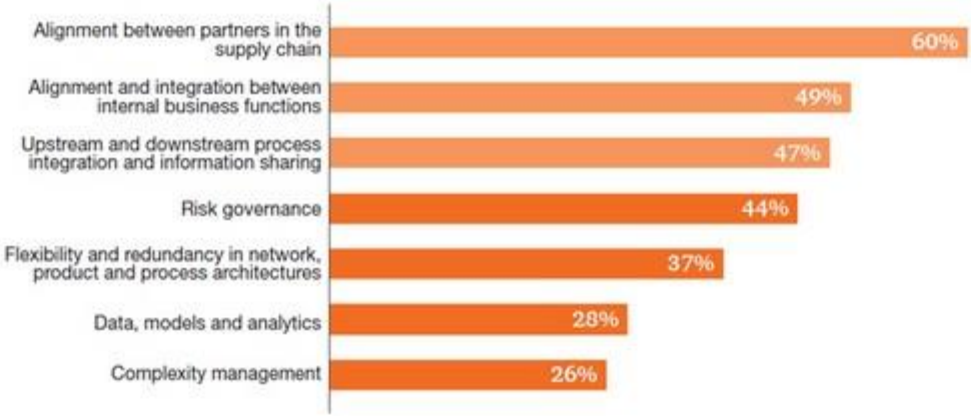


Figure 2. 3 Survey Participants' View on Which Capability Enabler They Consider the Most Important (PwC, 2013)

Generally, SCRM is similar to normal risk management except for the special features (e.g., interconnections of supply chain partners) of SCRs which make the SCR identification and management more difficult (Moeinzadeh & Hajfathaliha, 2009; D. Wang & Yang, 2007). Risk management in supply chains does not mean managing discrete risks by using different independent approaches (Bandaly et al., 2012). They provided three reasons: SCRs are interrelated; mitigating one risk can increase the occurrence probability of another risk; and mitigating risks by one supply chain member may produce risks for other members in the supply chain. Decision making regarding SCRs may become risky with narrow information (Gaudenzi & Borghesi, 2006). Giunipero and Eltantawy (2004) pointed out the need to holistically manage supply chains by using extensive risk management systems. After reviewing numerous articles which apply either qualitative or quantitative methods, Ho et al. (2015) concluded that the majority of researchers focus on individual or fragmented SCRM processes (identification/ assessment/ mitigation/ monitoring) instead of integrated processes. Research on integrated SCRM processes is significant due to interrelationships among different processes.

Although numerous tools and methods exist in SCRM, they are not used in an effective and systemic way. Thus, S. Kumar et al. (2013) presented a closed-loop risk-management system. Some existing tools have been integrated into this proposed system. This management system is expected to help companies with SCRM programs. Likewise, Oehmen, Ziegenbein, Alard, and Schönsleben (2009) highlighted the role of system about SCRM. A system-oriented and generic method was proposed to analyse both causes and effects of SCRs, as well as their dynamic behaviour. However, S. Kumar et al. (2013), and Oehmen et al. (2009), confessed that quantitative risk modelling is needed in future research. O. Tang and Musa (2011) conducted a literature survey and citation/co-citation analysis to detect the research development of

SCRM, and identified the lack of quantitative modelling for system analysis. Ghadge, Dani, Chester, and Kalawsky (2013) pointed out that extant research methodologies in the SCRM area do not depict risk behavioural performance holistically; rather, they proposed a systemic and quantitative approach to model SCRs. This quantitative risk modelling enabled the demonstration of behaviours under various portfolios of SCRs. However, the research lacked sensitivity analysis in the micro level to distinguish risk behaviours under different risk attribute combinations.

After conducting a systematic literature review, Kilubi (2016) advised that there is a clear lack of application of mixed research methods in studying SCRM. Overall, a systematic study using mixed methods contributes to managing SCRs. The interactions of various SCRs can therefore be investigated. Singhal, Agarwal, and Mittal (2011) raised that risks for different sectors are diversified, and SCRM strategies should be developed specifically for a sector or industry. Hence, it is significant to conduct systemic SCRM research in a specific industrial sector.

2.3 Corruption as a risk factor in supply chains

Virtually all large multinational companies focus on supplier identification, and supply control, etc. in their supply chain management processes; however, few put the same energy into corruption in the supply chain (United Nations Global Compact, 2010). According to Webb (2013), after the introduction of the UK Bribery Act, bribery and corruption was regarded as one of the leading risk factors in procurement. However, it was found in a survey conducted in 2012 among UK-based companies that the concern dropped markedly. This could be because companies are immune to the effects of the so-called toughest anti-bribery law.

According to a report by Dezenski (2012), the ranking of corruption by the World Economic Forum rose from 13th to 9th among global SCRs in 2012. The lack of transparency existing in complex supply chains was regarded as a particular challenge and needs improvement. This may be due to the external supply chain partners (usually small and medium-sized enterprises), who have inadequate power to combat corruption. van Marle (2014) compared SCRs in different areas and points out different ranks of corruption (Latin America: 1st, Asia: 4th, sub-Saharan Africa: 3rd, etc.). In the World Economic Forum Supply Chain and Transport Risk Survey 2011, corruption was listed as one of the triggers of widespread and systemic supply chain disruptions (World Economic Forum, 2012).

When corruption is mentioned in the private sector, literature mainly focuses on corruption itself and anti-corruption activities (LRN, 2010; United Nations Global Compact, 2010), without discussion about the detailed impacts of corruption. Although works on corruption are abundant in the area of individuals and organisations, little research focuses on corruption from the operations and supply chain management perspective (Arnold et al., 2012). They filled this gap by conducting research on factors that affect firm inclination towards corruption. However, the impact of corruption on supply chains was not discussed in their research. Some research only focuses on a particular area, rather than the whole supply chain. For example, Habib and Zurawicki (2001) studied the impact of corruption on foreign and local direct investments.

In this research corruption is studied as a risk factor for supply chains, meanwhile, it can also be a risk event triggered by its risk factors when perceived from a different perspective. This is in line with ISO (2018), which indicated that an event can also be a risk source. The International Road Transport Union (IRU) and the UN Global Compact have recently collaborated together to fight against extortion and corruption to safeguard global supply chains through the Global Anti-Corruption Initiative (EU reporter, 2014). Lawson (2012) summarised ten practices from different experts for reducing corruption in the supply chain, mainly including: 1) Implementing high standards in business; 2) Requiring highest ethical behaviour for top employees; 3) Assessing risks (internal, country, transaction and partnership); 4) Monitoring accountability of employees; 5) Using and testing the internal hotlines for information delivery; 6) Knowing bribery signs; 7) Using a team approach dealing with suppliers; 8) Improving documentation for expenses and transactions; 9) Increasing transparency in the whole supply chain (Transparency is "an important anti-bribery tool".); and 10) Keeping away from corrupt partners. United Nations Global Compact (2010) presented a framework for reducing corruption in the supply chain. Practical tools and guidance were delivered for both customers and suppliers (businesses can be both). General and specific guidance on corruption prevention and responses were provided and a specific one was detailed in 11 scenarios from three main categories: vender selection process, contract performance, and third parties (government officials or others).

2.4 Supply chain robustness against corruption

2.4.1 Concept of supply chain robustness

Owing to the increasing supply chain complexity, Christopher and Peck (2004) paid attention to the nature of systemic SCRs, and underlined the importance of resilient supply chains. The term “resilience” remains vague and the way to accomplish resilience is still not well studied (Wieland & Wallenburg, 2013). According to Christopher and Peck (2004), the two terms “resilience” and “robustness” should be distinguished in the supply chain context. They claimed that resilience indicates flexibility and agility, and defined resilience as “the ability of a system to return to its original state or move to a new, more desirable state after being disturbed”. In their mind, robustness emphasises physical strength and differs from resilience. However, Hansson and Helgesson (2003) considered robustness to be a special form of resilience. In line with this view, Qiang, Nagurney, and Dong (2009) found that a robust network is resilient on the condition that performance is close to the original level after perturbations. Wieland and Wallenburg (2012) demonstrated that both proactive (robust) and reactive (agile) strategies significantly enhance a customer’s value of a supply chain. Wieland and Wallenburg (2013) suggested that a supply chain is resilient when it can withstand the original stable state, or when it can achieve a new stable state. Following Wieland and Wallenburg (2012), Wieland and Wallenburg (2013) claimed that resilience consists of two dimensions, robustness and agility. The difference between the two dimensions is that supply chain robustness is a proactive strategy while supply chain agility is reactive (Wieland & Wallenburg, 2012, 2013). Wieland and Wallenburg (2012) defined robustness as “the ability of a supply chain to resist change without adapting its initial stable configuration”, and agility as “the ability of a supply chain to rapidly respond to change by adapting its initial stable configuration”. Considering the overlap among the relevant concepts, Klibi, Martel, and Guitouni (2010) distinguished the difference between robustness, responsiveness, and resilience. They considered robustness as “the quality of a supply chain network to remain effective for all plausible futures”, responsiveness as “the capability of a supply chain network to respond positively to variations in business conditions”, and resilience as “the capability of a supply chain network to avoid disruptions or quickly recover from failures”. Their main difference lies in whether disruptions occur.

According to Wieland and Wallenburg (2012), robustness has direct impact on both customer value and business performance of a supply chain, while agility only has direct impact on customer value of a supply chain. They claimed that agility, rather than robustness, had received much attention in previous years, and that it was essential to be concerned about robustness. Robustness has a variety of meanings in different contexts. From the perspective of IT, robustness can be defined as the capability of a computer system to deal with errors in the execution process (Christopher & Peck, 2004). Robustness has also been studied in the context of supply chains (Asbjornslett & Rausand, 1999; Durach, Wieland, & Machuca, 2015). Vlajic, Van der Vorst, and Haijema (2012) defined supply chain robustness as the extent to which a supply chain shows an acceptable performance in and after an unexpected event that disturbed one or more logistics processes. Durach et al. (2015) argued that not all of the changes can be resisted and measures need to be taken to avoid the changes. They conducted a systematic literature review and defined supply chain robustness as the supply chain's ability to resist or avoid change.

Because of the proactive nature of robustness, Vlajic et al. (2012) proposed two types of supply chain redesign strategies, which are: (a) preventing disturbance, and (b) reducing the impact of disturbance. In spite of various studies on supply chain robustness, little research focuses on its measurement (Qiang et al., 2009; Vlajic et al., 2012). Qiang et al. (2009), and Vlajic et al. (2012), proposed approaches to measure the supply chain robustness. SCP was compared before and after disruptions. The difference lies in the way of calculation, where Qiang et al. (2009) considered robustness at a pre-specified disruption level, and Vlajic et al. (2012) pre-defined a desired robustness range for key performance indicators.

2.4.2 Approaches for studying supply chain robustness

Studies on supply chain robustness are conducted from both qualitative conceptual and quantitative modelling levels (Vlajic et al., 2012). In their research, Vlajic et al. constructed an integrated framework to design a robust supply chain. The procedures can be followed to identify disturbances and sources of vulnerability, and thereafter explore appropriate redesign strategies for a robust supply chain. From the purpose of understanding the construct, Durach et al. (2015) built a theoretical framework of supply chain robustness. They considered robustness from both intra-organisational and inter-organisational levels, and the robustness dimensions, antecedents, and moderators were combined to form this framework. Propositions were established in terms of relationships between supply chain robustness and the antecedents.

With regard to the quantitative modelling level, Vlajic et al. (2012) stated that supply chain robustness is primarily employed in modelling solutions or solving supply chain problems (planning, inventory management, network design, etc.). Through numerical analysis on a discrete-event simulation model, Schmitt and Singh (2012) focused on disruption risks, risk mitigation, and system resilience by considering supply chain networks as a whole. They underlined the importance of proactive planning for a system's overall robustness. Based on critical reviews on relevant literature, Qiang et al. (2009) recognised the significance of studying SCRM from a holistic perspective. Therefore, to study supply chain network robustness, Qiang et al. constructed a network equilibrium model, and reflected on the multiple decision makers within supply chain networks. Wieland and Wallenburg (2012) are the pioneers in the study of the relationships among SCRM, resilience (robustness and agility), and performance. Structural equation modelling was applied to test hypotheses, and case study research was then adopted for non-hypothesised exploration. They emphasised the importance of SCRM for both robustness and agility, while Jüttner and Maklan (2011) stressed that SCRM cannot affect supply chain resilience if SCRM simply addresses the probability of the disruption. In their further research, Wieland and Wallenburg (2013) examined the importance of relational competencies on supply chain resilience. They claimed that, in addition to SCRM, relational competencies contribute to further enhancing resilience. Responsiveness and resilience were highlighted by Klibi et al. (2010) in optimisation models when exploring risk mitigation constructs for designing robust supply chain networks.

Many studies consider robustness for network design or redesign. Baghalian, Rezapour, and Farahani (2013) concurrently considered supply and demand uncertainties, rather than the demand-side uncertainty which occupies most of the studies on probabilistic supply chain network design. They examined the relationships between modification of parameters and the supply chain network structure. In the robust optimisation model, maximising profit and minimising risk are considered as the objective functions, however, the indicators they used to measure SCP are fairly restricted. According to Vlajic, van Lokven, Haijema, and van der Vorst (2013), the first step to redesign a supply chain for robustness is to identify its vulnerabilities through a structured approach. Supply chain vulnerability was not measured by using average values of key performance indicators in their research. Instead, they considered various measures of variability in those indicators. Appropriate strategies for process redesign were thereby derived to enhance supply chain robustness. The important analysis was employed for a multiple state system by Artsiomchyk and Zhivitskaya (2013), which contributes to robustness and reliability analysis in supply chain design. Pan and Nagi (2010) studied the robust supply chain design problem under demand uncertainties. Production planning was considered together with supply chain design, and a robust optimisation program was established for analysis.

In the face of supply chain disruptions, numerous scholars focus on the decision making or strategies for attaining a robust supply chain. At the stage when SCRM was still immature, C. S. Tang (2006) raised nine robust strategies for better managing supply chains either under normal situations or under disruption. By introducing three successful cases of resilient supply chains, C. S. Tang proposed the robust strategies from the perspective of supply and demand management, and confessed that lots of research could be conducted, for example, quantitatively explore the effectiveness of a particular robust strategy. T. Yang, Wen, and Wang (2011) developed various information-sharing strategies which result in different supply chain structures. For different scenarios of information-sharing strategies, the selected performance indicators are examined regarding their robustness of SCP under uncertain circumstances. Han and Shin (2016) also investigated the robustness of different supply chain structures. Connectivity between supply chain nodes and disruption propagation were considered when evaluating structural robustness. Nevertheless, Han and Shin calculated the robustness based on supply chain structures, rather than SCP. To evaluate various decision making in a supply chain with disruptions, Sawik (2014) compared the robust solution with the risk-averse solution (considering worst-case performance) and risk-neutral solution (considering average-case performance). In terms of the equally important objectives, Sawik emphasised the importance of generating a robust solution where the average-case and worst-case performance measures of both objective functions are equitably focused on. The solution results revealed the conflict of the two objective functions: minimising the cost, and maximising the customer service level, and Sawik argued that equitably efficient solutions need to be explored by future research. Jabbarzadeh, Fahimnia, and Sheu (2017) recognised the significance of simultaneously considering supply and demand uncertainties, and showed a production-distribution planning model that can effectively manage those variations. In their model, a new robustness approach called Elastic p-Robustness was developed, which does not need to estimate the probability distribution of random parameters and can embody different risk preferences of a decision maker.

2.4.3 Robustness in the presence of corruption

Wieland and Wallenburg (2013) pointed out a limitation that they do not distinguish between various SCRs such as exceptional risks vs everyday risks. Risks interfering supply chain activities can be with distinct features indeed. As discussed in this research, corruption modifies the effects of SCRs. This particular disruption is worth studying regarding its impact on supply chains. However, to my best knowledge, no research has been identified that specifically focuses on that.

As a risk factor, corruption would trigger the occurrence of risk events and bring supply chains enormous direct and indirect costs. There are two methods of mitigating the associated risks:

1) reducing the probability of corruption, and 2) reducing the impact of corruption. Preventing corruption is better than mitigating the risks modified by corruption at a later stage, and prevention is an appropriate way in the long run from a systemic perspective. There are guidelines proposing measures to prevent or respond to corruption. However, United Nations Global Compact (2010) underlined problems in implementing anti-corruption programmes: high cost and low cost-effectiveness. No business can afford to apply the highest standard of anti-corruption efforts. The huge efforts would not be cost-effective. In discussing supply chain redesign strategies, Vlajic et al. (2012) claimed that disturbance impact reduction is chosen when disturbance prevention is either impossible to perform or needs huge investment. To proactively cope with potential corruption, minimising the impact of corruption should be the highest priority before its occurrence can be significantly diminished. However, there is limited research about the impact of corruption on supply chains. Researches focus on prevention of the occurrence of corruption. Even if the risk impacts of corruption are mentioned, they are fairly general such as in Sööt et al. (2016). The impact of corruption on supply chains lacks exhaustive analysis on the affected indicators, both directly and indirectly.

The previous section identifies various approaches for robustness studies. Corruption, an exceptional disruption to supply chains, can be studied from the quantitative modelling perspective about supply chain robustness. To minimise corruption's impact on SCP, the interactions between corruption and SCRs need to be explored. Moreover, there are complex interconnections among risks and other indicators. Modelling on constructs or optimisation appears inadequate for studying robustness within such a complex system. The feedback and nonlinear relationships reflect the suitability of SD modelling in solving this problem. As mentioned above, SCRM contributes to supply chain robustness. In the plausible presence of corruption, SCR effects would experience modification. Therefore, risk mitigation needs exploration to enhance supply chain robustness in this situation.

2.5 Corruption risk in the context of dairy supply chains

2.5.1 Dairy supply chain

Supply chain is a network of connected and interdependent organisations working together, mutually and cooperatively, to control, manage and improve the flow of material and information from suppliers to end users (Aitken, 1998). In the agri-food supply chain, activities exist among entities including suppliers, producers, processors, exporters and buyers. Gereffi and Lee (2009) depicted some agri-food value chains containing dairy products. Enlightened by Gereffi and Lee (2009), Junqueira (2010) adapted their value chain structures and proposes a basic agri-food value chain (see Figure 2.4).

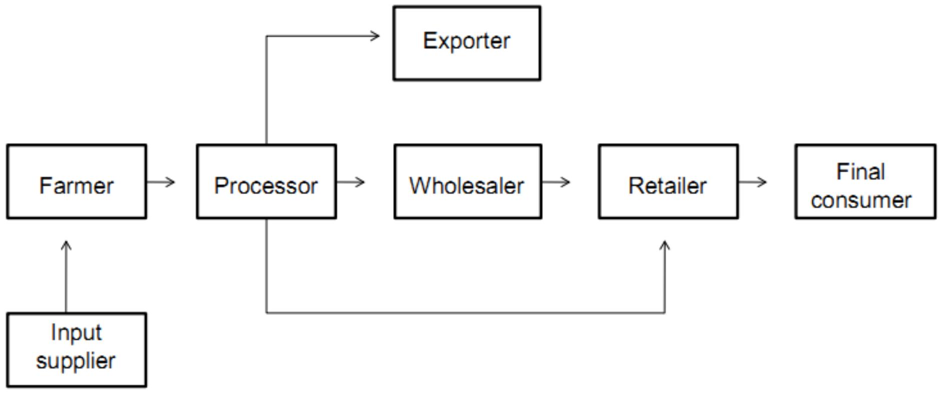


Figure 2. 4 Basic Agri-food Value Chain (Junqueira, 2010)

Douphrate et al. (2013) identified the distinctive features of dairy production, including the liquid state of milk (high-cost transportation, perishability, subject to adulteration), dairy producers' socioeconomic position, cooperatives' strong position, and dairy cattle's converter function. After conducting a structured literature review, Mor, Bhardwaj, and Singh (2018) summarised the primary aspects that distinguish dairy supply chains from others, such as effective information system and cold chain, perishability, traceability and demand fluctuation.

Junqueira (2010) proposed a dairy value chain structure consisting of four stages which are input suppliers, milk production, processing and marketing. Input suppliers represent supplies to farmers including feed, veterinary services, etc. Milk production means the operators who produce milk, which includes dairy farmers, corporate farmers and smallholders. Processing refers to companies which process the delivered milk. The forms of companies are co-operatives, multinational/national companies, and small dairy companies. Marketing expresses the way dairy products are sold, including export, supermarkets, and small retailers. This value chain structure illustrates the conversion process through these links and the entities involved.

According to Schlecht and Spiller (2009), vertical coordination refers to how the relationships between producers and processors are formed. For food supply chains, vertical coordination is among the most controversial topics. Dries, Germenji, Noev, and Swinnen (2009) analysed the modern dairy supply chains' transition and globalisation. Foreign investment emerges in the dairy products' process and retail stage. Supply chain restructuring uses vertical coordination between the farmer level and processor level, and provides more suitable products than those under old structures. They collected much wider survey data by conducting cross-country analysis in central and eastern European countries, which differs from previous studies. Vertical coordination is found important for small dairy farms because it can address major weaknesses and enhance the competitiveness of the whole supply chain. C. Chen, Zhang, and Delaurentis (2014) considered the vertical control issue in food supply chains. They employed exploratory case study research in the Chinese dairy industry, and found that China's adulterated milk incident in 2008 is due to the poor vertical control strategy. However, there are scholars arguing that forming stronger vertical coordination is not very likely. Schlecht and Spiller (2009) suggested that agricultural producers, regardless of industry differences, prefer entrepreneurial freedom and independence. They mentioned another reason - dairy farmers' high specific knowledge. Junqueira (2010) admitted that every section in the dairy supply chain is important, but the link between dairy farmers and milk processors is of critical importance.

2.5.2 Dairy SCRM

The safety and risk issues of food products are attracting increasing concerns. Septiani, Marimin, Herdiyeni, and Haditjaroko (2016) realised that there is a broad range of literature on agri-food SCRM, and it is complex and hard to understand this subject. Therefore, they critically reviewed literature on agri-food SCRM in three stages: risk identification, risk assessment, and risk mitigation. Methods and approaches were summarised within different categories, which enhances the clarity and understanding of agri-food SCRM. Singhal et al. (2011) argued that supply chain elements in the food sector are not firmly connected, and need to be studied through additional transparent and integrative models.

In terms of the dairy sector, because of the perishability of dairy products, Pant, Prakash, and Farooquie (2015) proposed a framework to manage transparency and traceability in dairy supply chains. They aimed at managing food quality and safety risks, and improving the effectiveness of dairy supply chain management as well. Enderwick (2009) analysed the melamine contamination in the Chinese dairy industry, and focused on effective management of quality risks in this industry. He asserted that effective governance structures and effective management of environmental conditions are key to minimise the quality risk. The relationship between governance mechanisms and food safety was discussed by Abebe, Chalak, and Abiad (2016). Ma, Han, and Lai (2013) also paid attention to dairy safety risk. They identified risk indicators of food safety in dairy supply chains, calculated the weights of different risk indicators, and assessed the risk level of dairy safety. Murigi (2013) focused on mitigation strategies of potential supply chain disruptions due to natural disasters. Pinior, Conraths, Petersen, and Selhorst (2015) studied the risk of deliberate contamination in the dairy industry.

Traceability was discussed by Pant et al. (2015), Dabbene, Gay, and Tortia (2014), and Zhou, Nanseki, Hotta, Shinkai, and Xu (2010) about its importance to food safety and quality.

There are various risks including quality and safety risks that exist in the dairy supply chain. Table 2.5 lists many risk sources from literature. Many researchers focus on risks for the farm, rather than for the whole supply chain. Daud, Putro, and Basri (2015) expressed that most risk sources are derived from the upstream of the milk supply chain, especially smallholder farmers. In this table, some of the risk sources are focused on the farm level.

Table 2. 5 Dairy SCRs

Dairy SCRs	**Literature sources**
Milk price variations, lack of hygienic conditions, and meat price variability	Akcaoz, Kizilay, and Ozcatalbas (2009)
High risks (low milching cattle, illiteracy of the milk producers, etc.), medium risks (high cost of fodder and medicines, delivery risks, etc.), and low risks (seasonal fluctuations in production, process/control/quality risks, etc.)	P. K. Mishra and Raja Shekhar (2011)
Demand side risk (forecast, demand fluctuation, etc.), supply side risk (quality risk, changes in technology/design, etc.), logistic side risk (storage, transportation issues, etc.), external risk (natural disasters, legal, economic downturn, etc.), and informational risks (improper planning, access to key information, distorted information, etc.)	Zubair and Mufti (2015)
Production risks, animal condition risks, personal risks, and input and output market risks	Daud et al. (2015)
Production risks (notifiable/non-notifiable cattle diseases, drought, flood), market risks (milk spoilage, etc.), and enabling environment risks (abrupt regulation, human disease, etc.)	The World Bank (2011)
Financial risk, technological risk, human resource risk, absence of fixed government policy, political risk, mismanagement and unethical behaviour of employees, natural risk, hazard risk, input risk, poor infrastructural facilities, and unethical behaviour of middlemen	Nasir et al. (2014)
Production risk, price risk, input risk, systematic risks, and idiosyncratic risks	Ramaswami, Ravi, and Chopra (2004)
Production risk, institutional risk, animal disease, input/output market risk, milk contamination risk, and personal risk	Zhou, Nanseki, and Takeuchi (2012)

Literature on SCRM in the dairy sector is limited (Nasir et al., 2014). A review of these current studies indicates that researchers are mostly focused on either specific risks or part of a dairy supply chain. Risks in the whole supply chain are interconnected, and affect the ultimate SCP. Dairy SCRs also need to be analysed in an integrated form. However, limited researches focus on the systemic analysis of the entire dairy supply chain. Zubair and Mufti (2015) indicated that risk identification and assessment in the dairy sector is insufficient and needs more investigation. They conducted a broad literature review to identify SCRs. Based on questionnaire results, the risks fit into a risk matrix according to their risk scores. P. K. Mishra and Raja Shekhar (2011) identified risks within the whole supply chain. The SCRs were categorised into high, medium, and low levels based on their impact values. They implied that high risks need early management as they are crucial. Meanwhile, the medium and low risks should not be ignored since risks can propagate in a supply chain. Thus, their research demonstrated both direct and indirect impacts of risks at different levels. In their further research, P. K. Mishra and Raja Shekhar (2012) discussed management strategies to minimise high risks. However, the strategies were proposed without considering the interactions among risks in the dairy supply chain. After conducting a single case study, Yu and Huatuco (2016) explored dairy SCRM in China. However, further study is required as it is studied in a general way without exploring the internal relationships among risks. Also, the generalisability of the findings to other dairy supply chains needs to be explored. Prakash, Soni, Rathore, and Singh (2017) proposed an integrated method for risk management in the perishable food supply chain, with a focus on the Indian dairy industry. The dairy food supply chain (shown in Figure 2.5) is illustrated for one federation with seven major stakeholders.

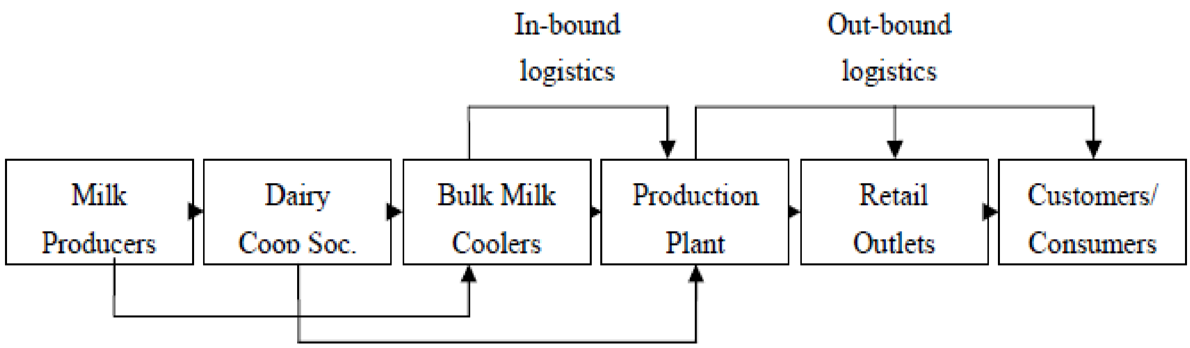


Figure 2. 5 Dairy Food Supply Chain (P. K. Mishra & Raja Shekhar, 2011)

Various risks have been identified within different stages of this supply chain. As the supply chain is integrated, risks in one stage may impact other stages. P. K. Mishra and Raja Shekhar (2011) identified fourteen dairy SCRs. Based on the described impact of risks on the supply chain, a causal loop diagram (CLD) can be established as Figure 2.6. The main objective of this diagram is to display the described causal relationships in a more straightforward form. This does not show all the relationships among variables in the dairy supply chain. Moreover, several relationships in this diagram are with conditions. First, "Production – Production cost", this negative relationship exists only when milk is less than 60 litres per day. Second, "Milk producers illiteracy – Production cost" and "Milk producers illiteracy – Produce quality", these two relationships sometimes exist. Third, "Quality of milk – Brand switching", the situation may happen that customers cannot survive with the federation and need to switch to competitors' brands. Last, "Customer satisfaction – Market share", this relationship may exist according to P. K. Mishra and Raja Shekhar (2011). Overall, P. K. Mishra and Raja Shekhar did not study dairy SCRs with a systemic view.

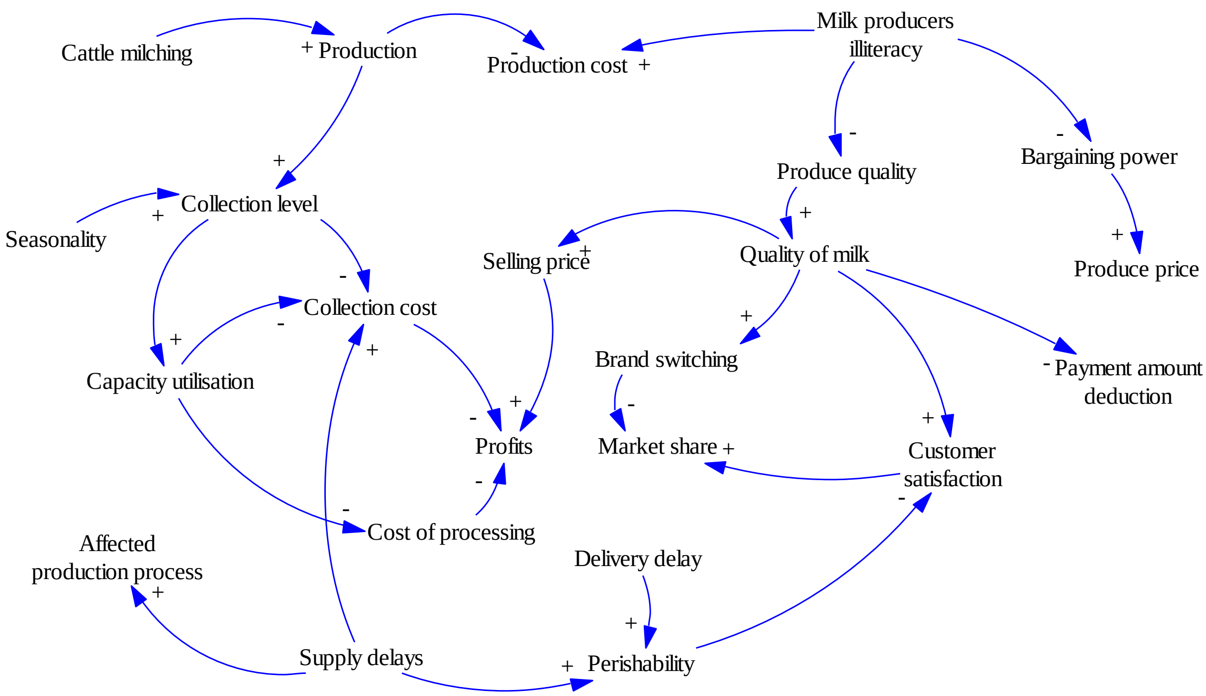


Figure 2. 6 Part of Dairy Supply Chain Involving Certain Risks

2.5.3 Corruption risk in dairy supply chains

Enderwick (2009) suggested that widespread corruption is one of the causes of possible quality deterioration. He discussed the Chinese dairy industry case, and mentions that it is challenging for businesses based in the least corrupt economies (e.g., Fonterra from NZ) to operate in economies with extensive corruption. In China, it is regarded as quite common for milk collection agents to take the greatest opportunity to falsify raw milk. Nasir et al. (2014) identified corruption as a risk variable in the dairy industry. In their context, corruption refers to mixing water with milk. One interviewee mentioned the link between the limited income level of employees and corruption in their behaviour. When talking about the risk factor, "Government policy and support", the interviewee described the passive corruption in dealing with unfair situations and gaining easy loans.

3 Research Topic

3.1 Interactions among entities

Risks penetrate in the nodes and links of the dairy supply chain. The interactions of various risks lead to the ultimate SCP. However, as discussed in the literature review, many scholars focus on dairy farmers when analysing risks in the dairy sector. There are inadequate systemic researches on the entire dairy supply chain.

Supply chain corruption may occur in different areas such as suppliers and the focal firm. Corruption would trigger various events in a supply chain. As such, corruption acts as a risk factor for the supply chain, and it would generate various consequences. In this research, corruption-associated risks in supply chains are regarded as *the risks induced by supply chain corruption, which show different likelihood and impact*. To avoid such long winding expression, this thesis uses the phrase “corruption risks” to mean “corruption-associated risks”.

Research on corruption risk in supply chains is significant for both academia and industry. Figure 3.1 displays a whole system about a supply chain affected by risks, where some risk effects are modified by corruption. This figure distinguishes factors by two parts: corruption and supply chains. The term “supply chain corruption” refers to corruption in various forms within a supply chain. Corruption has its risk factors and impacts, and their causal relationships are indicated by the arrows. Risk factors of supply chain corruption trigger the occurrence of corruption, which leads to probable risk impacts. The term “supply chain risk indicators” stands for indicators that are associated with risk events interfering supply chain operations. In a supply chain, risk indicators are interrelated to each other with arrows showing causal linkages. SCP indicators such as profit, are used to measure the performance.

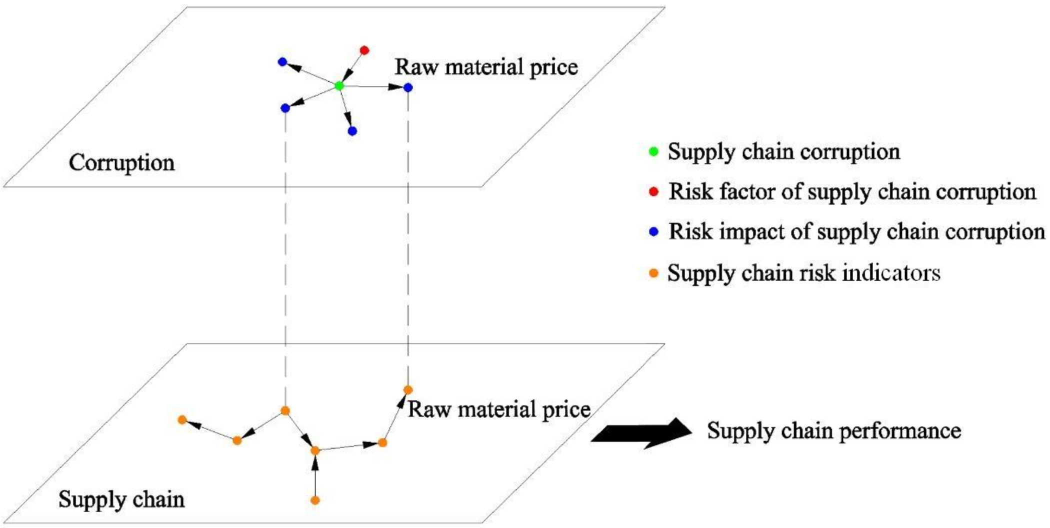


Figure 3. 1 Interactions between Corruption and the Supply Chain System

This research explores the interaction between corruption and a supply chain. Triggered by risk factors, risk events in supply chains have various consequences and interfere normal operations. Corruption modifies SCP through modifying the likelihood or impact of SCRs. This study aims to mitigate corruption's impact on supply chains, therefore, risk factors of supply chain corruption are not discussed. The interaction can be explicated by an example. From the perspective of corruption, raw material price is impacted by supply chain corruption. From the perspective of a supply chain, raw material price is one SCR indicator, namely, raw material price is modified in presence of supply chain corruption. Corruption modifies the effect of the SCR indicator, thus causing the modification of SCP.

Based on previous exploration of the research topic, this research proposes three questions to explicate the research gap, which are as follows:

(1) What are the primary risk events and their risk factors in dairy supply chains?
(2) How does corruption modify the effects of SCRs and thereby change SCP?
(3) What measures can be taken to effectively enhance supply chain robustness against corruption?

3.2 Research rationale

After mitigating the certain risks, the supply chain would become the least sensitive to corruption. Thereby we have a supply chain that is robust against corruption. Risk mitigation efforts cost the organisation differently depending on the current levels of risks, so it becomes important to identify which risks and how much mitigation efforts need to be applied in the selected risks to get the best value for the risk mitigation efforts. For this purpose I define, a leverage risk below:

> *A risk is called a leverage risk, in case with minimum change in its level, the difference in the SCPs, at high- and low-levels of corruption, becomes as small as possible.*

The term *leverage risk* is proposed in analysing supply chain robustness against the plausible corruption. It refers to the specific risks whose mitigation can facilitate the minimising of corruption's impact on SCP.

Figure 3.2 shows an example of SCP curve, with Y-axis showing SCP and X-axis showing corruption level. The variable "Risk" indicates that the supply chain is affected by risk at a specific level. Corruption modifies the effect of SCR, thereby modifying SCP. For different corruption levels, SCP varies and forms the curve. ΔSCP denotes the difference between SCP values under low and high corruption levels. A more horizontal curve leads to less |ΔSCP|, signifying less impact of corruption on SCP.

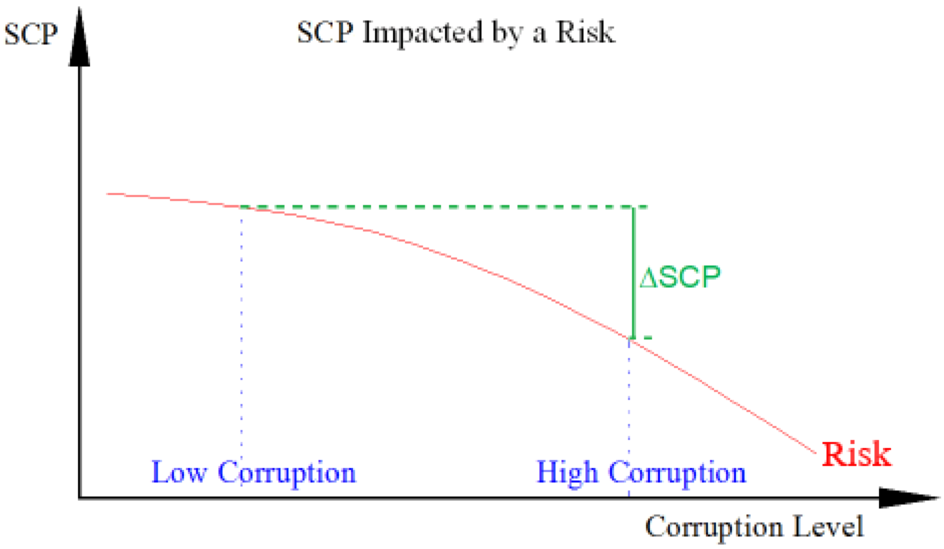


Figure 3. 2 Example of SCP Curve Impacted by a Risk with Different Corruption Levels

Figure 3.3 presents an example of SCP curves with different risk and corruption levels. This figure displays a more complex situation by considering different risk levels. For Risk A, Risk A_i (i = 0, 1, 2, 3) is used to describe different levels of risk mitigation. As indicated in the preceding section, supply chain risk indicators are utilised in studying the interactions among corruption and supply chain system. In describing Risk A (for example raw milk quality risk), a risk indicator (for example, probability of contamination) is used. Risk A_0, Risk A_1, Risk A_2, Risk A_3 stand for different values of probability of contamination, i.e., present value, 10% less, 20% less, and 30% less respectively. For these risk levels, the SCP curves would behave differently along with the variation of the corruption level. Four ΔSCPs can be generated from the four performance curves, following the discussion of Figure 3.2. According to the above definition, Risk A (for example raw milk quality risk) is regarded as a leverage risk when the least |ΔSCP| is achieved at the curve of Risk A_1 (when the probability of contamination is mitigated to 10% less of the present value).

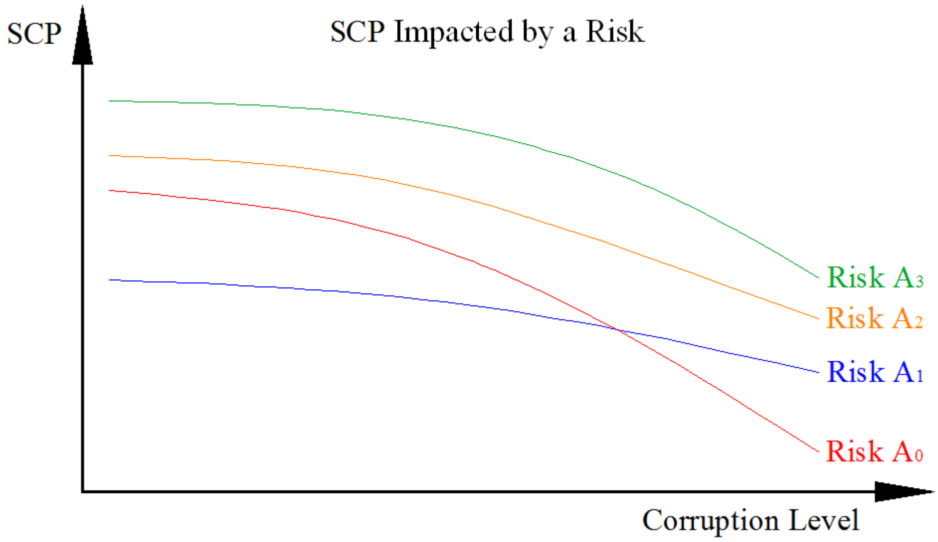


Figure 3. 3 Example of SCP Curves Impacted by Different Risk and Corruption Levels

To enhance supply chain robustness against corruption, a SD model was simulated to delve into the dynamic relationships and explore the leverage risks. By mitigating leverage risks, the impact of corruption on SCP can notably reach the lowest value. This research is novel in proposing measures to enhance supply chain robustness in the presence of corruption.

Risks have spillovers throughout the supply chain; mitigating one risk could enhance or reduce SCP. Figure 3.4 presents a simplified system structure. The innermost layer is a group of interconnected operational indicators, including SCP indicators. The middle layer shows indicators that are associated with each risk, such as risk factors and risk impacts. The outermost layer presents indicators associated with supply chain corruption. The overlaps show the interactions among risk indicators and operational indicators in a supply chain, as well as the connection between supply chain corruption and SCR indicators. Hence, various risks are interrelated as a result of these relationships. For example, risk factors (or risk impacts) of Risks 1 and 5 are external to the normal operations, and impacts (or risk factors) of Risks 1 and 5 are among the operational indicators. Then Risks 1 and 5 are related through the connection of operational indicators. Risks 3 and 4 are an example for risk interactions. Their causal linkages could be reflected as: the impact of Risk 3 triggering the occurrence of Risk 4. There are overlaps between corruption and risks, implying that corruption could impact SCR indicators and accordingly change SCP. The impact of corruption could be a SCR indicator, for example, raw material price in Figure 3.1. In this regard, corruption is connected with Risk 2, thereby is linked to the operational indicators.

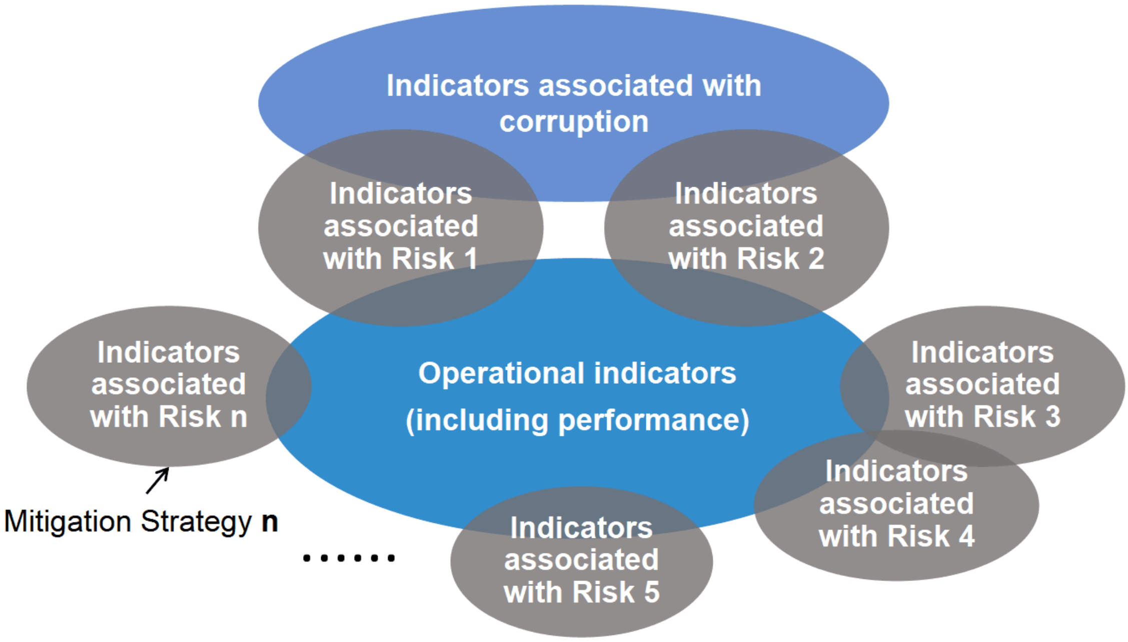


Figure 3. 4 Simplified System Structure

4 Research Methodology

4.1 Research philosophy in general

A paradigm includes four elements, which are ontology, epistemology, methodology and method. Ontology is the study of being, concerning with "what is" (Crotty, 1998). It determines whether reality can be separated from human practices or not (Braun & Clarke, 2013). Then they mentioned two distinct positions which are realism (reality is independent of human practices) and relativism (reality is entirely dependent on human understanding and knowledge). Epistemology is concerned with the nature of knowledge and what is possible to know (Braun & Clarke, 2013). It can be either realism or relativism, and their difference lies in whether thinking reality can be discovered or created. The positions of epistemology such as positivism, interpretivism, and criticism were introduced and explained in detail by Mack (2010). According to Scotland (2012), each paradigm is on the basis of the ontological and epistemological assumptions, which are conjecture, and cannot be proven/disproven from the empirical way. The methodology and methods can reflect the underlying philosophy in the research. Mack (2010) also suggested that the ontological assumption informs the epistemological assumption, which can inform the methodology and then the research methods are determined. The terms methodology and methods are different. Braun and Clarke (2013) claimed that methodology is broader, and contains theories and practices about the research conduction. They thought methodology can be regarded as a theory of how research should proceed to generate valid knowledge with respect to the psychological and social world. Methods are tools/techniques that researchers use to collect or analyse data (Braun & Clarke, 2013).

4.2 Ontological and epistemological position

In this research, the position of relativism and interpretivism is used. Table 4.1 summarises interpretivist ontology and epistemology proposed by Mack (2010).

Table 4. 1 Interpretivist Ontology and Epistemology (Adapted from Mack (2010))

Ontological assumptions	Epistemological assumptions
Reality is subjective and based on individual interpretation.	Knowledge is obtained by respecting discrepancies between people and natural objects of science, requiring social scientists to gain the subjective meanings.
Individuals interpret events.	Knowledge is obtained in an inductive way to build a theory.
Events are distinctive and not generalisable.	Knowledge emerges from specific situations.
More than one perspective exists on one incident.	Knowledge is obtained by means of personal experience.
Interpretation and symbols establish causation in the social sciences.	

This research focuses on the social phenomenon and tries to explore how corruption modifies the risk effects in the dairy supply chain. Interviews are conducted among different people, with the researcher seeking perceptions of the participants. The interview data are expected to be understood and interpreted instead of pure repetition. Mack (2010) stressed that, research must be observed from the inside instead of objectively from the outside. According to Myers (2013), interpretive researchers assume that the reality can only be accessed via social constructions, e.g., language, consciousness, shared meanings and instruments. For this kind of researcher, the meaning of a word shall depend on its context within a sentence or paragraph, or even the culture.

Participants may express their opinions differently on the same issue even in the same company. Mack (2010) clearly mentioned that in natural science, the uniform causal relationships can be determined, however, for the interpretivist scientist, this cannot be achieved. Therefore, perceptions of different participants are essential, and the researcher should interpret based on the understanding and the context.

For interpretivism, qualitative methods dominate, however, the quantitative ones may also be employed (Mackenzie & Knipe, 2006). The next section describes the methods employed in this research.

4.3 Research methods

This section proposes a conceptual framework of the management of corruption risk in supply chains (Figure 4.1). As mentioned in the literature review, the researcher rests on the two components identified by Musa (2012): risk analysis and risk control, to clarify the process of risk management. A supply chain is a complicated system, which could be composed of a focal company and its various suppliers and customers. A supply chain operates under both external and internal circumstances, leading to the existence of various risks. As indicated by blue lines, supply chain operations with risks generate the SCP, and corruption modifies the effect of SCRs. The red lines represent the feedback information, which provides appropriate guidance for risk management. Generally, this proposed framework aims at discovering how corruption modifies SCP and exploring effective strategies for mitigating corruption's impact.

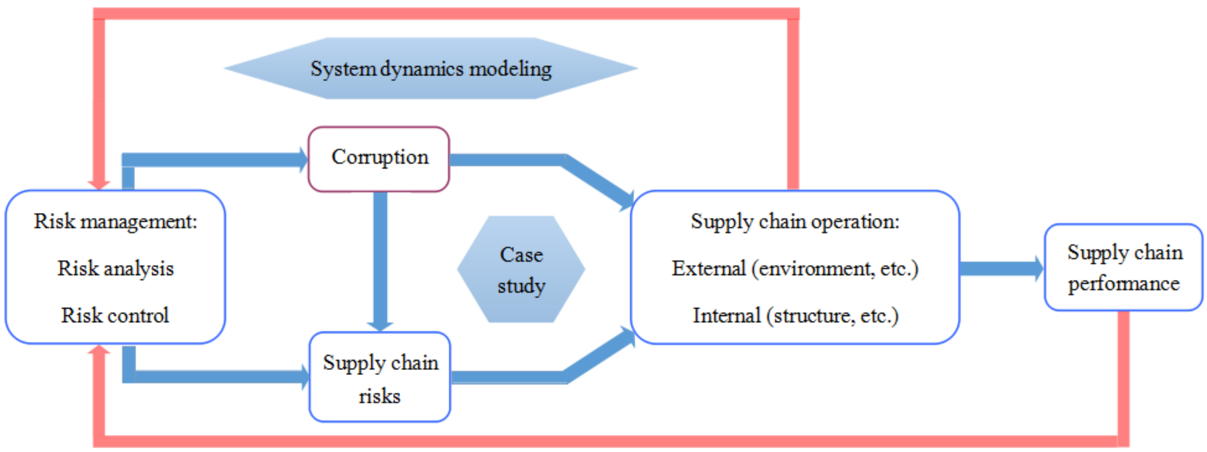


Figure 4. 1 Conceptual Framework of the Management of Corruption Risk in a Supply Chain

Research methodology is "a way to systematically solve the research problem" (Kothari, 2004). To implement research methodology smoothly, the researcher applied the following two research methods by combining qualitative and quantitative research methods, and the reasons are elaborated in the next two sections. Case study research could be used for risk identification, while SD modelling for risk estimation and mitigation.

4.3.1 Case study research

Social research is an activity to solve a research question by adopting a particular research strategy, research design, and methods of data collection and data analysis (Kelly, 2016). A research strategy may affect the selection of the research design, the data collection method, and the data analysis method. Furthermore, the strategy is associated with the research questions that can be addressed (Kelly, 2016). Qualitative and quantitative approaches are two primary research strategies. In terms of the nature of the qualitative research, scholars have a variety of descriptions, for example, a human-oriented and exploratory approach (Fidel, 1993), and an interpretive and naturalistic approach (Denzin & Lincoln, 2000). The qualitative approach is applied to "explore the general, complex set of factors surrounding the central phenomenon and present the broad, varied perspectives or meanings that participants hold" (Creswell, 2014). Furthermore, the qualitative research often copes with questions starting with "how" or "what" (Kotzab, Seuring, Müller, & Reiner, 2005). In this research, risk factors of dairy SCR events and the impact of corruption on dairy supply chains need exploration.

The lack of qualitative research in logistics, supply chain management, and operations management is a persistent problem. For the field of logistics, Mentzer and Kahn (1995) conducted a literature review and identified the dominance of quantitative approaches. Näslund (2002) questioned the dominance of a particular paradigm and approach in advancing a discipline, and proposed that the predominance of quantitative approaches shows a serious deficiency in logistics research. In the discipline of logistics and supply chain management, Sachan and Datta (2005) also pointed out the dominant position of quantitative methods. Gammelgaard and Flint (2012) identified the inappropriateness of a tacit agreement which is approaching the supply chain management and logistics discipline with a positivistic paradigm. In this editorial of a special issue on qualitative research in this discipline, they introduced and analysed eight papers, aiming at guiding future research in this direction. Until recently, qualitative approaches remain relatively sparse in the discipline of supply chain management, although there is a growing number of papers adopting qualitative methods (Houé & Murphy, 2017). Recognising this problem, they demonstrated the value of the qualitative approach on logistics networks. Carter (2011) identified that the supply chain management discipline is lacking in its own theoretical bases, and called for the development of the conceptual theory. Likewise, Narasimhan (2014) raised concerns about the theory development of operations management. Qualitative research is emphasised to contribute to theory development, and to extend knowledge frontiers in this mature discipline. Soltani, Ahmed, Liao, and Anosike (2014) pointed out the problem of the dominance of analytical and quantitative approaches, and emphasised the importance of qualitative research on the operations management discipline.

After reflecting on this persistent problem and research questions, the qualitative approach is to be used. Case study research was utilised to explore answers to the research questions. Case study research does not necessarily utilise the qualitative approach. R. K. Yin (1984) suggested that case study research can also use quantitative data fully. Likewise, Fidel (1984) emphasised that case studies can be qualitative and/or quantitative, and that the case study method is one of the different types of qualitative research methods.

In the supply chain, corruption may affect risks in different dimensions of supply chain operations. Interrelated factors and their causes or effects can be established by using case study research. R. Yin (1994) defined the case study method as "an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clear evident and it relies on multiple sources of evidence". Myers (2013) stated that the purpose of the case study method in business and management is "to use empirical evidence from real people in real organizations to make an original contribution to knowledge". He pointed out that case study research can be used for both exploratory and explanatory research, and the former one is more common. This research method is especially applicable in the early stages of research about rising topics. In this research, the objective of using case studies is to discover (as in exploratory research) instead of to test or explain (as in explanatory research). Case study research can take the forms of positivism, interpretivism, or criticism, and as mentioned previously, the interpretivist epistemology is employed. Relying on this underlying epistemology, the interpretivist case study research has been adopted.

Case study research is suitable for this research for the following reasons. First, it provides the opportunity of understanding the phenomena in real situations. Investigators are able to explore cases in organisations and this enhances the practice credibility through empirical research. Second, intensive information will be gained from case study research. The unit of analysis can be studied comprehensively by using data collection methods such as semi-structured interviews. For this research, data collected through these methods can provide abundant information on supply chain corruption. Third, case studies are more suitable for the stages of exploration, classification, and hypothesis development during the knowledge building process, and the investigators need to hold a receptive attitude when exploring (Benbasat, Goldstein, & Mead, 1987). Various factors related to supply chain corruption remain unclear, which need exploration for deeper understanding. Finally, case study research is useful to answer the "why" and "how" questions which deal with operational links to be traced over time instead of with frequency or incidence (Benbasat et al., 1987). This research aims at answering "how" questions, thus case studies are suitable for this research.

Myers (2013) suggested that three things should be considered in the choice of data collection techniques: research topic, research method, and the availability of data. Collis and Hussey (2013) stated that the availability of data is crucial to the successful outcome of research. In this research, semi-structured interviews were selected for data collection, in order to explore and verify the factors. Myers (2013) admitted that the interview is the most common, and maybe also the most important technique for data collection in business. The interview helps discover what the people in the company are thinking. He believed that in more in-depth case study research, other techniques such as documents also play quite an important role in supplementary evidence. There are three categories of interviews, which are structured, semi-structured, and unstructured interviews (Braun & Clarke, 2013). The structured interview may be with pre-set interview questions and responding categories, which is the more common type of interview in quantitative works. The semi-structured interview may have some fixed questions, as well as the scope for participants to pose issues out of the researcher's anticipation. This is the most common type of interview in qualitative works. The unstructured interview, just as the name suggests, is without fixed questions, and at most, with a list of topics/themes. This is utilised by some qualitative researchers. Myers (2013) suggested that in semi-structured interviews, some pre-formulated questions will be used without strict adherence to them. This encourages new questions and insights during semi-structured interviews, which are likely missed out in structured ones. Therefore, in this research, semi-structured interviews are employed.

4.3.2 SD models

4.3.2.1 Systems thinking and modelling

The SD method was proposed by Jay W. Forrester during the mid-1950s, who was a professor at the Massachusetts Institute of Technology. It has been widely applied in different areas such as engineering (Dukkipati, 2005; Wolstenholme, 1983), economics (Smith & van Ackere, 2002; Sterman, Forrester, Graham, & Senge, 1983), energy (Bodger & May, 1992; Shin, Shin, & Lee, 2013), environment (Ford, 1999), and so forth. SD was initially applied to supply chain management by Forrester (1958). Angerhofer and Angelides (2000) gave a general discussion of SD, and the corresponding application in the field of supply chain management. According to different purposes, they classified related research into three categories: building theories, solving problems, and improving modelling approaches.

Systems are widespread in the world, for instance, our body system, ecological systems, social systems, etc. A system is a set of interacting/interdependent components forming an integrated whole (See Webster's dictionary (n.d.)). J. G. Miller (1965) regarded that "the universe contains a hierarchy of systems, each higher level of system being composed of systems of low levels". Harary and Batell (1981) provided an interesting definition which is "a system should be taken as a nested network, with the underlying structure of a nested graph". Daellenbach, McNickle, and Dye (2012) considered the ingredients of a system as components, the relationship between components, behaviour or activities of the system, relevant environments, inputs from the environment, outputs to the environment, and special interests of the observer. The last ingredient means systems are observer-dependent and this is supported by Minati (2007), who argued that the observer models a phenomenon as a system. That is to say, different systems can be seen in the eyes of different people in a particular situation.

Systems thinking is a discipline for perceiving the whole and has been defined diversely. Recently Shaked and Schechter (2017) presented part of the various definitions that were proposed ever since 1990s. Despite their differences, Shaked and Schechter summarised two features that these definitions share: "rises above the separate components to see the whole system", and "views each separate component as a part of the whole system". Gharajedaghi (2007) suggested that the way of knowing has shifted from analytical thinking (dealing with independent sets of variables) to systems thinking (handling interdependent sets of variables). Even if highly regarded mathematical tools are used in analytical thinking, they encounter difficulty with complex behaviour. As Richmond (2001) said, *"The way we think is outdated. As a result, the way we act creates problems, and then we are ill-equipped to address them because of the way we think."*

Richmond (1997) explained a systems thinking paradigm by using four categories of thinking, which can be displayed in a picture (see Figure 4.2) in this research. Forest thinking emphasises the holistic approach and the interaction among components as well. Dynamic thinking means the world is dynamic and things are always changing. Operational thinking is understanding how things really work and influence each other. Closed-loop thinking is realising the nonlinearity between causes and effects, and the effects can usually affect the causes.

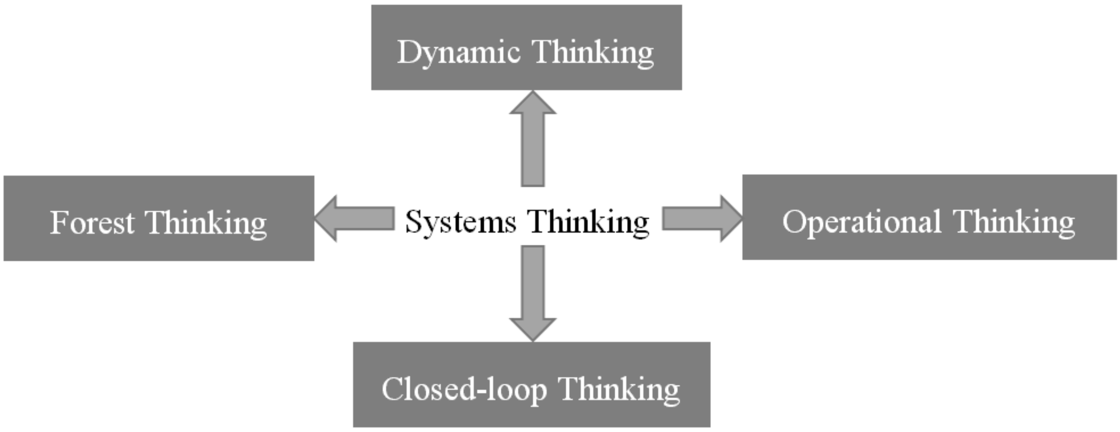


Figure 4. 2 Four Categories of Thinking

Systems thinking has seven principles (Anderson & Johnson, 1997):

(1) The big picture (larger forces and interactions)

(2) Short and long term (necessary short-term measures & long-term outcomes)

(3) Soft indicators (e.g., morale, loyalty, confidence)

(4) System as a cause (the internal mental models are emphasised)

(5) Time and space (time delays and chain effects of actions)

(6) Cause versus symptom (root causes of a problem)

(7) Either-or thinking (multiple causes and effects for a given problem/situation).

SD is computer-aided and applies to dynamic systems featured by interdependence, interaction, information feedback, and circular causality (Richardson, 2013). Both SD and systems thinking construct CLDs, including feedbacks and delays. The difference is that SD uses simulation to study system behaviour over time, as well as the impact of alternative policies (System Dynamics Society, n.d.).

CLDs provide "a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots" (Senge, 1990). A CLD consists of variables and arrows. Variables linked together can form different causal loops. The causal loops can be reinforcing (positive) or balancing (negative) feedback. Maani and Cavana (2007) suggested that reinforcing loops can represent growing or declining actions, and can be either a virtuous or vicious cycle, depending on the situation and choice of variable names. Balancing loops seek stability/return to control/a specified target, and are also regarded as counteracting or negative feedback loops. The effect of delays plays an important role in balancing loops.

Although CLDs are powerful and can show the relationships within different variables, they can only provide a qualitative impression. Generally, stock and flow diagrams (SFDs) are constructed from CLDs and are able to quantify the variables. The stock (level) represents the accumulation of a variable. The flow (rate) can be classified into inflows and outflows, which shows the increasing and decreasing rate of the stock over time respectively. There are also converters incorporating other relationships, graphs, parameters, constants, etc. Sterman (2000) indicated that SFDs show not only the components of the structure and their relationships, but also the accumulation and flow processes. Among different kinds of SD software, *iThink* was used as a tool to build SD models in this research.

Five advantages of SD modelling were highlighted by Maani and Cavana (2007):

(1) CLDs and SFDs can show the nature/direction of the relationships within the system being modelled, and give the modeller a better understanding of the system.

(2) Decision rules/policies can be varied in simulation, because feedback effects exist in the models and the state of the system will be affected by the past actions, which affects current decision making.

(3) Both non-linear and linear relationships can be contained.

(4) Both physical and information delays can be easily involved.

(5) Information which lacks adequate statistical data (e.g. ‘soft’ behavioural relationships) can be incorporated.

The systems thinking and modelling process presented by Maani and Cavana (2007) can be taken for a deeper understanding (shown in Table 4.2).

Table 4. 2 Systems Thinking and Modelling Process (Maani & Cavana, 2007)

No.	Phases	Steps
1	Problem structuring	1) Identify problems or issues of concern to management and main stakeholders 2) Collect preliminary information and data 3) Conduct group sessions for creative problem structuring
2	Causal loop modelling	1) Identify main variables 2) Prepare behaviour over time graphs (reference mode) 3) Develop CLD (influence diagram) 4) Analyse loop behaviour over time and identify loop types 5) Identify system archetypes 6) Identify key leverage points 7) Develop intervention strategies
3	Dynamic modelling	1) Develop a system map or rich picture 2) Define variable types and construct SFDs 3) Collect detailed information and data 4) Develop a simulation model 5) Simulate steady-state/ stability conditions 6) Reproduce reference mode behaviour (base case) 7) Validate the model 8) Perform sensitivity analysis 9) Design and analyse policies 10) Develop and test strategies
4	Scenario planning and modelling	1) Plan general scope of scenarios and modelling 2) Identify key drivers of change and keynote uncertainties 3) Construct forced and learning scenarios 4) Simulate scenarios with the model 5) Evaluate robustness of the policies and strategies
5	Implementation and organisational learning	1) Prepare a report and presentation to management team 2) Communicate results and insights of proposed intervention to stakeholders 3) Develop a microworld and learning lab based on the simulation model 4) Use learning lab to examine mental models and facilitate learning in the organisation

In this research, SD modelling was employed to assist in examining the research topic. The motivation to select SD is: (a) features of SD; and (b) insufficient application of SD in relevant fields.

(a) Features of SD:

(1) A good combination with case study research. A supply chain is a complex system with interconnected factors. The complex relationships exist within the whole entity. Corruption is within a system that also consists of various factors. The interactions between corruption and a supply chain contribute to the behaviour of the integrated system. On the one hand, the interrelationships obtained from a case study lay the foundation of the SD model. The case study shows the relationships among SCR factors, and brings forward the initial concept of the whole system. On the basis of the case study research and relevant literature, CLDs can be generated to clarify internal causation. On the other hand, SD provides dynamic simulation, which is not provided by case study research. SD can deal with high-order, nonlinear, and complex time-varying problems that exist in the open complex supply chain systems (F. Yang, 2012). Kilubi (2016) reviewed studies on SCRM and pointed out the significance of combining qualitative and quantitative studies to expand knowledge in this research field. Thus, the combination of case study research and SD modelling was employed with the target of exploring this research topic.

(2) A closed boundary. Complex interrelationships exist among entities of a supply chain network. This would be challenging and difficult to take everything into consideration. Lu, Byrne, and Maani (2000) reviewed literature on systems boundaries from the perspective of different disciplines. As to boundaries in SD, they mentioned the definition proposed by Forrester (1968). He claimed that a systems boundary should contain the least possible number of components, which are connected with a quantified causality.

(3) Decision making. This research aims at finding measures to robustify supply chains against corruption risk. SD models can be used because they judge the varying tendencies through dynamic simulation, then relevant decisions can be made (F. Yang, 2012). In addition, Mula, Campuzano-Bolarin, Díaz-Madroñero, and Carpio (2013) proposed that SD is most suitable in problems with continuous processes, where feedback information can largely influence system behaviour by generating dynamic changes.

(b) Insufficient application of SD in relevant fields:

Tako and Robinson (2012) argued that both discrete event simulation and SD are extensively applied to solve problems in the context of logistics and supply chain management. Größler, Thun, and Milling (2008) claimed that SD is highly appropriate for studying operations management. SD models can cope with supply chain problems from a high-level view, and the simulation under different scenarios facilitates policy selection for business decision-makers. SD modelling has been employed to study supply chain management with a wide range of topics, such as inventory decision, supply chain design, bullwhip effect, and capacity planning (Botha, Grobler, & Yadavalli, 2017; S. Kumar & Nigmatullin, 2011; Langroodi & Amiri, 2016; Chong Li, 2013; Sudarto, Takahashi, & Morikawa, 2017). Angerhofer and Angelides (2000) reviewed studies on supply chain management that apply SD modelling, and classified those literature into three types according to their purposes: (1) modelling for theory-building, including international supply chain management and decision-making in stock management; (2) modelling for problem-solving, including inventory management, demand amplification, supply chain re-engineering, and supply chain design; (3) improving the modelling approach, including integrated SD framework and participative business modelling.

This method has also been employed specifically for risk management issues in supply chain context. Mehrjoo and Pasek (2016) constructed a SD model for assessing risks and exploring risk impact on SCP in fast fashion apparel industry. Using SD modelling, Bala et al. (2017) focused on the rice supply chain and simulated SCP under different risk scenarios. Critical factors can be identified and managed which contributes to the formation of an efficient supply chain. Sidola et al. (2011) employed SD modelling to identify the effective policy in mitigating SCRs. Chaoyu Li et al. (2016) performed scenario analysis using the SD method, which assists in finding appropriate strategies for mitigating risks in chemical supply chains. Langroodi and Amiri (2016) modelled a five-level supply chain with multiple products and multiple regions. The SD model was simulated to facilitate the supply chain design under uncertain customer demand. Demand variation was also studied by Dégrés, Pierreval, and Caux (2008), who applied SD to explore the variation's impact on performance in the steel industry. These studies mainly utilise SD's superiority of scenario analysis without changing the real system. The model simulation helps explore SCP under different risk scenarios, and this facilitates the identification of effective strategies to mitigate SCRs.

However, Thiel, Le Hoa Vo, and Hovelaque (2014) suggested the scarcity of simulation used in food supply chain management. A SD model was created to simulate a poultry supply chain. They explored measures to enhance supply chain stability in face of uncertain customer demand and production capacity. S. Kumar and Nigmatullin (2011) developed a SD model for non-perishable product food supply chain. They studied how uncertain demand and lead time impact SCP, which assists the effective design of the supply chain. Minegishi and Thiel (2000) employed SD to study the logistic performance of a particular food supply chain. Georgiadis, Vlachos, and Iakovou (2005) developed a SD model which contributes to tackling strategic decision-making issues for food supply chains.

There are only a few studies of corruption using SD. Dudley (2001) underlined the importance of constructing a holistic and logical framework of corruption. Four preliminary sub-models of corruption were presented using SD modelling. Dudley suggested that a holistic model capturing all aspects of corruption could be developed to contribute to analysing and managing corruption. Washington de Queiroz (2015) built CLDs to explore corruption in the context of Brazil. Queiroz examined corruption-related variables and their relationships. However, no further simulation was conducted which could provide deeper insight about the complex corruption system. To the best of our knowledge, Ullah et al. (2012) are the first to construct and simulate a SD model for a holistic corruption system, including various corruption-related aspects such as culture, economy, and politics. Cosenz and Noto (2014) studied firm-level corruption on company performance by SD modelling. They considered firm-level corruption from the perspective of bribery, and the connection between firm-level and country-level corruption was taken into consideration. They adopted the idea of Ruhashyankiko and Yehoue (2006), who argued that the higher proportion of private customers in a firm's customer portfolio, the lower the firm-level corruption. These researchers investigated corruption in the public sector, which attracts numerous concerns. However, there is little SD research on corruption in the private sector.

From the above discussions, the researcher finds it insightful to apply SD to: (1) explore issues in supply chain management; (2) identify underlying dynamics in dairy supply chains; (3) examine the holistic corruption-influenced supply chains for effective management.

4.3.2.2 SD modelling basics

This section introduces the basic knowledge of SD concepts. This would contributes to the understanding of the construction and simulation of SD models.

4.3.2.2.1 CLDs

The CLD is a tool used to show causal relationships among a set of factors/variables in a system (Maani & Cavana, 2007). Within the CLD, two types of elements exist, which are variables and arrows. The variable can be quantitative or qualitative (or called soft). It is an advantage for CLDs that qualitative variables can also be included in the systems thinking approach. The arrow connects the variables, demonstrating the causal relationship between these two variables. At the head of the arrow, there is a notation indicating the relationship direction, with "s" (or "+") showing the same direction and "o" (or "-") showing the opposite direction (see Figure 4.3). The same direction means that the increase (decrease) of the variable A at the tail of the arrow brings the increase (decrease) of the variable B, which is at the head of the arrow. Likewise, the opposite direction means the increase (decrease) of the variable A at the tail of the arrow brings the decrease (increase) of the variable B.

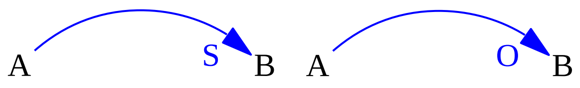


Figure 4. 3 Arrow Notations

The causal loop is formed when a group of related variables are joined together in a connected and closed route (Maani & Cavana, 2007). Each loop tells a story and shows the dynamic process. Following a particular starting variable, different links including variables and the directions on arrows, are considered until back to the original variable. This closed loop demonstrates the effect of the circular chain. There are two kinds of loops in Figure 4.4, which are reinforcing (or positive) and balancing (or negative) loops, reflecting reinforcing and balancing feedback systems respectively. For the reinforcing (or positive) feedback, it not only refers to the growing actions, but also the declining ones. The word positive does not represent good. The growing or declining actions rely on the situation and the selection of variable names. The balancing (or negative) feedback aims for stability or coming back to control or a specified goal. An easy way to distinguish the reinforcing feedback from the balancing one is to count the number of "o"s (or "-"s) within a loop. If the number is zero or even, then this loop is a reinforcing loop. In the case of Figure 4.4, the first loop has no "o"s (or "-"s), so it is reinforcing feedback. On the contrary, the second loop is a balancing loop.

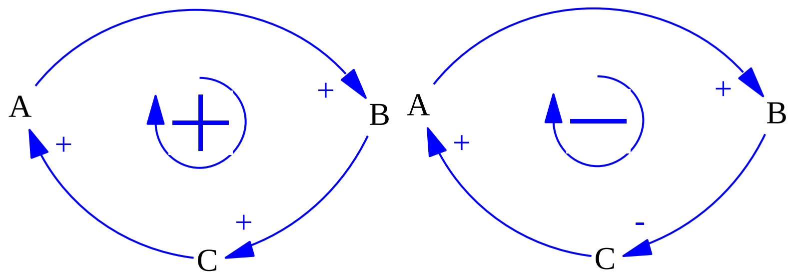


Figure 4. 4 Causal Loops

The system's behaviour is determined by its inner feedback structure. Sterman (2000) illustrated three basic modes of system behaviour, which are exponential growth, goal seeking, and oscillation. The behaviour of exponential growth is generated by the reinforcing feedback. Goal-seeking behaviour comes from the balancing feedback. The oscillation arises from negative feedback with delays. The nonlinear interactions of these basic modes brings about more complex modes of behaviour, which are S-shaped growth, S-shaped growth with overshoot, and overshoot and collapse. The S-shaped growth is different from exponential growth, because in the later stage, the growing trend slows down till the equilibrium. In its inner structure, both reinforcing and balancing feedback exist. The interaction between these two feedbacks should not be linear. The other two behaviours are on the basis of S-shaped growth and remove its two assumptions. S-shaped growth with overshoot means the situation (which is quite often) is when the balancing feedback in S-shaped growth is with delays. In the S-shaped growth, the carrying capacity is assumed to be fixed. The overshoot and collapse behaviour considers the situation when the carrying capacity is not fixed and may decrease. The above basic modes and their interactions are the major patterns of behaviour. There are also some minor patterns such as stasis (or equilibrium), randomness and chaos. These mechanisms contribute to the understanding during the model building process, as well as the identification of the dominant loops based on the behaviour.

Maani and Cavana (2007) differentiated the conventional problem solving and systems thinking problem solving. In conventional problem solving, the environment and external issues are not considered, and the optimal solution is anticipated to be found. Nevertheless, in systems thinking, the problem is considered in its context. A leverage instead of a mere solution is expected. They regarded leverage as the actions/interventions which could have an enduring impact by either reversing the trend or breaking a vicious cycle. The leverage can bring fundamental and lasting changes rather than just short-term and superficial solutions to the problems. The leverage points are to be found in the model to produce suitable intervention strategies.

4.3.2.2.2 SFDs

CLDs are rather useful in cases such as reflecting causal relationships among variables and showing feedback from a general and basic perspective. However, there are some limitations in the CLDs, for example, they cannot distinguish the nature of variables in the system. The limitations result in the inability to express the logical connections among different elements, which is essential for dynamic analysis. SFDs can show the nature of variables, distinguish stocks from flows, identify the various logical relationships, and delve into the feedback process within the system. Thus, SFDs need to be developed based on CLDs, for exploring the process of management and control. Sterman (2000) pointed out that feedback, and stocks and flows, are two predominant concepts in the dynamic systems theory.

Stocks (or levels) are accumulations such as inventory and population. They reveal the system's state and provide the basis for making decisions and actions (Sterman, 2000). Sterman indicated that they are the origin of disequilibrium dynamics within the system. Flows (or rates) are the changes of the stocks over a certain period of time. Stocks vary through their related flows, and no causal relationships should be directly linked into the stocks. Flows are often the results of decisions coming from either management or external forces (Maani & Cavana, 2007). Different from stocks, the values of the flows cannot be observed at a particular point of time, but can be seen within a period of time. Converters (or auxiliaries) are intermediate variables, including constants, and graphical and behavioural relationships (Maani & Cavana, 2007). They are intermediate between stocks and flows, helping information transfer and conversion. Converters are essential for the modelling of systems and expression of the decision process. In the case of complex flow equations, converters can help simplify those equations by describing part of them. The symbols of stocks, flows, and converters are shown in Figure 4.5.

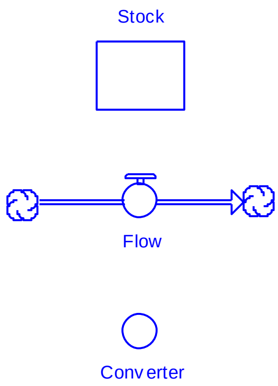


Figure 4. 5 Elements in SFDs

Clearly identifying stocks and flows lays the foundation for system modelling and analysis. Sterman (2000) proposed two ways of identification. The first method is to check the units of measure and then to judge whether a variable is a stock or a flow. Stocks are often a quantity while the flows are measured in the same units as the related stocks per time period. The time unit is not fixed as long as they are unified in the model. The second method for distinguishing stocks from flows is the snapshot test. Imagine that the time is stopped at a point of time, then all the flows are frozen and only the stocks can be measured. This means that the rate of change in stocks cannot be determined. The snapshot test also works for the less tangible stocks, which are mental rather than physical. The mental state can be captured, while the rate of belief updating cannot be measured at that particular time.

Delay is an important concept. Sterman (2000) claimed that all delays contain at least one stock. He defined the delay as a process where output falls behind its input in some manner (shown in Figure 4.6). Because of this gap between the input and the output, a stock must exist within this process for accumulation. The researcher follows Sterman in this description of delays.

Figure 4. 6 Concept of delay

Generally, there are two types of delays: material delays and information delays. The material delays seize the physical flow of materials with delays. Sterman described the general structure of this kind of delay (shown in Figure 4.7). He regarded information delays as the adjustment of perceptions/beliefs in a gradual way. When new information comes, our mental models cannot be updated instantly, thus information delays exist in the perception/belief. Different from material delays, information delays do not contain conserved flows and cannot be modelled with the structure in Figure 4.7. Although information delays do not have physical flows, they still have stocks, for example, the belief about orders, which is a psychological state in the mental model.

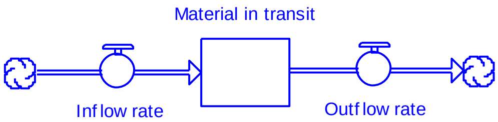


Figure 4. 7 General Structure of Material Delays

Much information is needed for the completion and simulation of the SD model. Initial values of stocks should be gained, parameter values should be discovered for describing the relationships, and mathematical functions (or constants, graphs) should be identified for the structural relationships among variables (Maani & Cavana, 2007).

The first step to formulate a model is to identify variables with causal relationships. Determining relevant variables is fundamental to system construction and analysis. The next chapter elaborates the process of case study research. Empirical findings are presented in Chapter 6, which are crucial for variable establishment and the subsequent model construction.

5 Case Study Research

A multiple-case study was used in this research. Benbasat et al. (1987) suggested that most researches need to investigate multiple cases, and they considered multiple-case research is appropriate when the research aim is description, theory building, or theory testing. Dubé and Paré (2003) proposed that multiple cases are preferred to be utilised in exploratory and explanatory case research. As this research intends to explore an unfamiliar field, a multiple-case study was selected. This chapter elaborates the process of case selection, data collection, and data analysis, in order to gain insight from the industry.

5.1 Case selection

An appropriate selection of the industry and companies is essential for the research. Data collected from the studied industry and companies affects research contribution. A research topic with likely contribution to the field could be weakened because of improper industry or company selection.

In this research, the NZ dairy industry was selected for the source of data. The main reasons are as follows:

1) The agri-food industry is different from other industries. NZ agribusiness is even more special in four respects: it involves pastoral farming, no government subsidies, technological innovation, and value chain efficiency (New Zealand Trade & Enterprise, n.d.). As discussed in section 2.5.1, the dairy industry can be distinguished from other sectors of agriculture based on characteristics such as the liquid state of raw milk, the socioeconomic position of the dairy producers, the strong position of cooperatives, and the efficient converter function of dairy cattle (Douphrate et al., 2013).
2) The dairy industry is a representative industry in NZ, and a major participant in the global market. Statistics New Zealand (2015) stated that the primary earnings of this country come from farm products including dairy products. The dairy sector remains the largest goods export sector in NZ, and occupies 3.5% of the total GDP of this country (Ballingall & Pambudi, 2017). NZ dominates 28% of the global dairy trade, and only less than 4% of its milk is used for domestic consumption (N. M. Shadbolt & Apparao, 2016). According to New Zealand Trade & Enterprise (n.d.), dairy production in NZ has witnessed huge growth in recent years, owing to leading farm efficiency.

3) Risks penetrate in various links and nodes of the dairy supply chain. Some can bring disastrous loss to companies, or cause health, or even life problems to consumers. Dairy SCRs have attracted increasing concern, especially after crises such as the 2008 Chinese milk scandal (Branigan, 2009), and the 2013 Fonterra botulism scare (Gray, 2013). The dairy supply chain would be penetrated with issues such as matters about markets within and out of NZ, uncertainties occurring in production and prices, and returns for stakeholders; an integrated supply chain managing all the issues contributes to its competitiveness (N. M. Shadbolt & Apparao, 2016). N. Shadbolt, Apparao, Hunter, Bicknell, and Dooley (2017) highlighted that since there is growing unpredictability and uncertainty in the dairy industry, it is imperative to explore the underlying mechanisms that influence the dairy industry in NZ. Corruption is a disruption for the operations of dairy supply chains, and corruption cases are not rare in the dairy industry. However, not much research can be found exploring corruption risks in the dairy supply chain.
4) As mentioned previously, NZ is consistently among the least corrupt countries, however, this does not mean businesses in this country are free from corruption. Jeong and Weiner (2012) claimed that little relationship exists between the Corruption Perceptions Index (CPI) of a country and its firms' actual bribery. Moreover, being in quite a transparent country, people's perception is expected to provide insight for this research.

The NZ dairy industry has various, specific features such as a small population compared with many other countries, a vast majority of dairy products exported, advantageous natural conditions, seasonal differences in milk supply, and an efficient farming system. Dairy supply chains have various structures, thus bringing about diverse risks. It is meaningful and distinctive to study SCRs in the NZ dairy industry. The dairy supply chain of focus is a simplified three-echelon supply chain (shown in Figure 5.1) made up of suppliers, dairy processors, and customers. About 40% of dairy farms use the structure of share-milking, a unique system to NZ (New Zealand Dairy Careers, 2017). The farmers can own a certain percentage of stock and share the income and costs. Raw milk is collected from farms and taken to the processing plant. In some emergency situations, dairy processors will take milk from other dairy processors with good partnerships. As well as raw milk, the dairy company needs to purchase other raw materials (this thesis uses "raw materials" to refer to other raw materials). Raw milk, together with raw materials, are transformed to various dairy products.

Then, the products are distributed to the customers in the form of finished products or ingredients.

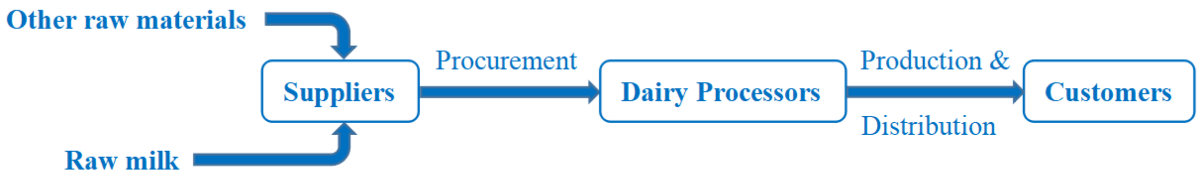


Figure 5. 1 Simplified Dairy Supply Chain Structure

Following the industry selection, the next procedure is to search and contact companies. The first step is to be familiar with the historical and present NZ dairy industry (see Table 5.1).

Table 5. 1 Major Events in NZ Dairy Industry (Adapted from DCANZ (n.d.))

Time	Major events
The early 19th century	European settlers imported dairy cattle for local supply.
1846	First exports started.
1871	The first cheese company was established, since then dairy co-operatives have been part of NZ's history.
By the 1930s	There were over 400 separate dairy co-operatives, focusing on export.
By the 1960s	There were 168 dairy co-operatives due to industry consolidation.
By 1995	There were only 13 dairy co-operatives left because of the continuing consolidation.
From 1980s to 1995	The number of subsidiaries and associated companies of the Dairy Board grew from 19 to 80, becoming the largest dedicated dairy marketing network in the world.
1996	The ownership of the Dairy Board's assets were transferred to the 12 dairy co-operatives.
2001	Fonterra was formed, while the two co-operatives Tatua and Westland remained independent.
Since 2001	The dairy industry has kept on growing. New dairy companies such as Open Country and Synlait were formed, focusing on export.

NERA Economic Consulting (2015) enhanced the understanding of current situations of this industry. This report described the competition in both the farm and factory gate markets. Processors in the NZ dairy industry include Fonterra (the largest participant), independent processors (IPs), along with other processors such as Goodman Fielder and 'niche' processors. The major IPs are Tatua, Westland, Open Country Dairy, Synlait, Miraka, Oceania and Gardians, which was indicated by NERA Economic Consulting (2015). Only two of the IPs, Tatua and Westland, are farmer owned co-operatives. Fonterra collects the largest share of raw milk, especially in the North Island. However, IPs have their own advantages. NERA Economic Consulting (2015) indicated that IPs generally have significantly higher shares in their collection zones, compared with their national/Island levels. This contributes to lower transportation costs and then higher farm gate price than Fonterra. NERA Economic Consulting (2015) noted that every existing IP, except Tatua, is expanding or planning to expand its capacity. Fonterra forecasts that this trend will continue.

The upstream of the dairy supply chain consists of dairy farmers and raw material suppliers. Federated Farmers of New Zealand Incorporated is an organisation on behalf of its member farmers (including dairy farmers), dealing with farming issues to support rural communities and the agricultural industry (Federated Farmers of New Zealand, n.d.). The downstream of the dairy supply chain are primarily overseas companies. There is a small domestic dairy market in NZ, that exports around 95% of the dairy products (Fonterra team, 2016). It is ideal to interview people from all nodes of the dairy supply chain to obtain complete information. However, it is impossible to fully achieve this goal due to practical restrictions.

5.2 Data collection

In this case study research, semi-structured interviews were conducted to explore and verify the risk variables. Before the interviews, the Ethics Approval was gained from the University of Auckland Human Participants Ethics Committee. Participants were selected primarily based on their positions within the company. They are mainly high level managers who work in dairy companies in NZ exporting dairy products to other countries. Interviewees in this research are mainly managing directors, general managers (supply chain), and supply chain managers. Some interviews were conducted among logistics managers and specialists to acquire additional information.

The researcher contacted as many organisations as possible, via various methods. The first step was to contact relevant associations such as Dairy Companies Association of New Zealand and Federated Farmers of New Zealand Incorporated. The researcher contacted them through email or phone, requesting them to invite their members to participate in this research. The response was not encouraging, so the researcher explored interview opportunities. Online resource was utilised to obtain company information, leading to the contact with potential interviewees. The participant information sheet (shown in Appendix A) and consent form (shown in Appendix B) were sent to them for a better understanding and consent.

As indicated in Figure 5.1, the focused three-tier supply chain mainly consists of suppliers (providing raw milk and raw materials), dairy processors, and customers. No response was received from suppliers and customers. The researcher planned to gain access to suitable farmers through Federated Farmers of New Zealand Incorporated, from where no response was received. Most of the customers that were contacted were overseas companies, because the dairy companies in NZ primarily focus on export. Those customer companies either cannot be reached or do not respond. As such, although the researcher approached organisations in each tier of the supply chain, only 7 dairy companies participated eventually. Most of the dairy companies in NZ were contacted, including foreign-investment companies. There are not many dairy processors in this country, which adds to the outcome of the small number of participating companies. According to the report of NZ dairy industry issued by Coriolis and MBIE (2017), 21 out of 27 firms are suitable for this research since the selected firms in this study are mainly focused on non-perishable products. Based on this guideline, one third firms were interviewed, including largest, independent, and other processors.

A brief profile of interviewed companies has been shown in Table 5.2. As there is limited number of dairy companies in this country, this research does not elaborate further details such as turnover and number of employees, in order to prevent companies from being readily identified. The companies and participants are respectively marked as A, B, C and A1, B1, C1, etc. All these companies are highly engaged in the NZ dairy industry, and they almost occupy the whole dairy industry of this country. Therefore, the collected data is impressive for studying NZ dairy supply chains.

Table 5. 2 A Brief Profile of Interviewed Companies

	Supply chain position	Entity type	Scale	Participant(s)
Company A	Focal firm	NZ co-operative company	Large	A1; A2
Company B	Focal firm	NZ co-operative company	Large	B1; B2
Company C	Focal firm	NZ limited company	Small and medium-sized	C1
Company D	Focal firm	NZ limited company	Large	D1; D2
Company E	Focal firm	NZ limited company	Large	E1
Company F	Focal firm	NZ limited company	Large	F1
Company G	Focal firm	NZ co-operative company	Large	G1

Besides this, only gaining access to focal firms (dairy processors) does not largely affect the validity of interview data, because the interviewees are predominantly high level managers. They have a comprehensive view of the whole supply chain and their perception can be greatly relied on. After gaining the consent from those organisations, the researcher made appointments with interviewees at their convenience. As a result of time coordination, the interviews were carried out over a long span of time. Overall, 10 participants were interviewed between November 2015 and October 2016. The number of cases is considered appropriate, as Eisenhardt (1989) suggested that 4 to 10 cases generally work well for developing theories. Furthermore, Marshall, Cardon, Poddar, and Fontenot (2013) demonstrated that the number of interviews in qualitative research is affected by world region. Among three groups of regions (i.e., North America, Europe and Asia), the number of studies with less than 10 interviews is found the largest in Europe (including Australia and NZ in this study) and the least in North America (Marshall et al., 2013). Also, the sample size adequacy questions coming from quantitative research mindset is not applicable in qualitative research of exploratory nature (Marshall et al., 2013).

Both face-to-face interviews and telephone interviews were used. The advantages and disadvantages of the different types of interviews were discussed by Braun and Clarke (2013). For example, the face-to-face interview has strengths such as rich and detailed information, flexibility, smaller samples, more control over the interview process for the researcher, and ideal for sensitive issues. The strength of telephone interviews is reflected in aspects such as convenience, and accessibility without geographical restriction and anonymity. This research determined the types of interviews by realistic conditions such as the participant's requirement. Considering their respective advantages, the researcher found it acceptable to collect data through both face-to-face and telephone interviews.

Four of the ten interviews were conducted face to face. Face-to-face interviews allow the interviewer to assess the body language of the interviewees. In telephone interviews, the interviewer observed their reaction and tone when answering interview questions. Most interviews lasted around one hour. Interviews were recorded after gaining consent from interviewees. Supplementary information was obtained by emailing interviewees when necessary.

The topic of concern, especially corruption risk, is a sensitive issue for interviewees. Asking straightforward questions increases interviewees' tension and may misinterpret research intentions. In addition, the participant information sheet underlines that "no issues or stories of corruption within the companies you have worked for should be raised". This research explores interviewees' perceptions rather than experiences pertaining to the topic of corruption. Explicating research aims before and during interviews helps clarify the objectives of the interviews, hence the researcher is likely to obtain more valuable information. In general, it is essential for interviewers to keep control of the interview process and to encourage interviewees to express their thoughts.

Using semi-structured questions would make sure that all participants answered the same questions (Charles, 1995; Kirk & Miller, 1986). Interview questions (shown in Appendix C) were prepared as a guide for the interview process, and not strictly followed one by one. For the reliability of the qualitative research, the colleagues reviewed questions to ensure the consistency before conducting interviews. Mock interviews were conducted in front of colleagues, in order to refine the interview questions. The interviewer carefully listened to and reflected on the answers of interviewees. Relevant questions were further asked based on their answers, while not deviating from the research topic. For the purpose of triangulation, some questions were repeated with another interviewee in the same company when possible.

5.3 Data analysis

The researcher analysed secondary data in terms of risks that were confronted by Fonterra, the largest participant in NZ dairy industry. Being a large NZ dairy co-operative and world leading dairy exporter, Fonterra occupies a quarter of the whole country's exports (Fonterra Co-operative Group, 2016). Reports, interviews, academic research, and other archives were consulted to delve into Fonterra's SCRs. As a dairy giant, Fonterra met with however several major crises in the latest ten years, such as melamine contamination in China and contaminated whey powder, discussed by Chaturvedi (2013). The melamine contamination scandal of Fonterra/Sanlu joint venture led to numerous victims and the disastrous ending of partnership between the two companies. Enderwick (2009) attributed this incident to regulatory, institutional and market issues in China, Fonterra's minority joint venture position, and quality complacency within Fonterra's management team. However, Chaturvedi (2013) held different views and claimed that Fonterra's quality control systems should be applied despite which country it operates in. Government Inquiry into the Whey Protein Concentrate Contamination Incident (2014) demonstrated that the WPC80 incident was a false alarm because the suspected *Clostridium botulinum* was not detected in the WPC80 in the end. Nonetheless, the Inquiry elaborated causes of the incident and revealed the existing noteworthy risks, anticipating for Fonterra's improvement. There were other incidents such as factory explosion due to faulty placement of chemical into a tank (Conway, 2009) and silo collapse where there is cracking of the weld (Hutching, 2016). Integrating the secondary data, we summarized several risk factors learnt from Fonterra's operations, which are imprecise roles and incoherent information communication due to relentless company restructuring, contamination due to non-standard equipment, non-standard processes, out of product specifications, human errors, and ineffective audits. Such information provides significant guidance for interviews, because of Fonterra's critical role in NZ dairy industry.

Regarding the interview data, the unit of analysis is the participant within the dairy supply chain. The collected interview data were analysed using Nvivo 11, a qualitative data analysis software provided by QSR International Pty Ltd. Thematic analysis was employed to analyse the interview data. Boyatzis (1998) indicated that thematic analysis is not another qualitative method but a process that can be used with most qualitative methods. It is a method for identifying and forming themes from the data. The transcribing process was time consuming, however, Bird (2005) regarded transcribing to be a key phase of data analysis in an interpretative qualitative methodology. This process develops familiarisation with the interview data collected, and contributes to the coding process. Open coding was performed line by line in transcripts to generate codes. Coding is one of the simplest ways for qualitative data analysis, and a code can be a word to express the meaning of a sentence, paragraph or text

(Myers, 2013). Codes refer to the most basic segment/element of the raw data or information which can be evaluated in a meaningful way concerning the phenomenon (Boyatzis, 1998). An iterative approach was used to establish the ultimate codes and themes. Categories were formed by reading interview transcripts. Initial categories were updated with new ones through further reading of new interview transcripts. After this iterative process, codes and themes were formed.

Table 5.3 presents an example of the analysis results of themes, sub-themes, and codes. Key words like bacteria and disease were identified by open coding. The identified codes were classified according to their common features. For example, milk chilling in farm vats and restrictions on holding times are both preventive measures on the farm. These two codes were categorised into a sub-theme named farm action. All the sub-themes were further categorised into a theme. In this example, the four sub-themes all focus on raw milk quality, therefore the theme "raw milk quality" was formed. In this research, the generated themes are various risk-prone links or nodes in the dairy supply chain. The detailed results of the analysis are in Appendix D.

Table 5. 3 Example of Data Analysis Result

Themes	Sub-themes	Codes
Raw milk quality	Contamination	Bacteria, disease, chemicals, seasonal conditions of cows
	Inspection error	Raw milk quality audit inaccuracy
	Plant action	Quality audit, product selection
	Farm action	Milk chilling in farm vats, restrictions on holding times

6 Empirical Findings

Risk events discussed by interviewees are: raw milk delivery delay, collection cost fluctuation, raw material delivery delay, product delivery delay, product delivery cost fluctuation, information asymmetry, poor raw milk quality, milk solids price fluctuation, raw milk volume fluctuation, raw material price fluctuation, poor raw material quality, processing cost fluctuation, process instability, poor product quality, product price fluctuation, and customer demand fluctuation. As stated by Jüttner et al. (2003), SCRs can be classified into three types: environmental risks, network-related risks, and organisational risks. In this chapter, environmental risks are not listed in a separate section, because the impacts of environmental events were considered as risk factors of organisational or network-related events. Those environmental events are not explored regarding their risk factors, thus the environmental risks are not discussed separately. Corruption is widespread and could affect various dairy SCRs to different degrees.

6.1 Network-related risks

6.1.1 Raw milk delivery time

According to Barnao (2009), raw milk is milk that is produced in line with a registered risk management programme, and has not been subjected to any processing expected to modify its quality or composition characteristics. Raw milk is collected by tankers from the farms to the processing plant. Raw milk is essential for dairy processors. If there is a delay in raw milk delivery, the raw milk and production in the plant would be affected. Some interviewees did not regard this as a risk to their supply chains. Other interviewees also mentioned this risk, but pointed out that not many raw milk delivery delays actually occurred.

Table 6.1 displays the thematic analysis on raw milk delivery time. This theme is described from three sub-themes, which are external disruption, internal disruption and capacity improvement.

Table 6. 1 Thematic Analysis on Raw Milk Delivery Time

Sub-themes	Codes	Explanation or Evidence
External disruption	Natural disasters and road closures	One interviewee attributed raw milk delivery delay to natural disasters and road closures. This interviewee estimated the probability as once per year for three days, and thought that the delivery time may increase 10%. The perishable feature of milk may result in disposal after a long time delay, which rarely took place.
Internal disruption	Farmers delay milking	Disruption within the supply chain was also mentioned for the occurrence of raw milk delivery delays. The disruption arises from either the farm or the processing plant, as mentioned by an interviewee. If farmers delay milking, the raw milk cannot be delivered to the plant on time.
	Full silo	The silos may be full during peak time, and tankers have to be held up which extends the delivery time.
Capacity improvement	Extra tankers or silo space	One interviewee advocated capacity improvement to reduce delays. Using extra tankers contributes to reducing the total delivery time. If the plant invests in more silo space, there will be fewer occasions for tankers to be held up outside at peak times.

6.1.2 Collection cost

The collection cost refers to costs in regard to picking up raw milk from farms then to the plant. Interviewees pointed out two essential influences: diesel cost in transportation, and raw milk volume. Table 6.2 demonstrates the thematic analysis on collection cost, which can be clarified from the perspective of resource expense variation.

Table 6. 2 Thematic Analysis on Collection Cost

Sub-themes	Codes	Explanation or Evidence
Resource expense variation	Diesel cost in transportation	Two interviewees underlined diesel cost as one primary component. Fuel price fluctuation largely contributes to the cost fluctuation. The collection cost has actually come down in the last few years because fuel prices have come down.
	Raw milk volume	Raw milk volume affects the collection cost per litre of milk. *It is more expensive at this time of season [off-season] because there is less to pick up. One tank may go to 6 farms, while in peak might only 2 or 3. So more expensive per litre of milk at this time of season. (D1)*

6.1.3 Raw material delivery time

In this research, raw materials refer to ingredients such as protein and lactose. Raw materials and raw milk are processed for various dairy products. The on-time delivery of raw materials is important for normal operation in the plant. Many interviewees mentioned the problem of raw material delivery timing. One interviewee stated that delays of ingredients happened often, and that they would have to alter production to a different item until the other one arrived, which impacted on production efficiencies. The delays in raw material delivery could also result in plant downtimes. Table 6.3 is the thematic analysis on raw material delivery time. This theme is interpreted from four sub-themes: supplier disruption, shipping disruption, backup for raw material supply, and collaboration.

Table 6. 3 Thematic Analysis on Raw Material Delivery Time

Sub-themes	Codes	Explanation or Evidence
Supplier disruption	Labour strike	A labour strike was indicated to bring about delivery delays.
	Suppliers have a number of different distribution schedules	Various disruptions may occur in the suppliers' link, which delay raw material delivery. *They are large and complex organisation, and they have a number of different distribution schedules from manufacturing plant to us, cause delays. Some of the products have very tight specification levels, the supplier may find it hard to meet, which may cause delays. (B2)*
	Hard to meet the tight specification levels	
	Natural disasters	Natural disaster is something out of their control, which may affect supplies.
	Limited manufacturers for some ingredients	There is not so much risk around raw material volume. One interviewee stated that from time to time there may be shortages, but they were pretty easy to procure. However, according to an interviewee from the company processing goat and sheep milk, there were only one or two manufacturers for some ingredients in the world. When the global demand exceeds manufacturing capacity, they could not get enough supply.
Shipping disruption	Shipping schedules change	Delivering raw materials on time has two essential factors: fully prepared raw materials and on-time shipping. Shipping schedules change, which may cause delays, as indicated by an interviewee.
Backup for raw material supply	Increase inventory coverage	Three interviewees considered increasing inventory coverage for risk management. Raw milk comes in every day, so they have to make sure they can always get the raw materials for daily production. Keeping inventory is utilised because more inventory stands for higher buffer levels.
	Backup suppliers	Alternative suppliers can be turned to when one supplier cannot supply in time.
Collaboration	Send suppliers the forecast	One interviewee also put forward the idea of collaboration. By sending suppliers forecast, means they can have full projections to prepare their products in advance.

6.1.4 Product delivery time

Most dairy companies in NZ focus on export. For outbound logistics, various factors can occur which delay delivery to customers. Table 6.4 demonstrates thematic analysis on product delivery time. This theme has been categorised into three sub-themes: external disturbance, internal disturbance, and preparations.

Table 6. 4 Thematic Analysis on Product Delivery Time

Sub-themes	Codes	Explanation or Evidence
External disturbance	Accident	Three interviewees attributed product delivery delay to shipping accidents, although there is a minimal chance of this happening. One interviewee stated that this is actually a risk to customers. Products are sold on the basis that once the container vessel leaves NZ waters, they are owned by the customers.
	Government regulations	Local government regulations can interrupt delivery even if products have arrived in the export countries. Countries have their own regulations, for example, the weight limits on roads. As one interviewee expressed, *"In NZ we have a restriction that we can load, say 25 tons of products into one container, that is no problem to move around the country on the road network. In the country that we shift to, there might be weight limit because of the conditions of the road and the trucks over there, there might be a local government regulation that we can take 20 tons for example." (D2).*
Internal disturbance	Product quality	Products identified with quality problems cannot be delivered to customers as expected. The quality issue was emphasised by an interviewee. Brand reputation is impacted in this situation.
Preparations	Inventory	Keeping inventory was suggested as a method of mitigating delivery delay risk due to quality problems. This however is achieved by incurring additional inventory carrying costs.
	Use flight to catch up	Airlifting the product in times of logistic break down was also suggested.
	Be familiar with government regulations in export countries	Being familiar with local government regulations is essential in dealing with international trade with different countries. *We should make sure that we are on the right page of our customers before we shift our products, otherwise when you shift there, one may not leave the port because it is over the limit. (D2)*

6.1.5 Product delivery cost

Thematic analysis on product delivery cost is shown in Table 6.5. The theme has been analysed from the perspective of logistics fluctuation.

Table 6. 5 Thematic Analysis on Product Delivery Cost

Sub-themes	Codes	Explanation or Evidence
Logistics fluctuation	Shipping availability	Availability of shipping was mentioned by one interviewee. Shipping companies merge and become bigger, which incurs higher delivery costs for customers.

6.1.6 Information symmetry

In the dairy industry, information asymmetry is harmful not only to the safety and quality of the dairy products, but also to dairy supply chain management. Table 6.6 describes thematic analysis on information symmetry, focusing on two sub-themes, information incompleteness and disruption of information flow.

Table 6. 6 Thematic Analysis on Information Symmetry

Sub-themes	Codes	Explanation or Evidence
Information incompleteness	Lack of upgraded system	Two interviewees suggested that there are good systems and high supply chain visibility. *Systems are pretty good, we use a latest software technology to do all the tracking. This part not really likely to have any issues. We make quite big investment in software and tracking systems and information technology side of the business. Not what I consider really a risk area. (C1)* However, one interviewee admitted that there might be some information asymmetry problems. The lack of an upgraded system was considered as a probable source, but with low probability of occurrence.

One interviewee argued that low supply chain visibility brings about the problem of traceability. Sales would be affected if information of products for sale was not available. Without this transparent information, there was the likelihood of people taking advantage and doing something bad to the company. One interviewee said:

> *They will raise acception on a non-compliance against the business. They will need to be sorted out. If we do not have a high transparency, the degree [of acception on a non-compliant product] would be high. (B1)*

6.2 Organisational risks

Figure 6.1 presents the dairy production process, with the green parts indicating quality risk-prone links or nodes. For example, raw material composition errors mean poor quality of other inputs, which affect the quality of finished products. Contamination and inspection error may cause quality problems over the whole process. This figure covers quality risks in the dairy supply chain, including raw milk quality risk (see section 6.2.1), raw material quality risk (see section 6.2.5), and product quality risk (see section 6.2.8).

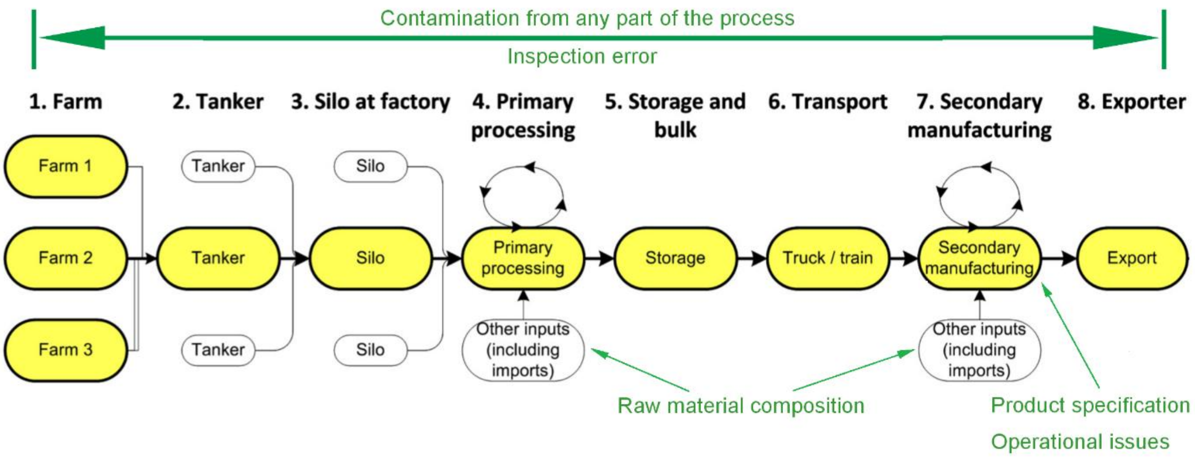


Figure 6. 1 Quality Risk-Prone Links and Nodes within the Dairy Production Process (Based on Dairy traceability working group (2014))

6.2.1 Raw milk quality

Raw milk quality is crucial for the finished dairy products. Raw milk undergoes successive quality tests from farm collection to plant processing. The tests are conducted by drivers when raw milk is collected on the farm, and by people in the plant when raw milk is processed till the end of the production run. Most interviewees attributed raw milk quality deterioration to contamination, although with low probability.

A raw milk quality audit helps prevent poor quality raw milk from flowing into the processing plant, although the probability of audit inaccuracy exists, it is low. Raw milk is collected from different farms and tankers collect from several farms at a time. Unidentified quality problems can result in contamination of the whole tanker. Table 6.7 presents thematic analysis on raw milk quality with four sub-themes being: contamination, inspection error, plant action, and farm action.

Table 6. 7 Thematic Analysis on Raw Milk Quality

Sub-themes	Codes	Explanation or Evidence
Contamination	Bacteria	There is a temperature requirement for the collected raw milk. If this requirement is not met, the milk can potentially breed bacteria. One interviewee mentioned that coliform tends to occur in a particular season.
	Disease	Milking diseased cows was discussed; however, many interviewees stated that disease is not common.
	Chemicals	Chemical issues were considered by three interviewees. Sick cows are treated with antibiotics, and continuous milking without separating the sick cows results in contamination. Milk quality produced on farms is closely associated with farmers or farm workers. *Unhappy farm workers (with the boss, etc.) may do some corruption act (add some chemicals into the milk). (A1)* *Our company is cooperative, we don't buy any milk, farmers provide milk to us. The biggest risk is the farmers contaminating the milk for whatever reason. (B2)*
	Seasonal conditions of cows	One interviewee discussed seasonal impact on raw milk quality. At the end of the milking season, cows are tired and produce lower quality milk.
Inspection error	Raw milk quality audit inaccuracy	One interviewee described that: *"The audit inaccuracy overall is medium, while there may be gaps in any single audit point. i.e. samples of whole milk are not tested for each parameter each day." (A2).*
Plant action	Quality audit	Stringent testing regimes contribute to the mitigation of raw milk quality risk, which was emphasised by many interviewees. Instead of simply testing milk, one interviewee stated the importance of test result analysis: *"Monitoring of Somatic Cell Counts of milk from each farm – to identify unfavourable trends before milk quality limits are exceeded." (A2).* A variety of tests are in the process for identifying milk quality problems. Poor quality of raw milk could be detected by subsequent tests. Despite the function of detection, the incentive effect of multiple tests was mentioned by an interviewee. *Subsequent/downstream samples are tested for more/additional parameters. This may not directly reduce the overall risk, but incentivises farmers/operators to implement practices to protect the milk quality. (A2)*
	Product selection	Raw milk is not necessarily discarded if it does not meet all the requirements. It can be used to produce a particular product with less requirements. This risk mitigation was mentioned by two interviewees. *Raw milk does not really have quality problems when it comes in. There might be something like coliforms. We put it into a particular product where the customer does not care about it at all. It depends on what customers use it for. If the customers are going to put the product into the high heat plant themselves and get it retreated, it does not matter to them. (D1)*

Table 6.7 (*Continued*)

Farm action	Milk chilling in farm vats	It is essential for the farm to prevent milk from contamination after milking. One interviewee mentioned milk chilling in farm vats and restrictions on holding time to limit microbial proliferation.
	Restrictions on holding times	

6.2.2 Milk solids price

Milk solids price directly affects profits gained by farmers. For example, Fonterra decided to cut the milk solids price forecast from $5.25 to $3.85 per kilogram, bringing many farmers into a survival situation. This slump caused 90% of farmers to take on extra debt and operate by covering great losses (Lin & Piddock, 2015). The boost of the milk price would encourage dairy farmers and contribute to its recovery after enduring a sluggish dairy market. Fonterra's 2016/17 milk solids price forecast was increased to $6 per kilogram, and this boosted average farmers' incomes by $260,000 since the start of the season (Autofile, 2016). Even though, in general, price fluctuation impacts farmers, it does not do so if they are dealing with niche markets. One of the companies interviewed processes goat and sheep's milk, which is not a commodity and its price is quite stable. Table 6.8 shows thematic analysis on milk solids price.

Table 6. 8 Thematic Analysis on Milk Solids Price

Sub-themes	Codes	Explanation or Evidence
Global market variation	International supply and demand	Four interviewees from companies that process cow milk suggested that the price is market driven and depends on international supply and demand. *Every two weeks it goes up by 10%. Over one year, the price could drop by half, for example, from 4,500 dollars/tub down to 2,000 dollars/tub. We may pay farmers 8 dollars per kg milk solids to 5 dollars per kg milk solids. (B1)* Among all the factors, international supply and demand was regarded as the foremost cause. *The payments vary hugely, but that is all based on what the international markets doing. Mostly affected by the international supply and demand. (D1)*
Company financial variation	Budget to farmers	The milk solids price also depends on factors such as budget to farmers, previous payments in the last several months, season, and regional effect on protein and fat levels. *Down in the southland, the milk solids price tend to be high because it is cold down there, whereas up in the northland the protein and fat levels are less. (D1)*
	Previous payments in last several months	
Natural factors	Season	
	Regional effect on protein and fat levels	

6.2.3 Raw milk volume

Raw milk comes into the plant every day, with volume largely depending on the season - highest in the peak season and lowest in the off-season. Table 6.9 helps better understand the uncertainty of raw milk volume. The theme, raw milk volume, is analysed from three sub-themes: natural environment, global problem, and rational use of raw milk.

Table 6. 9 Thematic Analysis on Raw Milk Volume

Sub-themes	Codes	Explanation or Evidence
Natural environment	Weather	Weather conditions bring about the fluctuation of raw milk volume. Unanticipated weather changes can seriously affect milk production. Three interviewees mentioned weather turns such as flooding and drought, which may lead to a lack of milk to meet customer orders.
Global problem	Worldwide shortage of goat and sheep milk	This cause specifically lies with the company processing goat and sheep milk. As stated by an interviewee, there is a big shortage of goat and sheep milk.
Rational use of raw milk	Wet processing	Cooperative dairy companies are expected to take all the milk that farmers offer because of their contract. Even if the milk is more than needed and is dumped, they still have to pay for it. An interviewee suggested that surplus milk should be turned into milk powder, kept in store, and reused to make infant formula. However, another interviewee argued that it costs approximately $300 per ton in energy to put the milk through the dryer again and there is no value to them in reprocessing it. Therefore, they do not perform wet processing.
	Plan well in advance	Good planning was highlighted by one interviewee. Milk production must be planned well in advance, and sales must also be planned accordingly. The sales forecast is adjusted according to the milk forecast.

6.2.4 Raw material price

Raw material price is linked to the cost of processing plants. Table 6.10 is the thematic analysis on raw material price. The theme raw material price fluctuation is explained from the perspective of global market fluctuation.

Table 6. 10 Thematic Analysis on Raw Material Price

Sub-themes	Codes	Explanation or Evidence
Global market fluctuation	International supply and demand	Two interviewees mentioned the international supply and demand dynamics as the cause. The raw material could be a kind of dairy product such as lactose. One interviewee indicated that they buy lactose from the US or Europe, and as a dairy product, its price goes up and down like the price of milk powder.
	Dairy product price	

6.2.5 Raw material quality

Raw materials refer to ingredients such as protein and lactose. Raw materials and raw milk are processed for various dairy products. The quality of raw materials and raw milk contributes to the quality of the final product. Table 6.11 presents thematic analysis on raw material quality, which contains two sub-themes, raw material composition, and plant action.

Table 6. 11 Thematic Analysis on Raw Material Quality

Sub-themes	Codes	Explanation or Evidence
Raw material composition	Out of specifications	Three interviewees attributed the raw material quality problem to specifications. All ingredients undergo testing. The test results are compared with the product's specification sheet and requirements for ingredients. Ingredients out of specifications are rejected.
Plant action	Quality audit of raw materials	Raw material quality testing was mentioned by two interviewees. The testing is conducted in NZ, and there is no likelihood of corruption by quality auditors. *We test it here as well and they have to send statistical analysis, the product has to be tested and show the test results before we can put into food. (E1)* *There is no chance in NZ for quality auditors to do some corruption. There is some risk overseas. We don't test overseas, we test here when they arrive. (C1)*
	Supplier selection	To guarantee good quality raw materials, supplier selection is critical. As stated by three interviewees, there is a fairly strict process to go through before a supplier is selected. One interviewee regarded raw material problems as the biggest threat. Supplier and ingredient assessment were emphasised. *Before selecting the suppliers, we will review the qualification, check their license and plant settings. We will also audit their quality control system. (F1)*

6.2.6 Processing cost

Various dairy products are manufactured in the plant, generating processing costs. Table 6.12 demonstrates thematic analysis on processing cost, which is expressed from the perspective of resource variation.

Table 6. 12 Thematic Analysis on Processing Cost

Sub-themes	Codes	Explanation or Evidence
Resource variation	Cost of assets	Interviewees mentioned resources such as milk volume, labour expense, assets and utilisation of the plant. The processing cost fluctuation can be measured by the resource variation. However, there were two interviewees underlining that this cost is quite stable.
	Utilisation of the plant	
	Milk volume	
	Labour expense	

6.2.7 Process stability

Most interviewees commented that there is a low chance of process instability. The dairy industry is highly regulated and heavily audited by customers and the Ministry of Primary Industries (MPI). The processors have a hazard identification plan and a hazard critical control plan, showing probable points of risk and mitigation strategies. However, one interviewee suggested that there is a high chance of process instability due to plant downtime and supply. Table 6.13 provides the thematic analysis on process stability. The theme process stability is elaborated from three aspects, internal fault, external fault and flexibility.

Table 6. 13 Thematic Analysis on Process Stability

Sub-themes	Codes	Explanation or Evidence
Internal fault	Plant downtimes	As one interviewee stated, plant downtime can bring process instability, which may change production by 10% and require a product remake by altering production orders. Planned plant downtime was emphasised by three interviewees. *Every factory there is always downtime, it might be a part that fails and things need to be replaced. At this time of the year, we have a lot more downtime because we have planned downtime. But in October, our plant is very, very full, we can only plan 3 hours downtime per day and that is for washing the plant. So if we have a breakdown, it has to be less than 3 hours. (E1)*
	Human errors	One interviewee pointed out that human error is a possible cause of process instability. People can do the wrong things and may use the wrong ingredients. However, there is a very small chance of this happening because everything is monitored. Another interviewee mentioned the use of double confirmation and double validation to avoid human errors.
External fault	Procurement of raw milk and raw materials	According to two interviewees, problems with raw milk or raw materials can generate process instability. The probability was felt to be very high.
Flexibility	Investment in more dryers	Investment in more dryers was regarded by an interviewee as a way of mitigating risks. Process instability generally causes a loss in processing or plant availability. Therefore, a backup dryer would be available for risk mitigation in situations such as fire.
	Cooperation with other dairy companies	In the cases of natural disasters and too much plant downtime, there is too much milk. Cooperation with other dairy companies was considered by another interviewee as risk mitigation. *Natural disaster, if something happens here, we have an earthquake in the plant, we will talk to another dairy company and divert our milk to the other dairy company. (E1)*

6.2.8 Product quality

The buying behaviour of customers and the brand image are vastly related to reliable product quality. Interviewees stated that they never sell products to customers that do not meet the standard. Everything is tested both in the plant and in the external lab. Products with quality problems are rejected and go to animal feed. Product remakes may affect other productions by taking milk from other orders. However, according to several interviewees, there is a very low chance of this happening. Generally there is time between producing and shipment, and the production plan has to be revised in just a couple of hours. Table 6.14 displays thematic analysis on product quality.

Table 6. 14 Thematic Analysis on Product Quality

Sub-themes	Codes	Explanation or Evidence
Product quality disruption	Contamination from any part of the process	Five interviewees attributed the product quality problem to contamination, which can come from any part of the process. Contamination can be a consequence of either microorganisms, chemicals or unclean equipment. One interviewee stated that microorganisms in the milk can enter the finished product. Chemicals are used to clean all the production lines and are then flushed out with water. If the cleaning is improper, contamination could occur. However, this situation was thought to be rare.
	Raw material quality	Raw materials are mixed with milk to produce dairy products. Two interviewees pointed out the significance of raw materials with the correct specification. If the purchased materials do not meet the specification, product quality is hugely impacted.
	Product specification	Product quality problems can arise from the specification matter.
	Operational issues	One interviewee mentioned operational issues such as solubility. However, the interviewee said that this kind of issue is generally not on a large scale and is limited to a few different bags or unit numbers.
Backup plans	Downgrade	An interviewee discussed the role of downgrade. *When a given product does not meet the specification of the customer, the production run may be downgraded to a different specification. If it is so far out of spec and no longer fit for human consumption, then it is finally downgraded to the dog food company. (B2)*
	Inventory	Keeping an inventory of milk powder with general specifications was suggested by one interviewee. With inventory, product delivery is not necessarily delayed when identifying quality problems.

Interviewees commented that the probability of poor product quality is very low. One interviewee asserted that,

> *The product quality risk remains, but that is very minimal, everything is tested for these days. The test results are really good, there are two equipped labs in NZ, they are very accurate. Very strict principles for how to handle products. The risk of anything that actually leaves ahead of the problem is really very very minor. The risk of anything having a problem across a large number of products is also very minor these days. (D1)*

There may be products that have quality problems, but these were not identified by the company. However, if the product reaches the market and the problem is discovered, it is an external failure and has its consequences.

> *Generally this does not affect/interrupt production, but in some cases product may be directed away from sensitive markets. (A2)*

6.2.9 Product price

Company profits are associated with product price. Three interviewees attributed product price fluctuation to international supply and demand. There is a global dairy auction every two weeks and the dairy product price fluctuates along with that. Table 6.15 illustrates thematic analysis on product price, which is analysed from two sub-themes, global demand fluctuation, and product category.

Table 6. 15 Thematic Analysis on Product Price

Sub-themes	Codes	Explanation or Evidence
Global demand fluctuation	International supply and demand	Product price fluctuates as a result of the global dairy auction. This fluctuation was suggested to have a big impact on demand. Another interviewee indicated that they contract with the customer. A certain price will be agreed upon on the next day of auction, and remain the same for a certain period.
	Weather	One interviewee asserted that the weather can also bring about product price fluctuation. For instance, when the weather is dry, people anticipate that future supplies of milk will reduce. Sales therefore increase and the price becomes stronger. This factor can be merged with international supply and demand, as this is essentially one type of international supply and demand.
Product category	Better product	With less dependence on commodity products, the company can resist international volatility in the dairy supply chain. Pursuing a better product was mentioned by two interviewees. *With more profits, we will process into making innovative products that reduce the risk of international volatility of the supply chain and can be less relied on commodity products and have more volatility. (B1)*

6.2.10 Customer order

Customer order fluctuates and is hard to predict. Among the countries to which milk products are exported, customer order in one country could go up and simultaneously go down in another, causing unpredictability of the total demand. If there are urgent situations in some countries, it is possible for products to suddenly run out. Table 6.16 demonstrates the thematic analysis on customer order, which is categorised by five sub-themes, including macro environment changes, product feature variation, natural environment, market assessment, and inventory amount.

Table 6. 16 Thematic Analysis on Customer Order

Sub-themes	Codes	Explanation or Evidence
Macro environment changes	Economic conditions	Three interviewees pointed out the high level effect of economic conditions on customer order. An example was given by one interviewee. *"China for example, in the last two years, has been very little [urgent situations] because things have changed over there." (D1).*
	Legal and political issues	When the company focuses on export, overseas government regulations are of great importance to the company. If the regulations change frequently in one country to support its local manufacturers, the situation of exporting products to that country becomes difficult. *So we try to keep ahead, make up people who specialize in watching what's going on in the government, tell us what's going to happen so that we can try to be prepared for that. Otherwise we will lose the market. (C1)* *Political and regulatory change can have a lot of impact on demand. (G1)*
Product feature variation	Technology innovations	Technology innovation was considered by two interviewees. New products can be produced with technology innovations, which in turn can affect customer order.
	Compliance required by export countries	When exporting products to some countries, compliance is regarded as a big risk. Clinical trials and a variety of different processes are needed. One interviewee mentioned the requirement of extra testing, that the product will not be accepted without testing in some countries.
Natural environment	Weather	One interviewee mentioned the impact of weather on customer order, with a particular focus on the ice cream market.

Table 6.16 (*Continued*)

Market assessment	Overseas market assessment	Before entering a market, it is important to be equipped with the necessary information. One interviewee claimed that they may obtain all the necessary country information through the MPI. *We have something called the overseas market access requirement. Before we shift to any country, we have to look at the access requirement for each country, and find out what exactly we have to do before we shift to a country. (E1)*
	Reduce proportion of higher risk countries	Some countries have attractively big markets, but with higher risks. One interviewee suggested trying to reduce the proportion of sales to these countries.
Inventory amount	Inventory held by customers	As pointed out by two interviewees, customer order depends on the customers' inventory. With more consumption of finished products, customers have less inventory, therefore producing more orders. Customer inventory management was emphasised by an interviewee, who suggested that they stop by three or four months and come to a better inventory level.

6.3 Corruption

6.3.1 Impact of corruption

Interviewees discussed how corruption could impact dairy supply chains. Different aspects may be affected such as sales in the market, raw material price and product delivery cost. They are summarised into three groups manifestly, which are sales, procurement, and product delivery (shown in Figure 6.2).

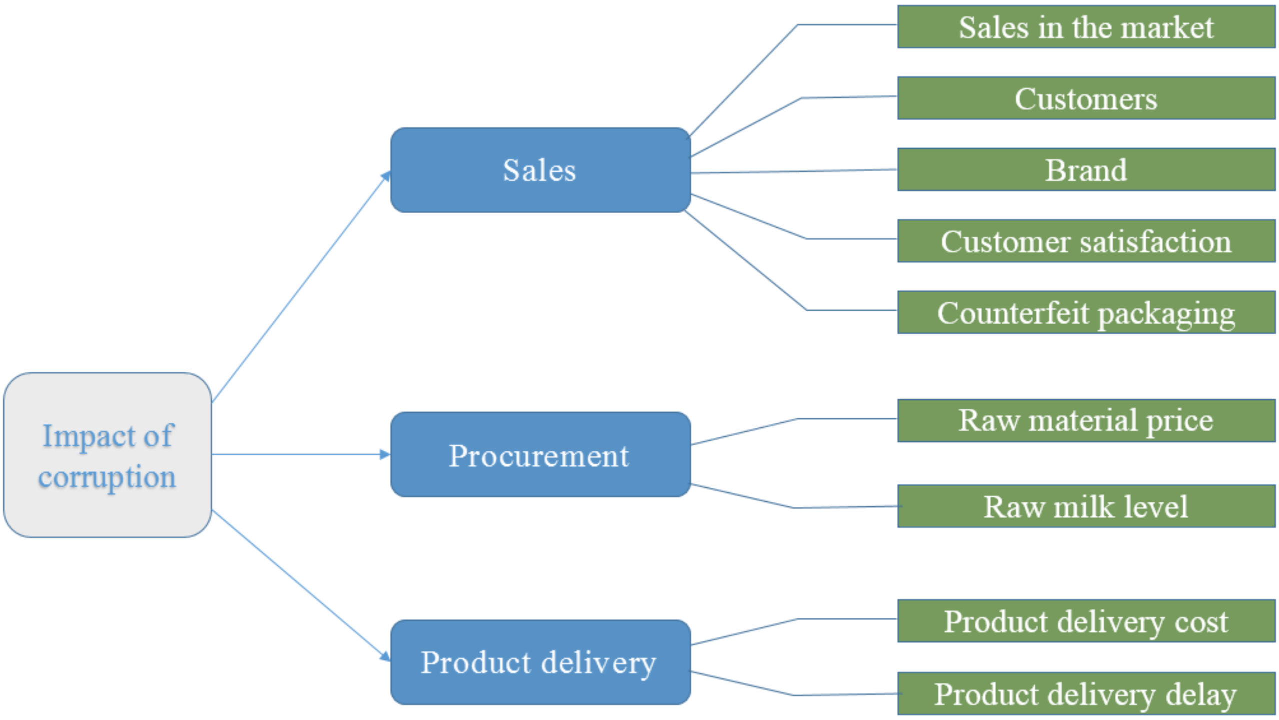


Figure 6. 2 Impact of Corruption

6.3.1.1 Sales

Corruption can present itself in different forms and have various consequences on the dairy supply chain. The most mentioned impact by interviewees was sales in the market. For example, because of a contaminated infant formula threat, products would be taken off the shelves in the supermarkets which affects manufacturing and sales with a very negative impact on customer satisfaction. Although there are many forms of prevention, corruption remains a big risk.

> *All those things like that have a lot of steps taken to try to make sure it is very difficult for someone to sabotage the product. But I guess that is one of the biggest risks for the industry is someone doing it, because you actually cannot stop people. You can get clever people who can still do that. If you get someone working in the site, you don't know that he is unhappy about something, and then they do something stupid. The probability is very, very low. But if it happens, the impact is enormous. (D1)*

> *The risk of corruption that someone puts something in the product is pretty low. (C1)*

Corruption can take place at the border of the country that imports, thus affecting sales in that country. There is a possible situation in which importers experience trade sanctions at the border and products are not permitted entry. Corruption makes it much harder to sell and it is necessary to use people located in the market and can negotiate through discussion. The sales decision is associated with the business's behaviour in that country. An interviewee implied that in one case they had not sold anything to a country for a long time because they were not comfortable with how the businesses in that country were running.

> *An excuse is then made to send the shipment back, saying the word on the document does not match the word on the box. We cannot resell the products and we have to dump. (C1)*

Interviewees regarded that some of the impacts of corruption were mostly felt by customers, rather than themselves.

> *It will affect the customer at the other range, so we do everything we can but if something is happening in the country, not much we can do. (E1)*

The impact on the brand was emphasised by interviewees. Some countries carry more risks and any counterfeit packaging has a massive impact on the brand. Any falsely stated quality problem can also affect the brand's reputation and damage the company. One interviewee explained the cause of this situation:

> *If the distributor cannot sell the products well or is not a very good distributor, he pays somebody in the lab, tests and then makes a problem, which actually has no problem. (C1)*

6.3.1.2 Procurement

When corruption occurs in the procurement phase, the raw material price and raw milk level are affected, and the cost of ingredients is increased owing to the existence of corruption. One interviewee explained the situation as follows:

> *They say we cannot sell to you, you need to buy through this person here. So you buy it through someone else who is clipping the ticket, where I considered that to be quite a fee. I mean it is a business transaction, but we just want to do business directly with those people. There are lots of people in the dairy industry who have worked in the dairy industry and then go out on their own, and they use their old relationships. There is massive opportunity for people to clip the ticket or get backhanders. (D1)*

Two interviewees felt that corruption can also have an impact on raw milk level in that the level can be modified. One interviewee stated, *The farm workers and the farmer could ask the driver to record the milk at a higher level than it actually is. That is a big cost to business, but to the suppliers, it would be another story. (B1)*

However, the probability of this is very low because milk levels are checked back at the site every day and drivers will be changed to different farms.

6.3.1.3 Product delivery

Dairy companies commonly export products by shipping them. One interviewee indicated that shipping companies have merged and become bigger, leading to less competition and thereby higher delivery costs for customers. The product delivery time was pointed out as another factor of concern. One interviewee stated that if something happens in the export country, the product delivery time might be affected, which means that there might be delayed delivery.

6.3.2 Management strategies of corruption

Corruption brings adverse consequences to dairy supply chains, hence a variety of strategies should be developed to cope with corruption. Based on the case study analysis, I divided the management strategies into two parts: internal control and external control (see Figure 6.3).

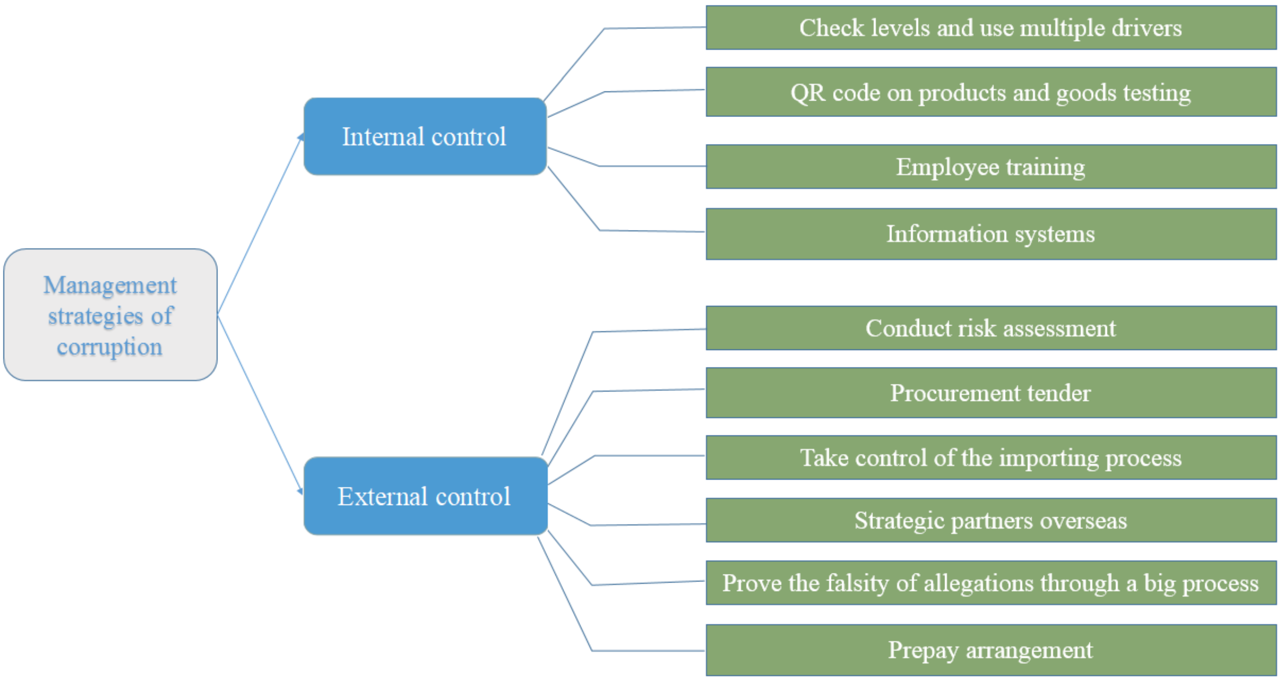


Figure 6. 3 Management Strategies of Corruption

6.3.2.1 Internal control

Interviewees mentioned two approaches to mitigating corruption risk in the milk collection phase. One approach is checking milk levels back at the site. After drivers test and collect milk, testing is conducted again back at the site. Even if there is substandard milk due to corruption, it can be detected by subsequent tests at the site.

> *There is lots of risk mitigation along the way. That will stop us from collecting milk that is not our spec. We have lots of tests along the way to make sure that everything we do is this quality. (E1)*

The other approach is using multiple drivers to prevent them from recording a false milk level. Drivers can be sent to farms using an alternating system. This makes driver corruption nearly impossible, otherwise farmers would be forced to bribe multiple drivers.

A particular printing technology was suggested as a method of dealing with the counterfeit packaging problem. A QR code can be used on products for identification, and goods can be tested by sending them to the lab.

According to an interviewee, most raw materials are procured from countries with robust legal standards. The interviewee was aware that some sales teams work with developing countries, therefore, it is beneficial to have annual anti bribery and corruption training for particular individuals within the company. Another interviewee underlined industrial self-discipline when liaising with regulatory authorities.

In terms of the threat of contaminated infant formula, one interviewee emphasised the importance of an information system such as site security for risk mitigation.

6.3.2.2 External control

Public sector corruption levels of different countries are distinguished by the CPI (Snively, 2017). Likewise, companies should also be assessed concerning their corruption risk. The need for risk assessment was emphasised by an interviewee, who expressed that some countries carry more risks. For countries with many political issues, it is at times quite risky to sell products there. The prepay arrangement was suggested as a way of risk mitigation.

Procurement tender was suggested by an interviewee. This method contributes to a cost-effective option in selecting suppliers. It was also felt necessary to take control of the importing process, or to have strategic partners overseas who have shares in the company and can provide protection. In terms of the falsely stated quality problem, the interviewee claimed that the company needs to go through a big process to prove that the allegations are false.

6.4 Discussion on the qualitative analysis results

Research findings show that the interviewees have a practical understanding of risks that exist in their dairy supply chains. This research explored risks mentioned in relevant literature, and also risks derived from interviewees' practices by using semi-structured interviews. Risks are primarily explored from aspects including risk factors, consequences of risk events, and risk mitigation strategies. This indeed, answers the first research question: *What are the primary risk events and their risk factors in dairy supply chains?*

Findings on risks from this study were compared with those learnt from the literature. In the findings, nine out of the sixteen risks are frequently mentioned by interviewees, and they are regarded as primary risks in the dairy supply chain. Table 6.17 presents the risks and relevant supporting evidence, with most of the risks mentioned in previous studies. However, the risks are scattered throughout a number of different researches that have focused mostly on risks from the perspective of farmers. Therefore, further risk analysis of the whole dairy supply chain would contribute to a deeper understanding of this supply chain.

Table 6. 17 Primary Risks in the Dairy Supply Chain

Primary risks in the dairy supply chain	Supporting evidence
Raw milk quality risk	Zubair and Mufti (2015), Daud et al. (2015), and Food Standards Australia New Zealand (2006)
Milk solids price risk	Akcaoz et al. (2009), Ramaswami et al. (2004), and Zhou et al. (2012)
Raw milk volume risk	Akcaoz et al. (2009), Ramaswami et al. (2004), P. K. Mishra and Raja Shekhar (2011), The World Bank (2011), Nasir et al. (2014), and Zhou et al. (2012)
Raw material quality risk	No literature found
Customer order risk	P. K. Mishra and Raja Shekhar (2011), Zhang and Wu (2006), and Zubair and Mufti (2015)
Process stability risk	P. K. Mishra and Raja Shekhar (2011) and Rangpur Dairy & Food Products Limited (2011)
Product quality risk	P. K. Mishra and Raja Shekhar (2011) and Rangpur Dairy & Food Products Limited (2011)
Product price risk	P. K. Mishra and Raja Shekhar (2011), Harwood, Heifner, Coble, Perry, and Somwaru (1999), and Martin (1996)
Product delivery time risk	P. K. Mishra and Raja Shekhar (2011) and Nasir et al. (2014)

Among these primary risks, only raw material quality risk was not found in literature. Raw milk is the major part of procured materials, which has attracted most attention. Risks about raw materials have not been found by existing literature. Rangpur Dairy & Food Products Limited (2011) found that the costs of imported materials occupy only a small part of total production costs, which is common to the whole industry. However, raw material quality risk was emphasised by three interviewees. As interviewee E1 pointed out, “Within the dairy industry, with the milk coming in, we cannot stop production because we always get the raw milk to be processed. So in the supply chain team, we have to make sure we always got the raw materials available to produce in every single day.” This indicates the importance of raw materials.

Exploring risk factors of risk events is significant for risk management. The following discussion is a comparison between research findings and current studies with the outcome presented in Tables 6.18 - 6.26.

Food Standards Australia New Zealand (2006) summarised the key risk factors affecting raw milk quality. They proposed 12 risk factors, including animal health, herd size, and storage, which relate to contamination. In line with Food Standards Australia New Zealand (2006), this research found that contamination causes deterioration in raw milk quality. Zubair and Mufti (2015) and Daud et al. (2015) pointed to the perishable nature of milk, which is sensitive to contamination. Research findings also illustrated that raw milk quality audit accuracy is essential in ensuring the quality of raw milk flowing into the processing plant. However, this indicator is not often discussed in literature. Quality control was mentioned by Rangpur Dairy & Food Products Limited (2011) with regard to ensuring the quality of fresh milk.

Table 6. 18 Risk Factors of Poor Raw Milk Quality

Risk factors of poor raw milk quality	Research findings	Current studies
Contamination	Yes	Yes
Raw milk quality audit inaccuracy	Yes	Not much - quality control is mentioned

Milk price variability was considered to be the most important risk by Akcaoz et al. (2009), and Zhou et al. (2012); however, no risk factors were discussed in their research. The research findings underline this risk, and risk factors were explored regarding milk price variability. The risk factors were discussed by interviewees based on their practices in NZ. In contrast to many other countries, NZ has a much smaller domestic market and exports about 95% of its dairy production, which determines that the milk solids price in NZ has stronger dependency on international situations (Fonterra team, 2016).

Table 6. 19 Risk Factors of Milk Solids Price Fluctuation

Risk factors of milk solids price fluctuation	Research findings	Current studies
International supply and demand	Yes	No

In terms of low milk yield, researchers have put forward different causes, such as animal diseases (Akcaoz et al., 2009; The World Bank, 2011), seasons (P. K. Mishra & Raja Shekhar, 2011), droughts (Nasir et al., 2014; The World Bank, 2011), and floods (The World Bank, 2011). P. K. Mishra and Raja Shekhar (2011) estimated that raw milk production in lean seasons could be 40% less than that in flush seasons. These factors are consistent with the research findings. Seasons, droughts, and floods are indeed the weather or weather turns, which are factors in the research findings. Although animal diseases are not discussed in the risk factor analysis of raw milk volume, they are considered in that of raw milk quality. Disease is thought to cause the deterioration of raw milk quality, which leads to the reduction of milk production. Nasir et al. (2014) also attributed production fluctuation to input risk, including insufficient supply of quality feed, scarcity of feed, and a lack of upgraded vaccination and veterinary services. The input risk was not mentioned by interviewees, which means that it is not a risk factor for them.

Table 6. 20 Risk Factors of Raw Milk Volume Fluctuation

Risk factors of raw milk volume fluctuation	Research findings	Current studies
Weather	Yes	Yes
Input risk	Not a risk factor	Yes

As mentioned above, no research has been found highlighting raw material quality risk in dairy supply chains. In this research, raw material quality risk was emphasised by many interviewees, and this risk was attributed to being out of specifications.

Table 6. 21 Risk Factors of Poor Raw Material Quality

Risk factors of poor raw material quality	Research findings	Current studies
Out of specifications	Yes	No

Although customer order fluctuation has been studied in some dairy supply chain studies, its risk factors have not been discussed at all. Therefore, research on customer order that is not specific to an industry is a good reference. Manuj and Mentzer (2008) maintained that the sources of demand risk lie in the process of goods movement from the focal firm to its customer's customers. They considered that demand variations depend on fads, seasonality and new product introductions by competitors, and that demand amplification is due to the bullwhip effect. Minnich and Maier (2006) claimed that functional, commodity-like products have higher demand stability than innovative products. However, they also discussed the typical bullwhip effects faced by many commodities, which are derived from order batching, delays, and a variety of other causes. Westlake Chemical (2009) suggested there are external factors which affect customer demand, such as economic conditions, technological innovations, government regulations, severe weather, natural disasters, and currency fluctuations. Economic conditions were also emphasised by Maverick (2015). The research findings are mostly consistent with the literature regarding demand variation. Demand amplification was not emphasised by interviewees; however, one interviewee underlined the importance of customer inventory management and expressed that they "stop by three or four months and come to a better level". Furthermore, the interviewees reflected on essential aspects such as the compliance required by export countries. The focal firm's customer orders may decline because of compliance issues regardless of consumer demand.

Table 6. 22 Risk Factors of Customer Order Fluctuation

Risk factors of customer order fluctuation	Research findings	Current studies
Economic conditions	Yes	Yes, but not specifically for dairy supply chains
Legal and political issues	Yes	Yes, but not specifically for dairy supply chains
Technology innovations	Yes	Yes, but not specifically for dairy supply chains
Compliance required by export countries	Yes	No
Demand amplification	No	Yes

Current studies on the dairy supply chain mainly analyse risk factors of process instability from three perspectives: plant downtime, manpower, and raw milk supply. P. K. Mishra and Raja Shekhar (2011) mentioned machine failure and unskilled manpower, while Rangpur Dairy & Food Products Limited (2011) discussed disruption in the power supply, lack of treated water, faulty machinery, and an insufficient supply of raw milk. The findings confirm these three aspects.

Table 6. 23 Risk Factors of Process Instability

Risk factors of process instability	Research findings	Current studies
Plant downtime	Yes	Yes
Human errors	Yes	Yes
Procurement of raw milk and raw materials	Yes	Yes
Lack of treated water	No	Yes

Scant research discusses the risk factors of poor dairy product quality. Rangpur Dairy & Food Products Limited (2011) indicated the importance of chilled water in preserving the quality of raw milk and subsequent dairy products. This shows that contamination in the process has an impact on product quality. Food Standards Australia New Zealand (2006) proposed that dairy product safety depends on factors such as raw material quality, formulation, processing effectiveness, recontamination, and maintenance of temperature control. This research found that product quality disruption can be a result of contamination from any part of the process, raw material quality, product specification, and operational issues. These findings are essentially in line with the literature.

Table 6. 24 Risk Factors of Poor Product Quality

Risk factors of poor product quality	Research findings	Current studies
Contamination from any part of the process	Yes	Yes
Raw material quality	Yes	Yes
Product specification	Yes	Yes
Operational issues	Yes	No
Processing effectiveness	No obvious emphasis	Yes
Maintenance of temperature control	No obvious emphasis	Yes

Scanty literature discusses the risk factors affecting dairy product price fluctuation in detail. Harwood et al. (1999) discussed the risks in farming and attribute price risk to the commodity's stock level and export demand. Fonterra team (2016) indicated that global supply and demand factors impact what the market is willing to pay for Reference Commodity Products. The findings confirm global supply and demand factors.

Table 6. 25 Risk Factors of Product Price Fluctuation

Risk factors of product price fluctuation	Research findings	Current studies
International supply and demand	Yes	Yes

The findings indicate both external and internal factors which may delay the product delivery process. These three factors are accident, government regulations, and product quality. There is little research that explains the risk factors of dairy product delivery delays. Nasir et al. (2014) attributed product delivery delays to an overly long chain, and poor road conditions. In the NZ dairy industry, most dairy products are targeted for export markets, which leads to the specific features of risk perception.

Table 6. 26 Risk Factors of Product Delivery Delay

Risk factors of product delivery delay	Research findings	Current studies
Accident	Yes	No
Government regulations	Yes	No
Product quality	Yes	No
Overly long chain	No	Yes
Poor road conditions	No	Yes

7 Modelling and Simulation

The previous chapter analyses dairy SCRs from a qualitative perspective. Based on the empirical findings, this chapter carries out the process of modelling and simulation, for exploring the internal dynamics within the holistic system. In the chapter of research methodology, five phases have been elaborated in the systems thinking and modelling process. Accordingly, this chapter introduces the application of SD modelling in this research.

7.1 System structure

7.1.1 Supply chain operations incorporating risks

The process of supply chain operations illustrates the transformation from raw milk and raw materials to products, and the order information from customers to the other end of the supply chain, that is, the suppliers. The operation structure could mostly refer to Sterman (2000). For the dairy industry, there are studies about dairy SCRs, which have been discussed in the literature review. However, there is limited literature about risk factors and risk impacts for this specific supply chain. Combined with interview findings in the previous chapter, the dairy SCRs can be established in the model structure. Nine SCRs are most frequently mentioned by interviewees. According to the empirical findings, process instability can be attributed to internal fault (plant downtimes and human errors) and external fault (procurement of raw milk and raw materials). Because quality test results during the manufacturing process are assumed to be recognised at the end of the production run, the quality of raw milk and raw materials is regarded as no impact on process stability. Therefore, only plant downtimes and human errors are considered as the causes of process instability. Table 7.1 shows the primary causes, risk events and effects. These risks are the main risks considered in the SD models.

Table 7. 1 Main Risk Indicators

Causes	Risk events	Effects
Contamination Raw milk quality audit inaccuracy	Poor raw milk quality	Milk production volume
International supply and demand	Milk solids price fluctuation	Payment to farmers
Weather	Raw milk volume fluctuation	Raw milk volume
Out of specifications	Poor raw material quality	Volume of accepted raw materials
Plant downtimes Human errors	Process instability	Loss of processing or plant availability Product quality
Contamination from any part of the process Raw material quality Product specification	Poor product quality	Product remake Product delivery delay
International supply and demand	Product price fluctuation	Product price Customer order
Accident Product quality	Product delivery delay	Product delivery time
Economic conditions Legal and political issues Noncompliance Technology innovations	Customer order fluctuation	Sales in the market

The rich picture in Figure 7.1 presents a three-tier dairy supply chain structure, which shows supply chain operations incorporating risks in general. A rich picture is an established tool to obtain understanding from multiple perspectives in a complex situation (Bronte-Stewart, 1999). Relationships among various factors are clearly displayed within the complex system. The variables and their interactions are based on literature and case study analysis. The lower part with orange lines reveals normal operations of the dairy supply chain. Materials flow through suppliers, the focal firm, and then customers. Information from the customers' end is transferred to the upstream. The production and procuring schedules are determined based on the customer order forecast and inventory. The upper part with blue lines reflects the SCR variables and their interactions. Risks occurring in different nodes and links are shown with dotted blue lines. The solid blue lines are causes and effects among different variables.

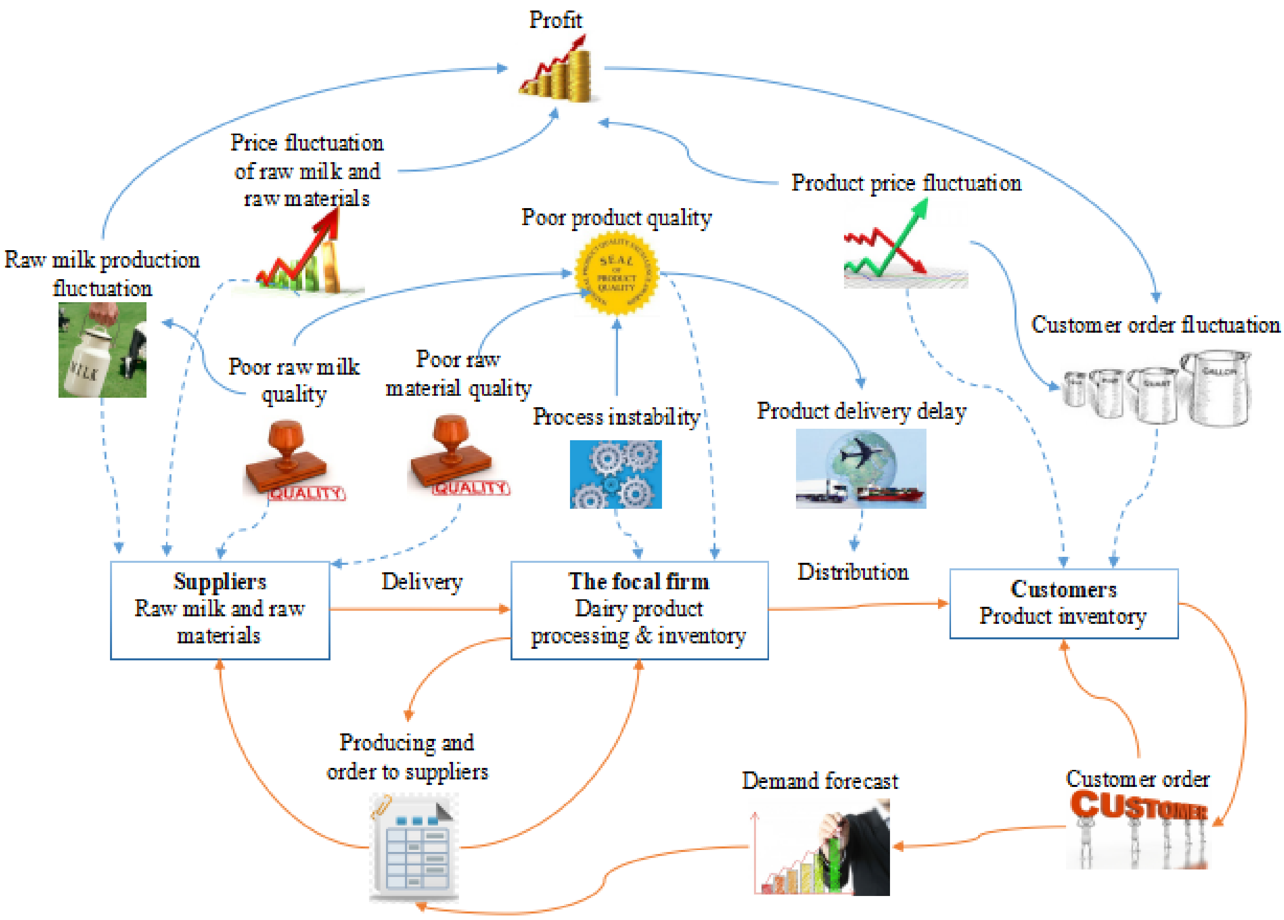


Figure 7. 1 Overview of Dairy Supply Chain Operations Incorporating Risks

7.1.2 Supply chain corruption

Corruption is a complex phenomenon, and the complexity of supply chains would be enhanced in the presence of corruption. After reviewing the relevant literature, this section forms rich pictures on supply chain corruption, which is beneficial for a general understanding of corruption at the supply chain level. Most researches about corruption focus on the country level, and recently scholars have been using firm-level data to measure their perceptions and experiences about corruption (Jensen et al., 2010). However, there is little academic research found about corruption at the supply chain level (Arnold et al., 2012; Webb, 2016). Current literature on corruption from different perspectives could enlighten studies on supply chain corruption.

Rich pictures were constructed from the perspectives of suppliers, the focal firm, customers, and third parties. These pictures clearly present the relationships in each sector, and provide guidance to the following empirical research.

(1) Suppliers

Corruption among suppliers is related with various constructs (shown in Figure 7.2). Suppliers may be located in different countries, whose CPI affects the corruption degree of suppliers. LRN (2010) suggested that in more corrupt countries, businesses have more contact with corruption. LRN (2010) mentioned factors such as size, leverage of suppliers, training, and evaluation. The guide by United Nations Global Compact (2010) expanded on this to fight supply chain corruption. The focal firm can provide training to its suppliers and help educate them on anti-corruption. Evaluating suppliers' corruption control measures monitors the implementation and effect. Corruption may cause damage to product quality. Argandoña (2001) classified corruption based on the benefits of the company or manager/employee. Thus, it depends on different situations as to whether the cost increases or decreases.

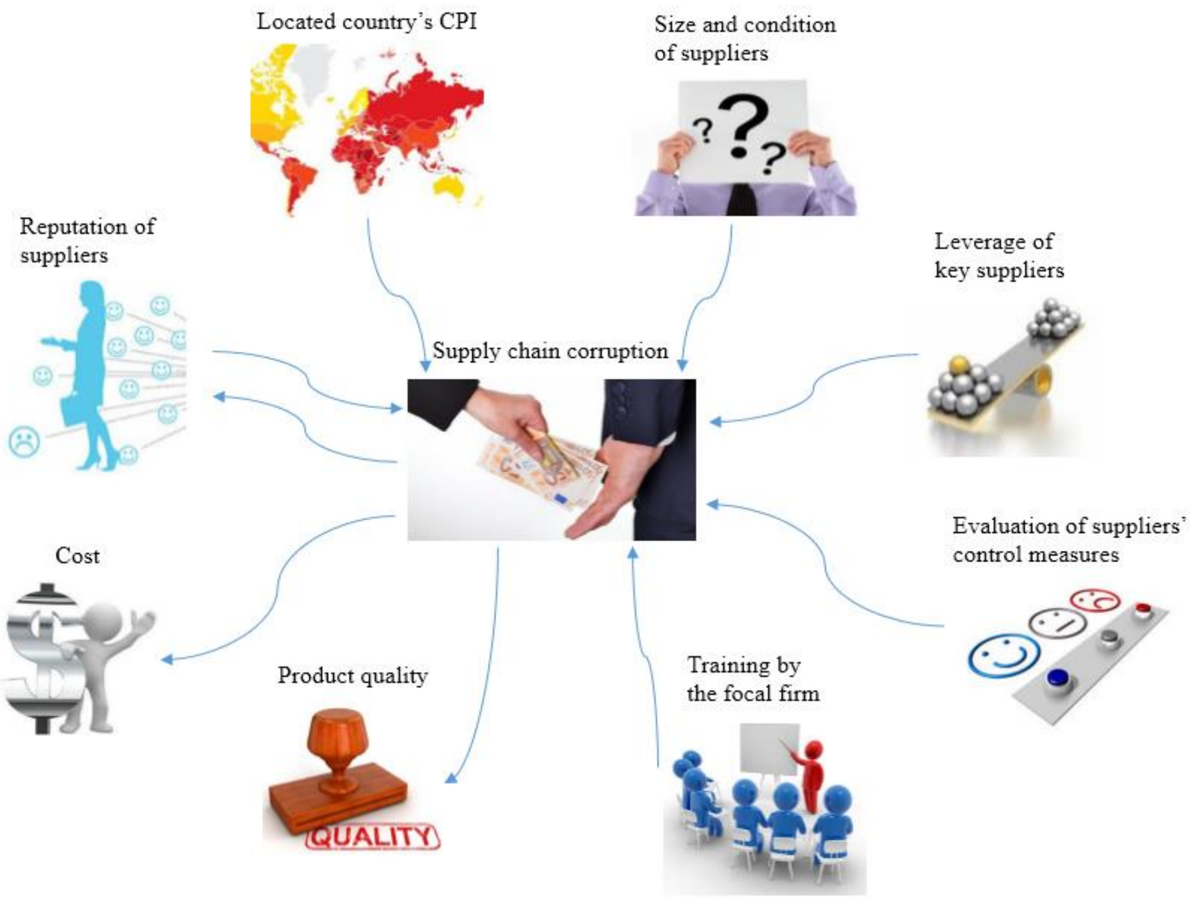


Figure 7. 2 Corruption Risk from the Perspective of Suppliers

(2) The focal firm

Regarding government officials, Collins, Uhlenbruck, and Rodriguez (2009) stated that executives' social ties with them increase the possibility of corruption. Berg, Jiang, and Lin (2012) explored the effect of government regulation on corporate corruption. They found negative relationships between regulatory governance and corruption in the telecom sector. The importance of information sharing, control, employee training and other factors was mentioned by United Nations Global Compact (2010). LRN (2010) highlighted procurement fraud as a significant, direct loss to the firms, and also mentions indirect losses such as reputational losses, legal liability and so on. Argandoña (2001) noted the comparison between costs and benefits brought by corruption, and indicates some bad effects of corruption, for instance, harm to fair competition, and lasting advantages.

The managers/employees may perform corrupt act for the benefit of the company or themselves. Under both conditions, the corrupt acts have indicated a lack of internal governance and control (Argandoña, 2001). All the relationships are presented in Figure 7.3.

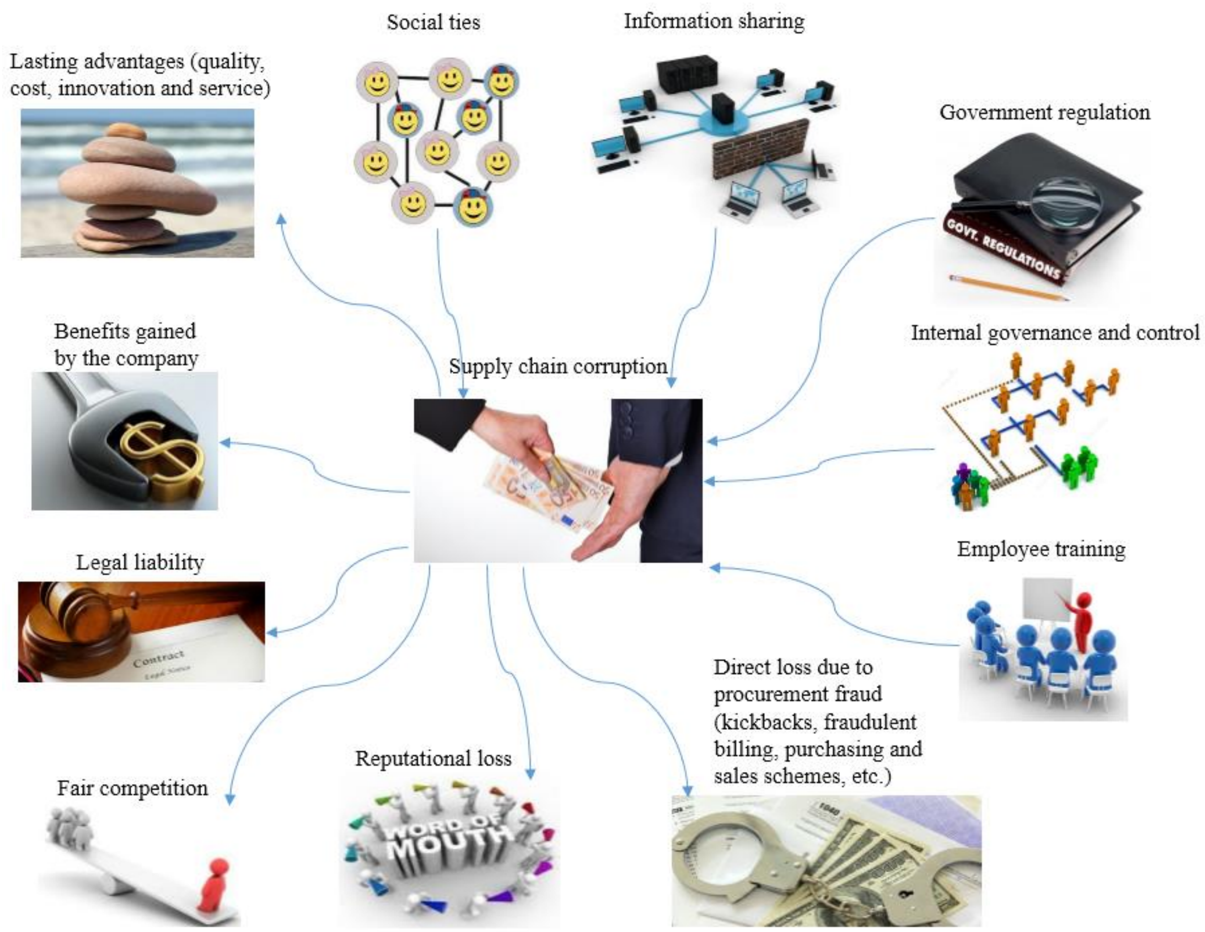


Figure 7. 3 Corruption Risk from the Perspective of the Focal Firm

(3) Customers

As shown in LRN (2010), questions prepared for assessing corruption risk focus on the same aspects for suppliers and distributors. Meanwhile, LRN (2010) pointed out that "preventing corruption among suppliers and distributors is not a homogeneous exercise", and the possible corruptive conduct in the sales process was noted for distributors. Figure 7.4 elaborates the factors pertaining to corruption risk from the perspective of customers.

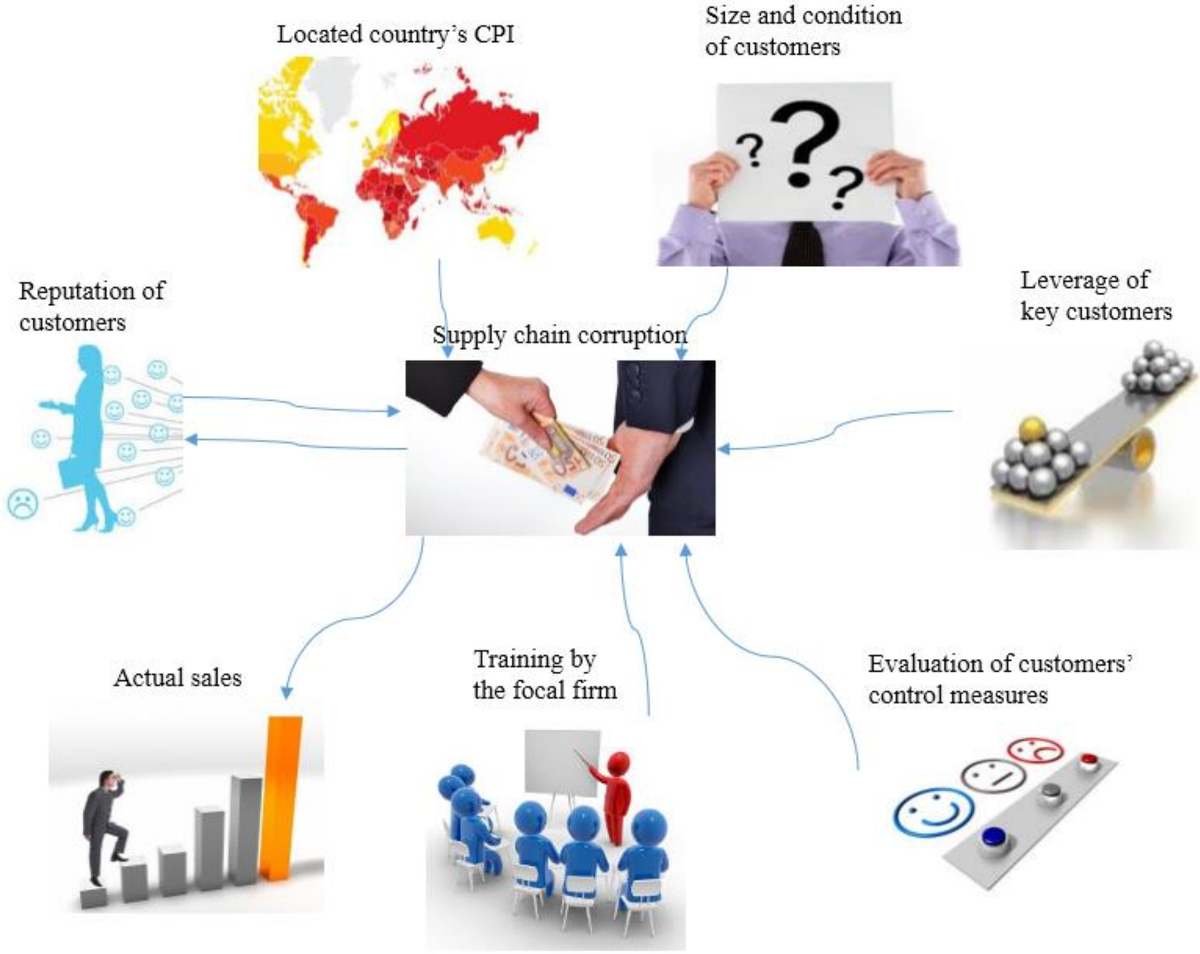


Figure 7. 4 Corruption Risk from the Perspective of Customers

(4) Third parties (government agencies, agents, etc.)

In spite of suppliers and customers, third parties can be found within the supply chains. Their corruption is associated with the located countries' CPI. In some cases, licenses or permits are required, which increases the likelihood of corruption (LRN, 2010). United Nations Global Compact (2010) referred to the scenario that suppliers bribe auditors to pass audits, which harms product quality, etc. It is important to monitor those third parties on key contracts. According to the *Global Corruption Report 2009* (Transparency International, 2009), almost two out of five business executives have been faced with bribery solicitation when dealing with public institutions, and half reckon that corruption raises project costs by at least 10%. Figure 7.5 depicts the interrelationships among those different aspects.

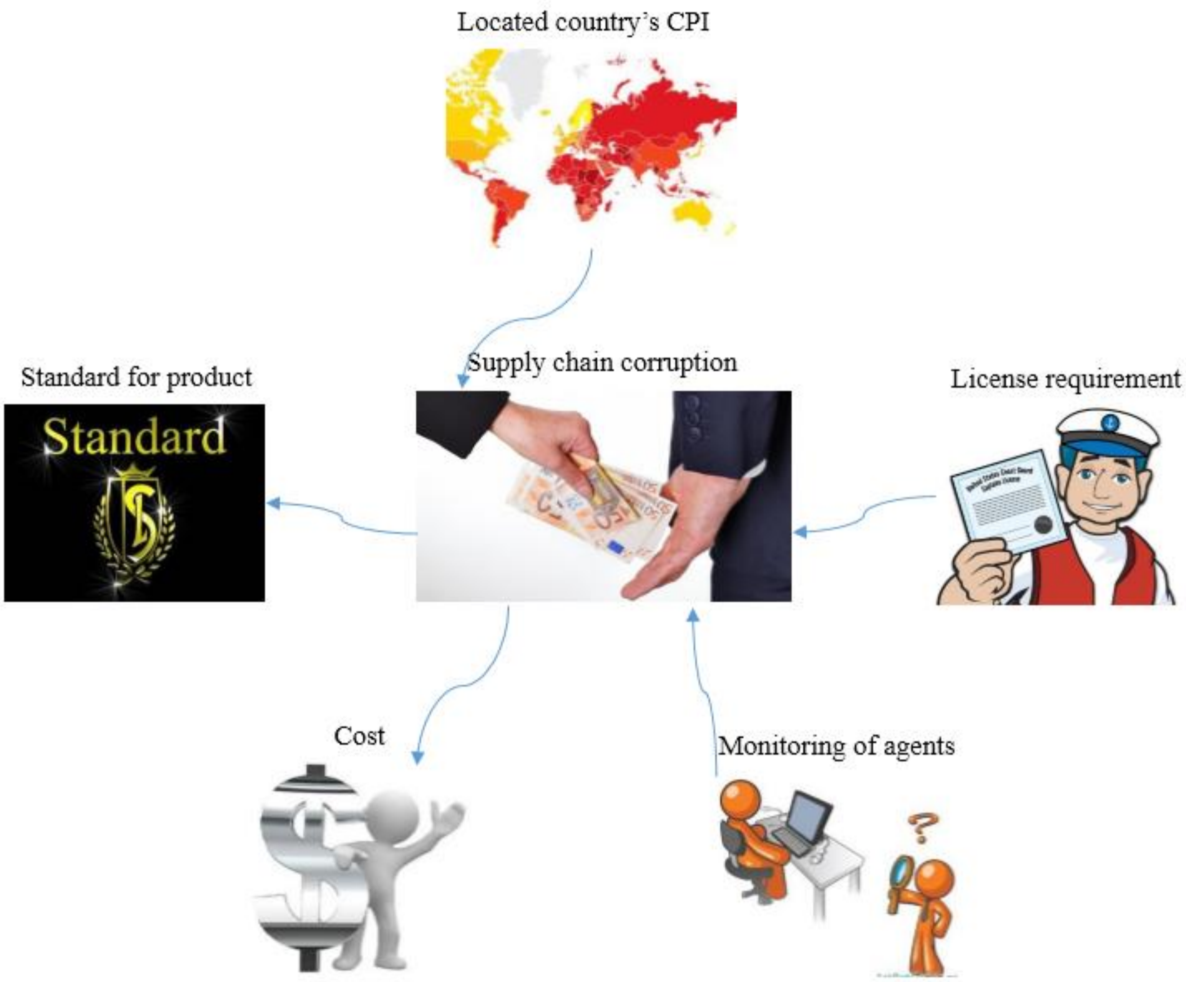


Figure 7. 5 Corruption Risk from the Perspective of Third Parties

In this research, the impacts of corruption in dairy supply chains are established based on extant studies and interview findings. The structure of the whole system is formed by combining Figure 7.1 with corruption risks. This structure identifies dairy SCRs in the presence of corruption, and lays a foundation for modelling and simulation in the following research.

7.2 Modelling structure

This section introduces the modelling structure and presents interrelationships among a variety of factors. Figures 7.6 and 7.7 illustrate the basic structures for the CLD, and the SFD respectively.

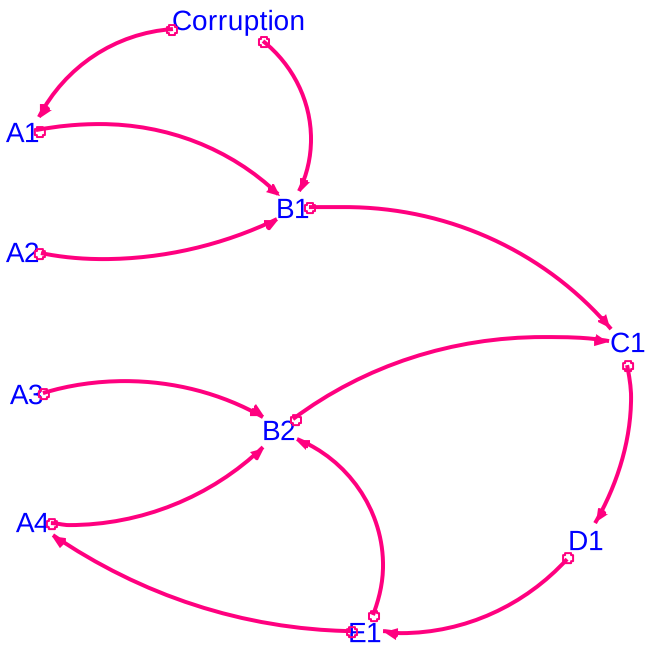


Figure 7. 6 Structure of the CLD for SCRs in the Presence of Corruption

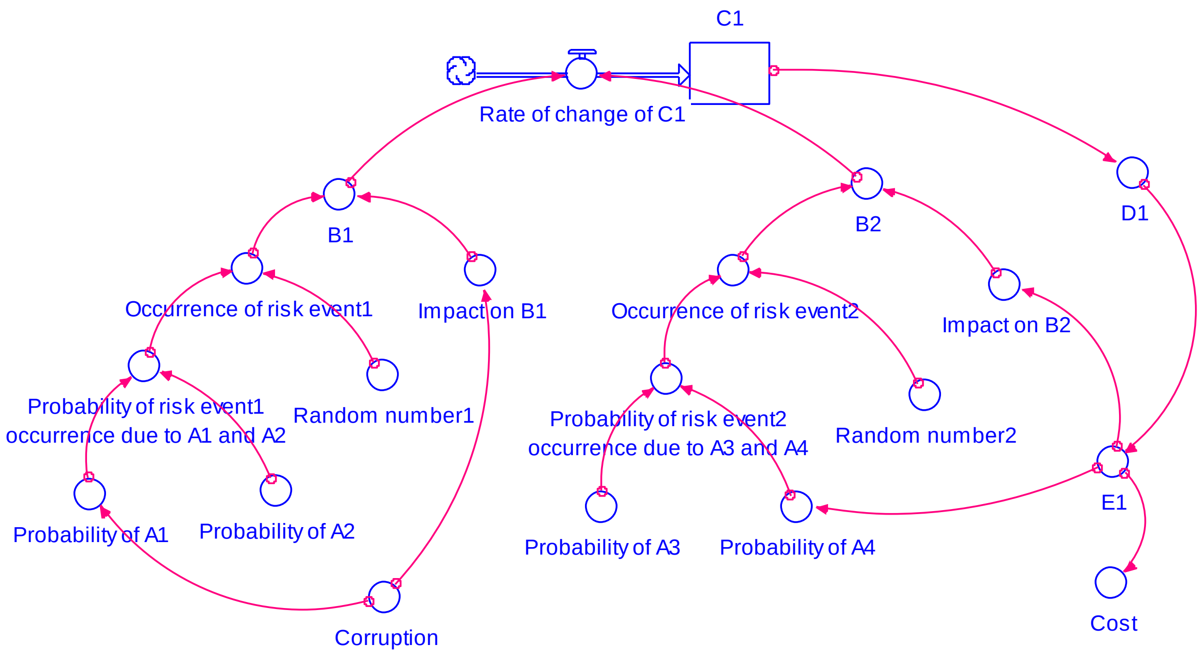


Figure 7. 7 Structure of the SFD for SCRs in the Presence of Corruption

A1, A2, A3, A4 --- Potential causes of risk events

B1, B2 --- Variables affected by risk events

C1 --- Potential effects of B1 and B2

D1 --- SCP

E1 --- Mitigation strategies (There are two possibilities: (1) minimise the probability of the occurrence of the risk event; and (2) minimise the risk impact.)

The risk factor is regarded as the basis to quantify the risk which is presented to any threat-asset pair (Pai et al., 2003). They estimated a risk factor as the expected value of loss that happens to assets because of the threat. Its calculation formula was proposed as follows:

Risk factor = Probability of occurrence of threat * Consequence * Value of Asset

However, the risk factor is meant to be a factor, instead of a number. For the sake of rigor, the above formula is decided to be modified as:

Risk factor impact = Probability of occurrence of threat * Consequence * Value of Asset

This concept was used in the model construction. Each risk is the unity of a risk factor, risk event, and loss. The probability of risk occurrence, risk impact, and the original value of an asset should be obtained respectively to calculate the value of loss.

A1 and A2 are risk factors of risk event 1, meanwhile A3 and A4 are risk factors of risk event 2. Risk events occur randomly and impact particular variables (B1, B2). The interactions among variables within the system means that SCP (D1) can be affected by risk events indirectly (e.g., through variable C1) or directly. The number of variables used in the modelling structures is arbitrarily selected, for example, the number of risk factors can be one or more.

Corruption is a modifier for the original system. By modifying the probability of risk occurrence or risk impact, corruption modifies SCP. To minimise the impact of corruption on the supply chain, suitable strategies are needed to mitigate relevant risks. The costs of management strategies can be not only money, but other adverse consequences resulting from the strategies. Therefore, the costs should be balanced against benefits, which are interpreted when analysing the simulation results.

7.3 CLD development

With the identification of the main variables, the CLD can be developed based on their interrelation and the feedback structure.

The CLD (shown in Figure 7.8) exhibits how corruption modifies effects of SCRs and SCP. The normal dairy supply chain shows the operation process. Corruption is considered in the system by modifying SCR effects within the normal process. For a particular risk, it is clear to show the risk factor, risk event, and consequence. However, when various risks are considered together in the same system, the relationships become complicated. For example, the consequence of one risk event may trigger the occurrence of another risk event. Language description seems insufficient when illustrating these interrelationships among numerous variables. The CLD shows causal relationships among different variables. The formed causal loops present the dynamic processes in this system. In this case, the CLD contributes to the clarity of the system’s demonstration.

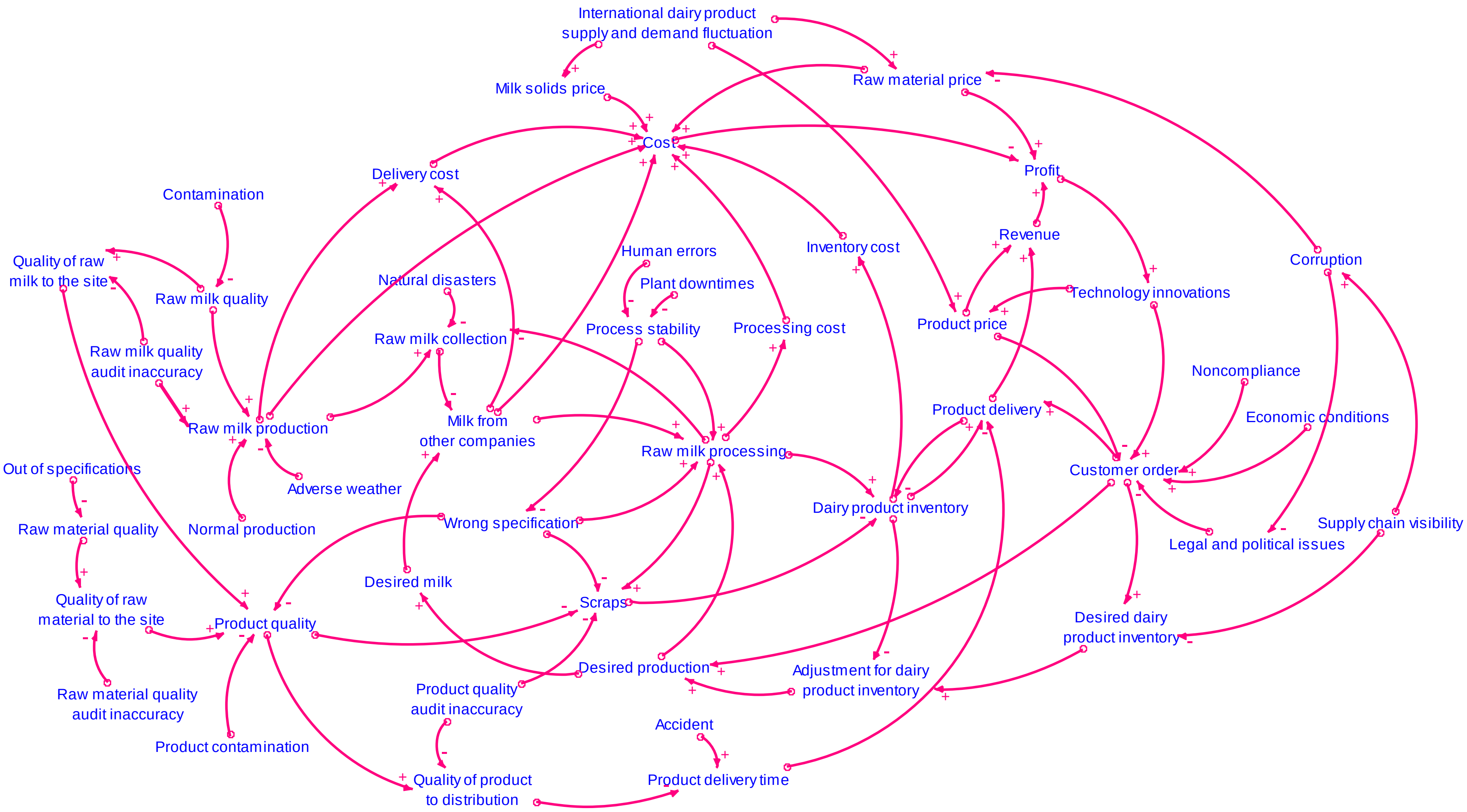


Figure 7. 8 CLD for Dairy SCRs

7.3.1 Internal structure of the CLD

This CLD primarily consists of two parts: normal operations, and risks penetrating in supply chains. Figures 7.9 and 7.10 display the process of dairy supply chain operations. Sterman (2000) focused on manufacturing companies, and described inventory and the ordering system among the supply chain partners. Customer order rate, demand forecasting, order fulfilment, and production scheduling were fully discussed. Feedback loops of supply chain operations are formed based on that model.

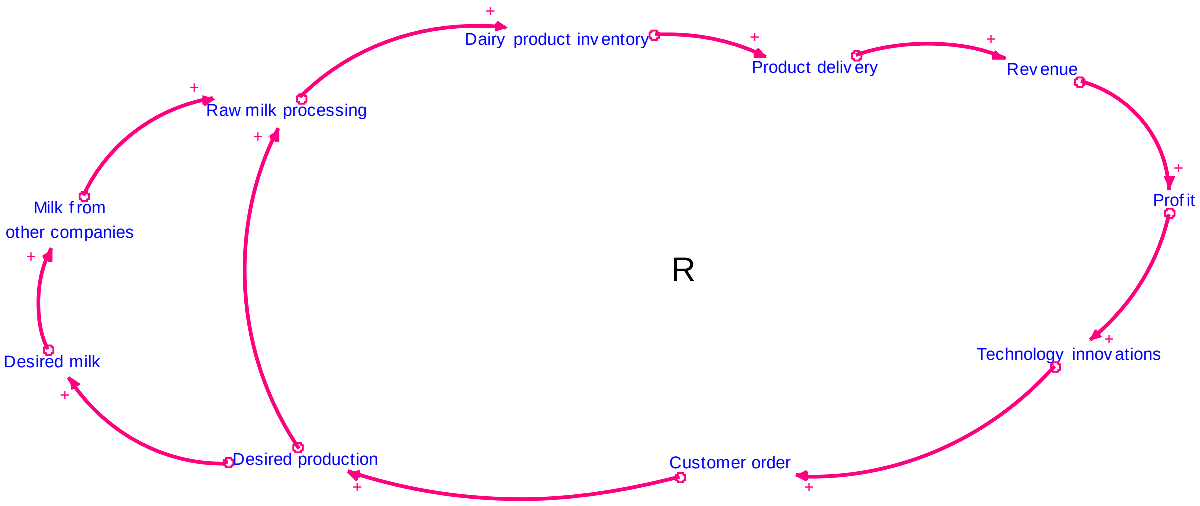


Figure 7. 9 Dairy Supply Chain Inventory Stimulation Loop

Figure 7.9 shows how the consumption of the dairy product inventory reinforces the inventory level through internal operations. Raw milk and raw materials are delivered to the plant and processed into dairy products. Sales of dairy products contribute to the decrease of the product inventory. Meanwhile, the heightened product sales lead to profit growth and thereby technology innovations are raised. Customers tend to expand their orders for the innovative products. Accordingly, the dairy processor adjusts production and procurement plans.

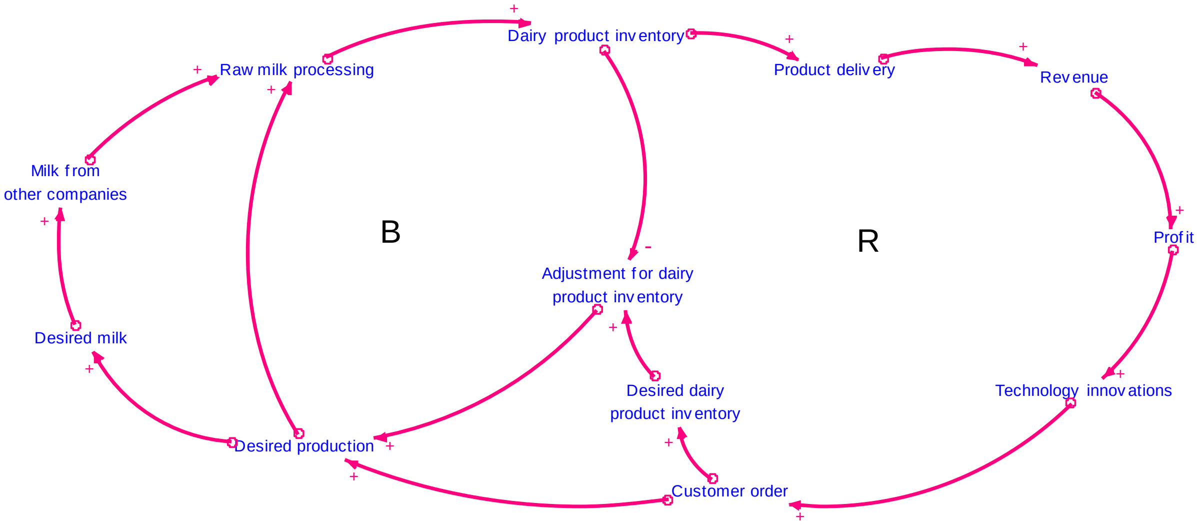


Figure 7. 10 Dairy Supply Chain Inventory Balancing Loop

The stimulation of the inventory does not occur continuously, due to the inventory threshold. The threshold helps to maintain the inventory at a desirable level, rather than increasing without restrictions. This is achieved by adding the variable "adjustment for dairy product inventory", which controls the inventory by comparing desired and current inventory levels. As such "desired production" can be determined which contributes to balancing the inventory. This balancing feedback loop is presented in Figure 7.10.

Various risks interfere with normal supply chain operations. Figure 7.11 highlights the reinforcing and balancing operational loops by purple and green lines respectively. The reinforcing loop presents the flow from raw milk collection, processing, profit, to production and purchase scheduling. The balancing loop considers the costs accompanying the whole process. Risks interfere supply chain operations by affecting operational indicators, thus causing the variation of SCP. The causal relationships among different variables are established by thematic analysis results and literature information. Figure 7.11 demonstrates risk events such as poor product quality, product delivery delay, and customer order fluctuation. The risks are also indicated in Table 7.2, which presents interactions between risks and operational loops. In this table, indicators about risks in bold help identify the way of interaction. A certain risk is linked to the operational loop directly or indirectly. The risk could interact with another risk and then be connected with indicators within the operational loop. For example, process instability increases the risk of poor product quality, and the dairy product inventory in the reinforcing loop is ultimately affected. Therefore, the risks are not necessarily involved in feedback loops by themselves. Instead, they can influence the whole feedback loop by affecting indicators within the operational loop. Appendix E includes equations that explain how risks are connected with operational indicators.

The CLD displays the whole picture which consists of dairy supply chain operations, risks, and corruption. Corruption is incorporated into the model by modifying the effects of SCRs. Table 7.3 elaborates the interactions between corruption and supply chains. The original risk effect such as raw material price is modified in the presence of corruption. This leads to changes in profit and cost, and their related indicators. The interactions among risks and operational indicators instigate the impact on various indicators, as well as the eventual SCP. This answers the second research question: *How does corruption modify the effects of SCRs and thereby change SCP?*

Volejníková (2007) analysed the relationship between asymmetrical information and corruption, and posited that asymmetrical information is a typical form of potential corruption effects in the microeconomic scope. Therefore, in this model, corruption is assumed to be directly linked to supply chain visibility, which was regarded by Christopher and Lee (2004) as transparency in sharing information among supply chain members. Shared information is beneficial for the reduction of safety stock (Christopher & Lee, 2004). In this sense, dairy product inventory is associated with supply chain visibility.

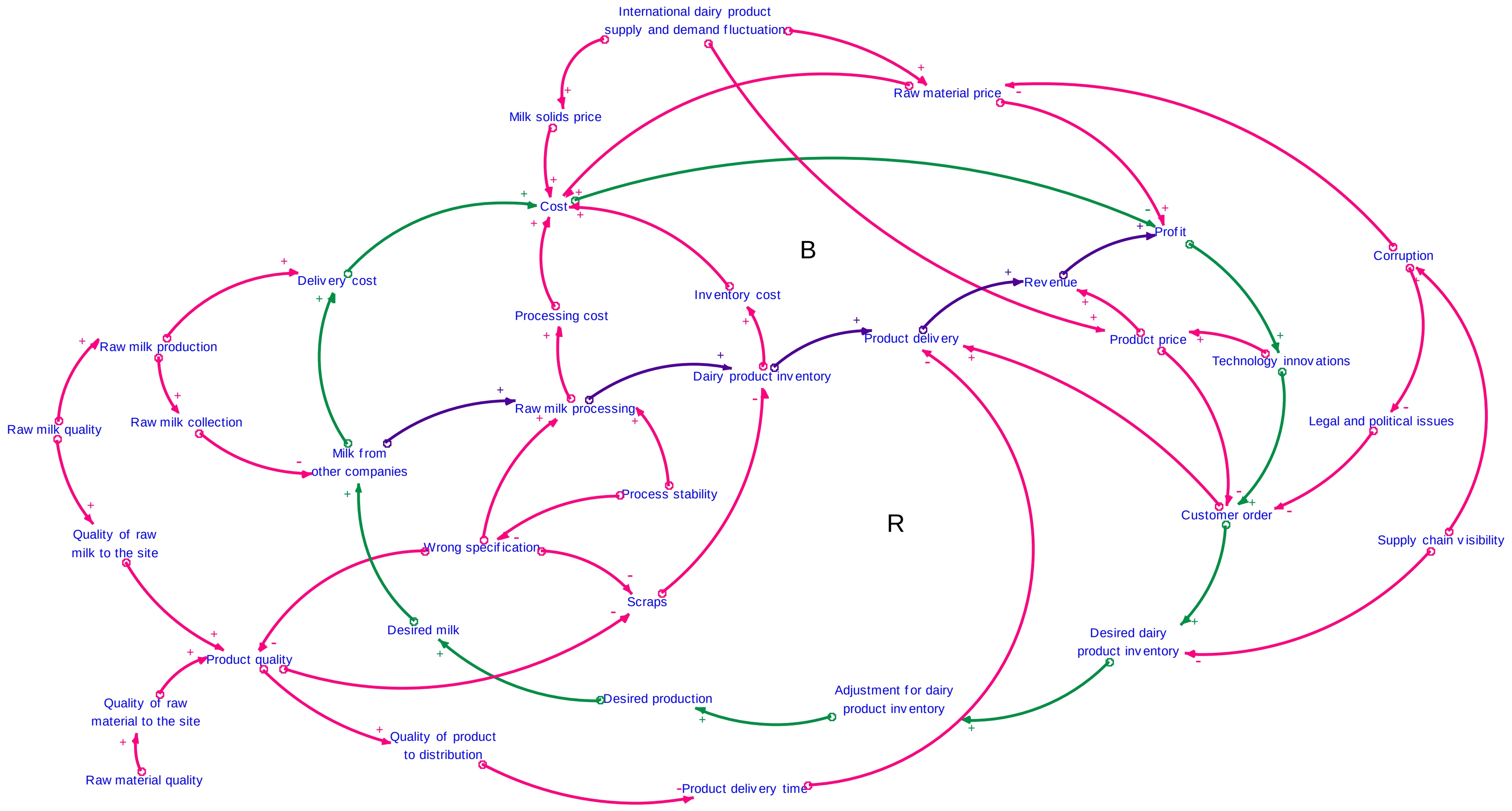


Figure 7. 11 Incorporating Risks within Operations

Table 7. 2 Interactions between Risks and Operational Loops

Primary risk events	Interactions between risks and operational loops	Explanation
Poor raw milk quality	(1) **Raw milk quality** → Raw milk production → Delivery cost (2) **Raw milk quality** → Raw milk production → Raw milk collection → Milk from other companies	"Milk from other companies" reflects that in case of milk shortage, other companies are assumed to provide help if the volume of shortage is up to a certain level.
Milk solids price fluctuation	International dairy product supply and demand fluctuation → **Milk solids price** → Cost	The international supply and demand fluctuation affects dairy product price, and the establishment of milk solids price is also influenced.
Raw milk volume fluctuation	(1) **Raw milk production** → Delivery cost (2) **Raw milk production** → Raw milk collection → Milk from other companies	Risks exist in the process of both raw milk production and raw milk collection, which affect milk volume.
Poor raw material quality	(1) **Raw material quality** → Quality of raw material to the site → **Product quality** → Scraps → Dairy product inventory (2) **Raw material quality** → Quality of raw material to the site → **Product quality** → Quality of product to distribution → **Product delivery time** → Product delivery	"Quality of raw material to the site" is of similar meaning to "quality of raw milk to the site". "Product delivery" refers to the volume of delivered products per unit of time.
Process instability	(1) **Process stability** → Raw milk processing (2) **Process stability** → Wrong specification → Scraps → Dairy product inventory (3) **Process stability** → Wrong specification → **Product quality** → Scraps → Dairy product inventory	Wrong specification is supposed to be one situation brought by process instability. As a range of products can be downgraded in the case of wrong specification, "scraps" is affected by "wrong specification".

Table 7.2 (*Continued*)

Poor product quality	(1) **Product quality** → Scraps → Dairy product inventory (2) **Product quality** → Quality of product to distribution → **Product delivery time** → Product delivery	"Quality of product to distribution" is also similar to "quality of raw milk to the site". Product delivery delay could be caused by the product quality problem. Hence, "product delivery time" is connected with "quality of product to distribution".
Product price fluctuation	(1) International dairy product supply and demand fluctuation → **Product price** → Revenue (2) International dairy product supply and demand fluctuation → **Product price** → **Customer order**	As mentioned in "milk solids price fluctuation", dairy product price is affected by international dairy product supply and demand fluctuation. Product price is one of the factors affecting the quantity of customer orders.
Product delivery delay	**Product delivery time** → Product delivery	Product delivery delay affects the number of delivered products per unit of time.
Customer order fluctuation	(1) **Customer order** → Product delivery (2) **Customer order** → Desired dairy product inventory	"Product delivery" is established by customer order, under the constraint of available inventory.

Table 7. 3 Interactions between Corruption and Supply Chains

Indicators modified by corruption	Interactions between corruption and supply chains	Explanation
Raw material price	Supply chain visibility → Corruption → Raw material price	The level of "corruption" is associated with the degree of "supply chain visibility". The higher supply chain visibility, the lower corruption level, thereby the higher value of "corruption".
Legal and political issues	Supply chain visibility → Corruption → Legal and political issues → Customer order	Corruption is considered to be affecting the probability of legal and political issues. The impact of corruption on customer satisfaction is reflected on customer orders. As dairy products in NZ are focused on export, corruption's impact on customer satisfaction in this research is included in the modification of "probability of legal and political issues", thereafter customer order is influenced.

7.3.2 Behaviour analysis

The system's behaviour is determined by the feedback structure (Sterman, 2000). The behaviour of SCP indicators is analysed through the feedback loops. SCP can be measured from different perspectives. Beamon (1999) suggested three groups of performance measures in manufacturing supply chains, that is, resource, output, and flexibility. R. Kumar (2014) classified dairy SCP into three categories, including marketing performance, operational performance, and flexibility. Likewise, three categories of performance (operational performance, competitive performance and customer satisfaction) were envisaged by Zhao, Huo, Sun, and Zhao (2013). Based on these literature, this research uses profit, rate of cost, processing cost, delivery cost, product delivery time, order fulfilment ratio, and expected order to measure SCP. The performance indicators within the feedback loops (Figures 7.12, 7.13, 7.14, 7.15, and 7.16) are analysed to explore their behaviour.

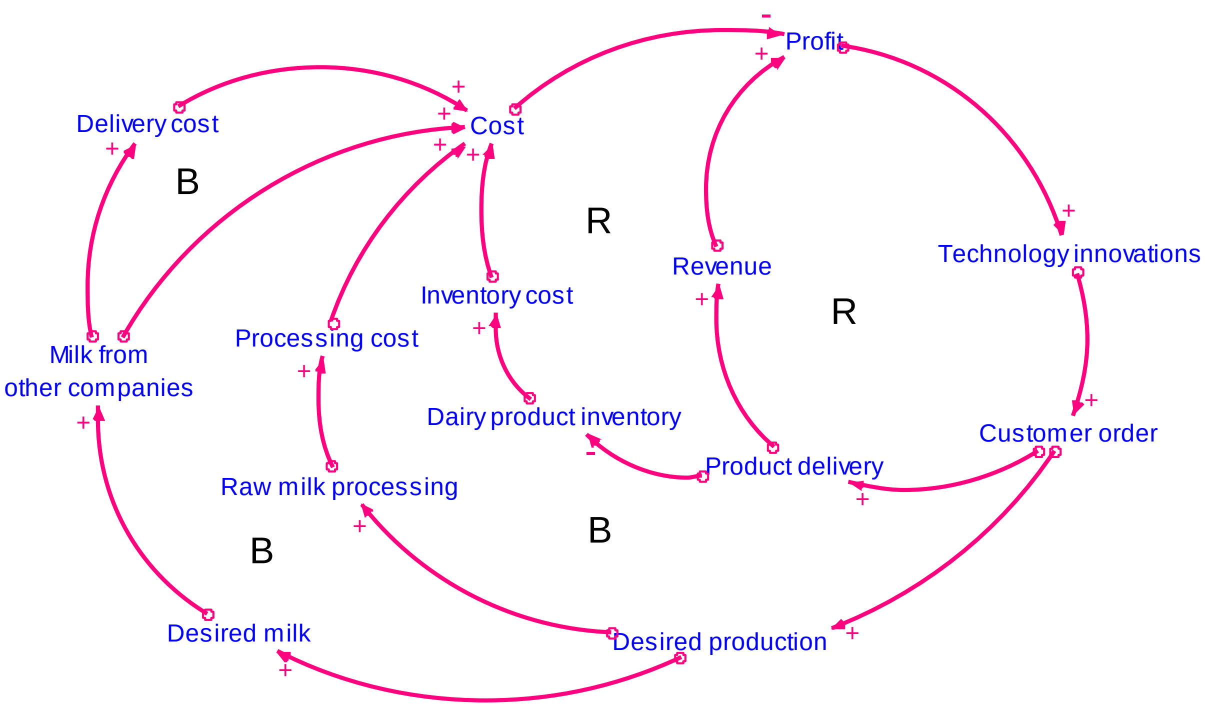


Figure 7. 12 Feedback Loops for Profit

Technology innovation is a way for dairy companies to reduce the risk of international volatility of the supply chain. With the increase of profits, companies can further input on technology innovations. There will be additional customer orders and product deliveries on innovative products, thus generating added revenue and profits. Meanwhile, product delivery causes less dairy product inventory. The decline in inventory cost results in extra profits.

At the same time, there are three balancing loops. An increased in desired milk raises the probability of procuring raw milk from other companies, which incurs higher delivery cost, greater procurement cost and lower profit. Another balancing loop indicates higher processing cost accompanying further desired production. Reinforcing and balancing loops jointly explain the dynamics of profit.

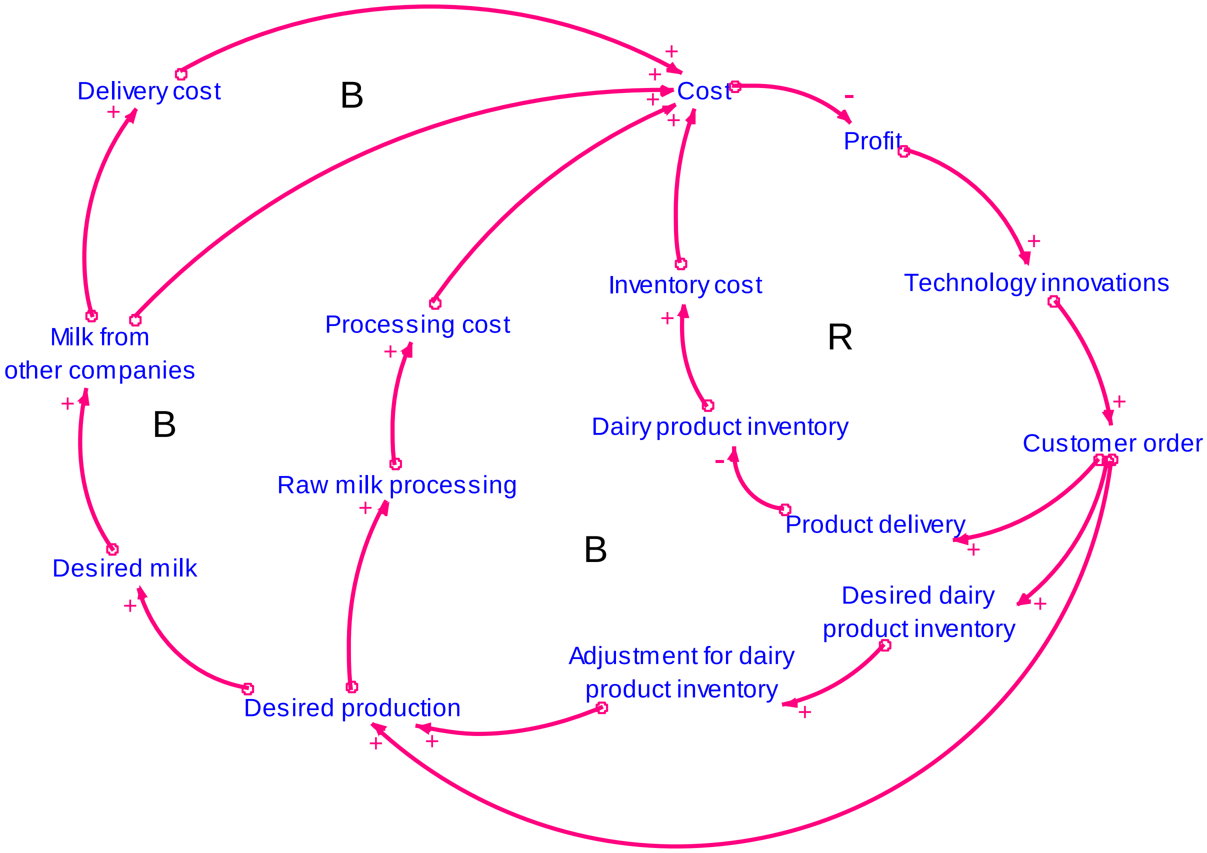


Figure 7. 13 Feedback Loops for Cost

Both balancing and reinforcing loops exist to interpret the behaviour of the cost. The cost is reinforced in the loop involving profit, technology innovations, customer order, product delivery, dairy product inventory and inventory cost. The cost is balanced in the three causal loops involving delivery cost, processing cost, and milk from other companies respectively.

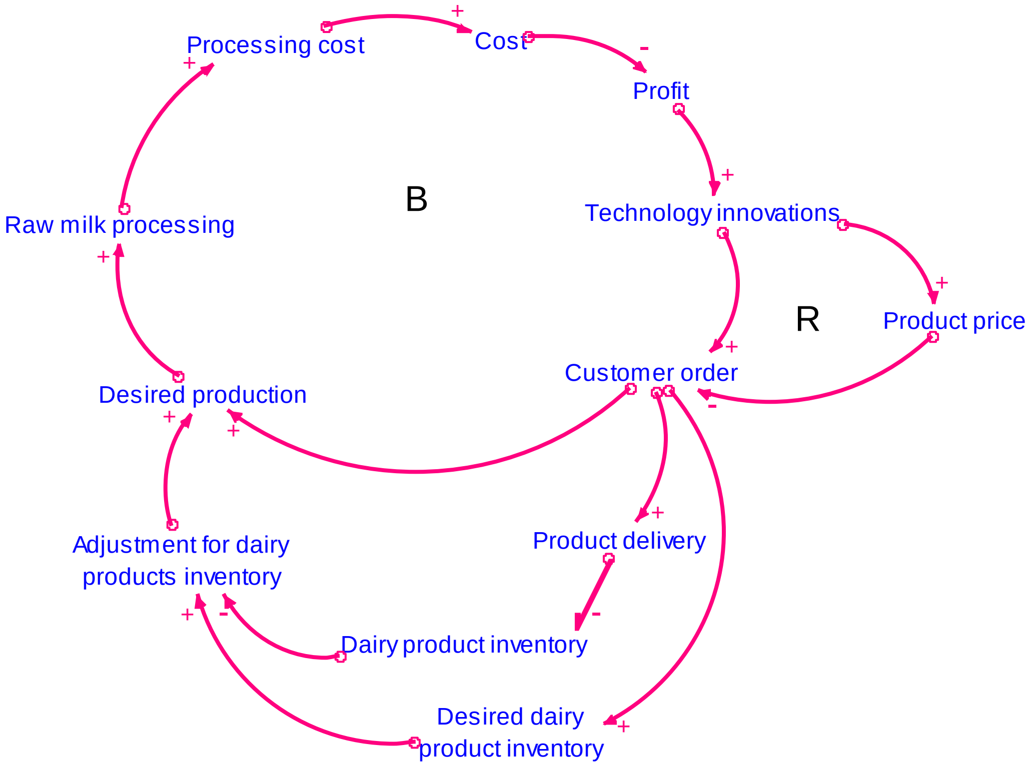


Figure 7. 14 Feedback Loops for Processing Cost

There are two primary loops with regard to processing cost: the balancing loop and the reinforcing loop. The reduction of processing cost arouses profit growth, thus incurring further technology innovations. Products with an enhanced level of technology innovations may attract customers' interest and raise customer orders. However, the product price also changes as a result of technology innovations. In this regard, customer orders are reduced as a result of a higher product price.

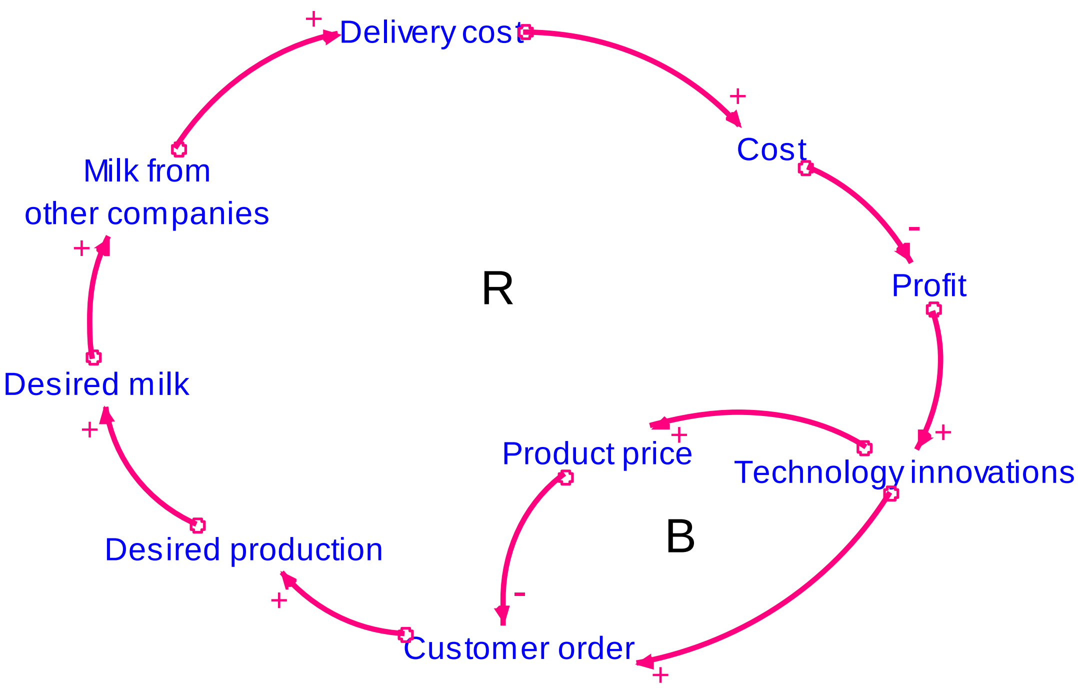


Figure 7. 15 Feedback Loops for Delivery Cost

Similar to the analysis about processing cost, there are both reinforcing and balancing loops. The growth of the delivery cost leads to the shrinkage of profit. Technology innovations change in the same direction as profit. Reduced profit brings about lower technology innovations, which leads to cheaper products and therefore additional customer orders. Meanwhile, in correspondence with the decrease of technology innovations, customer orders also decrease. Growth of customer orders leads to higher desired production, which causes a higher demand of milk from other companies and higher delivery cost. This forms the reinforcing loop and the other one with fewer customer orders forms the balancing loop. The combination of these loops contributes to the behaviour of delivery cost.

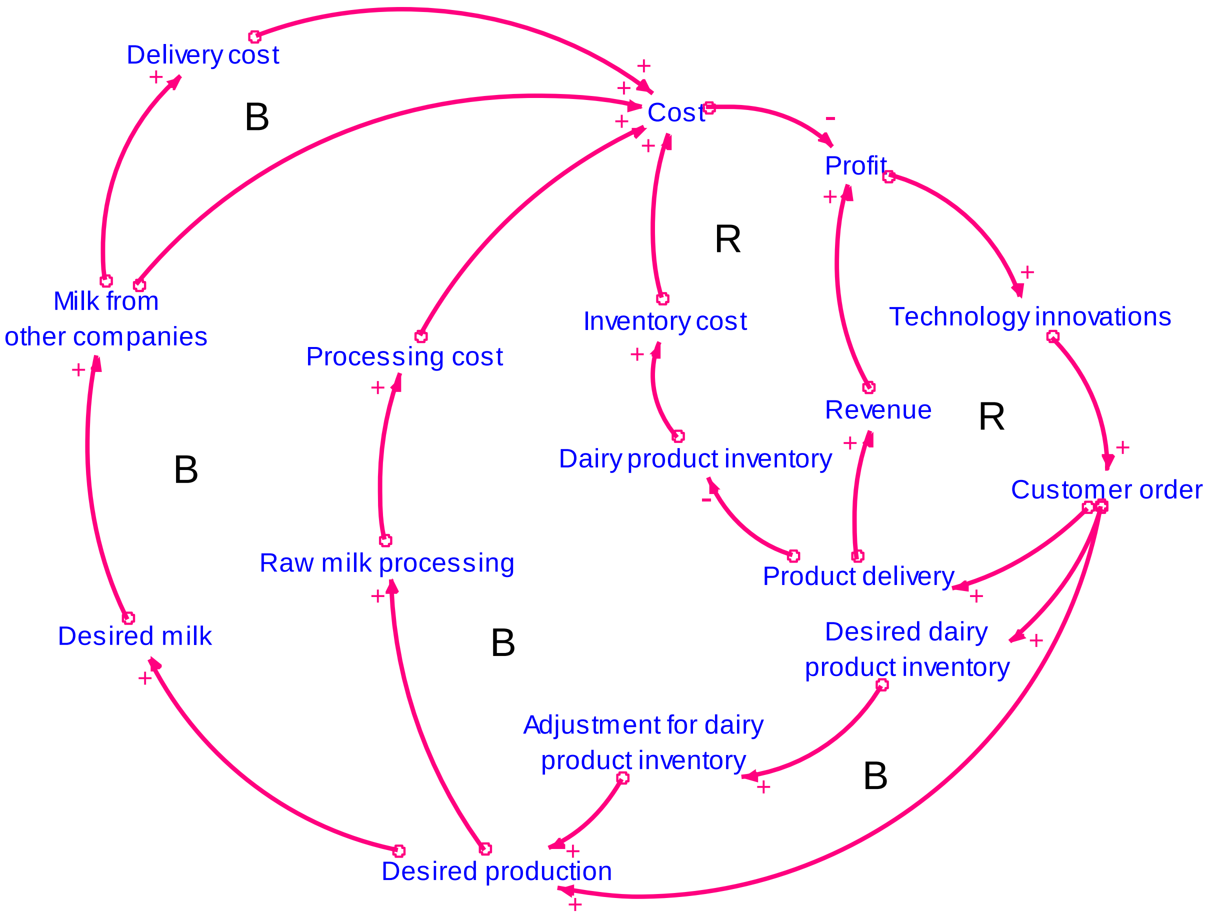


Figure 7. 16 Feedback Loops for Customer Order

Figure 7.16 is almost the same as Figure 7.13, except that there is another reinforcing loop in this figure. More customer orders result in more product delivery, therefore, more revenue. Higher profit brings about further technology innovations, which promote customer orders.

7.4 Dynamic model construction

7.4.1 SFDs

Although a CLD illustrates the interrelationships and feedback structure among key variables, it is primarily conceptual, applied in the early stage of model construction, and cannot carry out simulation of system's behaviour over time. An SFD quantitatively describes variables and their logical relationships. By means of SFDs, the numerical foundation is acquired for a SD model (Forrester, 1961; Sterman, 2000). In this regard, an SFD is needed to distinguish variable types and illustrate the internal structure thoroughly, thus providing the basis for the simulation of the system's behaviour over time.

An SFD can be formulated on the basis of a CLD. In this research, the model was constructed and simulated via the software iThink 9.1.4 - a model builder with graphical interface provided by *isee systems*. In accordance with the CLD, the SFD is elaborated in two parts: normal operation, and risks. The variables are distinguished by different types and converted to be stocks, flows, or converters. As variables need to be elaborated in equations, more indicators appear in the SFD than in the matching CLD.

Figure 7.17 displays the operational process with eight stocks, which are raw milk production, raw milk collection, dairy product inventory, expected order, profit, milk solids price, raw material price, and product price. This diagram generally depicts the transition process of dairy products. "Expected order" is used for the customer's order forecast, and "rate of change in expected order" equals the difference between "customer order" and "expected order", divided by "time to average order". The production scheduling depends on the forecasted customer order and inventory. "Desired production" consists of two parts, the forecasted order and inventory adjustment for a desired inventory level. Two stocks are established in terms of raw milk, which are raw milk production and raw milk collection. Raw milk production stands for the volume farmers can supply, whereas raw milk collection refers to the volume ultimately collected by the dairy processor, and may also include the raw milk collected from other dairy companies. The volume collected from the farm does not necessarily equal the volume supplied by farmers. For example, risks such as natural disasters could cause loss on milk volume. The loss of milk belongs to the dairy processor, and this does not affect farmers' payment. Therefore, it is sensible to have these two separate stocks regarding raw milk volume. The stock "profit" is calculated based on various cost and revenue. This research assumes a table function between "profit" and "probability of technology innovations", and also between "profit" and "profit impact on technology innovations". As there is no precise data describing their relationships, the table functions are chosen to reflect the perceptions of the interviewees. The operational process contains feedback among indicators, and the nonlinear relationships increase the computational complexity.

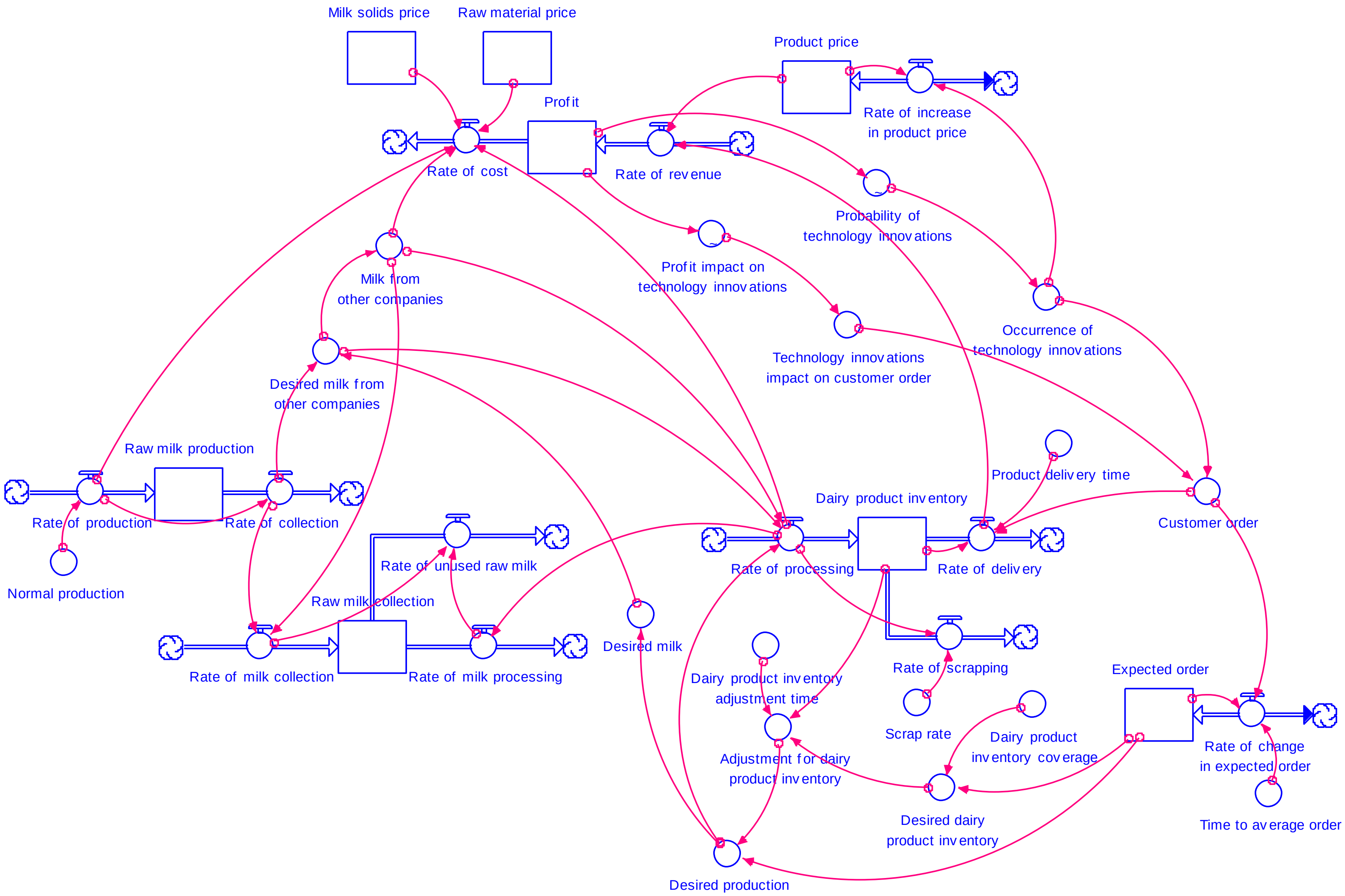


Figure 7. 17 SFD for Supply Chain Operations

Within the operational process, a range of risks could occur to interfere with the supply chain. The risk structure is demonstrated in Figure 7.18. This basic structure illuminates how risks affect the supply chain operations. Risk factors trigger the occurrence of risk events. The indicator "probability of risk event occurrence due to risk factors" is based on the combination of various risk factors. If only one risk factor exists, this indicator has the same value as the probability of the risk factor. If there are two risk factors, the combined probability of the risk factors is regarded as "1 - (1 - Probability of risk factor 1) * (1 - Probability of risk factor 2)". The occurrence of risk event is calculated by the equation "IF (Random number > Probability of a risk factor) THEN 0 ELSE 1". A random number is generated using the function, "RANDOM (0, 1)", as a probability ranges from 0 to 1. Random numbers are used to simulate the randomness of risk events.

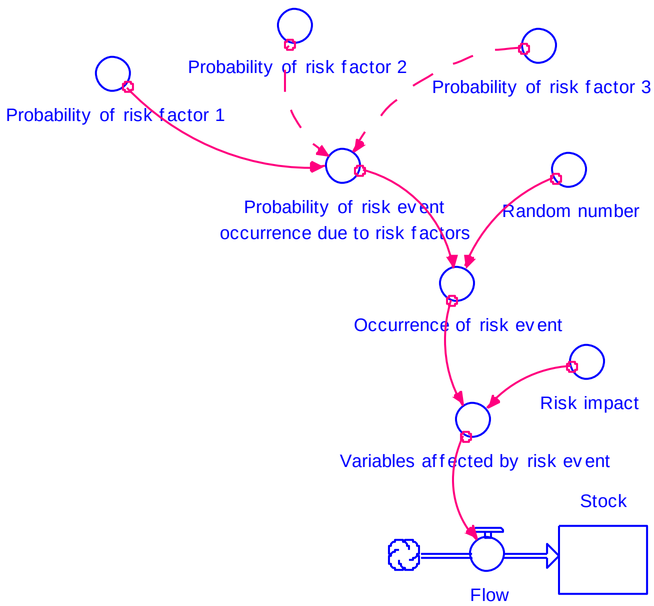


Figure 7. 18 SFD for the Risk Structure

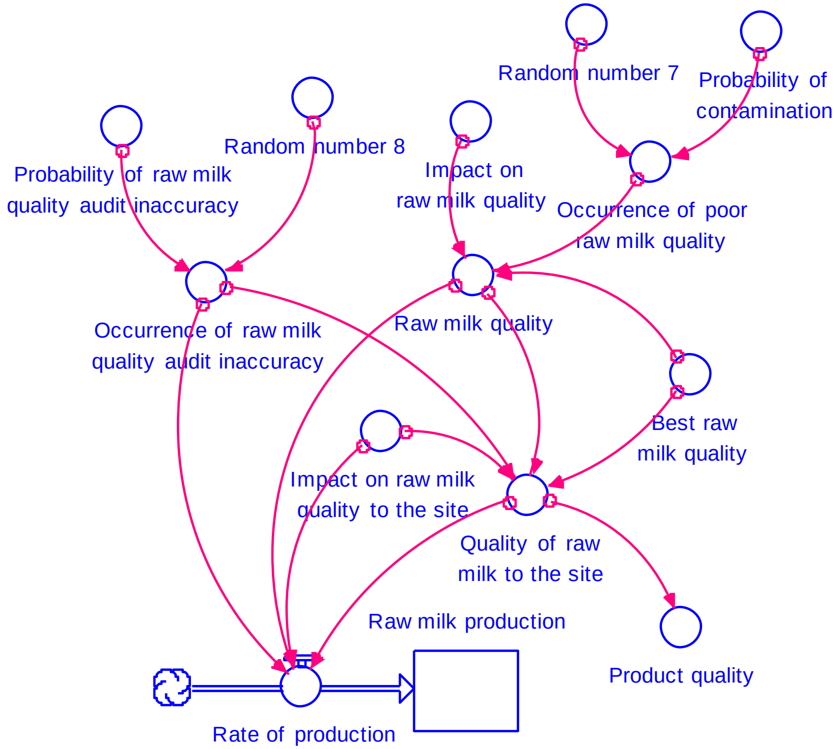
The occurrence of a risk event may affect relevant variables, and the process includes the indicator "risk impact", which represents the level of impact on the affected variables when the risk event occurs. There would be a consequence probability accompanying this process because the occurrence of a risk event does not necessarily affect the variable. For simplicity, probability of risk factor is given considering both the probability of risk factor leading to risk event occurrence and the consequence probability.

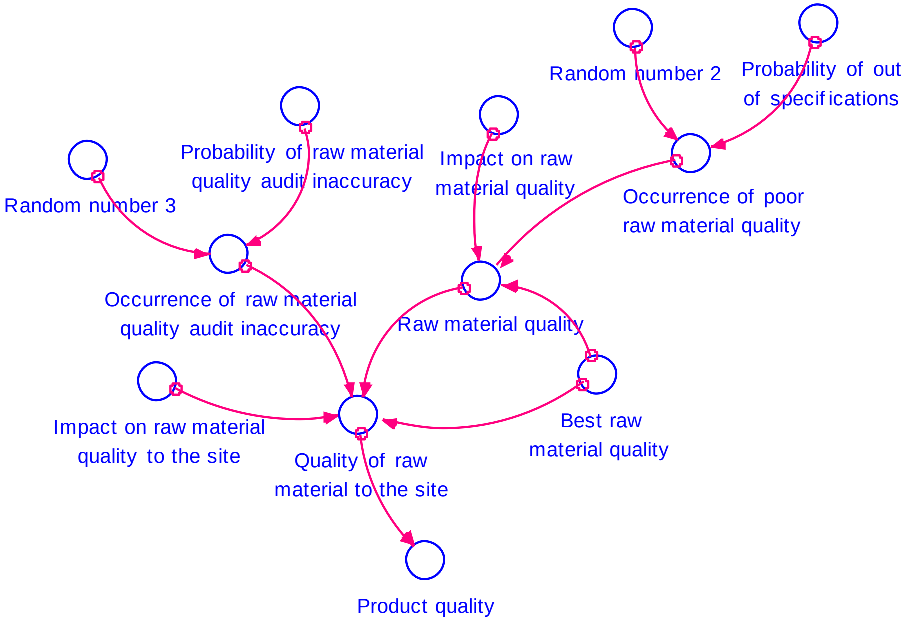
The affected variables are connected with flows and stocks either directly or indirectly. Due to the memory attribute of stocks, risks can further affect the SCP. This research explores how corruption modifies SCR effects, rather than the accurate situation of SCRs. Hence, for simplicity, the indicators “probability of risk factor” and “risk impact” are set as constant, except when they are affected by other variables in the system.

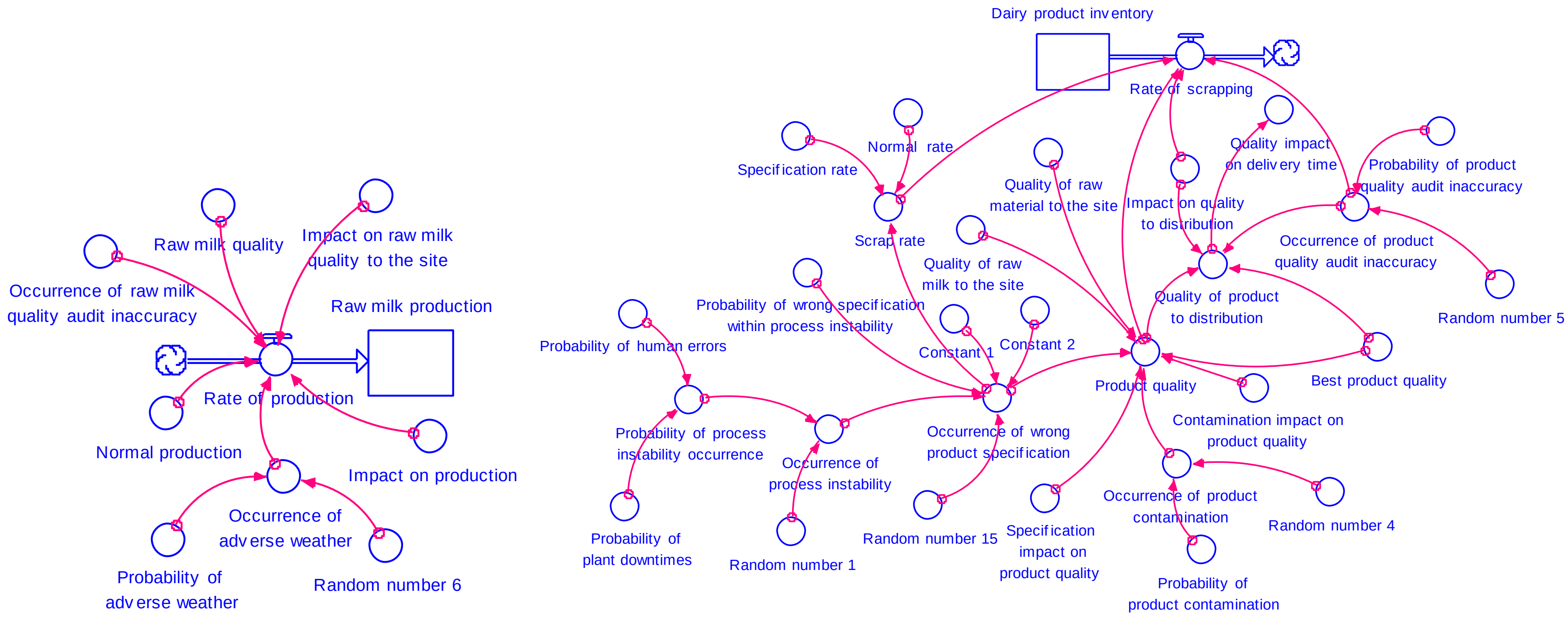
Based on the risk structure presented in Figure 7.18, risks described in the CLD were transformed into the risk indicators in the SFD. Figure 7.19 presents some risks using SFDs. The risks are elaborated by demonstrating risk factors, occurrence of risk events, and the relevant consequences. The impacted variables due to risk events will, in turn, affect other indicators, constituting a complex network.

Interrelated indicators are used to describe each risk, and they ultimately point to one or more variables in supply chain operations. The meanings of risk indicators can be understood according to indicators shown in Figure 7.18. For example, the indicator “impact on raw milk quality” corresponds to the indicator “risk impact” in Figure 7.18, which refers to the level of impact on the affected variables when the risk event occurs. In this study, raw milk quality does not refer to the quality level. Instead, the quality stands for the percentage of qualified raw milk.

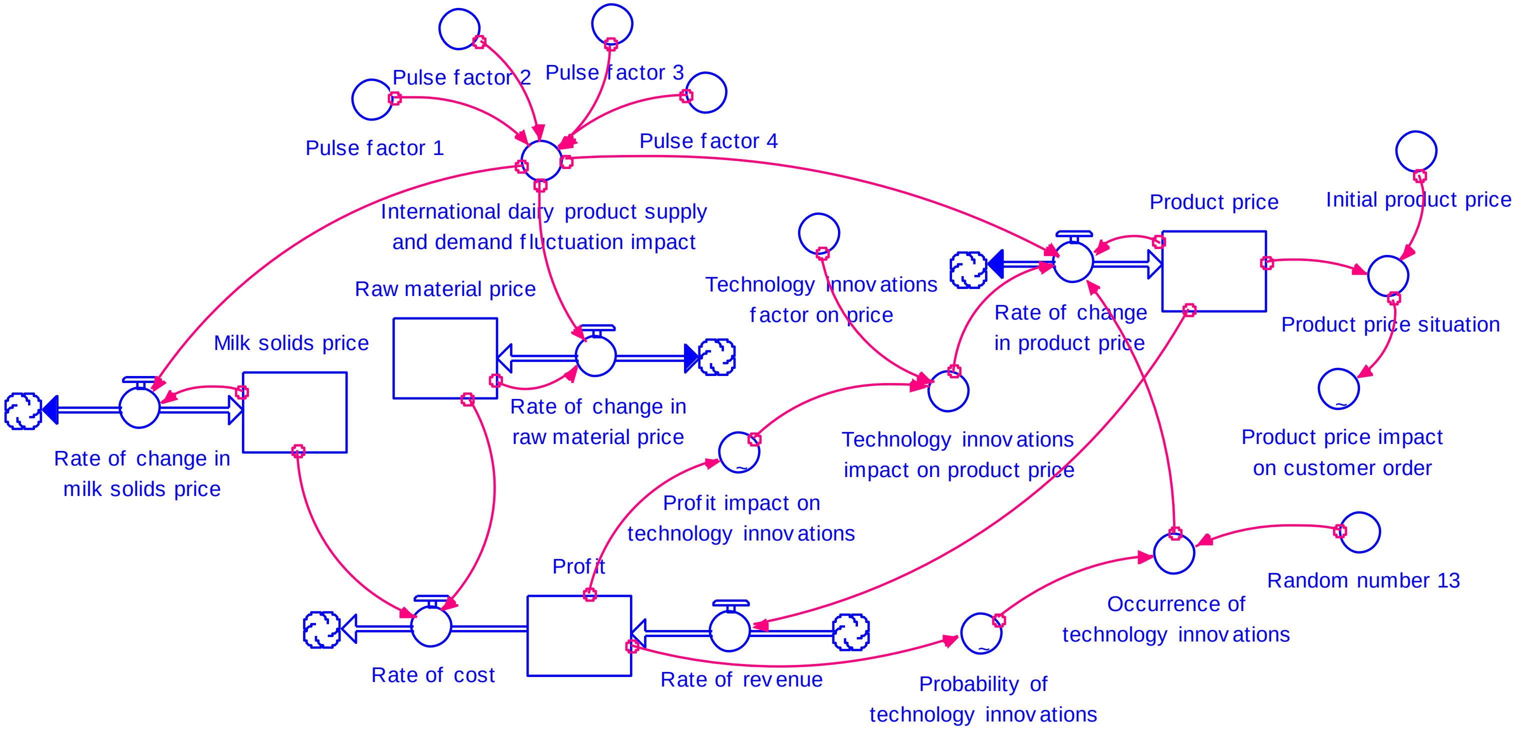
Empirical findings help establish the causal linkages among risk indicators, and also interactions between different risks. For example, the first diagram in Figure 7.19 depicts the risk of raw milk quality. This risk event is caused by contamination and inspection error according to the case study analysis. The diagram describes this risk through two variables: raw milk quality, and quality of raw milk to the site. Contamination brings about poor raw milk quality, and the quality inspection error determines the ultimate quality condition. “Quality of raw milk to the site” is calculated as: (1 - Occurrence of raw milk quality audit inaccuracy) * Best raw milk quality + Occurrence of raw milk quality audit inaccuracy * Raw milk quality / ((1 - Impact on raw milk quality to the site) * Raw milk quality + Impact on raw milk quality to the site), where “Best raw milk quality” equals 1 and means that all the raw milk is qualified.


Random number 7
Probability of contamination
Probability of raw milk quality audit inaccuracy
Random number 8
Impact on raw milk quality
Occurrence of poor raw milk quality
Raw milk quality
Occurrence of raw milk quality audit inaccuracy
Best raw milk quality
Impact on raw milk quality to the site
Quality of raw milk to the site
Raw milk production
Product quality
Rate of production


Random number 2
Probability of out of specifications
Probability of raw material quality audit inaccuracy
Impact on raw material quality
Random number 3
Occurrence of poor raw material quality
Occurrence of raw material quality audit inaccuracy
Raw material quality
Impact on raw material quality to the site
Best raw material quality
Quality of raw material to the site
Product quality



Raw milk quality
Impact on raw milk quality to the site
Occurrence of raw milk quality audit inaccuracy
Raw milk production
Rate of production
Normal production
Impact on production
Occurrence of adverse weather
Probability of adverse weather
Random number 6
Dairy product inventory
Rate of scrapping
Normal rate
Specification rate
Scrap rate
Quality impact on delivery time
Probability of product quality audit inaccuracy
Quality of raw material to the site
Impact on quality to distribution
Occurrence of product quality audit inaccuracy
Quality of raw milk to the site
Quality of product to distribution
Random number 5
Probability of wrong specification within process instability
Probability of human errors
Constant 1
Constant 2
Product quality
Best product quality
Contamination impact on product quality
Probability of process instability occurrence
Occurrence of process instability
Occurrence of wrong product specification
Occurrence of product contamination
Random number 4
Probability of plant downtimes
Random number 1
Random number 15
Specification impact on product quality
Probability of product contamination


Pulse factor 2
Pulse factor 3
Pulse factor 1
Pulse factor 4
International dairy product supply
and demand fluctuation impact
Product price
Initial product price
Technology innovations
factor on price
Rate of change
in product price
Product price situation
Raw material price
Milk solids price
Rate of change in
raw material price
Technology innovations
impact on product price
Product price impact
on customer order
Rate of change in
milk solids price
Profit impact on
technology innovations
Profit
Random number 13
Occurrence of
technology innovations
Rate of cost
Rate of revenue
Probability of
technology innovations

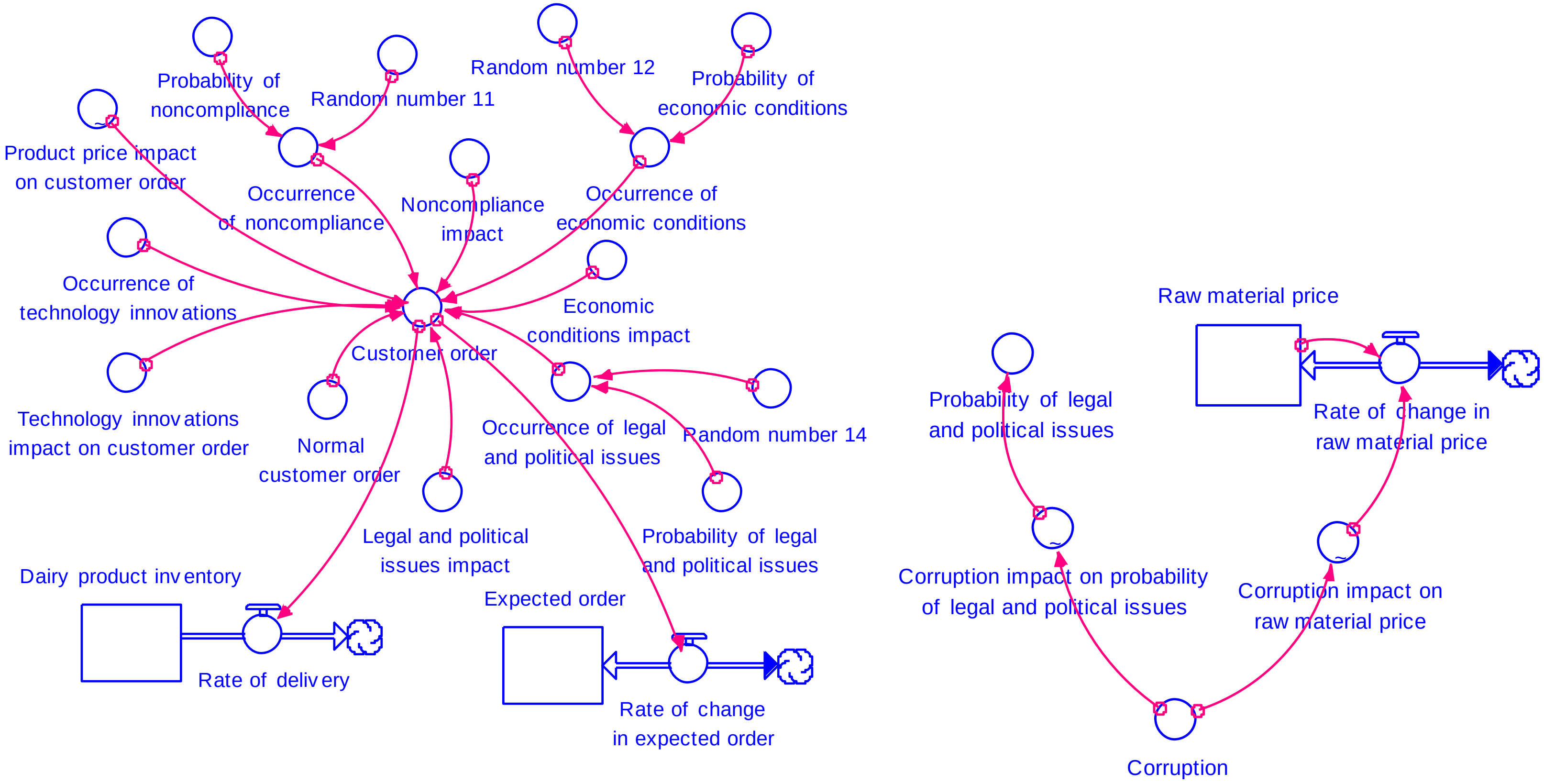


Figure 7. 19 SFD for Risks

The risk indicator "probability of wrong specification within process instability" is used to identify wrong product specification out of process instability. This indicator is assumed to be 0.3, which means 30% of process instability leads to incorrect product specification and deteriorates product quality. "Occurrence of wrong product specification" is calculated as: Occurrence of process instability * (IF (Random number 15 > Probability of wrong specification within process instability) THEN Constant 1 ELSE Constant 2), where Random number 15 equals RANDOM (0, 1), Constant 1 equals 0, and Constant 2 equals 1.

The normal operational process is influenced by risks. Corruption modifies risk effects and therefore SCP. The last diagram in Figure 7.19 describes how corruption modifies the effects of SCRs. Empirical findings in Chapter 6 help establish the indicators about corruption risks. The impact of corruption is classified into three categories: sales, procurement, and product delivery.

(1) For sub-categories under sales, "corruption impact on probability of legal and political issues" can be used to summarise the impact discussed in empirical findings. In terms of the probable damage of brand's reputation, an interviewee regarded overseas corruption as its cause, for example, a falsely stated quality problem. In this model, such a reputation problem has been summarised to "corruption impact on probability of legal and political issues".

(2) For sub-categories under procurement, "corruption impact on raw material price" can be used to reflect corruption's impact in this category. Corruption's impact on raw milk level is considered to be with very low chance, hence, this impact is overlooked in the model.

(3) For sub-categories under product delivery, the impact of corruption is focused on product delivery cost and product delivery delay. As the product delivery cost belongs to customers rather than the dairy processors, this factor is thus not taken into account in the model. Product delivery delay was discussed by one interviewee, who claimed that corruption might affect product delivery time. However, when discussing product delivery time, no interviewees mentioned corruption as the cause. Therefore, this factor is also ignored in the model's construction.

Equations signify comprehensive relationships among correlated variables. The main equations and their explanations in the model have been listed in Appendix E.

7.4.2 Simulation assumptions and data settings

The supply chain of focus consists of three main entities: raw material suppliers, dairy processors, and customers. The raw material suppliers consist of farmers supplying raw milk and suppliers providing raw materials for processing dairy products. Dairy products are assumed to be non-perishable products such as milk powder. Dairy processors can produce milk powder as ingredients for their customers. In the model construction and simulation, this research has made the following assumptions for simplicity:

(1) Raw milk is assumed to have only two levels: qualified and unqualified raw milk. The qualified milk can be of different grades. Since the inclusion of milk grades does not change the structure of the model, this assumption is made without loss of generality.

(2) Raw milk from other companies is assumed to be enough. As one interviewee mentioned, there could be situations where there is enough milk, but the risk of not being able to meet customer orders was considered relatively low because they have a bit fixed capability. There exists partnership between dairy processors, and raw milk can be obtained when needed. Therefore, this model assumes that insufficient raw milk is replenished by other companies.

(3) Unused raw milk is assumed as unscheduled to produce dairy products. Raw milk comes in every day. In reality, the production can be planned to allocate raw milk to different products. There is flexibility in production planning according to customer order and milk availability. Also, there will be situations when surplus milk is dumped, and when raw milk needs to be purchased from other dairy companies. To demonstrate such flexibility, this model assumes “unused raw milk” and “milk from other companies” to simplify the internal process. This affects profits in this model, however, it does not generally influence the study of corruption’s impact on the supply chain.

(4) The semi-manufacturing process is not elaborated in the model. Quality testing continues throughout the whole process and quality problems can be identified during this process. Those identified in the semi-manufacturing process are assumed to be problems recognised at the end of the production run.

(5) The processing is assumed to be within the maximum processing capacity. Meanwhile, the processing cost and other costs in this model are simplified regarding the calculation. Costs like salaries are not taken into consideration in this system, which impacts profits rather than research validity.

(6) Material delay is not considered in simulating the dairy system. Considering the complexity of simulating various risks in dairy supply chains and corruption's moderated impact, the model at this stage is attempted to be presented in a simplified form, in order to demonstrate the research topic directly. More complex and realistic issues could be explored in future research.

The model was simulated over a period of 260 weeks, that is, 5 years. The time step is suggested by Forrester (1961) to be 1/4 to 1/10 of the smallest time constant, as a much larger time step could produce integration error. In this research, the time step was set to be 0.25 of a week, representing that all the values in the model were calculated every quarter week over the whole simulation run. Euler Integration was selected as the numerical method in this model, which is generally regarded as the most convenient explicit method. Data were mainly based on companies' financial reports and interviews. There were various participating companies, therefore, parameters are not set as actual data of a particular company. Moreover, data in the model are disguised to ensure confidentiality. Some initial values are presented in Table 7.4. The input data about risk indicators such as probability of risk factors and risk impacts are based on interviewees' perceptions, with values elaborated in Table 7.8. For the sake of consistency, the unit of raw milk volume takes the weight unit "lbs", instead of the volume unit "litres".

Table 7. 4 Initial Values in the Model

Variable types	Variable names	Initial values (Unit)
Stock	Raw milk production	0 (lbs)
	Raw milk collection	0 (lbs)
	Dairy product inventory	35,000,000 (lbs)
	Expected order	4,160,000 (lbs/week)
	Milk solids price	2.5 (USD/lbs)
	Raw material price	2 (USD/lbs)
	Product price	5.3 (USD/lbs)
	Profit	40,000,000 (USD)
Constant	Normal production	60,000,000 (lbs/week)
	Probability of adverse weather	1/364 (Unitless)
	Impact on production	0.2 (Unitless)
	Dairy product inventory adjustment time	8 (weeks)

In regard to the CPI, NZ ranked first for eight years until 2013, second and fourth respectively in 2014 and 2015, and back to the first in 2016 (shown in Figure 7.20, where y axis is ranking). NZ is among the least corrupt nations, however, there is occasional degradation in the ranking. The CPI is used to assess corruption in the public sector, and does not represent or take the private sector into consideration. According to a survey conducted in NZ and Australian businesses, 34% of participants from companies with offshore operations stated foreign bribery/corruption occurrence over the last five years (Manning, 2015). Meanwhile, Manning (2015) emphasised the situation of domestic corruption, where 23% of participants talked about experiencing one or more domestic corruption incidents over the past five years. Meadows (2015) also analysed the survey report and highlighted domestic corruption and offshore exposure to corruption. Dairy companies in NZ primarily focus on export and will more or less be faced with corruption. The corruption level does not reach the highest or lowest value because these two situations are not realistic for the current simulated system. As corruption is a hidden phenomenon, firms rarely have particular knowledge on it and can only estimate this parameter (Søreide, 2009). Based on the above information, the score of corruption is set at eight for model simulation (detailed information regarding corruption scores is discussed in Section 7.5.1). Parameters are adjusted based on this level of corruption.

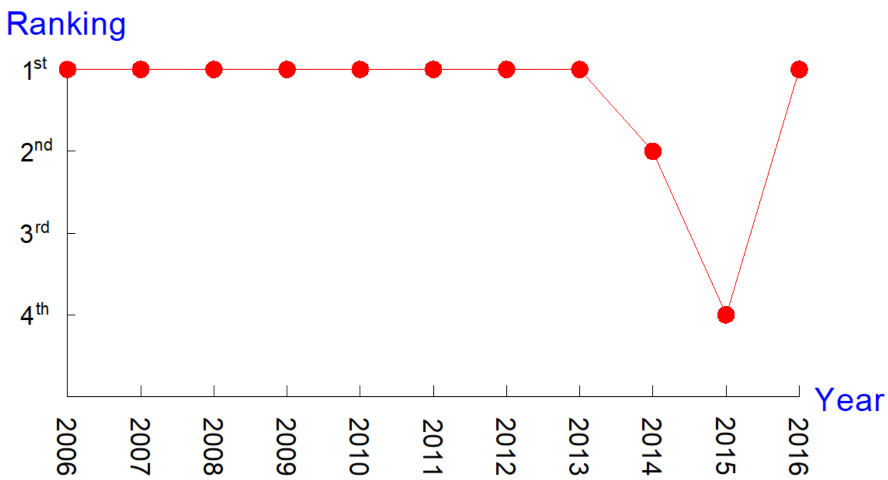


Figure 7. 20 NZ's Ranking in the CPI

7.4.3 Model validation

Sterman (2000) mentioned that all models are wrong and no model is valid or verifiable regarding the establishment of its truth. Therefore, model usefulness is more important than it being the true model. Based on various proposed, specific tests, Sterman (2000) summarised twelve main tests, the corresponding purposes and tools, and procedures. The tests include boundary adequacy, structure assessment, dimensional consistency, parameter assessment, extreme conditions, integration error, behaviour reproduction, behaviour anomaly, family member, surprise behaviour, sensitivity analysis, and system improvement.

Model testing helps identify model's problems and improve model's robustness. Conducting model tests is an iterative process. Not all the tests are needed for a particular model validation. In this research, the model is validated by the following tests.

The model is consistent in dimensions. The software iThink has the built-in function "Check Units". Dimensions in the model are checked for consistency. Units are confirmed as consistent.

The constructed model also passed through the behaviour reproduction test. The simulation curves of seven performance indicators (shown in Appendix F) were emailed to the interviewees. A succinct introduction was made to clarify the intention of request and the meaning of those figures. There was a response rate of nearly 50%. All the respondents have confirmed these simulation trends, apart from one interviewee feeling confused about the simulation curve of rate of cost. However, this research simplified the equation for dairy cost fluctuation, and assumed that the rate of cost generally decreases over the simulation period, reflecting a situation with a weak global dairy market. This is a limitation of this model which does not reveal all situations showing up over the long term.

The simulation results conform to the reality. The test is performed on international dairy product supply and demand fluctuation impact, and corruption.

The value of the international dairy product supply and demand fluctuation impact is adjusted by altering the parameter "pulse factor 4". This parameter shows the degree of reduction. Pulse factor 4 is changed from -0.31 to -0.155. Its impact on expected order and profit is shown in Figure 7.21. Scenario 1 represents that the degree of reduction of price due to international dairy product supply and demand fluctuation is 31%, and in scenario 2 it is 15.5%. Generally, the milk solids price, raw material price, and product price are higher in scenario 2. In the long term, both customer order and profit are lower in scenario 2. Figure 7.21 conforms to the reality.

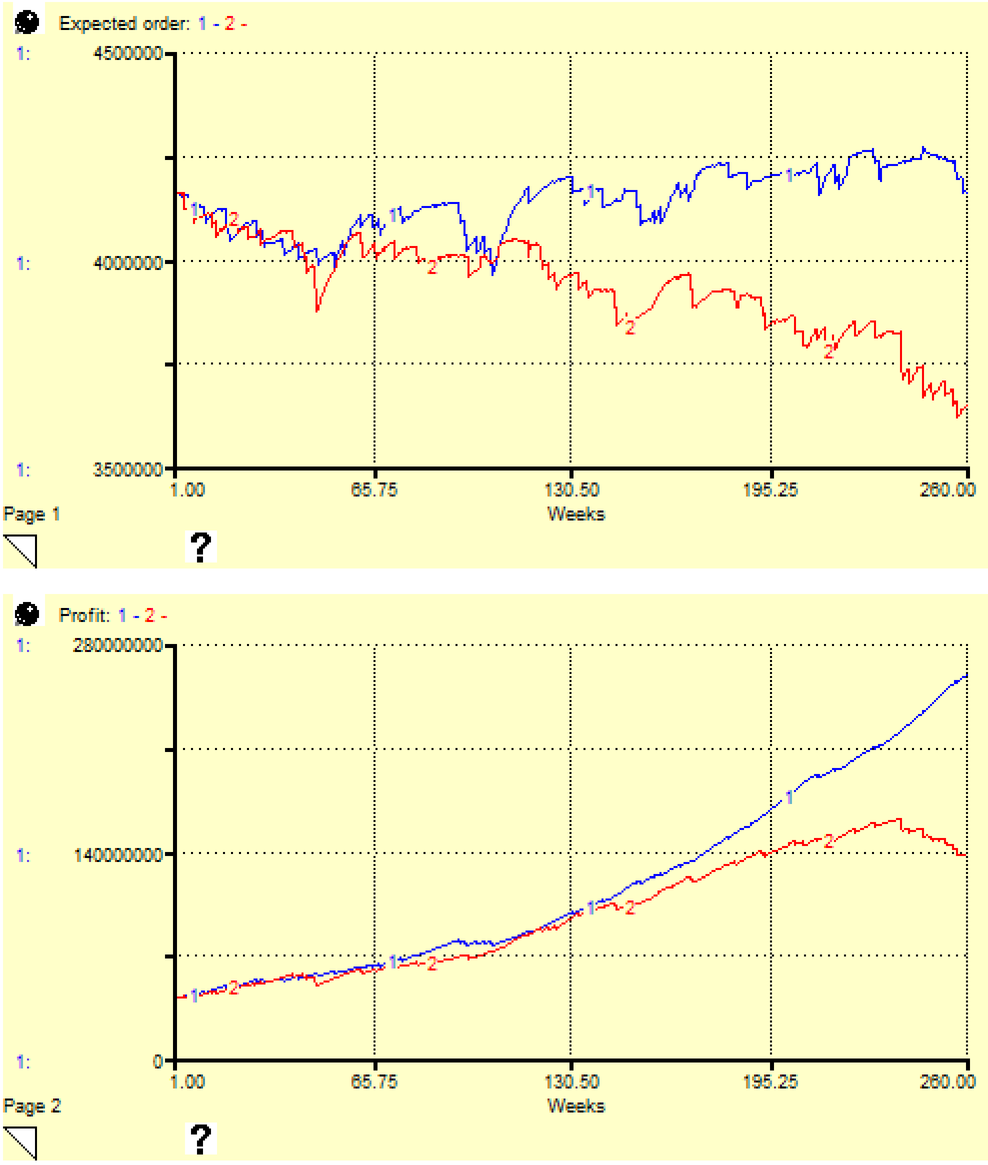


Figure 7. 21 Expected Order and Profit under Different International Dairy Product Supply and Demand Fluctuation Impacts

Another test is conducted on the corruption score, which is changed from 6 to 3. Figure 7.22 displays corruption's impact on expect order and profit. A higher corruption score stands for less corruption situation. The following two figures show that expected order and profit are generally less in more corrupt situation. This also conforms to reality.

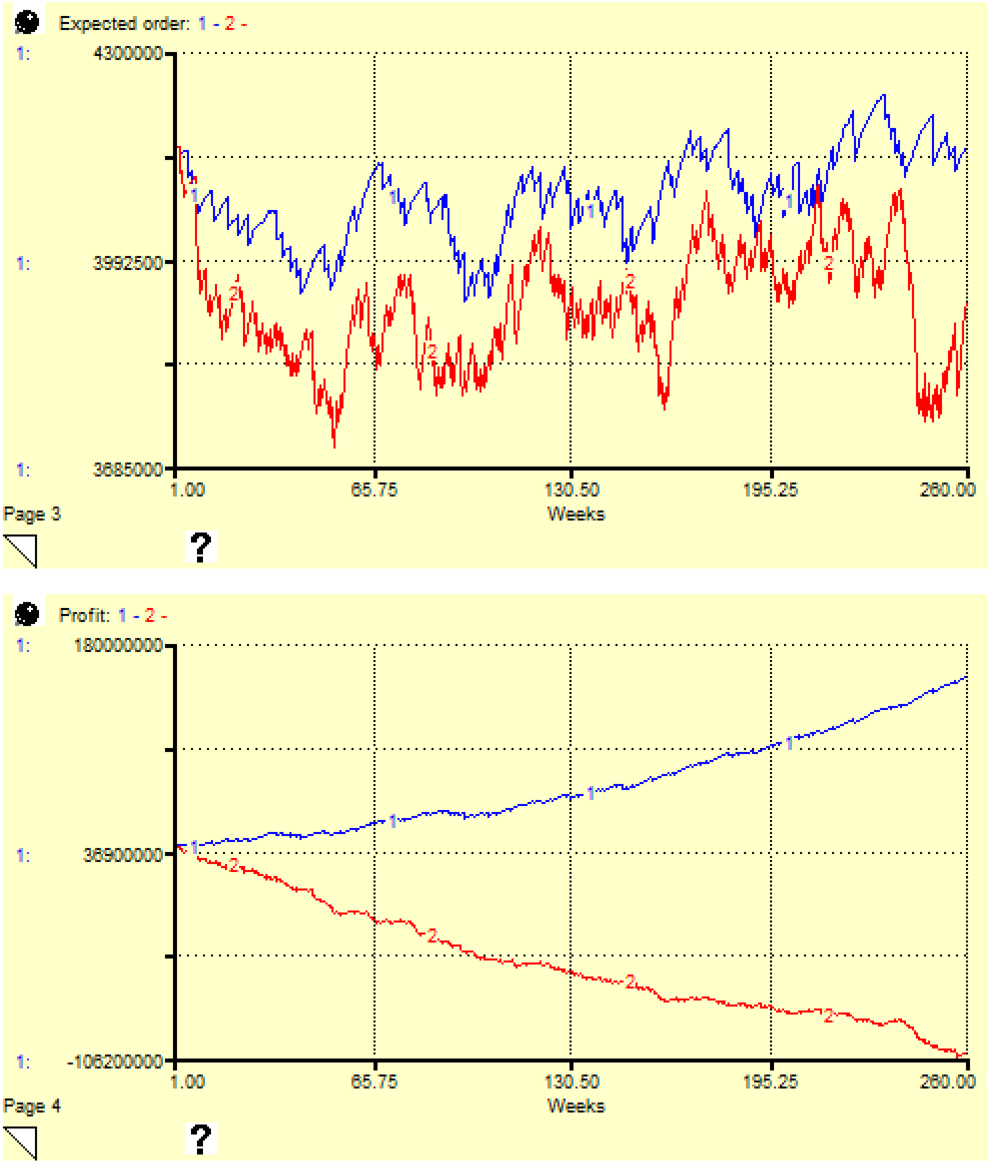


Figure 7. 22 Expected Order and Profit under Different Corruption Levels

The extreme conditions test is performed on customer order. Figure 7.23 shows the performance of profit, order fulfilment ratio, and expected order when the customer order is zero. In this model, raw milk comes in regardless of the demand, therefore, profit reduces steadily. The order fulfilment ratio remains zero as the figure shows. The expected order has a sharp decline and then becomes zero. All these results are meaningful.

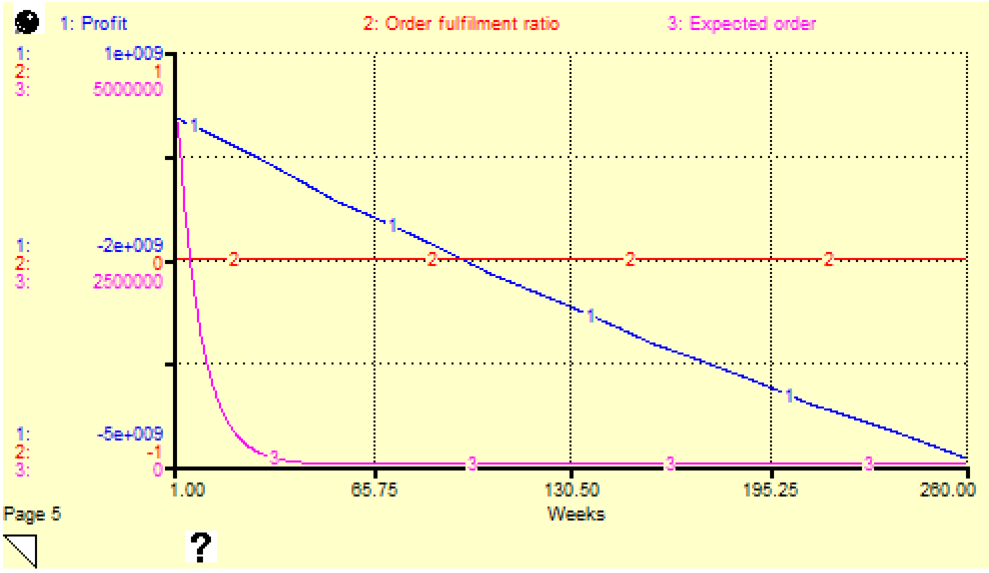


Figure 7. 23 Profit, Order Fulfilment Ratio, and Expected Order under Extreme Conditions

7.5 Scenario analysis and results

7.5.1 Scenario analysis

In this model, risks occur within various supply chain links and nodes. The probabilities of risk factors, and impacts of risk events, determine the level of disturbance on the normal supply chain operations. To identify leverage risks, all the risk factors and impacts of risk events need to be simulated. The most sensitive risks are targeted as leverage risks.

Eight scenarios were formed which stand for different states of risk and corruption. Scenarios 1-4 stand for situations with low corruption levels, and different risk levels: (1) Risk; (2) Risk - 10%; (3) Risk - 20%; (4) Risk - 30%. Here, “risk” means the values of risk indicators that are associated with a risk, and the adjustment stands for risk mitigation. For example, the risk indicator “impact on raw milk quality” is a risk indicator related to the raw milk quality risk; “risk - 10%” means reducing this risk indicator’s value by 10%, which is a way to represent risk mitigation. Scenarios 5-8 stand for situations with high corruption levels, and different risk levels (the same as 1-4). Transparency International ranks corruption in different countries regarding public sectors. Scores are used to measure corruption ranging from 0 (most corrupt) to 100 (least corrupt). In this research, supply chain corruption is set to scale from 0 to 10, where 0 represents the highest corruption level and 10 represents the lowest corruption level. According to the scores of the CPI for 176 countries (Transparency International, 2017), the countries ranking from 1 to 88 and from 89 to 176 are averagely scored as 58.24 and 27.66 respectively in 2016. In consulting this average data, supply chain corruption is assumed to be scored as six and three for low and high corruption levels. Therefore, four pairs can be generated from these scenarios (see Table 7.5).

Table 7. 5 Four Pairs of Scenarios

Pairs	Scenarios
Pair 1 (Scenarios 1 & 5)	risk (original level) + low corruption level & risk (original level) + high corruption level
Pair 2 (Scenarios 2 & 6)	risk (-10%) + low corruption level & risk (-10%) + high corruption level
Pair 3 (Scenarios 3 & 7)	risk (-20%) + low corruption level & risk (-20%) + high corruption level
Pair 4 (Scenarios 4 & 8)	risk (-30%) + low corruption level & risk (-30%) + high corruption level

SCP is measured by indicators such as profit and expected order. The overall SCP takes into account all the performance indicators. A simulation curve can be generated for each scenario. The curves indicate various performance values within the simulation period, and a mean value is calculated to represent the performance value for each curve.

Table 7.6 indicates the way to identify leverage risks, which has been defined in Section 3.2. Risk mitigation level represents the mitigation magnitude of risk probability or impact. P_{ij} (i = 1, 2, 3, 4; j = 1, 2) stands for SCP under different risk mitigation levels and corruption levels. ΔSCP mentioned in Section 3.2 is the performance difference between less and more corruption, for example, the difference between P_{11} and P_{12}. Four ΔSCPs are generated in these four risk levels. Considering SCP is measured by indicators with various dimensions, this model adopts the relative change rather than absolute change (ΔSCP) to measure the performance difference. The relative change of performance is denoted as P_{rc} ($P_{rc} = (P_{i2} - P_{i1}) / P_{i1}$, i = 1, 2, 3, 4). The absolute value of P_{rc} (that is, $|P_{rc}|$) is used to eliminate the confusion in description caused by negative numbers. The least value of $|P_{rc}|$ stands for the situation that corruption has the least impact on SCP, signifying that supply chain robustness against corruption achieves the maximum value. Such robustness is achieved when a particular risk is mitigated at a particular level, as described in Table 7.6. In order to efficiently enhance supply chain robustness against corruption, the mitigation level need to be considered and the concept of leverage risk is therefore proposed (see Section 3.2).

Table 7. 6 Identification of Leverage Risks

Risk mitigation level	Corruption (less)	Corruption (more)	Absolute relative change of performance
0	P_{11}	P_{12}	$\|P_{rc1}\|$
-10%	P_{21}	P_{22}	$\|P_{rc2}\|$
-20%	P_{31}	P_{32}	$\|P_{rc3}\|$
-30%	P_{41}	P_{42}	$\|P_{rc4}\|$

The way to identify leverage risks is illustrated as follows:

1) If $|P_{rc2}|$ is minimum for risk mitigation level -10%, this risk can be regarded as a leverage risk. This corresponds with the key issues highlighted in the concept of leverage risk: a) minimum change in risk mitigation level; and b) the smallest performance difference between high- and low-levels of corruption.
2) If $|P_{rc3}|$ or $|P_{rc4}|$ is minimum for risk mitigation level -20% or -30%, this risk is not a leverage risk because it requires more mitigation efforts.
3) When $|P_{rc1}|$ is minimum for risk mitigation level zero, no risk mitigation is needed and thus the risk is not a leverage one.

7.5.2 Results

Figure 7.24 presents simulation results from one of the five replications. Data in the figures were calculated and listed in corresponding tables such as Table 7.7. The results are enumerated using seven performance indicators in Table 7.7, which displays the relative changes of SCP between high and low corruption levels for different risk mitigation levels. As there is randomness due to probable occurrence of risk events, five replications are performed in model simulation to reduce the impact of randomness. For each performance indicator, the value of P_{rc} for a risk at a particular level is established after averaging the relative changes in five replications. Considering there are four different risk levels, four P_{rc} values would be generated.

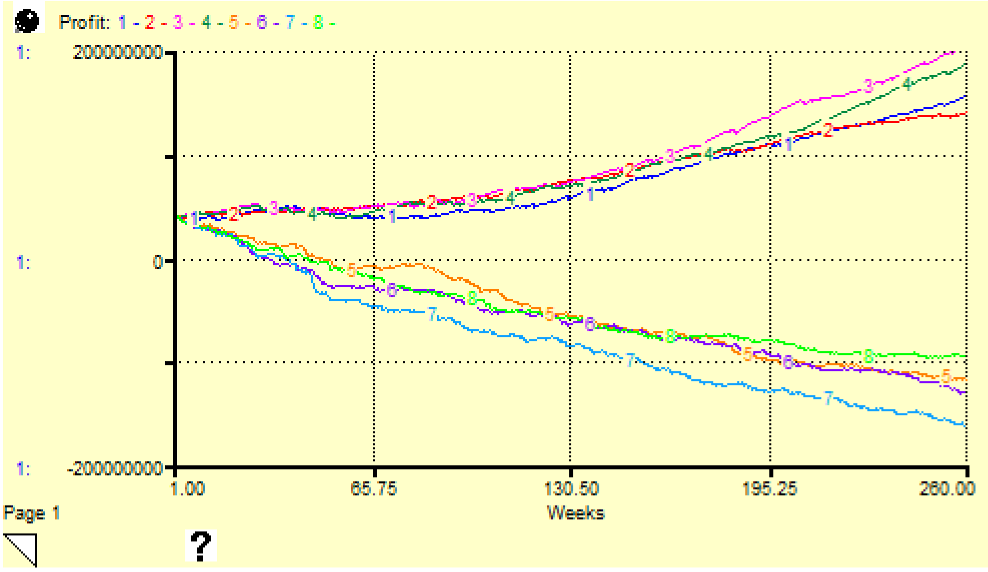
These four P_{rc} values are listed in the last column in Table 7.7 for each performance indicator, and two minimum $|P_{rc}|$ values are bolded and underlined. To discover the minimum $|P_{rc}|$ value considering all these seven performance indicators, the aggregate number of these bolded values is counted. In this research, by finding the largest number in the column "count" in Table 7.7, we can identify the minimum $|P_{rc}|$ value considering all seven performance indicators, where corruption's impact on SCP achieves the least value. This aids to the identification of level in mitigating a specific risk indicator, under which situation corruption has the least impact on supply chains. If two mitigation levels are simultaneously identified (just as “0” and “-30%” in Table 7.7), the level with a smaller absolute value is selected considering effectiveness and efficiency.

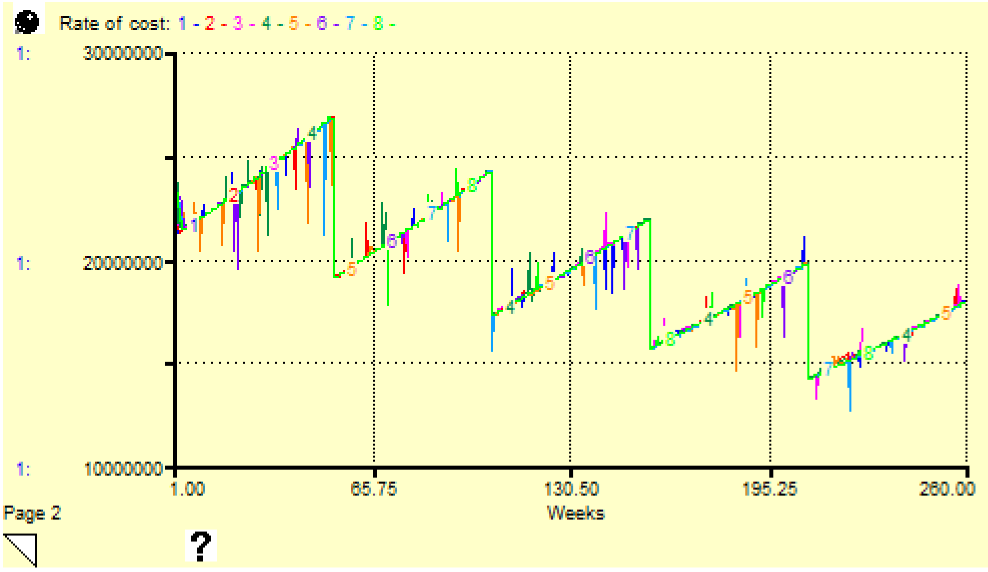
Table 7. 7 Excerpt of Simulation Results

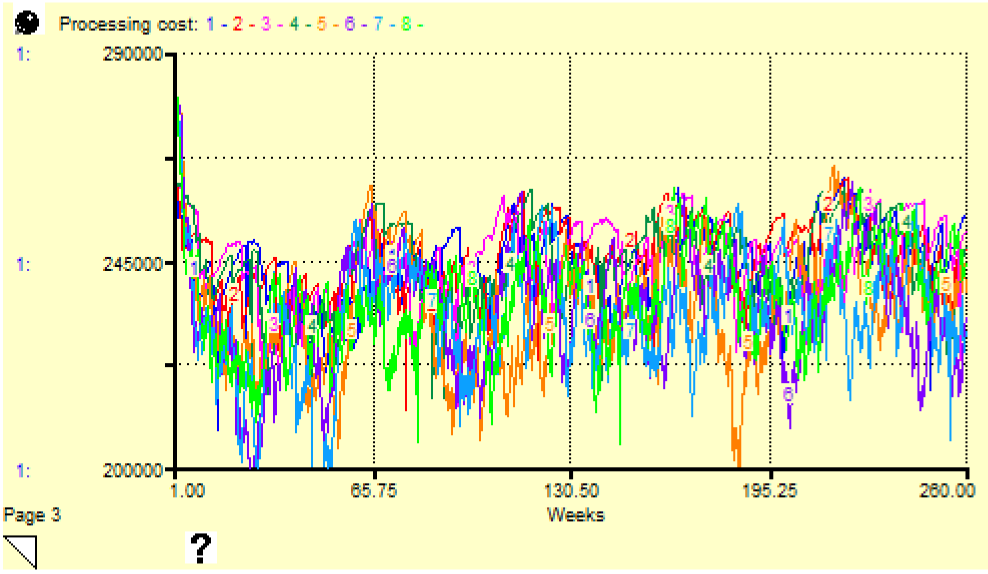
Change of probability of contamination	Profit (1,2,3,4,5, mean)						Rate of cost (1,2,3,4,5, mean)						Processing cost (1,2,3,4,5, mean)					
0	-1.6638	-1.5940	-1.5162	-1.4959	-1.6597	***-1.5859***	-0.0008	-0.0010	-0.0014	-0.0025	-0.0033	***-0.0018***	-0.0395	-0.0389	-0.0443	-0.0397	-0.0351	***-0.0395***
-10%	-1.7242	-1.7962	-1.8796	-1.5345	-1.7645	-1.7398	-0.0028	-0.0026	-0.0024	-0.0027	-0.0007	-0.0022	-0.0466	-0.0345	-0.0433	-0.0391	-0.0425	-0.0412
-20%	-1.8632	-1.5633	-1.8324	-1.5079	-1.4612	-1.6456	-0.0018	-0.0012	-0.0024	-0.0028	-0.0015	-0.0019	-0.0508	-0.0368	-0.0456	-0.0407	-0.0444	-0.0437
-30%	-1.5850	-1.8542	-1.4877	-1.5957	-1.4965	***-1.6038***	-0.0020	-0.0028	-0.0007	-0.0020	-0.0011	***-0.0017***	-0.0300	-0.0495	-0.0320	-0.0343	-0.0353	***-0.0362***

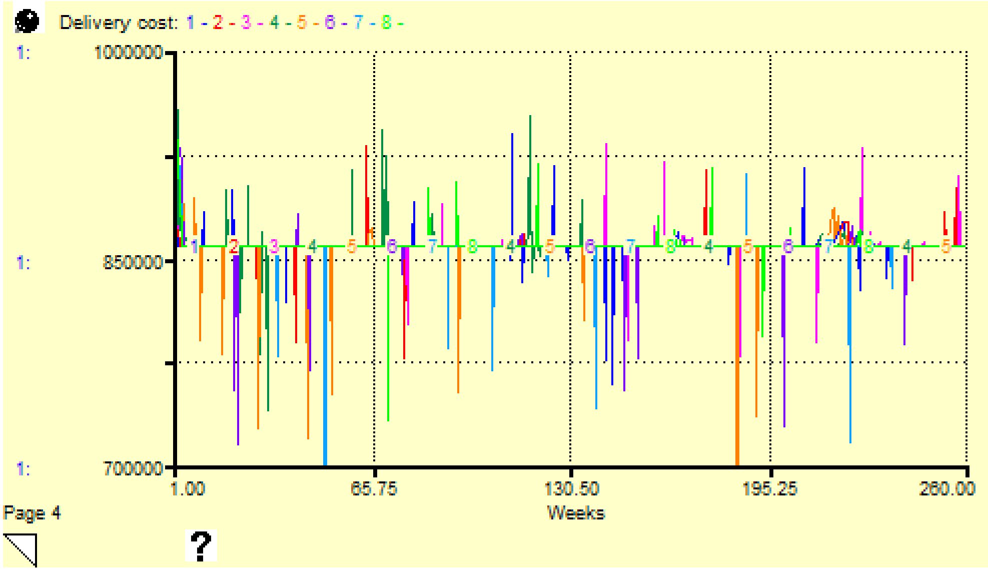
Change of probability of contamination	Delivery cost (1,2,3,4,5, mean)						Product delivery time (1,2,3,4,5, mean)						Order fulfilment ratio (1,2,3,4,5, mean)					
0	0.0010	0.0006	0.0003	-0.0013	-0.0019	***-0.0003***	-0.0005	-0.0010	-0.0010	-0.0034	0.0029	***-0.0006***	0.0018	0.0007	0.0009	0.0013	-0.0001	0.0009
-10%	-0.0010	-0.0010	-0.0007	-0.0012	0.0012	-0.0005	-0.0010	0.0010	-0.0019	0.0010	-0.0005	***-0.0003***	0.0002	0.0001	0.0007	0.0007	0.0014	***0.0006***
-20%	0.0004	0.0002	-0.0003	-0.0011	0.0002	***-0.0001***	0.0019	0.0005	0.0000	0.0000	0.0005	***0.0006***	0.0003	0.0005	0.0003	0.0009	0.0016	***0.0007***
-30%	-0.0006	-0.0010	0.0007	-0.0006	0.0002	***-0.0003***	0.0010	-0.0005	0.0005	0.0005	0.0014	***0.0006***	0.0003	0.0004	0.0015	0.0009	0.0015	0.0009

Change of probability of contamination	Expected order (1,2,3,4,5, mean)							Count
0	-0.0403	-0.0381	-0.0435	-0.0394	-0.0368	***-0.0396***		***6***
-10%	-0.0462	-0.0356	-0.0413	-0.0383	-0.0437	-0.0410		2
-20%	-0.0500	-0.0395	-0.0459	-0.0404	-0.0434	-0.0438		3
-30%	-0.0336	-0.0500	-0.0329	-0.0345	-0.0382	***-0.0378***		***6***

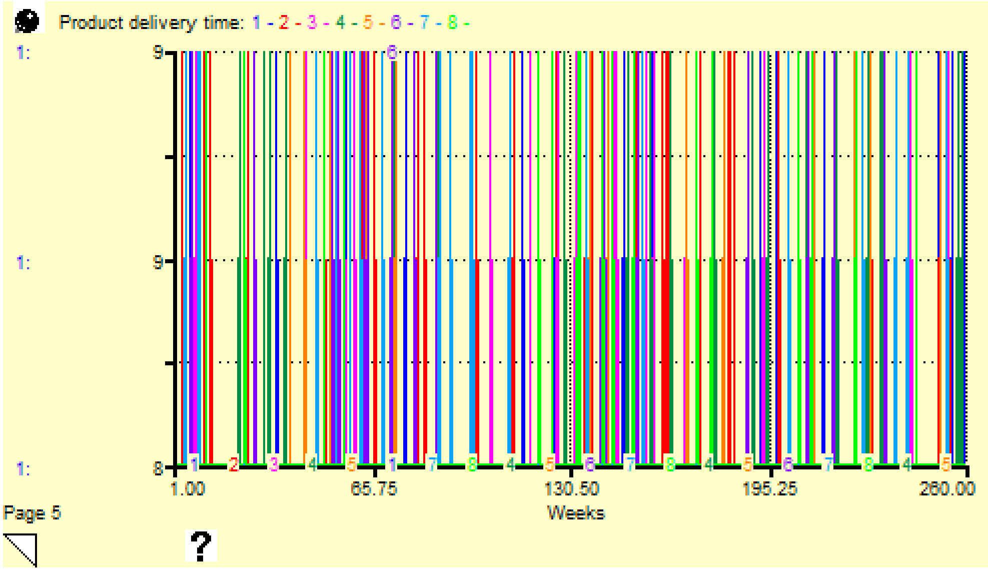

Profit: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 200000000
1: 0
1: -200000000
1.00
65.75
130.50
195.25
260.00
Weeks
Page 1


Rate of cost: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 30000000
1: 20000000
1: 10000000
1.00
65.75
130.50
195.25
260.00
Weeks
Page 2

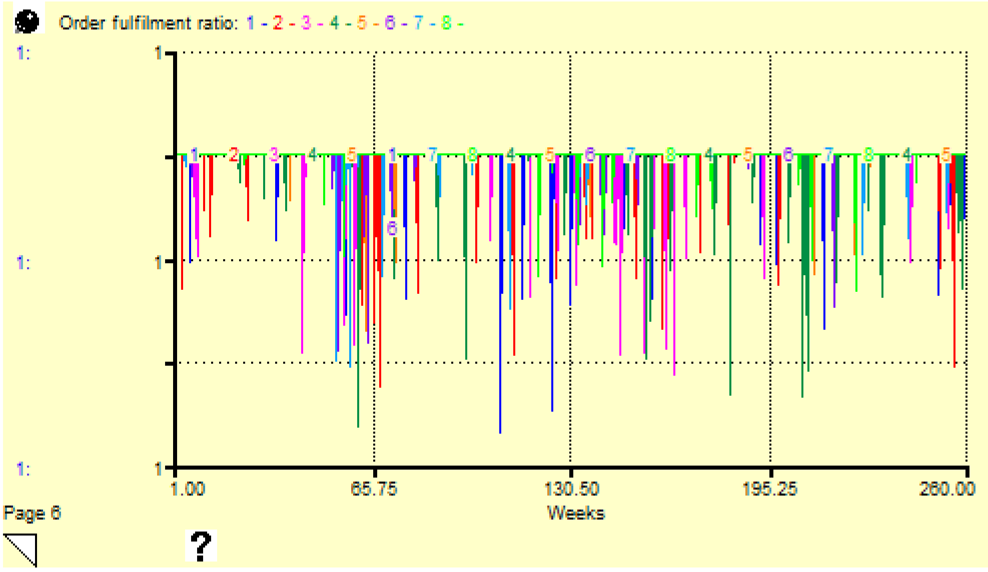

Processing cost: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 290000
1: 245000
1: 200000
1.00
65.75
130.50
195.25
260.00
Weeks
Page 3



Delivery cost: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 1000000
1: 850000
1: 700000
1.00
65.75
130.50
195.25
260.00
Weeks
Page 4
?



Product delivery time: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 9
1: 9
1: 8
1.00
65.75
130.50
195.25
260.00
Weeks
Page 5
?



Order fulfilment ratio: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 -
1: 1
1: 1
1: 1
1.00
65.75
130.50
195.25
260.00
Weeks
Page 6
?

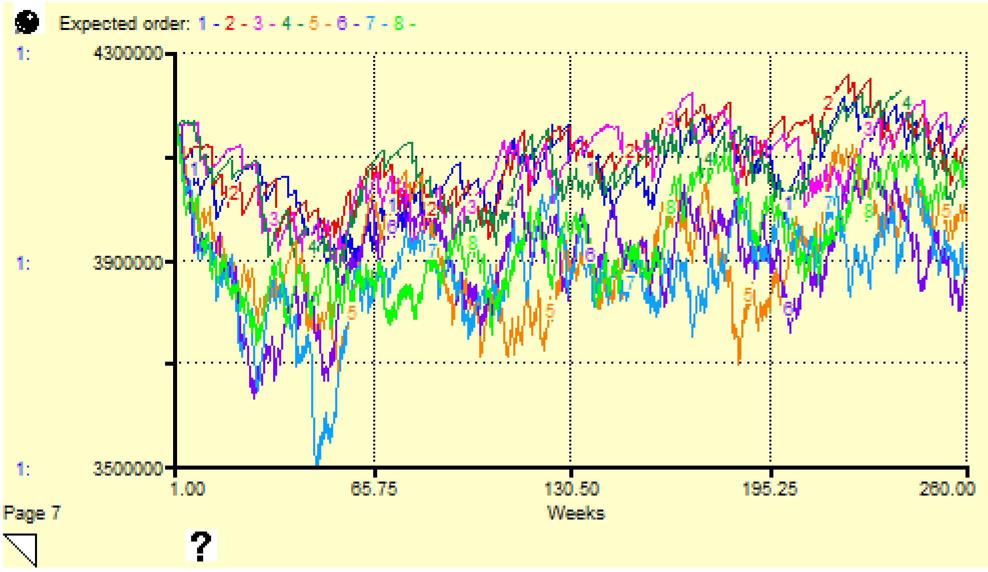


Figure 7. 24 Excerpt of SCP Simulation Curves under Different Scenarios

The scenario analysis results are listed in Table 7.8. In accordance with Section 7.5.1, the risk indicators with the mitigation level (-10%) meet the criteria of leverage risks. Thus, the identified risk indicators are impact on raw milk quality, probability of plant downtimes, impact on collection, probability of product contamination, pulse factor 4, and noncompliance impact.

As previously mentioned, risk indicators refer to indicators associated with risk events (for example, probability of contamination is associated with poor raw milk quality). The identified indicators are respectively summarised to relevant risks. The corresponding leverage risks are raw milk quality risk, process stability risk, raw milk volume risk, product quality risk, dairy product price risk, and customer order risk. Measures should be taken in this direction so that corruption's impact on the supply chain can be notably minimised.

The results have two implications: First, mitigating SCRs, which seem unrelated to corruption, could contribute to mitigating corruption's impact as a result of risk interactions. Second, some of the risks would outperform others in the effectiveness of mitigating corruption's impact. This answers the last research question: *What measures can be taken to effectively enhance supply chain robustness against corruption?*

Table 7. 8 Scenario Analysis Results

Risk indicator	Value	Mitigation level
Probability of contamination	1/182	0
Impact on raw milk quality	0.3	-10%
Probability of raw milk quality audit inaccuracy	1/364	0
Impact on raw milk quality to the site	0.2	0
Probability of adverse weather	1/364	-30%
Impact on production	0.2	-20%
Probability of human errors	1/728	0
Probability of plant downtimes	1/364	-10%
Probability of out of specifications	1/91	-20%
Probability of raw material quality audit inaccuracy	1/364	0
Impact on raw material quality	0.3	-20%
Impact on raw material quality to the site	0.2	-30%
Probability of natural disasters	3/364	-30%
Process instability impact on processing	0.1	-20%
Impact on collection	0.1	-10%
Probability of wrong specification within process instability	0.3	0
Specification impact on product quality	0.3	0
Probability of product contamination	0.005	-10%
Contamination impact on product quality	0.3	-30%
Impact on quality to distribution	0.2	-20%
Probability of product quality audit inaccuracy	1/728	0
Quality impact factor on delivery time	1	0
Accident impact on delivery time	1	0
Probability of accident	0.02	-30%
Technology innovations factor on price	0.04	-20%
Technology innovations factor on order	0.2	0
Pulse factor 2	0.01	-30%
Pulse factor 4	-0.31	-10%
Probability of noncompliance	1/300	0
Noncompliance impact	0.25	-10%
Probability of economic conditions	0.008	0
Economic conditions impact	0.35	0
Basic probability of legal and political issues	1/180	-30%
Legal and political issues impact	0.3	-20%

7.6 Discussion on the simulation results

The leverage risk indicators have been defined and identified by using simulation in this research. By mitigating these risks, the objective of minimising corruption's impact on the SCP can be achieved in an efficient way. The following discusses strategies dealing with the respective leverage risks.

In this model, "impact on raw milk quality" refers to the percentage of raw milk on the farm that is affected by contamination. The quality of raw milk on the farm largely depends on the manufacturing practice and quality control. Khaniki (2007) emphasised the importance of food safety and quality assurance in reducing chemical contaminants in milk. Relevant regulatory laws, personnel training, good manufacturing practices, and monitoring were also underlined in diminishing such contamination. Cempírková (2007) investigated the relationship between microbial contamination of raw milk and factors such as dairy cow management technology and milking methods. The statistical analysis indicates the positive effects of adopting proper methods on reducing relevant contamination indicators. Vilar et al. (2012) paid attention to both microbial and chemical contamination of milk on farms. They recommended implementing Hazard Analysis and Critical Control Points with some modifications, and it is significant for farm workers to participate in this program actively. All these strategies can be considered in ensuring that the farm produces raw milk with high overall quality.

Downtimes could hinder plants from normal operations. As milk has the characteristic of perishability and needs prompt processing, so plant availability is crucial for the dairy industry (Madanhire & Mbohwa, 2015). Systematic and regular examination of machinery and equipment was underlined by Madanhire and Mbohwa (2015) for plant availability. A fish bone diagram was drawn by Moohialdin and Hadidi (2017) to analyse downtime of the production line. They demonstrate that downtime is remarkably influenced by the types of failures. To reduce the probability of plant downtimes, the dairy plant needs to identify the main failures based on historical downtime reports. Targeted measures can be performed to decrease the occurrence of downtime.

Raw milk delivery from farm to plant may be affected by natural disasters. Milk is perishable and tends to deteriorate after a lengthy delivery delay. "Impact on collection" is an indicator standing for the percentage of affected raw milk in such situations. Reddy, Singh, and Anbumozhi (2016) studied disruptions to food supply chains in cases of natural disasters. Some strategies in their research can be consulted to reduce "impact on collection", such as developing a well-planned network for milk delivery, and taking advantage of technology and meteorological forecasts to make preparations.

Raw material procurement is followed by consecutive steps, which increase the risk of product contamination. To reduce the probability of product contamination, the points of risk within the procedures need to be analysed and precautions taken. FDA (2006) conducted hazard analysis on the processing of dairy products. Potential hazards and relevant control and prevention measures were identified. Three kinds of hazards (biological, chemical and physical hazards) were elaborated in each step of milk plant processing operations. This guide assists various milk plant Hazard Analysis and Critical Control Points teams, and the hazards and measures are different for various dairy processors. These measures can be referred to when developing precautions against dairy product contamination.

The global dairy supply and demand dynamics contributes to the fluctuation of dairy commodity price. As a result, dairy product price, milk solids price, and raw material price are all affected by such fluctuation. The reduction of global supply and demand fluctuation is beneficial for price stability. However, a dairy company is not able to change the international supply and demand. Therefore, this risk indicator cannot be mitigated by a dairy processor.

NZ dairy companies focus on export because of the small domestic market, with other customers located in various countries. Regulations and standards among overseas countries are important in international trade. Product noncompliance against the regulations or standards in a country would affect customer orders in that market. To reduce such impacts, it is critical to enhance the frequency and extent of communication with customers. Obtaining timely information and possessing the ability to observe trends contributes to preparedness. Moreover, customer selection is essential for a company’s operations in multiple overseas countries. The situation of regulations and standards in a specific country needs to be examined before cooperating with customers in that country. United Nations Economic Commision for Europe (1998) suggested that the success of companies competing internationally generally depends on their familiarity with regulations and standards in the export markets. It is regarded as a dangerous path to export to a country without examining its regulations and standards (International Trade Centre, 2016). Export managers are considered to be essential in the export process in order to achieve compliance with standards and regulations. Ashkenas (2012) proposed five steps to increase information levels: focusing on key indicators, distinguishing opinions from facts, observing trends and patterns, periodically checking the environment, and using information as a basis for team dialogue. Export managers can employ these steps for a better understanding of relevant regulations and standards, then the noncompliance impact could be reduced.

The above strategies demonstrate the ways in which to mitigate various leverage risks. These risks are called leverage risks because less mitigation is needed to achieve the same goal. However, in this research, the selection of leverage risks only considers the mitigation level of risks, ignoring the mitigation cost. The mitigation cost is associated with the particular mitigation strategy. Each strategy has its specific cost, because of different resources needed in implementing strategies.

Although in practice, it would be ideal to reflect on both mitigation level of risks and the mitigation cost when identifying appropriate leverage risks (see Table 7.9). For example, "impact on collection" and "probability of product contamination" are with the same mitigation level. If the mitigation cost of the former risk (C15) is higher than that of the latter risk (C18), it is then more sensible to mitigate the latter risk. In another case, "impact on collection" and "probability of natural disasters" are with different mitigation levels, -10% and -30% respectively. If the mitigation cost of the former risk (C15) is far more than that of the latter risk (C13), "probability of natural disasters" would be the leverage risk instead of "impact on collection".

Table 7. 9 Leverage Risk Identification based on Scenario Analysis Results

Risk indicator	Mitigation level	Cost
Probability of contamination	0	C1
Impact on raw milk quality	-10%	C2
Probability of raw milk quality audit inaccuracy	0	C3
Impact on raw milk quality to the site	0	C4
Probability of adverse weather	-30%	C5
Impact on production	-20%	C6
Probability of human errors	0	C7
Probability of plant downtimes	-10%	C8
Probability of out of specifications	-20%	C9
Probability of raw material quality audit inaccuracy	0	C10
Impact on raw material quality	-20%	C11
Impact on raw material quality to the site	-30%	C12
Probability of natural disasters	-30%	C13
Process instability impact on processing	-20%	C14
Impact on collection	-10%	C15
Probability of wrong specification within process instability	0	C16
Specification impact on product quality	0	C17
Probability of product contamination	-10%	C18
Contamination impact on product quality	-30%	C19
Impact on quality to distribution	-20%	C20
Probability of product quality audit inaccuracy	0	C21
Quality impact factor on delivery time	0	C22
Accident impact on delivery time	0	C23
Probability of accident	-30%	C24
Technology innovations factor on price	-20%	C25
Technology innovations factor on order	0	C26
Pulse factor 2	-30%	C27
Pulse factor 4	-10%	C28
Probability of noncompliance	0	C29
Noncompliance impact	-10%	C30
Probability of economic conditions	0	C31
Economic conditions impact	0	C32
Basic probability of legal and political issues	-30%	C33
Legal and political issues impact	-20%	C34

8 Discussions and Conclusions

This chapter makes concluding remarks on the thesis, highlighting major research findings, discussions about research findings with extant literature, contributions made in this research, managerial implications, existing limitations, and avenues for possible future research.

8.1 Major findings

A literature review is intended "to provide a historical perspective of the respective research area and an in-depth account of independent research endeavours" (Mentzer & Kahn, 1995). A critical review was conducted in relevant fields, such as corruption, SCRM, and dairy SCRs. The research gap was identified about the impact of corruption on supply chains. This research proposes a conceptual framework to probe into this research topic. It illustrates the research procedure, and two research methods that were employed to explore how corruption modifies SCP and to develop management strategies. After establishing the interacted variables derived from empirical research, a SD model was constructed and simulated to explore how to effectively mitigate corruption's impact on SCP.

8.1.1 Summary of empirical findings

Different risks in the dairy supply chain have been discussed by researchers. However, there appears to be very little analysis of risk factors. It is essential to perform systemic analysis of risk events and risk factors in dairy supply chains. Dairy SCRs, especially the risk factors, are mentioned infrequently in the literature. In terms of dairy SCRs, researchers tend to focus on risks from farmers' point of view. For dairy commodity products, complex supply chains exist consisting of suppliers, the focal firm, and customers. This results in various risks which can impede normal operations. However, little literature focuses on risks from the perspective of an entire dairy supply chain.

This research presents the most frequently mentioned risks by interviewees. Exploring risk factors contributes to risk analysis. The hidden risk factors were explored by conducting multiple case studies in NZ, which is a major dairy producing and exporting country. Research findings were compared with current literature, and major risks and relevant risk factors were demonstrated. This research therefore expands studies on dairy SCRM.

Despite extensive research on corruption, there is a lack in the study of the impact of corruption on supply chains. A broad description of the impact of corruption on supply chains and necessary prevention measures was specified in guidelines such as United Nations Global

Compact (2010); however, no research has analysed the impact of corruption on supply chains in an exhaustive way. This research explores how corruption modifies the dairy supply chain, and extends corruption studies on supply chains. The risks caused by corruption were discussed in the industry context, thus providing insight for practitioners in the dairy industry.

Moreover, the identification of dairy SCR events, their risk factors, and the impact of corruption on risk effects is significant for constructing a systemic model. The dairy supply chain is a complex system; risks interfere with the supply chains, thus making the system even more complex. Corruption modifies the effects of dairy SCRs. Therefore, SD modelling was employed based on the identified interrelated variables.

8.1.2 Summary of modelling findings

This research fills the gap by studying corruption in dairy supply chains with a systemic view. Researches on corruption in both public and private sectors primarily focus on how to reduce the occurrence of corruption. This research is among the first to examine corruption's underlying impact on the whole supply chain, and explore the way of minimising corruption's impact on supply chains by defining, identifying, and mitigating leverage risks.

There are complex interactions among SCR variables and corruption. Such interaction is conveyed by a CLD. The diagram presents dairy supply chain operations with risks from a systemic perspective, and considers the impact of corruption on this system. Analysing the relationships among different variables helps investigate both direct and indirect impact of corruption on the entire supply chain. SD modelling assists in exploring corruption's modification of SCP through modifying the effects of SCRs. Various scenarios were formed based on the combination of risk mitigation and corruption levels. Scenario analysis results facilitate the formation of management strategies, which focus on leverage risks for effectively improving supply chain robustness in the presence of corruption. This is a novel approach in mitigating corruption risks, and could be an effective method for fighting corruption in other supply chains.

8.2 Discussions

This research addresses the need for analysing dairy SCRs in a new context. A comprehensive investigation of risk-related variables is significant for risk management. This research finds that dairy SCRs are primarily consistent with previous literature, however, the risk variables also have specific features in the context of a different country. No comprehensive analysis of dairy SCRs can be found in the context of NZ. According to Section 5.1, it would be significant and impactful to study NZ dairy supply chains. This research conducted multiple case studies in NZ dairy companies, and this serves as a contribution to exploring dairy SCRM in a new context. Concerns about the impacts resulting from different contexts of countries are consistent with Ameseder et al. (2009), Zhao et al. (2013), and Kauppi, Longoni, Caniato, and Kuula (2016), who paid attention to countries' impacts on SCRs.

This research contributes to the field of dairy SCRM in that, a systemic model has been developed and simulated to derive the underlying dynamics. Although there are abundant studies on SCRM, research on dairy SCRM is regarded as limited (Nasir et al., 2014). This research considers it essential to construct a systemic model for analysing risk interactions and managing risks within dairy supply chains. This is in line with Prakash et al. (2017) who suggested that mutual relationships among SCRs contribute to forming effective mitigation strategies. Interpretive Structural Modelling was applied to identify the critical risks for effective risk management. In their research, the simple causal relationships between risks can be identified, but the causality between relevant variables are not elaborated. Differing from Prakash et al. (2017), this research studies risk factors, risk events, and risk consequences in terms of elaborate indicators, and both risk variables and operational indicators are connected in a systemic way. An uncertain future environment can be simulated by predefining risk parameters such as risk probability. Risk mitigation strategies can be tested regarding their various impacts on SCP. SD modelling could help illustrate the interactions among interrelated variables. Both direct and indirect relationships can therefore be clearly demonstrated among the risk variables.

The SD approach was also underlined by scholars such as D. D. Wu, Xie, Liu, Zhao, and Olson (2010), and Q.-F. Wang, Ning, and You (2005), because of its advantage in analysing risk interactions through feedback loops. It is among the various approaches which are applied in the field of SCRM. Peng et al. (2014) employed this method in a disaster relief supply chain in an uncertain environment, in order to find suitable replenishment solutions. The uncertain post-disaster environment was described through different degrees of information delay and road conditions. Chaoyu Li et al. (2016) managed transportation risks in chemical supply chains by simulating a SD model. They summarised risks from extant literature, and defined variables in different equations to describe the risk-affected system. Furthermore, various risk scenarios can be formulated in terms of probability and impact severity, which contributes to identifying suitable mitigation strategies. To the best of my knowledge, no research focuses on SCRM in dairy supply chains by using SD modelling. Due to the approach's characteristic of describing interactions among variables in a system, this research adopts SD modelling in managing risks in dairy supply chains. Similar to Chaoyu Li et al. (2016)'s studies, this research also quantifies risks for describing the uncertain system and proposes mitigation strategies based on simulation analysis. By applying this method, the mutual relationships between risks can express the internal cause of the directions between risks, which indeed complement Prakash et al.'s research in terms of exploring risk relationships, and meanwhile deepens the understanding of dairy SCR interactions. In addition, the impact of risk interactions on SCP is revealed through the connection between risks and the operational loops. This research contributes to delving into the understanding of performance modification due to risk interference. The performance would be changed from f(A) to $f(A, R_1, R_2, \ldots, R_n)$. Here, A stands for operational indicators and f(A) is a function to represent the normal performance of the supply chain. R_n stands for various risks, and $f(A, R_1, R_2, \ldots, R_n)$ is a function showing the performance of the risk-affected supply chain. Furthermore, R_n could be modified to $f(R_n, C)$ in the presence of corruption, where C stands for corruption.

This research is novel in analysing corruption's impact on supply chains from the perspective of robustness, and also unique in examining corruption as a disruption in studying supply chain robustness. As discussed in Section 2.3, little extant literature about corruption in the private sector studies the detailed impacts of corruption, and few studies focus on corruption from the perspective of operations and supply chain management. Therefore, this research focuses on mitigating corruption's impact on supply chains, and the approaches to mitigate are enlightened by the concept of robustness. Corruption, a specific disruption to supply chains, has not been studied with regard to supply chain resilience. Stevenson and Busby (2015) expanded resilience studies in the field of operations management by including threats due to counterfeiting. Likewise, this research aims at expanding resilience research within operations and supply chain management, by incorporating the disruption of corruption. Nevertheless, based on the qualitative analysis of secondary data, Stevenson and Busby advised the strategies for enhancing supply chain resilience against counterfeit; meanwhile, the effectiveness of these strategies cannot be measured in their study. Sawik (2014) focused on a problem about robust decision making under disruptions, and attempted to equitably optimise the average-case performance and worst-case performance, in order to maintain good performance under various situations. An equitable solution was to be identified, which means the normalised objective function values are with the smallest gap. However, Sawik (2014) indicated that the equitably robust solutions were not generated due to the conflict of simultaneously maximising service level and minimising cost, which still depend on future research for exploration. In terms of my research, corruption is a risk factor for a supply chain. Mitigating corruption's impact on the supply chain is to maintain SCP under various corruption levels, and this refers to enhancing supply chain robustness against corruption. For each performance indicator, a robust supply chain would achieve the minimum performance difference under different levels of corruption. Different from Sawik (2014), this research does not focus on optimisation of performance, therefore seven performance indicators can be simultaneously considered. The researcher selects robust solutions by identifying the risk mitigation level, under which there is the highest number of the seven performance indicators achieving the minimum performance difference (see Table 7.7).

This research finds that mitigating leverage risks can effectively enhance supply chain robustness against corruption. This is in line with Wieland and Wallenburg (2012), who proposed that SCRM contributes to supply chain robustness. However, they studied the relationships among SCRM, supply chain agility and robustness, and SCP. Their research does not focus on aspects about strategies to improve robustness. To study supply chain robustness under uncertain circumstances, T. Yang et al. (2011) employed the Taguchi method to investigate the signal-to-noise ratios of two performance indicators for the various information-sharing strategies. Based on the ratios, the strategies are evaluated regarding the robustness of performance within uncertain circumstances. This thesis also attempts to identify suitable strategies for enhancing supply chain robustness. Different from T. Yang et al. (2011), this research aims at enhancing the robustness against an external uncertainty, rather than merely the robustness of supply chain. They focus on the whole structure of supply chain, while this research is novel in studying supply chain robustness through mediators, which are the factors acting between external uncertainties and internal performances. The uncertainty in this research is corruption, nevertheless, the robustness of performance in the presence of this uncertainty is not directly analysed under different strategies. The SD model is constructed to model corruption's moderated impact through supply chain risk interactions on SCP. Leverage risks are identified as the mediating factors that fundamentally affect supply chain robustness against corruption. Hereafter, mitigation strategies can be developed in the light of the identified leverage risks. This expands the theory of robustness by providing a new perspective in studying robustness.

In this research, robustness analysis against corruption is performed through a SD model, which presents risks from the perspective of an entire supply chain. In the face of supply chain disruptions, scholars focus on exploring various strategies to attain supply chain robustness. The robustness of SCP is with respect to the entire supply chain rather than a particular node or link. This is consistent with Kim, Chen, and Linderman (2015), and Han and Shin (2016), who highlighted the network structural view in studying network disruptions. Recognising the importance of the realistic uncertainties in a supply chain, Baghalian et al. (2013), and Jabbarzadeh et al. (2017), concurrently examined the uncertainties deriving from both supply and demand sides, although there are also uncertainties from other aspects. A new robustness approach was proposed by Jabbarzadeh et al. (2017), who paid attention to various SCRs and the interactions within a supply chain. However, in their mathematical model for studying robustness, the objective function is limited to cost minimisation, without considering other performance indicators. Numerous studies (e.g., Han and Shin (2016); Sawik (2014); Pan and Nagi (2010); Jabbarzadeh et al. (2017); and Baghalian et al. (2013)) employed mathematical modelling to analyse supply chain robustness. V. L. M. Spiegler (2013) indicated that nonlinearities naturally take place in supply chains, and summarised methods that can be used for analysing nonlinear systems. SD was justified in V. L. M. Spiegler (2013)'s research for its application in studying supply chain resilience. This author was concerned with the probable interactions among disruptions, and supports the proposition of analysing supply chain resilience with a system view. Although SD modelling has the characteristics of feedback loops and nonlinear relationships, it is only found applied in a limited number of studies about supply chain robustness. V. L. Spiegler, Naim, and Wikner (2012) applied SD modelling to explore supply chain resilience, however, they define robustness from the perspective of control engineering. Abdelkafi and Täuscher (2015) adopted this approach to delve into the aspects that affect business model robustness. However, computer simulation was not further conducted by Abdelkafi and Täuscher, which could improve robustness analysis. This research considers risks from the perspective of the entire supply chain by constructing a SD model. SCR interactions are presented in a whole system. Dynamics is further identified by simulating the model, which provides a quantitative basis for robustness analysis.

8.3 Managerial implications

In addition to the public sector, corruption is also pervasive in the private sector. Taking NZ as an example, it is ranked by Transparency International as having the least corrupt public sectors in 2016, together with Denmark. Deloitte Australia and NZ conducted a survey in enterprises within various sectors, and found that 20% of respondents experienced foreign corruption, and the same percentage for domestic corruption over the last five years (Deloitte, 2017). Corruption in the private sector could damage a company's reputation, profitability, and even consumer health. It is essential for business managers to pay attention to this particular issue. Huge costs are needed for a company to prevent corruption from taking place. The interviewees tend to mention direct anti-corruption measures when asked about fighting against supply chain corruption. As interviewee G1 indicated, they "could control and invest to reduce the risk of corruption within our supply chain", and can execute "physical controls on products, or containers, vehicles, as well as having strong contractual relationships". In this regard, a vast range of measures need to be taken for anti-corruption activities, which would be beneficial to reduce corruption regarding occurrence probability. However, this is evidently costly to carry out an overall prevention of corruption.

Despite such direct mitigation of corruption, this research proposes a method to proactively mitigate corruption's impact on SCP. It can significantly minimise corruption's impact, and at the same time enhance robustness of performance in the presence of corruption. This research is conducted in NZ dairy supply chains. Earlier descriptions have highlighted the significance of dairy industry for NZ, as well as the accompanying challenges. As a global dairy trader, the NZ dairy industry needs to concern both international variations and its domestic responsibility (N. M. Shadbolt & Apparao, 2016). N. Shadbolt et al. (2017) claimed that NZ's resilient dairy farming systems contributes to its advantageous dairy industry. To ensure the future robust and resilient farm systems, they developed four distinct but plausible scenarios, which were anticipated to contribute to designing such systems. The future environment is uncertain and volatile, and a company is exposed to various risks within the supply chains it belongs to. This research focuses on the disruption of corruption, which affects dairy supply chains through modifying the effect of SCRs. Although this study concerns the moderated impact of corruption (i.e., an external variable) and is different from designing a robust dairy farm system, it is meaningful to explore the supply chain robustness against corruption risk in NZ dairy industry, because of the international coverage of NZ dairy industry, the severity of corruption, and costly prevention performed in the current industry.

This research conducted semi-structured interviews to explore dairy SCRs. A variety of SCR events, their triggering factors, and risk consequences are examined in the NZ dairy industry. This contributes to the dairy industry by viewing SCR variables from a holistic perspective. Formulating the dairy supply chain system helps managers comprehend the complex interrelationships among risks and realise the interdependence between supply chain entities. The research findings could provide insightful implications for industrial practice. Following the conceptual framework in Figure 4.1, business managers could identify their SCRs, build their specific models, and develop corresponding strategies for fighting against supply chain corruption. As such, companies could allocate their resources in an effective way.

8.4 Contributions, limitations and future research directions

In recent years, research on corruption has been experiencing a transform, with its dominance changing from the public sector to both public and private sectors. Reports stress the necessity of fighting corruption in the private sector. Precautions and responses of corruption are discussed in reports, which highlight the high cost and low cost-effectiveness at the same time. Even though there are increasing concerns on corruption in the private sector, scientific researches are insufficient and immature in this field. Defining key terms helps avoid ambiguity, and is significant for following discussions (Naylor, Naim, & Berry, 1999). Despite rising concerns, no definitions about corruption in the private sector can be found. For the purpose of clarification and uniformity, this research defines supply chain corruption in Section 2.1.2. This contributes to the field of corruption in the private sector, as corruption in supply chains is dominated by private sector corruption.

Scarce research focuses on the view of operations and supply chain management (Arnold et al., 2012; Webb, 2016). This research investigates corruption from the perspective of supply chains, which is the first study to mitigate corruption's impact on SCP through SCR interactions. By using SD models, the interrelationships and underlying dynamics between corruption and supply chain variables are presented. Corruption is incorporated into the supply chain system by changing the effects of "impact on raw material price" and "probability of legal and political issues". By modifying the effects of SCRs, corruption modifies the SCP. This can be illustrated by Figures 3.1 and 3.4, which exhibits the way of interactions between corruption and supply chains. Further to the concept of "supply chain corruption", the researcher defines "corruption-associated risks in supply chains", i.e., corruption risks in this thesis. Interactions between corruption and supply chains are attained by corruption risks, which include indicators showing corruption's impact. These indicators are associated with the supply chain system. Hence, the values of the indicators experience modification in the presence of corruption. Accordingly, SCP is modified. This research contributes to the exploration of corruption in the field of supply chain operations.

After reviewing literature on SCRs, the researcher sorted risks in terms of risk types and risk factors systematically. The researcher employed Jüttner et al. (2003)'s way of dividing risks: environmental risks, network-related risks, and organisational risks. Risk factors elaborate probable risks within each type. This is beneficial for risk identification during case studies in this research. The tabular presentation of SCR types and risk factors contributes to comprehending SCRs. For managing SCRs, this research reviewed literature for each process such as risk identification, risk assessment, and risk control. Extant methods and tools are critically reviewed, with a summary in Section 2.2.4 revealing the gaps in SCRM. This research fills the gaps by combining case study research and SD modelling, and SCRM is studied from a systemic, integrated, and dynamic perspective in the dairy industry.

Research articles on supply chain robustness were reviewed from qualitative and quantitative perspectives, with qualitative research focusing on a conceptual view, and quantitative research focusing on a modelling view. Quantitative studies on supply chain robustness are reviewed in terms of various purposes such as network design and decision making. The reviews assist in comprehending supply chain robustness and its application.

This research reviewed extant studies on dairy SCRs and the risk management. The researcher suggested that not much literature on dairy risks focuses on an entire supply chain. Interconnections between SCRs indicate risk propagation among SCP. Thus, systemic analysis would be beneficial for risk management in dairy supply chains. In this research, an empirical study explores dairy risks throughout the entire supply chain. Empirical findings show that risk events and their risk factors are generally mentioned in scattered literature. The primary risks such as raw milk quality risk, raw milk volume risk, and customer order risk can be identified in different studies, except for raw material quality risk. The extant research concerns raw milk quality risk, while ignoring the quality risk of raw materials to manufacture dairy products. Risk factors of a particular risk event vary in different contexts. Similarities and differences between the risk factors are discussed in Section 6.4. This research delves into the NZ dairy industry, and explores dairy risks with a view of entire supply chains. On this basis, risk-related variables are connected within the supply chain system, thus contributing to a holistic understanding.

This study introduces a novel method of examining supply chain corruption by means of the concept "supply chain robustness". As a potential disruption, corruption in supply chains needs to be prevented from occurrence with a long-term view. However, it is expensive and low cost-effective for businesses to carry out preventive measures. This research explores the alternative way to proactively manage potential corruption, and proposes measures to minimise corruption's impact if corruption disrupts supply chains. Measures are developed by considering supply chain robustness against corruption. The principle of achieving minimum corruption's impact is to effectively enhance supply chain robustness in the presence of corruption. In seeking strategies for maximum robustness, the leverage risk is defined and identified for effectively mitigate corruption's impact on supply chains. In the research, risks such as raw milk quality risk, process stability risk, and raw milk volume risk are recognised as leverage risks, by mitigating which the SCP could achieve the least variation in the presence of corruption. This expands the body of knowledge in the field of supply chain corruption. Furthermore, this was theoretically validated by an interviewee, who suggested that "corruption's impact will be large if it came through", and accepted the idea that the effects of several risks would be different from others in mitigating corruption's impact on SCP.

A dairy supply chain is a system in itself, which shows its operations and performance. This research incorporates corruption in the study of dairy SCRs, constituting a holistic system. Probabilities or impacts of SCRs, which are affected by corruption, act as the connections between dairy supply chains and corruption. The quantification of variables facilitates model simulation, and corruption's impact can be simulated and tested in different scenarios without altering the real system. Among the various adjustable risks, it would be efficient and effective to identify and manage leverage risks for mitigating corruption's impact on supply chains. Mitigation strategies have been developed in accordance with leverage risks. This could serve as a useful tool for practitioners in fighting potential corruption in their supply chains. The identified leverage risks could vary in terms of different supply chains or industries, however, the approach can be applied in various contexts to gain corresponding insights.

Despite these contributions made in relevant fields, some limitations need to be elaborated in this research.

First, the case study research is focused on dairy supply chains. This is only a specific supply chain, and the research findings cannot be generalised to other industries. However, the modelling ideas and rationale of analysis contribute to research on corruption in the supply chain context.

Second, limited dairy companies participated in this research. There is a fairly small number of dairy companies, and only a handful of companies that are highly engaged in the NZ dairy industry. The researcher could not gather enough data for qualitative analysis, which may restrict the understanding of this supply chain. This would be more compelling with a larger number of interviewed companies.

Third, case study samples do not cover the whole dairy supply chain. The researcher tried hard to collect data from various organisations throughout the supply chain. However, because of practical restrictions as described in Section 5.2, the researcher ultimately collected data from focal firms rather than suppliers and customers. Although the interviewees are mainly high level managers with a comprehensive view, it would be more valuable to interview people from different nodes of the supply chain.

Fourth, due to the nature of sensitivity, corruption risks were obtained by enquiring the perceptions of interviewees. Moreover, this research gained perceptions from interviewees in NZ, which is perceived to be among the least corrupt countries. It would be more enlightening if the researchers could gain access to companies in other countries and explore perceptions from those participants.

Fifth, supply chain corruption remains a nascent field, and this study acts as a novel first cut in this field. Further polishing the models by collecting additional data would contribute to obtaining insightful findings with regard to supply chain robustness against corruption.

Last, the proposed model could be further refined for better simulation of actual situations. For example, risk consequences can be catastrophic, however, expected values are utilised rather than presenting a variety of seriousness of risk events. Meanwhile, two corruption levels were selected to represent low and high corruption levels for simplicity. There could have been great number of scenarios by simultaneously adjusting several risk indicators rather than one. However, they were not performed due to the time restriction of this research project.

The study is limited to the NZ dairy industry. Hence, further research would be beneficial by applying the research ideas to other cultures/contexts, in order to gain a broader understanding of corruption risks in supply chains. In addition, different corruption levels can be simulated to gain better insight.

8.5 Conclusions

The research project focuses on mitigating SCRs to effectively enhance supply chain robustness against corruption. In the process of finding answers to the research questions, the researcher reviewed vast relevant literature for a solid foundation, conducted semi-structured interviews for gaining insights from industrial practitioners, and built SD models for systemic analysis.

The NZ dairy industry was investigated to explore this research topic from both theoretical and practical perspectives. Case study research was conducted to examine SCRs, and corruption's impact on risk effects and further on SCP. The empirical findings contribute to analysing dairy SCRs with a systemic view, and this extends the extant research on dairy SCRM. Furthermore, this is the first research that considers corruption as a disruption to existing SCRs, and studies corruption's modification of SCR effects.

SD models contribute to conveying risk interactions, and exploring underlying dynamics within the corruption-affected system. This research is unique in delving into corruption risks with a system view, which enables the analysis of both direct and indirect impact throughout the supply chain. In addition, strategies to mitigate corruption's impact are studied from the perspective of supply chain robustness. The researcher proposes the concept of the leverage risk, which could assist in managing corruption risks effectively. Instead of mitigating direct impacts that corruption causes, this research uses a novel approach for managing corruption risks - identifying and mitigating leverage risks to indirectly mitigate corruption's impact, by utilising interactions among SCRs. However, at this stage we do not have a method to identify them directly from what we know from the literature or the logical causal connections. In future studies, we could use the handle for any leverage risk to change the level and see whether the predicted robustness is achieved.

Appendix A – Participant Information Sheet

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Auckland, New Zealand

PARTICIPANT INFORMATION SHEET – FOCAL FIRM CEO

Project title: Measures to Safeguard Supply Chains against Risk Due to Corruption

Name of Researcher: Xiaojing Liu

Researcher Introduction

My name is Xiaojing Liu. I am a PhD candidate in the Department of Information Systems and Operations Management, Business School, the University of Auckland, New Zealand. The Principal Investigator is my supervisor, Associate Professor Tiru Arthanari in the Department of Information Systems and Operations Management, Business School, the University of Auckland.

Project description and invitation

My research topic is "Measures to Safeguard Supply Chains against Risk Due to Corruption". A company is a link of a whole supply chain and operates with different supply chain risks. Corruption in the supply chain mainly refers to commercial bribery, and private-public corruption constitutes only a small part. This can bring more or less loss to companies. I am not aiming at inspecting any corruption situation in any of the studied companies. No issues or stories of corruption within the companies you have worked for should be raised. Your perception on the interrelationships between various possible factors will be very valuable for this project. A simulation model will be used to discover the underlying relationships, which I expect to find in this research. I am asking your permission to invite your employees to participate in this project. It would be much appreciated if you can also participate!

Project Procedures

I am planning to conduct less than five semi-structured interviews. The interviewees will be relevant department managers, high level managers, as well as some employees. Each interview will take about 30 to 60 minutes. I will make an appointment with them to arrange an interview, in order to make the suitable time and place. The interviews will be audio-taped if permitted by them. If they feel uncomfortable when being taped, they can ask to turn off the tape at any time without any reason. If participants are hesitant to talk about their perception relevant to supply chain corruption, I can explain to them that all I need is their perception on different risk factors. Their identity will only be known to the researcher. This confidentiality will be maintained in all circumstances. We seek your assurance that the participation or non-participation of your employees will not affect their employment status.

Data storage/retention/destruction/future use

The printed data will be stored in a locked cabinet. The electronic data will be kept in the computer of the University of Auckland. All data will be kept by the principal investigator in the university for six years. The audio-tape data will be analysed regarding the important interview information, which will contribute to the future model construction. The research findings will be written up in my doctoral thesis. Besides, they will be prepared for a journal paper or conference paper. Participants will be offered the opportunity to receive a copy of their recordings within two months if they request. After six years, all the data will be destroyed. The electronic data will be deleted and the paper materials will be destroyed by using a paper shredder.

Right to Withdraw from Participation

The participation in this research is voluntary, and they are entitled to withdraw from involvement in the research project at any stage without explanation. They can withdraw the information they provided within one month after the interview.

Anonymity and Confidentiality

The information from interviews will be published in my PhD thesis, journal papers or conference proceedings. The publication of the research findings can be provided to you and participants if you wish to receive a copy. In addition, their identity will not be made public, and the researcher and those who read the published results cannot identify the specific participants.

If you agree them to participate in my research project, please fill in the consent form. Thanks so much for your support! If you have any queries, please do not hesitate to contact me.

Contact Details and Approval Wording

My contact details: Xiaojing Liu, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 373 7599. Email: xiaojing.liu@auckland.ac.nz.

Contact details for my supervisor and Head of Department, and the University of Auckland Human Participants Ethics Committee are as follows.

Supervisor's contact details: Associate Professor Tiru Arthanari, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 923 4857. Email: t.arthanari@auckland.ac.nz.

Head of Department's contact details: Professor Michael Myers, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 923 7468. Email: m.myers@auckland.ac.nz.

For any queries regarding ethical concerns you may contact:

The Chair, The University of Auckland Human Participants Ethics Committee, The University of Auckland, Research Office, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 373 7599 extn. 83711. Email: ro-ethics@auckland.ac.nz.

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON ……27/05/2015…… for (3) years, Reference Number …..013460……

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Auckland, New Zealand

PARTICIPANT INFORMATION SHEET – FOCAL FIRM EMPLOYEES

Project title: Measures to Safeguard Supply Chains against Risk Due to Corruption

Name of Researcher: Xiaojing Liu

Researcher Introduction

My name is Xiaojing Liu. I am a PhD candidate in the Department of Information Systems and Operations Management, Business School, the University of Auckland, New Zealand. The Principal Investigator is my supervisor, Associate Professor Tiru Arthanari in the Department of Information Systems and Operations Management, Business School, the University of Auckland.

Project description and invitation

My research topic is "Measures to Safeguard Supply Chains against Risk Due to Corruption". A company is a link of a whole supply chain and operates with different supply chain risks. Corruption in the supply chain mainly refers to commercial bribery, and private-public corruption constitutes only a small part. This can bring more or less loss to companies. I am not aiming at inspecting any corruption situation in any of the studied companies. No issues or stories of corruption within the companies you have worked for should be raised. Your perception on the interrelationships between various possible factors will be very valuable for this project. A simulation model will be used to discover the underlying relationships, which I expect to find in this research. I am inviting you to participate in this project. It would be much appreciated if you can!

Project Procedures

I am planning to conduct less than five semi-structured interviews. The interviewees will be relevant department managers, high level managers, as well as some employees. Each interview will take about 30 to 60 minutes. I will make an appointment with you to arrange an interview, in order to make the suitable time and place. The interviews will be audio-taped if permitted by you. If you feel uncomfortable when being taped, you can ask to turn off the tape at any time without any reason. You may be hesitant to talk about your perception relevant to supply chain corruption, I can explain to you that all I need is your perception on different risk factors. Your identity will only be known to the researcher. This confidentiality will be maintained in all circumstances. Your CEO has given assurance that your participation or non-participation will not affect your employment status.

Data storage/retention/destruction/future use

The printed data will be stored in a locked cabinet. The electronic data will be kept in the computer of the University of Auckland. All data will be kept by the principal investigator in the university for six years. The audio-tape data will be analysed regarding the important interview information, which will contribute to the future model construction. The research findings will be written up in my doctoral thesis. Besides, they will be prepared for a journal paper or conference paper. You will be offered the opportunity to receive a copy of your recordings within two months if you request. After six years, all the data will be destroyed. The electronic data will be deleted and the paper materials will be destroyed by using a paper shredder.

Right to Withdraw from Participation

The participation in this research is voluntary, and you are entitled to withdraw from involvement in the research project at any stage without explanation. You can withdraw the information you provided within one month after the interview.

Anonymity and Confidentiality

The information from interviews will be published in my PhD thesis, journal papers or conference proceedings. The publication of the research findings can be provided to you if you wish to receive a copy. In addition, your identity will not be made public, and the researcher and those who read the published results cannot identify the specific participants.

If you agree to participate in my research project, please fill in the consent form. Thanks so much for your support! If you have any queries, please do not hesitate to contact me.

Contact Details and Approval Wording

My contact details: Xiaojing Liu, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 373 7599. Email: xiaojing.liu@auckland.ac.nz.

Contact details for my supervisor and Head of Department, and the University of Auckland Human Participants Ethics Committee are as follows.

Supervisor's contact details: Associate Professor Tiru Arthanari, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 923 4857. Email: t.arthanari@auckland.ac.nz.

Head of Department's contact details: Professor Michael Myers, Department of Information Systems and Operations Management, Business School, the University of Auckland, Private Bag 92019, Auckland 1142. Telephone: (+64) 9 923 7468. Email: m.myers@auckland.ac.nz.

For any queries regarding ethical concerns you may contact:

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Appendix B – Consent Form

THE UNIVERSITY OF AUCKLAND
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Auckland, New Zealand

CONSENT FORM – FOCAL FIRM CEO
THIS FORM WILL BE HELD FOR A PERIOD OF 6 YEARS

Project title: Measures to Safeguard Supply Chains against Risk Due to Corruption
Name of Researcher: Xiaojing Liu
Email address: xiaojing.liu@auckland.ac.nz

I have read the Participant Information Sheet, have understood the nature of the research and why I have been selected. I have had the opportunity to ask questions and have them answered to my satisfaction.

- I agree for my employees to participate.
- I agree/disagree to participate.
- I confirm that the employee's participation or non-participation will not affect their employment status.
- I understand that the participants are entitled to withdraw from involvement in the research project at any stage without explanation, and they can withdraw the information they provided within one month after the interview.
- I understand that the interviews will be audio-taped and take about 30 to 60 minutes, and participants can ask to turn off the tape without any reason.
- I understand that the participants will be offered the opportunity to receive a copy of their recordings within two months if they request.
- I understand that all data will be kept in a secure manner by the principal investigator in the university. After six years, all the data will be destroyed.

- I understand that the information from interviews will be published in a PhD thesis and academic publications.
- I wish/do not wish to receive a copy of the publication of the research findings.
- I know that the copy of the publication of the research findings can be requested from Miss Xiaojing Liu.
- I understand that the identity of my company and the participants will not be revealed in the publications.

Name of company: …………………………………

Name of participant: ……………………………….

Signature: ………………………………………….   Date: ………………………………...

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON ……27/05/2015…… for (3) years, Reference Number …..013460……

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CONSENT FORM – FOCAL FIRM EMPLOYEES
THIS FORM WILL BE HELD FOR A PERIOD OF 6 YEARS

Project title: Measures to Safeguard Supply Chains against Risk Due to Corruption
Name of Researcher: Xiaojing Liu
Email address: xiaojing.liu@auckland.ac.nz

I have read the Participant Information Sheet, have understood the nature of the research and why I have been selected. I have had the opportunity to ask questions and have them answered to my satisfaction.

- I agree to take part in this research. I also understand that I am entitled to withdraw from involvement in the research project at any stage without explanation, and I can withdraw the information I provided within one month after the interview.
- I understand that my employer has given assurance that my participation or non-participation will not affect my employment status.
- I understand that the interview will be audio-taped and take about 30 to 60 minutes, and I can ask to turn off the tape without any reason.
- I understand that I will be offered the opportunity to receive a copy of my recordings within two months if I request.
- I understand that all data will be kept by the principal investigator in a secure manner within the university. After six years, all the data will be destroyed.
- I understand that the information from interviews will be published in a PhD thesis and academic publications.
- I wish/do not wish to receive a copy of the publication of the research findings.

- I know that the copy of the publication of the research findings can be requested from Miss Xiaojing Liu.
- I understand that the identity of the company and myself will not be revealed in the publications.

Name of company: …………………………

Name of participant: ……………………… Email address: …………………………...

Signature: ………………………………… Date: ………………………………..........

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE ON ……27/05/2015…… for (3) years, Reference Number …..013460……

Appendix C – Interview Questions

The part of supply:

1. How much raw milk is produced every day? Is there any risk that they cannot deliver enough milk?

2. What is the production cost? How will production cost be affected?

3. What is raw milk volumes coverage? What is raw milk adjustment time?

4. What is the collection cost? How will collection cost be affected?

5. What risks do you think mainly exist in the farm level and procurement level?

6. Is there any risk about the delivery delay from the farm?

7. What is the risk of quality of raw milk?

8. What is the risk of milk solids price?

9. What are the risks in procuring other raw materials?

10. Among the risks we talked about just now, what do you think corruption will affect (the change of both probability and probable impact)?

The part of manufacturing:

11. How much raw milk is processed and delivered every day?

12. What is the processing cost? How will processing cost be affected?

13. What is the dairy product inventory? What is the dairy product inventory coverage? What is the inventory adjustment time?

14. What risks do you think exist in the processing level?

15. What is the risk of dairy product quality?

16. What is the risk of dairy product price?

17. What is the risk of process stability?

18. What is the risk of delivery delay from the plant?

19. What is the risk of information asymmetry?

20. Among the risks we talked about just now, what do you think corruption will affect (the change of both probability and probable impact)?

The part of demand:

21. What is the customer's inventory? What is the customer's inventory coverage? What is the inventory adjustment time?

22. What is sales rate? How about customer order fulfilment ratio? What is customer order forecast accuracy?

23. What risks do you think exist in the sales level?

24. What is the risk of customer order fluctuation?

25. Among the risks we talked about just now, what do you think corruption will affect (the change of both probability and probable impact)?

Appendix D – Thematic Analysis Results

Themes	Sub-themes	Codes
Raw milk delivery time	External disruption	Natural disasters and road closures
	Internal disruption	Farmers delay milking, Full silo
	Capacity improvement	Extra tankers or silo space
Collection cost	Resource expense variation	Diesel cost in transportation, Raw milk volume
Raw material delivery time	Supplier disruption	Labour strike, Suppliers have a number of different distribution schedules, Hard to meet the tight specification levels, Natural disasters, Limited manufacturers for some ingredients
	Shipping disruption	Shipping schedules change
	Backup for raw material supply	Increase inventory coverage, Backup suppliers
	Collaboration	Send suppliers the forecast
Product delivery time	External disturbance	Accident, Government regulations
	Internal disturbance	Product quality
	Preparations	Inventory, Use flight to catch up, Be familiar with government regulations in export countries
Product delivery cost	Logistics fluctuation	Shipping availability
Raw milk quality	Contamination	Bacteria, Disease, Chemicals, Seasonal conditions of cows
	Inspection error	Raw milk quality audit inaccuracy
	Plant action	Quality audit, Product selection
	Farm action	Milk chilling in farm vats, Restrictions on holding times
Milk solids price	Global market variation	International supply and demand
	Company financial variation	Budget to farmers, Previous payments in last several months
	Natural factors	Season, Regional effect on protein and fat levels
Raw milk volume	Natural environment	Weather
	Global problem	Worldwide shortage of goat and sheep milk
	Rational use of raw milk	Wet processing, Plan well in advance
Raw material price	Global market fluctuation	International supply and demand, Dairy product price

Raw material quality	Raw material composition	Out of specifications
	Plant action	Quality audit of raw materials, Supplier selection
Processing cost	Resource variation	Cost of assets, Utilisation of the plant, Milk volume, Labour expense
Process stability	Internal fault	Plant downtimes, Human errors
	External fault	Procurement of raw milk and raw materials
	Flexibility	Investment in more dryers, Cooperation with other dairy companies
Product quality	Product quality disruption	Contamination from any part of the process, Raw material quality, Product specification, Operational issues
	Backup plans	Downgrade, Inventory
Product price	Global demand fluctuation	International supply and demand, Weather
	Product category	Better product
Information symmetry	Information incompleteness	Lack of upgraded system
Customer order	Macro environment changes	Economic conditions, Legal and political issues
	Product feature variation	Technology innovations, Compliance required by export countries
	Natural environment	Weather
	Market assessment	Overseas market assessment, Reduce proportion of higher risk countries
	Inventory amount	Inventory held by customers

Appendix E – Main Equations in the Model

1. Main equations for the operational process

(1) Raw milk collection (t) = Raw milk collection (t - dt) + (Rate of milk collection - Rate of milk processing - Rate of unused raw milk) * dt

INIT Raw milk collection = 0

Units: lbs

The rate of unused raw milk stands for the volume of collected raw milk which does not participate in the production in each simulation run. The volume of milk processed is supposed to be determined under the strategy of make to order.

(2) Dairy product inventory (t) = Dairy product inventory (t - dt) + (Rate of processing - Rate of delivery - Rate of scrapping) * dt

INIT Dairy product inventory = 35000000

Units: lbs

This shows the change of dairy product inventory.

(3) Expected order (t) = Expected order (t - dt) + Rate of change in expected order * dt

INIT Expected order = 4160000

Units: lbs/wk

The expected order is used to forecast customer orders for each week. This stock presents the adjustment of this forecasted value.

(4) Profit (t) = Profit (t - dt) + (Rate of revenue - Rate of cost) * dt

INIT Profit = 40000000

Units: USD

The stock shows the accumulated profit.

(5) Rate of milk processing = Rate of processing * 14

Units: lbs/wk

The volume of dairy products is transformed to raw milk volume. The value of this transformation is calculated by using data from various interviewed companies.

(6) Desired dairy product inventory = Expected order * Dairy product inventory coverage

Units: lbs

The desired inventory level is determined by the forecasted order and inventory coverage.

(7) Adjustment for dairy product inventory = (Desired dairy product inventory - Dairy product inventory) / Dairy product inventory adjustment time

Units: lbs/wk

The inventory is adjusted according to the difference between desired and current inventory levels. The volume of adjustment per week depends on the time needed to get the products ready.

(8) Desired production = MAX (0, Adjustment for dairy product inventory + Expected order)

Units: lbs/wk

The desired production consists of two parts: adjustment for the inventory and expected order. This value cannot be non-negative. The negative value means there is more inventory than needed. The desired production has to be 0 rather than a negative value, as the extra inventory can be adjusted automatically in the next simulation run.

2. Main equations for risks affecting supply chain operations

(1) Quality of raw milk to the site = (1 - Occurrence of raw milk quality audit inaccuracy) * Best raw milk quality + Occurrence of raw milk quality audit inaccuracy * Raw milk quality / ((1 - Impact on raw milk quality to the site) * Raw milk quality + Impact on raw milk quality to the site)

Units: Unitless

This indicator shows the ultimate percentage of qualified raw milk which enters the plant. It is valued at 1 when the quality audit is correct, and the poor quality milk is filtered by the audit. When there is quality audit inaccuracy, impact on raw milk quality to the site reflects the percentage of milk that is affected. The total volume of milk that passes the quality audit is "(1 - Impact on raw milk quality to the site) * Raw milk quality + Impact on raw milk quality to the site". Among the milk, the volume with good quality equals "Raw milk quality". Therefore, the equation to calculate "Quality of raw milk to the site" is derived.

(2) Milk from other companies = IF Desired milk from other companies >= 200000 THEN Desired milk from other companies ELSE 0

Units: lbs/wk

In case of milk shortage, raw milk is assumed to be fulfilled by other companies when the volume needed is above a certain level.

(3) Desired milk from other companies = MAX (Desired milk - Rate of collection, 0)

Units: lbs/wk

This shows how much milk is needed from other companies when milk supply cannot satisfy the dairy company's demand.

(4) Milk solids price (t) = Milk solids price (t - dt) + Rate of change in milk solids price * dt

INITIAL (Milk solids price) = 2.5

Units: USD/lbs

This stock displays the established price of milk solids.

(5) Rate of change in milk solids price = Milk solids price * International dairy product supply and demand fluctuation impact

Units: USD/lbs-wk

The change of milk solids prices accompanies the international dairy product supply and demand fluctuation.

(6) International dairy product supply and demand fluctuation impact = 0 + PULSE (Pulse factor 2, Pulse factor 1, Pulse factor 1) + PULSE (Pulse factor 4, Pulse factor 3, Pulse factor 3)

Units: 1/wk

This function is estimated based on participants' description and the changing tendency of international dairy price.

(7) Pulse factor 1 = 2

Units: weeks

(8) Pulse factor 2 = 0.01

Units: Unitless

(9) Pulse factor 3 = 52

Units: weeks

(10) Pulse factor 4 = -0.31

Units: Unitless

The values of Pulse factor 1, Pulse factor 2, Pulse factor 3, and Pulse factor 4 are estimated to reflect the perceptions of interviewees and the changing tendency of international dairy price.

(11) Delivery cost = Unit delivery cost * (Rate of production + Milk from other companies) * 0.13

Units: USD per week

Raw milk collected from both the farm and other companies contributes to the milk delivery cost. The parameter 0.13 is based on the study of Jacobson (1992), and it stands for the percentage of milk solids in milk.

(12) Rate of production = Normal production * ((1 - Occurrence of raw milk quality audit inaccuracy) * Raw milk quality + Occurrence of raw milk quality audit inaccuracy * ((1 - Impact on raw milk quality to the site) * Raw milk quality + Impact on raw milk quality to the site)) * (1 - Occurrence of adverse weather * Impact on production)

Units: lbs/wk

The “Rate of production” means the volume of raw milk which passes the driver’s quality audit. This takes the quality audit inaccuracy risk into consideration. When the quality audit is accurate, the percentage of milk equals “Raw milk quality”. When there exists quality audit inaccuracy, the percentage of milk consists of two parts: milk unaffected by quality audit inaccuracy (equals “(1 - Impact on raw milk quality to the site) * Raw milk quality”), and milk affected by quality audit inaccuracy (equals “Impact on raw milk quality to the site”).

(13) Rate of milk collection = Rate of collection + Milk from other companies

Units: lbs/wk

Milk is collected from two sources: regular collection (dominant), and milk from other companies (rare).

(14) Rate of collection = Rate of production * (1 - Occurrence of natural disasters * Impact on collection)

Units: lbs/wk

“Rate of collection” refers to the volume of milk which is successfully delivered to the processing plant per unit of time.

(15) Quality of raw material to the site = (1 - Occurrence of raw material quality audit inaccuracy) * Best raw material quality + Occurrence of raw material quality audit inaccuracy * Raw material quality / ((1 - Impact on raw material quality to the site) * Raw material quality + Impact on raw material quality to the site)

Units: Unitless

This means the ultimate percentage of qualified raw materials which enter the processing plant. The calculation process is similar to “Quality of raw milk to the site”.

(16) Best raw material quality = 1

Units: Unitless

This means that raw materials are all qualified.

(17) Raw material quality = Best raw material quality - Occurrence of poor raw material quality * Impact on raw material quality

Units: Unitless

Raw material quality is expressed by simulating the occurrence of poor quality.

(18) Product quality = Quality of raw milk to the site * Quality of raw material to the site * (Best product quality - Occurrence of product contamination * Contamination impact on product quality - Occurrence of wrong product specification * Specification impact on product quality)

Units: Unitless

Product quality depends on the quality of raw milk and raw materials, and is also affected by the manufacturing process.

(19) Quality of product to distribution = (1 - Occurrence of product quality audit inaccuracy) * Best product quality + Occurrence of product quality audit inaccuracy * Product quality / ((1 - Impact on quality to distribution) * Product quality + Impact on quality to distribution)

Units: Unitless

This stands for the ultimate percentage of qualified products which are delivered to customers. The calculation process is similar to “Quality of raw milk to the site”.

(20) Product delivery time = Normal delivery time + Quality impact on delivery time + Occurrence of product delivery delay * Accident impact on delivery time

Units: weeks

This shows factors contributing to the eventual product delivery time.

(21) Rate of processing = (Desired production - (Desired milk from other companies - Milk from other companies) / 14) * (1 - Occurrence of process instability * (1 - Occurrence of wrong product specification) * Process instability impact on processing)

Units: lbs/wk

Milk can be procured from other companies only when the volume is over a specific level. Therefore, processed milk would be desired production minus the unfulfilled part. Moreover, in the case of process instability, if there is no occurrence of wrong product specification, processed milk volume will be deducted by the volume of milk affected by process instability. If there is occurrence of wrong product specification, the volume of processed milk will not be affected because the products could be downgraded. The parameter 14 refers to the conversion ratio between milk volume and dairy product volume. This value is calculated and assumed based on data from various dairy companies.

(22) Occurrence of wrong product specification = Occurrence of process instability * (IF (Random number 15 > Probability of wrong specification within process instability) THEN Constant 1 ELSE Constant 2)

Units: Unitless

Under the premise of process instability, the occurrence of wrong product specification depends on the probability of wrong specification within process instability.

(23) Constant 1 = 0

Units: Unitless

This represents that when the random number is out of the range of probability of wrong specification within process instability, occurrence of wrong product specification equals 0.

(24) Constant 2 = 1

Units: Unitless

This represents that when the random number is within the range of probability of wrong specification within process instability, occurrence of wrong product specification equals occurrence of process instability.

(25) Occurrence of process instability = IF (Random number 1 > Probability of process instability occurrence) THEN 0 ELSE 1

Units: Unitless

This equation reflects how the occurrence of process instability risk is expressed through the probability of process instability occurrence.

(26) Random number 1 = RANDOM (0, 1)

Units: Unitless

This generates a random number varying from 0 to 1.

(27) Probability of process instability occurrence = 1 - (1 - Probability of human errors) * (1 - Probability of plant downtimes)

Units: Unitless

The probability of process instability occurrence is calculated based on probability of human errors and probability of plant downtimes. This equation shows that process instability risk occurs when at least one risk factor occurs.

(28) Rate of scrapping = Rate of processing * ((1 - Occurrence of product quality audit inaccuracy) * (1 - Product quality) + Occurrence of product quality audit inaccuracy * ((1 - Impact on quality to distribution) * (1 - Product quality))) * Scrap rate

Units: lbs/wk

When there is no audit inaccuracy, the identified percentage of products with poor quality is “Impact on quality to distribution * (1 - Product quality) + (1 - Impact on quality to distribution) * (1 - Product quality”, which equals “1 - Product quality”. When there is audit inaccuracy, the identified percentage of products with poor quality is “(1 - Impact on quality to distribution) * (1 - Product quality)”. Therefore, the identified percentage of products with poor quality equals “(1 - Occurrence of product quality audit inaccuracy) * (1 - Product quality) + Occurrence of product quality audit inaccuracy * ((1 - Impact on quality to distribution) * (1 - Product quality))”.

(29) Scrap rate = Occurrence of wrong product specification * Specification rate + (1 - Occurrence of wrong product specification) * Normal rate

Units: Unitless

The scrap rate depends on whether wrong product specification occurs or not. If there is wrong product specification, there is no need to dispose all the products because some products can be downgraded. Two different rates are employed in the equation, which are specification rate and normal rate respectively.

(30) Rate of delivery = MIN (Dairy product inventory/Product delivery time, Customer order)

Units: lbs/wk

The number of delivery per unit of time depends not only on the customer order, but also the inventory.

(31) Product price (t) = Product price (t - dt) + Rate of change in product price * dt

Units: USD/lbs

This shows the stock of product price. In this model, the price is calculated based on the price in the previous simulation run, that is, Product price (t - dt).

(32) Rate of change in product price = Product price * (International dairy product supply and demand fluctuation impact + Occurrence of technology innovations * Technology innovations impact on product price)

Units: USD/lbs-wk

The dairy product is a commodity product, therefore its price fluctuation depends on the international supply and demand. Besides, for a particular dairy product, the price is also affected by its technology innovations situation.

(33) Technology innovations impact on product price = Technology innovations factor on price * (1 + 0.4 * Profit impact on technology innovations)

Units: 1/wk

This equation assumes the parameter values to calculate technology innovations impact on product price. These parameters are assumed based on the reality to present the different impact values.

(34) Profit impact on technology innovations = Look up table (Profit)

Look up table ([(0, 0) - (5e+008, 0.070)], (0, 0), (5e+007, 0.010), (1e+008, 0.025), (1.5e+008, 0.030), (2e+008, 0.035), (2.5e+008, 0.045), (3e+008, 0.050), (3.5e+008, 0.055), (4e+008, 0.060), (4.5e+008, 0.065), (5e+008, 0.070))

Units: Unitless

This table function is used to describe the nonlinear relationship between profit and its impact on technology innovations, and such relationship is estimated to reflect the perceptions of interviewees.

(35) Product price impact on customer order = Look up table (Product price situation)

Look up table ([(-10, 0.190) - (10, -0.190)], (-10, 0.190), (-8, 0.180), (-6, 0.150), (-4, 0.080), (-2, 0.040), (0, 0), (2, -0.040), (4, -0.080), (6, -0.150), (8, -0.180), (10, -0.190))

Units: Unitless

This table function is used to describe the nonlinear relationship between two variables, and such relationship is estimated to reflect the perceptions of interviewees. The variable “Product price situation” is used to show the difference between product price and the initial product price. “Product price impact on customer order” varies along with the product price situation.

(36) Customer order = MAX (0, Normal customer order * (1 - Occurrence of noncompliance * Noncompliance impact - Occurrence of economic conditions * Economic conditions impact - Occurrence of legal and political issues * Legal and political issues impact + Occurrence of technology innovations * Technology innovations impact on customer order + Product price impact on customer order))

Units: lbs/wk

Customer order is set to be non-negative. It is assumed to be affected by various factors.

(37) Technology innovations impact on customer order = Technology innovations factor on order * (1 + 0.2 * Profit impact on technology innovations)

Units: Unitless

This equation assumes the parameter values to calculate technology innovations impact on customer order. These parameters are assumed based on the reality to present the different impact values.

(38) Occurrence of legal and political issues = IF (Random number 14 > Probability of legal and political issues) THEN 0 ELSE 1

Units: Unitless

This equation reflects how the occurrence of legal and political issues is expressed through the probability of legal and political issues.

(39) Random number 14 = RANDOM (0, 1)

Units: Unitless

This generates a random number varying from 0 to 1.

(40) Probability of legal and political issues = Basic probability of legal and political issues * (1 + Corruption impact on probability of legal and political issues)

Units: Unitless

This presents that corruption modifies the probability of legal and political issues.

(41) Corruption impact on probability of legal and political issues = Look up table (Corruption)

Look up table ([(0, 0.735) - (10, 0)], (0, 0.735), (1, 0.720), (2, 0.680), (3, 0.625), (4, 0.555), (5, 0.435), (6, 0.275), (7, 0.155), (8, 0.075), (9, 0.025), (10, 0))

Units: Unitless

This table function is used to describe the nonlinear relationship between two variables, and such relationship is estimated to reflect the perceptions of interviewees.

(42) Rate of change in raw material price = Raw material price * International dairy product supply and demand fluctuation impact * (1 + Corruption impact on raw material price)

Units: USD/lbs-wk

This presents that corruption modifies the change in raw material price.

(43) Corruption impact on raw material price = Look up table (Corruption)

Look up table ([(0, 0.905) - (10, 0)], (0, 0.905), (1, 0.665), (2, 0.475), (3, 0.355), (4, 0.275), (5, 0.230), (6, 0.185), (7, 0.150), (8, 0.115), (9, 0.070), (10, 0))

Units: Unitless

This table function is used to describe the nonlinear relationship between two variables, and such relationship is estimated to reflect the perceptions of interviewees.

(44) Corruption = 10 * Supply chain visibility

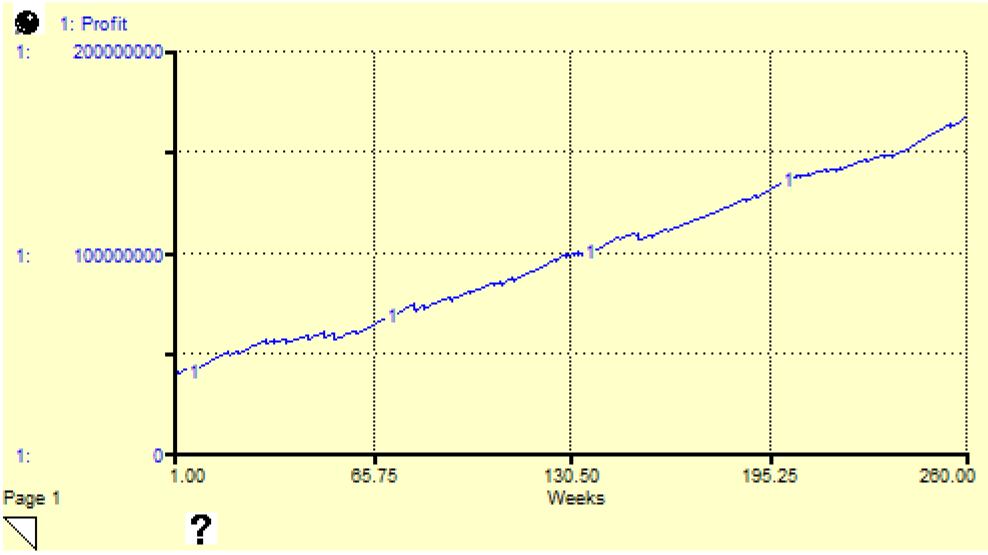
Units: Unitless

In this model, the level of corruption is assumed to be only associated with supply chain visibility. Considering the simulation scenarios, supply chain visibility is valued at 0.6 and 0.3 to respectively simulate the low and high corruption levels. There are various factors affecting the level of corruption. However, this model focuses on corruption’s moderated impact on SCP. Factors impacting the level of corruption are not the emphasis, hence it is reasonable to assume such an equation in this model.

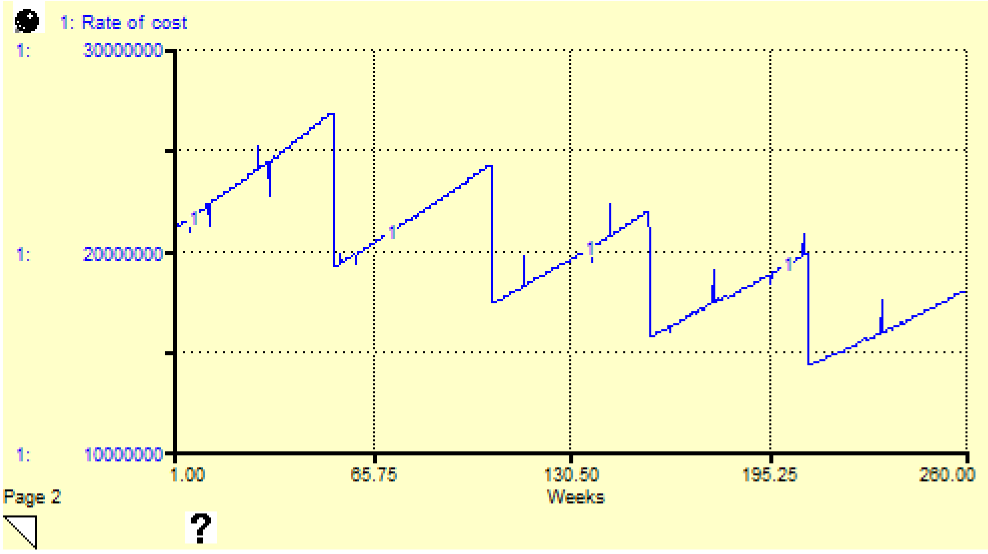
Appendix F – Empirical Validation of Performance Curves

The following figures are seven performance indicators' simulation curves. The horizontal axis is the simulation period, which is 260 weeks, that is 5 years. The vertical axis is performance indicators' values. The simulation curves represent the trend of the different performance indicators over five years. Could you please confirm if you think the trend is generally meaningful? You may reflect on your company's performance over the previous five years. You do not need to pay much attention to the specific simulation values and the trend is of more importance.

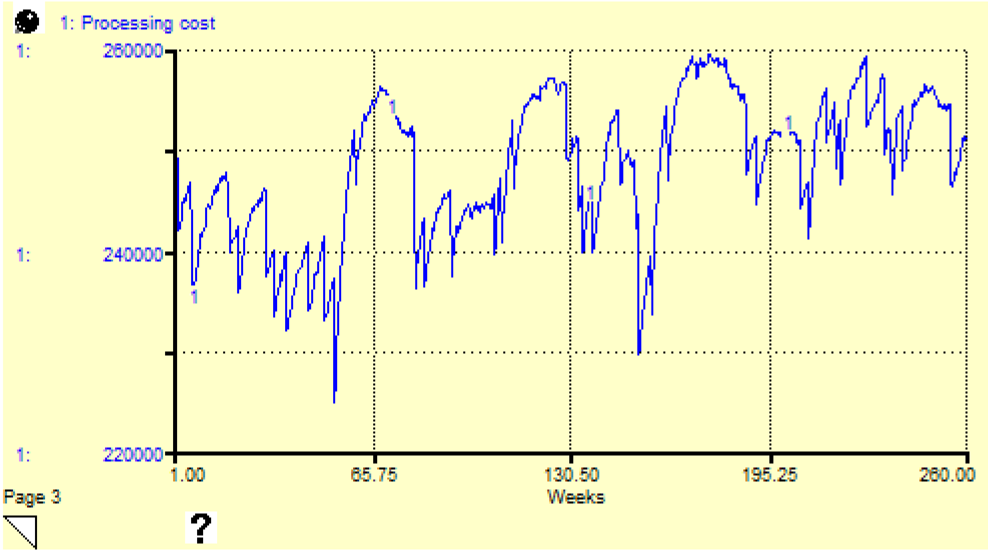
The profit at each week represents the accumulation value of the profit, for example, the profit at Week 10 means the total profit in the ten weeks. The unit of this vertical axis is Dollar. It shows the profit's trend from Week 1 to Week 260. Could you please confirm the profit trend based on your experience?



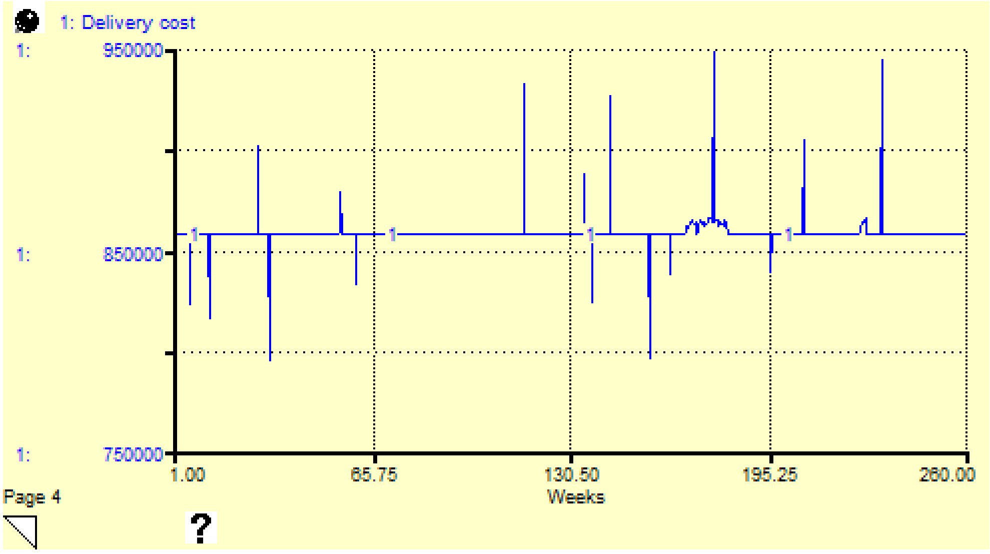
Rate of cost means the total cost at each week, including processing cost, raw milk delivery cost, inventory cost, etc. The unit of the vertical axis is Dollar. This simulation curve represents the value of cost at each week over the simulation period.



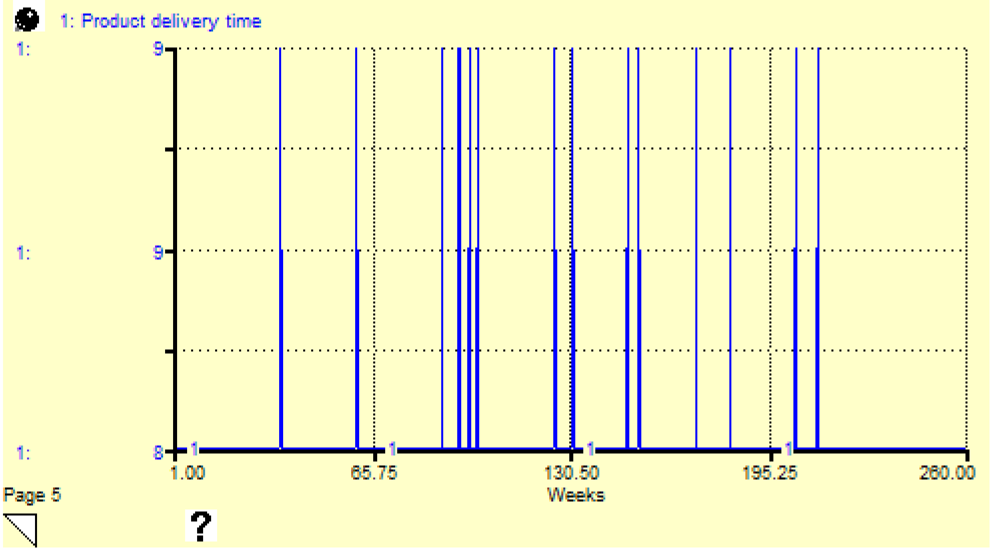
Processing cost is the cost of processing dairy products every week. The unit of the vertical axis is Dollar. The fluctuation shows that the processing cost is not fixed at each week. Due to some influencing factors, the processing cost will fluctuate.



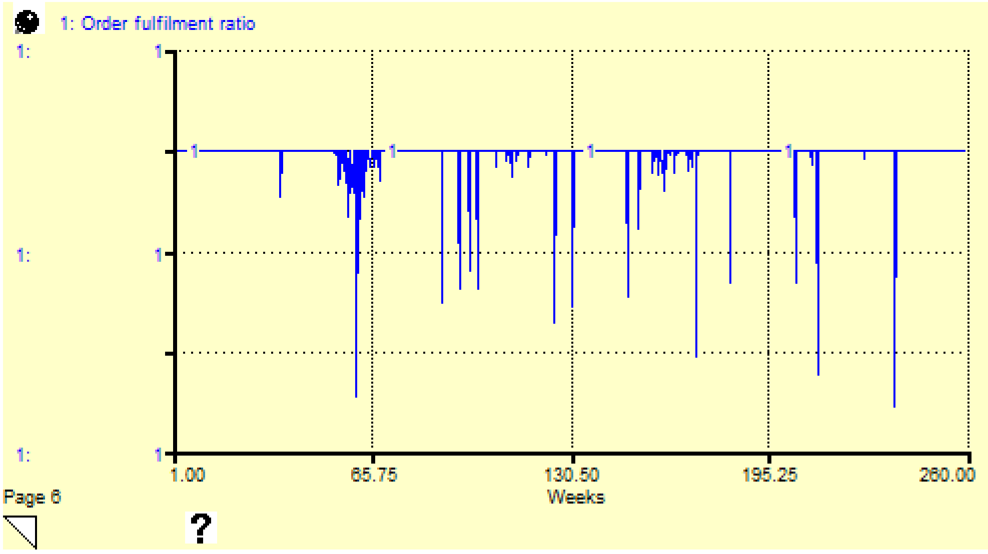
The delivery cost is the cost of delivering raw milk from farms to the plant every week. The unit of the vertical axis is Dollar. The simulation curve reflects that there are also some occasional changes in the raw milk delivery cost.



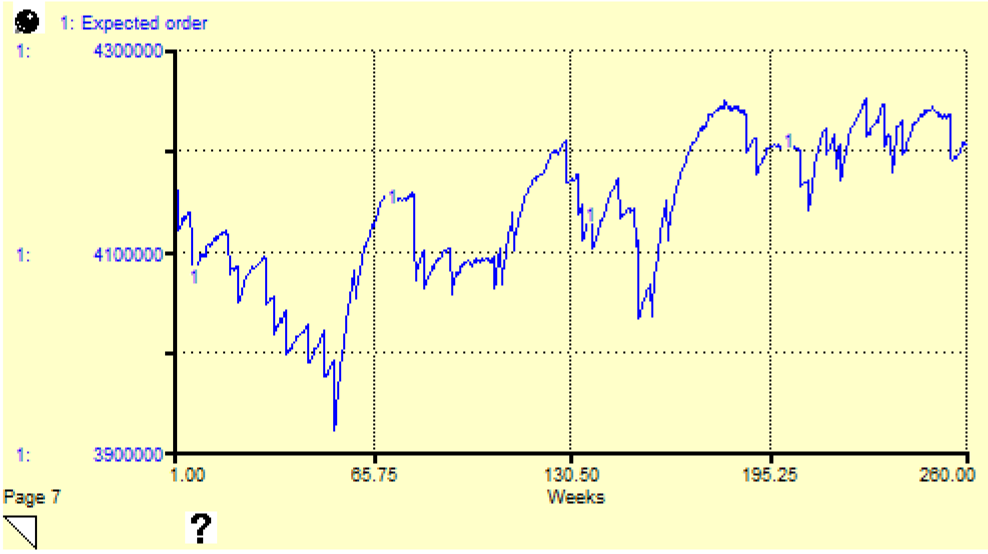
Product delivery time is the weeks needed to deliver dairy products to customers. The unit of the vertical axis is Week. The simulation result shows that there are occasional fluctuation in the product delivery time.



This simulation result reflects the order fulfilment ratio in each week over five years. Order fulfilment ratio is mostly 1.



Expected order is the expected customer order at each week. The expected order is the forecasted order based on the previous customer order. The unit of the vertical axis is Pound. The simulation curve shows the fluctuating expected customer order in five years.



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