PRODUCT DELETION AND SUPPLY CHAIN MANAGEMENT

by

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ABSTRACT

One of the most significant changes in the evolution of modern business management is that organizations no longer compete as individual entities in the market, but as interlocking supply chains. Markets are no longer simply trading desks but dynamic ecosystems where people, organizations and the environment interact. Products and associated materials and resources are links that bridge supply chains from upstream (sourcing and manufacturing) to downstream (delivering and consuming). The lifecycle of a product plays a critical role in supply chains. Supply chains may be composed by, designed around, and modified for products. Product-related issues greatly impact supply chains. Existing studies have advanced product management and product lifecycle management literature through dimensions of product innovation, product growth, product line extensions, product efficiencies, and product acquisition. Product deletion, rationalization, or reduction research is limited but is a critical issue for many reasons. Sustainability is an important reason for this managerial decision. This study, grounded from multiple literature streams in both marketing and supply chain fields, identified relations and propositions to form a firm-level analysis on the role of supply chains in organizational product deletion decisions. Interviews, observational and archival data from international companies (i.e.: Australia, China, India, and Iran) contributed to the empirical support as case studies through a grounded theory approach. Bayesian analysis, an underused empirical analysis tool, was utilized to provide insights into this underdeveloped research stream; and its relationship to qualitative research enhances broader methodological understanding. Gibbs sampler and reversible jump Markov chain Monte Carlo (MCMC) simulation were used for Bayesian analysis based on collected data. The integrative findings are exploratory but provide insights for a number of research propositions.

Key words: Product deletion, Product lifecycle, Supply chain management, Bayesian analysis, Markov chain Monte Carlo simulation, Gibbs sampler

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Two roads diverged in a wood, and I —

I took the one less traveled by,

And that has made all the difference. – Robert Frost

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CHAPTER I: INTRODUCTION

Before serving as president of the Procter & Gamble (P&G) Company, Neil H. McElroy wrote a famous 3-page internal memo in May 1931 that laid out the principles of modern product management (Brown and Anthony, 2011). In the memo, McElroy argued that companies should assign a separate management team to each individual product, as if it were a separate business. Only then would each of its products have a dedicated budget and managerial team and remain competitive in the marketplace.

In 1948, McElroy came to head P&G, and his memo became the basis on which most organizations including P&G have managed product portfolio dynamics ever since. One of the most critical drawbacks of expanding product portfolios lies in the fact that the winner products often happened at the expense of other products. However, even though McElroy was already aware of this "flight" within his company, he did not act on the idea of "product deletion".

The same is true for Unilever (Planning et al., 1989). Unilever carried 1,600 brands and more than 10,000 product variants in 1999. The entire product portfolio existed globally. Over 90% of global sales came from 25% of the product portfolio. Approximately 50% of the profits came from 1% of the portfolio. The remaining products made losses, at worst, and ate up the marginal contribution.

The implications are inescapable. Continuous product addition does not guarantee profit continuity. The truth is that most products just do not make money (Cooper and Slagmulder, 1999). A highly diverse product portfolio, though, enables firms to satisfy various needs and wants of heterogeneous consumers more precisely; more critically, draining resources and capabilities away from the profit generators. Even large companies often lose track of the vast product portfolio dynamics; it is also true of small and medium enterprises.

Yet today, seventy-one years after McElroy's memo, product deletion has remained a neglected topic in product management business practices. The impact of product deletion on firm performance, an

intuitive while complex relationship, calls for systematic and in-depth investigation. Product portfolio rationalization and product deletion open up a new era of product management issues today.

One of the most significant changes of modern business management evolution is that organizations no longer compete as individual entities in the market, but as supply chains that interlink with one another (Lambert and Cooper, 2000). Markets are no longer simply trading desks but dynamic ecosystems where people, organizations and the environment interact (Dibrell et al., 2011). Products and associated materials and resources are linkages that bridge supply chains from upstream (sourcing and manufacturing) to downstream (delivering and consuming). The lifecycle of a product plays a critical role for supply chains (Stark, 2015). Supply chains may be composed by, designed around, and modified for products. Product-related issues greatly impact supply chains.

Product management activities by marketing, operations, and finance functions have typically focused on the innovation, acquisition, growth, proliferation and management of product lines and products. Product life cycle and product portfolio rationalization play a significant role in organizational product decisions. Product deletion, discontinuation or reduction mostly occurring in the decline stage, has received less emphasis. Deletion is a critical supply chain issue for many reasons. Product capacity, manufacturing capability and sustainability are such important reasons for this managerial decision.

This dissertation work, grounded from multiple literature streams including the marketing and supply chain fields, identifies relations and propositions for a firm-level analysis. Interviews, observational and archival data from international companies -- those located in China, Australia, India and Iran -- are used as case studies for empirical support. Bayesian analysis, an underused empirical analysis tool, is utilized to provide insights into this underdeveloped research stream. Its relationship to case study research enhances broader methodological understanding by: (1) evaluating product deletion influencing factors; (2) prioritizing the products within the product portfolio; and (3) predicting product deletion performance on supply chain dimensions. Gibbs sampler and reversible jump Markov chain

Monte Carlo (MCMC) simulation are used for Bayesian analysis based on collected data. The integrative findings are exploratory but provide insights for a number of research propositions.

As one of the first initiatives integrating product deletion, supply chain management and sustainability literatures, this work challenges the traditional view that adding products is always preferred for firm performance. Second, it posits that product deletion directly impacts supply chain performance including competencies and sustainability across supply chain processes. Third it establishes a hypothesized framework to facilitate product deletion decision-making. The framework sets a conceptual and practical foundation for further investigation. This investigation also identifies various influencing factors from the perspectives of key organizational departments. Both the qualitative and quantitative studies provide insights for practical decision making and theory building.

This dissertation includes the following chapters:

Chapter II presents comprehensive theoretical argumentation on relevant literature streams and related conceptualizations. These literature streams include supply chain management, its competencies and operational activities; product portfolio management, product management, product lifecycle management; and supply chain sustainability. The theoretical foundation is derived from two major theories, respectively, the resource-based review and relational view. Another underlying theoretical thread is stakeholder theory. Overall, Chapter II starts with an introductory background for all theories and relevant variables; followed by major issues, controversies and the predicted impact of this study. Deductive reasoning is provided, starting broadly and narrowing the research focus as the chapter progresses. Research questions and investigation objectives are introduced. A general framework is given as the foundation to inform case study evaluation (Chapter IV) and model construction using Bayesian analysis (Chapter V).

Chapter III is the methodology chapter. First an introduction of the methodologies and measures is presented with evidence of reliability and validity for replication. Second, the research design is

detailed including a general description of design in this business environment and research questions, as well as possible threats to the internal and external validity of the selected design. Operational definitions and measurements of independent and dependent variables are listed and discussed. Third, the research procedures are presented. In the interview and survey-based case studies of qualitative work, the procedures of collecting data, the rate of return, and the description of sample and participants characteristics is provided. Copies of materials used in the intervention, including participant recruitment letters, the interview protocol and transcriptions are included in an appendix. Fourth, participants are discussed in detail, including the sample selection methodology, the number of subjects, information about the outputs, and missing data handling. The clearance from IRB regarding to the human subject's consideration is attached in Appendix B.

Chapter IV describes the qualitative study completed for this dissertation. In-depth case studies of multiple companies across four countries are analyzed to provide empirical insight into this underdeveloped organizational strategic decision-making process, product deletion. This chapter first presents a systemic and critical review of case study methodology, including its advantages and disadvantages, the legitimacy and validity of using case studies to provide qualitative reasoning, as well as the steps and processes for conducting in-depth case studies. Second, background for each company is detailed, including the company type (public or private), industrial sector, company size, country and cultural characteristics, supply chain dimensional comparisons including both internal and external involvement, the type, size and maturity of its supply chain, product categories and product portfolio size. Managers and executives from the four key cross-functional teams of each company are the key informants of the qualitative study. Third, the processes and steps of conducting this case study work are detailed with specific time, location and interviewee information. Nvivo 12 is used to conduct a thematic analysis on all transcriptions of the interviews. A general product deletion decision making processes flow chart is conceptualized. A performance matrix based on the antecedent factors is expected to arrive with the involvement of each cross functional relationship, along with the corresponding cross-functional

performance indicators. These identified cross functional relationships and key performance indicators/factors provide qualitative support for the quantitative evaluation (Bayesian analysis) in Chapter V. The identified cross functional relationships are grouped as decision making input dimensions. The critical key performance indicators are listed as factorial variables in both Bayesian inferencing and a predictive model for product deletion decision rationalization.

Chapter V presents the development of inferencing and predictive statistical models using Bayesian analysis for product deletion decision making. Building on the qualitative study results, this chapter captures empirical data -- archival product level data from 20 products and 9 companies. It further examines and estimates the impact of identified antecedent factors on product deletion. The qualitative study in Chapter IV informs the factors involved and their measurements in this chapter from a practical managerial perspective. Detailed data descriptions including data sources, data type, data measurement and boundaries are provided. Relevant literature streams are also included for empirical conceptualization.

Overall, three Bayesian models are introduced in Chapter V. Model 1 examines the predictive relationship between organizational cross functional departments and the odds of product deletion; Model 2 investigates the predictive relationship between supply chain management dimensional factors and odds of product deletion; and Model 3 depicts the predictive relationship between sustainability dimensional factors and odds of product deletion. Each model is introduced as a separate section with details of model development, model statement, results and discussions and managerial implications. Convergence tests are also conducted for each model to evaluate representativeness of posterior distribution through a Gibbs sampler algorithm. The utilized diagnostics include trace plots, auto correlation plots, and CODA (convergence diagnosis and output analysis) including Geweke, Gelman and Rubin, Raftery and Lewis, Heidelberger and Welch and Cross-Correlations. The convergence checks indicate pass, validity, for these three models.

Chapter VI provides the integrative analysis and research propositions. Overall, nine propositions are derived for further investigation. These propositions are derived using integrative findings from theory development (Chapter 2), qualitative study (Chapter 4) and quantitative study (Chapter 5). The listed propositions are structured to answer the three major research questions in Chapter 2. The theory development, qualitative study and quantitative study are designed to build upon and cross-validate one another. The integrated analysis incorporates the major findings into broader perspectives of discussions for strategic product deletion management; which involves multiple-level (i.e., macro, meso and micro) and multiple-actor (i.e., cross-functional department, supply chain partners, stakeholders of social and environmental dimensions) perspectives.

Chapter VII is the conclusion chapter. Summary implications of both the theoretical and managerial analysis are presented, as well as limitations and recommendations for future research directions.

CHAPTER II: LITERATURE REVIEW

Managing supply chains is important for organizational strategic management (Porter and Millar, 1985). Decisions related to sourcing, operations and manufacturing, and distribution and logistics, as well as product usage, are of great significance for supply chain operational competencies (Bechtel and Jayaram, 1997; Russell and Taylor-Iii, 2008). Products and associated material flows are important linkages across supply chain networks (Sahin and Robinson, 2002).

In this chapter, a number of key literature streams are reviewed as the theoretical foundation of this study. These literature streams include supply chain management and sustainability, product and product portfolio management, and product lifecycle management, as well as related marketing and supply chain theories.

Resource-based view (RBV), an extensively applied traditional organizational theory, and the relational view (RV), a relatively under-investigated theory, are employed to illustrate the associated relationships amongst these related literature streams and constructs. Product deletion, a strategic decision for organizations, is argued to be a supply chain decision involving all upstream and downstream processes; and one that greatly impacts supply chain competencies and performance including sustainability.

2.1 Supply Chain Management

The term “supply chain management” (SCM) emerged almost four decades ago (Oliver and Webber, 1982). As this concept evolved, divergences arose as to whether SCM is a strategy, a process, a business philosophy, or just another term for “logistics.” There is even ambiguity regarding where the SCM field fits within the business management disciplines.

The traditional strategic management perspective is on the verge of a major breakthrough for understanding how industrial organizations achieve competitive advantage from interactions between the

flows of material, finance, and information amongst stakeholders (Mentzer et al., 2001). The dynamics of these flow systems interlock and form supply chains.

Supply chain and operations management has risen to prominence over the past few decades (Lambert and Enz, 2017). There are many reasons for the emergence and significance of this concept within organizations. Drivers include trends in inter-organizational transactions in sourcing, manufacturing, delivering, product consuming and close-loop activities, as well as communications along supply chain linkages. This section introduces the definition of SCM and its processes in this work; followed by supply chain performance measurements relating to core competencies and sustainability.

2.1.1 Defining Supply Chain Management

SCM is largely practitioner-led and represents an evolutionary concept that encompasses more than traditional transportation and logistics. It further extends logistics by integrating the management of inter-organizational cooperation with capital, material, and information flows.

To be able to produce products or provide services, having the necessary resources, processes, and materials is necessary. The term SCM involves both external, upstream and downstream, and internal operations practices. Supply chain principles also relate to the value chain concept (Porter & Millar, 1985). The elements of the value chain include core processes of inbound logistics, operations, outbound logistics, marketing and sales, and service, supported with various non-core organizational functions.

There remains considerable discussion regarding the definition of SCM. Some define it within the domain of operations management, involving the flow of materials, information and finance (Carter et al., 2017; Mentzer et al., 2001; Mentzer et al., 2008), while some view it as a strategic issue within organizational management philosophy (Stadtler, 2015). Studies have included perspectives of organizational core operational competencies including flexibility, cost, quality and time (Jajja et al., 2014). Another viewpoint defines SCM as management processes with key activities of sourcing, operations, manufacturing, distribution, usage, and service (Christopher, 2016).

All four perspectives are included in this study. The supply chain is defined as an ecosystem of networks including organizations of both upstream (i.e., supply) and downstream (i.e., distribution) partners, tangible (i.e., material) and intangible (i.e., information) linkages, and direct (i.e., employees and investors) and indirect (i.e., government and media) stakeholders that are involved in a series of organizational processes and operational activities that produce value in the form of products and services delivered to the end users, while establishing and reinforcing competencies for the focal firms and their interrelated organizations. SCM stands for an integrative philosophy to implement value-creation processes as part of organizational strategic development.

2.1.2 Supply Chain Processes

The supply chain is a network of organizations linked through the upstream and downstream processes. The general supply chain processes include forward SCM; activities including sourcing, manufacturing, delivering, and usage and service. This dissertation also incorporates the reverse SCM; that is, close-loop activities such as reverse logistics, remanufacturing, recycling, reuse, and reclamation.

A broader perspective of supply chain activities may include upstream vendor and supplier management, manufacturing and operations, distribution and logistics, and product after-life and closing the loop. Although many definitions exist, this study's definition of supply chain includes all activities managing the flow and transformation of goods from raw materials and information through the end user, incorporating both forward activities and reverse logistics. Material and information may flow both up and down the supply chain (Handfield & Nichols 1999).

The conceptual framework proposed in this paper uses the supply chain operations reference (SCOR) model (Huan et al., 2004) which includes four supply chain processes, (1) sourcing, (2) operations and manufacturing, (3) distribution and logistics, and (4) usage and service.

The supply chain includes these processes and involves a number of organizational functions that participate vertically across, and horizontally within, organizations (Crane, 1998; Qiu, 2012). SCM will

result in inter-organizational relationships with suppliers and customers. There will also be a need to incorporate cross-functional participation such as engineering, manufacturing, purchasing, logistics, and marketing functions within the organization (Hillebrand & Biemans, 2003). The supply chain, by design and definition, is complex, and decisions affecting products or materials will reverberate throughout it. Although managing processes is one aspect of SCM, another important dimension is supply chain planning and control, which requires considerations of performance competencies.

2.1.3 Supply Chain Competencies

Flexibility, cost, quality, and time strategic performance competencies are important when planning, designing, implementing, and managing the supply chain (Jayaram et al., 2011; Koste and Malhotra, 1999). While acknowledging that other dimensions of performance competencies exist, these four -- flexibility, cost, quality, and time -- are the most commonly identified within the literature (Boyer and Lewis, 2002). These operational strategic performance dimensions can help organizations identify ways to differentiate themselves and build operational competitive advantage. They are also critical to organizational decision-making across the supply chain (Halley and Beaulieu, 2009).

Flexibility represents the ability to incur uncertainties with little penalty in time and cost (Upton, 1994). It is associated with dynamic market environments and risks as well as the firm's capability to identify, respond, and conform to those changes (Dreyer and Grønhaug, 2004).

Cost competency occurs when firms build their organizational competitiveness by committing to cost reduction as an operating principle (Porter and Millar, 1985). Cost competencies and savings can be achieved through the efficient use of technology, process, labor, materials, facilities, and sourcing decisions (Lado et al., 1992).

Quality can be defined as the features and characteristics of a product or service that satisfy customers' expectations consistently (Tam, 2004). Firms obtain quality competencies when they distinguish their market offerings to be of competitive quality in order to satisfy customer demand.

Time competency is a firm's ability to reduce cycle time in processes of operations, including product design, material purchasing, manufacturing, distribution and delivery, as well as offering a highly responsive service to customers (Stalk, 1988). Time-based competency, with responsiveness as the key measurement, is instrumental in improving both production efficiencies and customer satisfaction (Cooper and Kleinschmidt, 1995).

These four competencies relate closely to a firm's dynamic capabilities from RBV and RV perspectives (Dyer and Singh, 1998; Eisenhardt and Martin, 2000).

2.1.4 Supply Chain Sustainability

Sustainability, in general, has numerous definitions. Typically, the triple-bottom-line of economic, environmental, and social sustainability has been utilized to define organizational and supply chain sustainability (Bai and Sarkis, 2010a; Carter and Rogers, 2008). The concepts of SCM and sustainability have become increasingly aligned and connected, although sustainable SCM still represents a novel and evolving area of research (Sarkis, 2019; Seuring and Müller, 2008).

SCM decisions should include firms' responsibilities to their stakeholders including business partners, customers, society, and the natural environment. The sustainability dimension of decision-making on supply chains is based on an overview of current SCM literature, with a major focus on the environmental dimensions of sustainability. Sustainability concerns can build up natural resource-based competitive advantages for organizations (Hart, 1995).

The prime motivation of sustainable SCM is economic sustainability. The economic dimension of sustainability is premised upon the potential for reduced costs and monetary risks, and increased profits from operating eco-efficiently. The underlying idea behind economic sustainability is that firms should aim for stakeholder benefits in the future as well as today. Long-term financial returns is one aspect. Furthermore, the most important evolution of supply chain sustainability is the argument that economic sustainability alone is not sufficient for the overall sustainability of an organizational supply chain.

There are increasing stakeholder expectations for organizations to be fully responsible for business operations on the social and environmental dimensions of sustainability. The realization of economic capital also comes from social and natural capital. Economically, socially and environmentally sustainable supply chains guarantee financial returns to ensure sufficient liquidity while adding value to communities and society, preserving resources, and preventing pollution; with the incorporation of broader stakeholder requirements from the societal and natural environment.

A variety of research has indicated the joint consideration of three dimensions of sustainability yields to long term business continuity (Ferro et al., 2019; Hacking and Guthrie, 2008; Willard, 2012).

2.2 Product Management

Products can be linkages that integrate inter-organizational supply chain activities. Products are comprised of core tangible value that supply chain networks generate (Thomas and Griffin, 1996). Supply chains can be designed around products and modified to product characteristics (Petersen et al., 2005). The purpose of product management in supply chains is not limited to meeting market demand but also optimizing operational processes with respect to product lifecycle and product (portfolio) characteristics (Saaksvuori and Immonen, 2008).

2.2.1 Product Life Cycle and Product Lifecycle Management

Product Lifecycle Management (PLM) refers to the business activities of managing a company's products throughout its lifecycle from birth to retirement and end disposal (Ameri and Dutta, 2005; Stark, 2015). PLM's implementation takes place in all forms of products, including sourcing materials, components, finished parts, and finished goods, as well as collected remanufactured items.

Research in marketing and strategic management indicates that the PLM is a fundamental dimension that affects organizational corporate strategy (Anderson and Zeithaml, 1984; Li et al., 2015). The major stages of product life cycles includes product introduction, growth, maturity, and decline.

Introduction stage. Product management in the introduction stage focuses on the downstream buyer's perspective. Product development builds on marketing initiatives such as advertising and promotion. The purpose of product management in this stage is increasing product sales and customer purchase frequency. Most product management decisions focus on new product development (NPD).

Growth stage. Product management emphasizes product growth and extensions of product categories and variates such as stock keeping units (SKU). The purpose of this stage is to determine a product's strategic positioning within the organization's whole portfolio. Decisions on product usually include building capacities in product production and marketing.

Maturity stage. Decisions in this stage are complex and critical. Thus, decisions are based on improving efficiencies while reducing production costs in processes, further increasing product differentiation. The major purpose of this stage is to increase market share and enlarge customer segmentation to sustain and improve product profitability. Strategies around product growth, product line extensions, and product efficiencies, as well as product innovation, play a significant role in this stage's product management.

Decline stage. In the decline stage, challenges of a product result from the shifting of market traits and the nature of competition. Decisions on product management include product innovation and product modification, as well as product deletion.

2.2.2 Product Portfolio Management and Rationalization

Product portfolio management (PPM) is a decisive element leading to product success and portfolio performance (Tolonen et al., 2015). PPM not only defines new product development but also defines product revisions, modifications, updates, and even decisions on discontinuation and abandonment (Jugend and da Silva, 2014).

Decision-making evaluations related to PPM are considered one of the main critical factors for product development success, and these decisions' primary uncertainties lie in limited resources

availability, ineffective product prioritization, and the absence of substantial financial and information flow, making decision-making complex (Kang and Montoya, 2014).

Product portfolio rationalization seeks an optimized depth and breadth for a firm's product portfolio (Seifert et al., 2016). The optimal product portfolio can be defined as the assortment of products that best support the organizational mission, given a firm's positioning and the prevailing environmental situation. For example, a leaner product portfolio enables the firm to have lower per unit product costs when scale economies are present, a lower cost of product design, warehousing, inventory holding, and reduced complexity in assembly and distribution. Product portfolio rationalization can be achieved through changes, from the addition of new products, modification of the existing product lines, or deletion of products that detract from the attainment of the firm's strategic goals. Examination of the PPM literature shows a neglect of the deletion phase.

A literature summary of product management is provided in Table 2.1. Categorization of research themes or focus has been conducted using the list of selected publications from peer-reviewed journals. The investigation theme/focus is spread across product management decisions throughout its lifecycle within its product portfolio.

1: Table 2.1: Product Management Literature Summary

	THEMES / FOCUS						
Product Management **Product Lifecycle Management**	New Product Development	Product Introduction (i.e.: Acquisition)	Product Growth	Product Proliferation	Product Efficiency	Product Innovation	Product Deletion
(Rangan et al., 2005)	√	√	√	√	√	√	√
(Abramovici, 2007)			√	√			
(Ameri and Dutta, 2005)	√	√	√		√		
(Terzi et al., 2010)	√	√	√	√	√	√	√
(Matsokis and Kiritsis, 2010)					√	√	√
(Ming et al., 2008)			√		√		
(Hines et al., 2006)	√						
(Ming et al., 2005)	√	√	√			√	
(Subrahmanian et al., 2005)		√	√				
(Mourtzis et al., 2018)			√			√	
(He et al., 2019)					√	√	
Product Portfolio Management							
(Cooper et al., 1999)	√					√	
(Cooper et al., 2006)	√						
(Eggers, 2012)			√	√			
(Mcnally et al., 2009)	√						
(Oliveira and Rozenfeld, 2010)	√			√		√	
(Chao et al., 2009)	√				√		
(Rothaermel et al., 2006)			√			√	
(Sadeghi and Zandieh, 2011)			√	√	√		
(Pinheiro et al., 2018)	√					√	
(Dash et al., 2018)			√				
(Bordley, 2003)	√	√	√	√			
%	*20%*	*10%*	*22%*	*12%*	*14%*	*17%*	***5%***

Existing research has documented product decisions on proliferation, line extensions, efficiencies, innovation, growth and acquisition; as well as their critical influences on organizational strategic development. Relatively limited research (5%) has been completed on product deletion decisions in the product decline stage. Product deletion is a neglected area of academic research and a less appealing business practice, but a significant product management activity, because product portfolio strengthening requires not only the addition and modification of the existing products but also the deletion of products that no longer contribute.

2.3 Product Deletion

Product deletion or elimination is the strategic choice of a firm to discontinue, remove, or withdraw a product from its product line (Avlonitis and Argouslidis, 2012). There exists no systematic standard definition for product deletion. Product management gained research attention in the 1960s, when firms strategized product proliferation without considering its negative consequences such as rising costs, the consuming of disproportionate share of management time and effort, and the inefficient use of resources (Kotler, 1965; Weckles, 1971). Not surprisingly, firms soon realized that proliferation was draining their valuable resources and they needed to shift their focus from proliferation to rationalization by deleting weak products from their product lines (Johnson, 1975).

Diverse organizations such as Heinz, P&G, Kraft, Polygram, and Sony underwent a reduction of the scope of their product portfolios. Product deletion significance is increasing because of shortened product life cycles, customization, and the desire for new products.

Most of the earlier studies on product deletion have indicated that product deletion is a strategic decision for mature products. Thus, product deletion decisions often occur in the decline stage of a product life cycle. However, a decline in market demand or saturation of market penetration doesn't necessarily mean that the product has left its maturity stage or is about to reach the decline stage (Ayres and Steger, 1985; Day, 1981). The correlation between product deletion and its decline position at the product life cycle is misleading (Avlonitis, 1985b). A product could be deleted in any product lifecycle

stage. For example, new product failure represents the product being deleted upon its introduction stage (Avlonitis et al., 2000a).

Reasons for deletion vary across different stages of a product lifecycle. The major product deletion reasons include performance-related triggers, organizational strategy-related triggers, operational triggers, and external triggers (Avlonitis and James, 1982; Hart, 1988b). The first product deletion candidates are typically those that underperform. Poor performance may include: (1) decline in market potential; (2) poor sales; (3) poor profit; and (4) poor product quality (Avlonitis et al., 2000a). Strategic triggers derive from a broader organizational view, including: (1) resources required elsewhere; (2) development of an active variety reduction (rationalization); (3) poor fit with strategic plans and company capabilities; (4) rationalization due to mergers and acquisitions; (5) poor fit with company image; (6) parent company decisions and policies; and (7) the development of a new product. Operational triggers are problems associated with activities such as sourcing and manufacturing, while external triggers relate to external stakeholders such as (1) competitive activity; (2) third-party decisions such as logistics providers; (3) government policies and regulations; and (4) a change in world markets such as exchange rates. These reasons have not yet been systematically investigated by the reviewed literature. The relationships amongst product deletion and possible triggers are expected to be evaluated through further research.

Product deletion follows a multi-staged conceptualized process. The major steps are as follows:

Recognition of the deletion candidate. This purpose of this stage is to identify the product to be deleted. According to the triggers listed above that potentially cause deletion decision, the product portfolio will be examined using agreed upon performance criteria.

Analysis and revitalization of the identified candidate. Actions at this stage might include corrective activities for the identified deletion candidates based upon the deletion decision trigger, such as quality improvement, price decrease, or customer segment shift. It is assumed by the literature that all

identified product deletion candidates undergo this stage of the deletion process with equal attention and consideration. However, this doesn't always occur in practice.

Evaluation and decision formation on the deletion candidate. This stage is a decision finalization process. The overall organizational objective and strategy development are critical criteria; that is, whether it is in the best interest of the organization to kill or retain the product. For example, if the company pursues a "full-line" strategy where the variety of product types and variations are important, then the sole performance of an identified product deletion candidate might not result in a deletion decision. The evaluation process can be counterintuitive, and many influencing factors will impact the decision making process.

Implementation of the product deletion decision. Organizational implementation of product deletion may vary amongst different department managers. Deletion decisions can range from deleting brands across a product line, to the deletion of just one product SKU. The product can be deleted for a period of time and return; or the product can be deleted permanently from the product portfolio. Given the variation of product-, situation-, industry-, culture- specific conditional factors, the product might be immediately killed or slowly phased out.

While the decision to delete a product is equally as important as the decision to introduce a new product, it has received relatively little attention in the existing literature. Research-based investigations of the understanding of the product deletion decision-making process on supply chain processes from production to consumption are especially absent. The linkages of product deletion and the implications on supply chains are elaborated on in the next section.

2.4 Product Deletion and its Influences on Supply Chains from the RBV and RV Perspectives

Both RBV and RV reflect organizational strategic management. Product deletion is a strategic decision within a firm that may influence and be influenced by RBV and RV conceptualized perspectives.

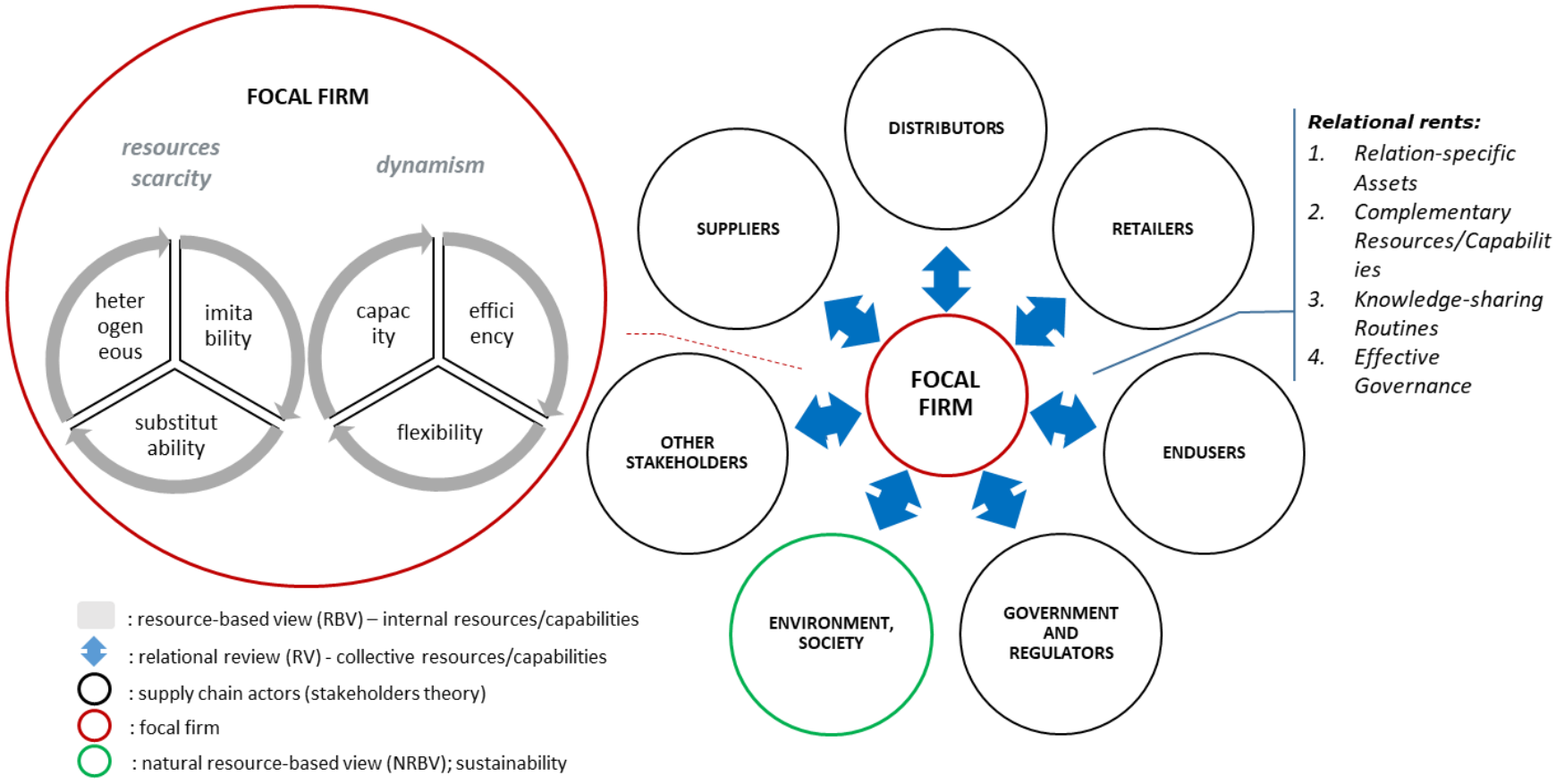
Resources and products are two sides of the same coin. Products may require various resources whereas the same resources will be used in different products. Determining the sound size of the firm's product portfolio can help infer the minimal amount of resources commitment; and the opposite is true: the total amount of the accessible resources may decide the optimal size of the entire product portfolio (Wernerfelt, 1984).

Resources and products are of strategic significance for firms. The traditional principle of corporate strategic management lies in the resource positioning of the firm (Andrews, 1971); whereas a majority of wide-recognized economic tools operate upon the determination of the product-market matrix (Wernerfelt, 1984).

The literature on product deletion is comparatively sparse and vaguely defined; no complete body of knowledge exists that can be referred to for clear guidance in this important area of research. The entire subject of product deletion has been neglected by professionals and has not been systematically brought into the supply chain domain. However, supply chains are designed around products and impacted by product decisions. Product deletion is one such decision requiring additional attention.

This paper conceptualizes how a product deletion decision will impact a focal firm's resource management and relational management, as well as stakeholder management. The grounded theories include RBV and RV (Figure 2.1).

1: Figure 2.1: Product Deletion on Supply Chains - Theoretical Foundations of RBV and RV Perspectives



2.4.1 The Resource Based View

RBV illustrates that firms can achieve competitive advantage over competing firms by accumulating resources that are rare, valuable, non-substitutable, and difficult to imitate (Barney, 1991; Dierickx and Cool, 1989; Rumelt and Lamb, 1984).

Resources refers tangible and intangible organizational assets. Those assets are tied semi-permanently to the firm. From a firm's internal supply chain perspective, examples of tangible resources include raw materials, product components, skilled employees and machinery, and capital. Examples of intangible resources include in-house knowledge of technology, pro-environmental certificates (e.g. ISO14000), waste management system, and relationships with stakeholders such as suppliers, employees, and customers.

RBV argues that resources can improve organizational competitive advantage through isolating mechanisms. Such mechanisms aim at three key perspectives: heterogeneity, imitability and substitutability. One basic assumption of RBV is that resource bundles and capabilities underlying a firm's operation are heterogeneous. That is, across organizational activities, productive factors involving resources, such as manufacturing and finished products, should have intrinsic levels of "differentiation." For example, firms might build their competitiveness through scarce resources to produce superior market offerings. In this way, they are able to position their products more economically and/or to better satisfy customer demand. Regardless of the nature of the resources, competitive advantage also requires the condition of heterogeneity to be sustained. In other words, if heterogeneity is a short-term phenomenon, the competitive advantage will be fleeting. Long-term competition may dispute the competitiveness when the supply of the scarce resource is increased.

There are two critical aspects of *ex post* limits to competition: imitability and substitutability of the resources. These aspects align with Porter's traditional five forces framework (Porter, 1980, 2008). Imitability and substitutability stand for the organizational capability of reserving ownership, such as in information asymmetries and product parents. Examples of resources that could help sustain imitability

are producer learning, transaction costs, reputation, and economies of scale. These elements compose the key elements for RBV-based sustainable competitive advantage.

Built upon RBV, the dynamic resource-based view (DRBV) was introduced later (Teece et al., 1997). Dynamic resources involve adaptation and change in building, integrating, or reconfiguring resources and capabilities. Within DRBV, the concept of capability lifecycle (CLC) provides the general patterns and paths of the organizational capabilities evolution, a dynamic approach to traditional RBV (Helfat and Peteraf, 2003). CLC incorporates the lifecycle from the founding, development, and maturity of capabilities in a manner that helps to create, maintain, and reinforce heterogeneous imitability and substitutability. The stages of a capability lifecycle are similar to a product cycle. These stages include the founding stage, the development stage, the maturity stage, and retirement stage. In the founding stage, an *ex-ante* attempt to develop a particular resource is initiated. Efforts will be devoted to the selected resources in the development stage. In the maturity stage, the resources provide an optimized value to the organization. In the retirement stage, a reduced overall unitization of resources is anticipated to degrade the level of competitive capability.

Overall, RBV generates a focal firm's capabilities in terms of resources scarcity (heterogeneous imitability and substitutability) and dynamism (capacity, efficiency, and flexibility). The overall discussion focuses on the given organization's internal competitive advantages, which depend on internal firm resources.

2.4.2 The Relational View

The idea of multiproduct firms benefiting from shared-resource linkages from product relationships, such as joint costs, is another aspect of corporate capabilities. A number of studies have revealed that firms become willing to make relation-specific investments and combine resources in many ways. RV helps explain this inter-organizational competitive advantage pattern.

One core idea of RV is that firm critical resources may span firm boundaries and may be embedded in inter-firm resources and routines (Dyer and Singh, 1998). That is, the competitive capabilities of an individual firm are often interlinked to the competitive capabilities of the network of relationships in which the firm is embedded. The strength of the linkages is called a relational rent.

Relational rent is defined as a supernormal profit jointly accumulated in an exchange relationship that cannot be generated by either firm in isolation and can only be achieved through the interlinked idiosyncratic contributions of the network alliance partners (Dyer and Singh, 1998). The relational rent can be achieved and preserved through isolating mechanisms. Such an isolating mechanism is initiated through four major sources of relational rents in the existing literature, including relation-specific assets, knowledge sharing routines, complementary resources/capabilities, and effective governance.

When a focal firm makes a product deletion decision, it effects a series of supply chain information governance issues from the massive shared-resource linkages of product and material relationships, such as joint costs and multiple collective capabilities.

Product deletion will affect supply chain relational rents, resulting in decreased levels of relation-specific assets, knowledge-sharing routines, complementary resources and capabilities and effective governance.

Relation-specific assets

A firm can obtain competitive advantage by seeking shared assets that are specialized in conjunction with the assets of an alliance partner (Klein et al., 1978). Capabilities will improve when firms and their counterparts are willing to make relation specific investments. Three types of relation-specific assets exist: specificity, physical asset specificity, and human asset specificity.

Site specificity refers to the location investments whereby successive production stages are immobile in nature but allocated close to one another. Research indicates that site specificity rents can reduce warehousing, inventory, and transportation associated costs. Physical asset specificity stands for

transaction-specific capital investments that adapt processes to particular business partners. These relational rents occur by increasing transaction integrity or fit. Human asset specificity refers to investments associated with specialized expertise, information, culture, and know-how. Examples of this relational rent include experienced technicians or systems that are idiosyncratic within the alliance partners.

The existing literature indicates that relational rents generated from relation-specific assets can help lower each firm's transaction cost, and ensure higher resource capacity, greater product quality, fewer defects in communication and collaboration, and faster product development cycles. There are two indicators to determine and measure the relation-specific assets. One is the length of safeguard (e.g., contracts) that influences the willingness of alliance partners to invest in relation-specific assets; the other is the total volume (scale) and breadth (scope) of transactions between the alliance partners.

When a product is deleted, two indicators that determine and measure the relation-specific assets will be affected. One is the length of safeguard (e.g., contracts). Product deletion might risk the willingness of alliance partners to invest in existing and future relation-specific assets. The second indicator is the total volume (scale) and breadth (scope) of transactions between the alliance partners. In product deletion, the transactions of these specific products may be withdrawn and the scale of related products may potentially be phased out as well.

Product deletion is likely to reduce the relational rents, with decreased supply chain partner investment in relation-specific assets.

Knowledge-sharing routines

Knowledge sharing routines are rooted in the perspective that inter-organizational learning is critical to competitive advantage acquisition; and organizations can learn by collaborating with their counterparts (Levinson and Asahi, 1995). Studies suggest that a firm's alliance partners are the most significant and valuable source of experience information and new ideas, such as performance-enhancing

technology and product innovations. Therefore, alliance partners can obtain and maintain relational rents by investing in inter-firm knowledge sharing routines.

An inter-firm knowledge sharing routine is defined as an inter-organizational interaction pattern that allows for creating, sharing and advancing specialized knowledge (Grant, 1996). Research has categorized knowledge into two types: information and know-how. By comparison, know-how involves knowledge that is tacit, complex, professional, and difficult to copy and transfer (Kogut and Zander, 1992; Szulanski, 2000). Know-how is more likely to achieve competitive capacity that is sustainable. Inter-firm knowledge sharing routines allows alliance partners to access and learn from each other. It allows individual organizations within the alliance network to acknowledge each other's capability, in terms of who knows what and where critical expertise resides within each firm.

The existing literature outlines how the capability of alliance partners to generate relational rents through knowledge sharing routines results in better transparency in communication, greater expertise sharing, and elimination of free riders in knowledge acquisition, and eventually greater product quality and service.

When a focal firm decides to delete a product, the capability of supply chain partners to generate relational rents through knowledge sharing routines is loosened. Product deletion will result in missing knowledge of product development and management expertise. Lack of communication and poor collaboration on product deletion issues will eventually lead to poor product quality and service.

Product deletion is likely to reduce the relational rents by loosened inter-firm knowledge-sharing routines.

Complementary resources/capabilities

Firms can also generate relational rents by leveraging the complementary resource endowments of other alliance partners. The individual firm may utilize their in-house resources in conjunction with the complementary resources amongst the alliance network. Compared with other sources of relational rents,

complementary resources have been widely acknowledged and discussed in the existing literature as the key driver of enhanced returns from alliances (Hamel, 1991; Harrigan, 1985).

Complementary resources are integrated resources of an alliance network they collectively generate. Collective complementary resources are greater than the summation of those owned from the individual partner resource endowments. The assumptions of this definition are as follows: first, these resources compose complementary resources that cannot be accessed by individual firms in a secondary market; second, these resources are expected to be indivisible, which motivates firms to form an alliance to acquire complementary resources. One example of complementary resources is co-branded reputation, which is not readily accessible in marketing but critical for much greater sustained returns than an individual firm would obtain alone.

Existing studies have illustrated that alliance partners contribute distinctive resources to the alliance, resulting in synergistic returns, whereby the collective resource endowments are more valuable, rare, and difficult to imitate. Consequently, all alliance partners achieve stronger competitive capabilities than those achievable by the firms operating individually.

If the focal firm decides to delete a product, particularly specialized expertise and intangible assets embedded within the deleted products will ultimately disappear. An example is a reputational asset.

Product deletion is likely to reduce the relational rents by decreasing the degree of the intra-supply chain resources that are valuable, rare, and difficult to imitate.

Effective governance

Governance plays a critical role in the creation of alliances. It influences the willingness of alliance partners to engage in capability-creation initiatives. An example of effective governance amongst alliance partners is a governance structure that minimizes overall costs while optimizing efficiency (North, 1990; Poppo and Zenger, 2002).

There are generally two categories of governance in alliances: one relies on the third-party enforcement of agreements (Kraakman, 1986) (e.g., legal contacts) and the other replies on self-enforcing agreements (Telser, 1980). The first category of governance suggests that the alliance requires a third-party enforcer. Such enforcement can be through stated contracts or a legitimate organizational authority, whereas the second category of governance may reply heavily on inter-organizational trust relations or reputation. The latter category has been shown to be more effective, with lower cost governance in alliance (Dyer and Singh, 1998).

Effective governance mechanisms will facilitate alliance partners in minimizing transaction costs amongst the relations and maximizing capability-enhancing initiatives. Product deletion will potentially break existing governance effectiveness; further resulting in reduced willingness of supply chain partners to engage in governance-oriented activities.

Product deletion is likely to result in fewer supply chain governance structures.

RV demonstrates that a firm's capabilities can also derive from alliances. The collective capabilities including resources are greater than the summation of those from individual firms. The overall discussion focuses on the given organization's collective competitive advantage from collaboration beyond firm boundaries. The resources of RV focus more on external relationships than internal situations.

Managing product deletion decisions while protecting relational rents is diverse and takes place at the product and variant level. Broader perspectives of involvement and joint efforts are dependent on the control of external supply chain alliances beyond the focal firm. There is limited investigation of the cross-functional, intra-organizational, multi-tier information generating and managing processes for product deletion decision-making from an RV perspective.

Comprehensive and systematic routines and antecedents for product deletion can help generate fewer effects on relational rents. Analyzing this decision for supply chains that have maintained a high

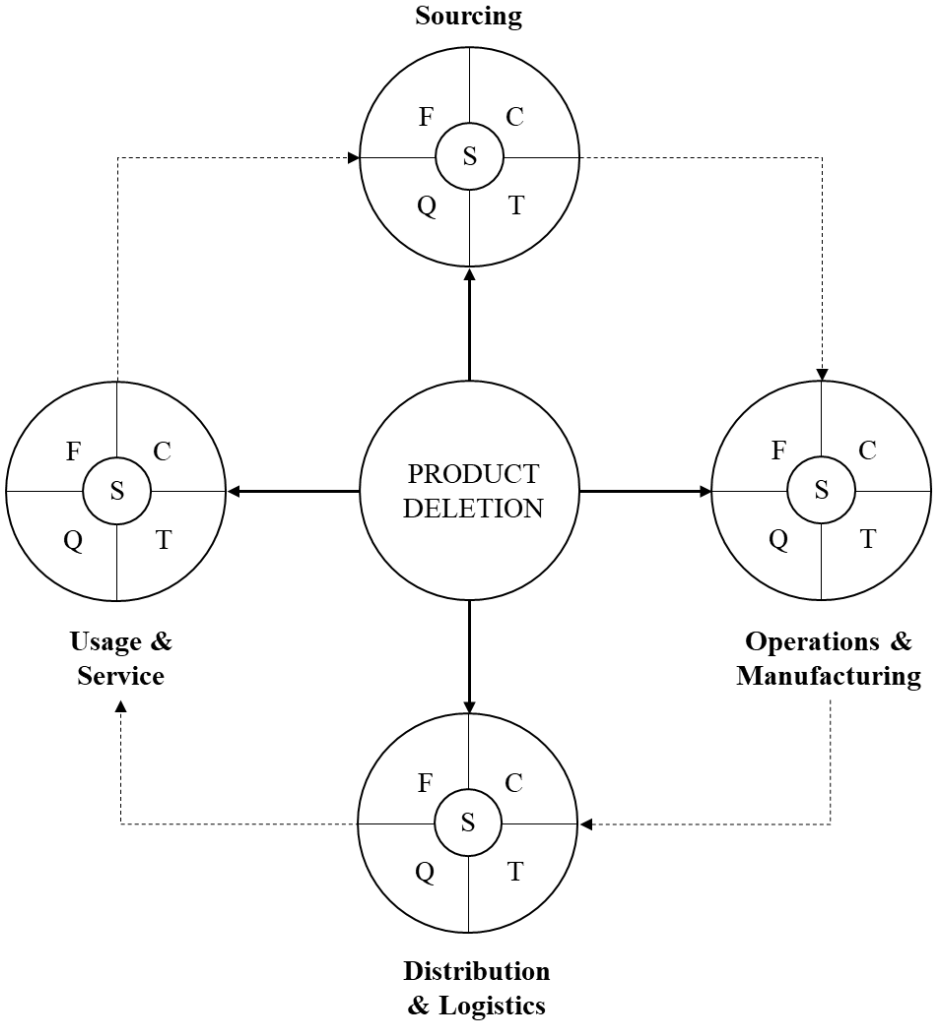
level of coordination and built relationships depend not only on products that supply chain actors trade; but other relationships may also be implicated.

2.5 Conceptual Framework

This research proposes an initial conceptual framework (Figure 2.2) to lay the foundation for understanding and studying the relationship between product deletion and supply chain performance on processes and competencies. The core of the framework is the focal firm's product deletion decision. This phenomenon is expected to impact five supply chain processes, which include sourcing, operations and manufacturing, distribution and logistics, usage and service, and reverse logistics and a circular economy, adjusted from the SCOR model (Huan et al., 2004). The SCOR model (Huan et al., 2004), which relates to the value chain, is a popular supply chain process reference model. Activities in the traditional SCOR model include: (1) sourcing, (2) operations and manufacturing, (3) distribution and logistics, and (4) usage and service. The four organizational supply chain operational competencies (flexibility, cost, quality and time) and sustainability performance (economic, social, environmental) will be impacted by the product deletion decision, through the four supply chain activity dimensions.

These supply chain processes typically follow a cycle, which is depicted in the framework with dotted arrows. It is also proposed that the four major strategic operational competencies within each process are also affected by product deletion. These competencies, based on the operations strategy literature (Flynn et al., 1999) include costs, flexibility, quality, and time.

2: Figure 2.2: Conceptual Framework of Product Deletion's Influence on Supply Chain Processes, Competencies and Sustainability



Note: The four circles surrounding the central circle represent supply chain management processes, which are impacted by product deletion. Four supply chain competencies play an important role within each supply chain management process. Product deletion also affects each of these four competencies. These supply chain competencies are C = Costs; F = Flexibility; Q = Quality; T = Time; S = Sustainability.

These supply chain processes and competencies all impact product deletion decisions. How each is influenced is now delineated.

2.5.1 Sourcing

Sourcing activity is critical in upstream SCM. Supplier selection, monitoring, communication, and collaborative development are among the important sourcing activities. Suppliers can fulfill the need for raw material, resources, technology, and knowledge of certain products. If their products are deleted, the relationship is likely weakened. Supplier inputs decrease, resulting in supplier deletion or supplier changes. Product deletion results in reduced dependency on certain suppliers; critical supplier evaluation and reselection becomes significant when product deletion decisions occur. Product deletion may decrease the overall supply chain resource consumption. A leaner product portfolio helps reduce the overall material sourcing, energy usage, and waste output to the environment as eliminated products are no longer manufactured, distributed, consumed, or disposed.

Selecting certain suppliers requires a consideration of capabilities and competencies related to product characteristics (Govindan et al., 2015). For example, certain environmentally based supplier selection criteria include the ability to supply recycled material and components, having green manufacturing processes, using certified environmentally sound materials, or having environmental certifications (Bai and Sarkis, 2010b; Genovese et al., 2013). Supplier monitoring involves supplier performance evaluation based on operational and strategic criteria. Different monitoring systems need to be established for different suppliers with regard to various sourcing materials, these monitoring systems and factors serve as fundamental performance indicators for product management.

Another strategic sourcing activity, supplier development, helps to build knowledge and expertise in suppliers. Supplier development includes product related expertise and knowledge transfer and communication, investment and resource transfer, and management and organizational practices. However, if a product is no longer a priority for the focal firm due to its deletion, there might be advantages and/or disadvantages associated with sourcing activities. These are further discussed in detail with respect to four competencies (flexibility, cost, quality, and time) that play an important role in sourcing processes.

Flexibility: If a sourced product or material is meant to have certain characteristics, these characteristics will no longer be required if the product is deleted. A minimal carbon footprint is an example of a green product characteristic (Onozaka et al., 2016). In some regions of the world, the carbon footprints of products are labeled on the packaging. To lower the carbon footprint, companies may practice a buy-local sourcing model, or may have their products delivered through low carbon delivery modes. These deliveries may be completed through alternative energy or electric vehicles that do not emit significant carbon and thus help reduce transportation emissions. If a company is discontinuing certain products, then they can choose from a broader set of delivery modes and locations for sourcing their materials and product components, improving supplier network flexibility (Thun and Müller, 2010). However, given too much flexibility in sourcing alternatives, the loss of knowledge related to certain materials or suppliers may limit the understanding of sourcing activities, causing difficulties in alternative evaluations (Vyas, 1993). Overall, there is a greater likelihood of an improvement in sourcing flexibility due to product deletion.

Cost: With product deletion, there is less need for organizations to integrate specific capabilities in the supplier selection process for that product. Therefore, potentially lower costs are possible due to increased negotiating power with a broader supplier choice set and greater competition among suppliers. Given more flexibility in sourcing activities, companies could delete those materials and components that are at a premium price due to lack of economies of scale and hidden cost inclusion (e.g., social cost) (Baumers et al., 2016; Martin et al., 2010). Thus, purchasing alternative counterparts reduces material cost. Overall, therefore, there is a greater likelihood of sourcing cost reductions due to certain product deletion.

Quality: When certain products are deleted, the emphasis on quality initiatives in supplier selection and monitoring may be greater due to the shift from the reallocation of supplier development resources away from certain programs to other development programs that might lead to a quality improvement in the overall product portfolio. Overall, sourcing quality improvement is more likely in the event of product deletion.

Time: The organization can insource the material or the product if certain product aspects are no longer essential. Insourcing, similar to vertical integration, allows for greater control and more efficient, timely processing (Foerstl et al., 2016). However, more time might be required to switch supplier resources and build supplier expertise from deleted products to other dissimilar products (Argouslidis et al., 2014; Fisch & Ross, 2014). Overall, there is a greater likelihood of saving time in sourcing activities due to product deletion.

Hence, after considering the pros and cons of product deletion on its sourcing activities and competencies, in general it is proposed that: *Product deletion will likely result in (a) greater flexibility, (b) lower cost, (c) higher quality, and (d) shorter time; and result in (e) greater economic sustainability, (f) better social sustainability, and (g) larger environmental sustainability in sourcing activities.*

2.5.2 Operations and Manufacturing

Product portfolio complexity relates directly to manufacturing capability. Product deletion provides a novel angle for managing manufacturing capability issues. When a product deletion occurs, product portfolio complexity decreases, resulting in the freeing of manufacturing capability. Deleted products free up drained resources and material while reducing manufacturing complexity. Increased manufacturing capability will yield better quality and delivery performance for the remaining products due to freed up resources. Deleted products and planned reclamation of deleted products can reduce waste in manufacturing processes. These influences are depicted next with respect to the four competencies (flexibility, cost, quality, and time) that play an important role in operations and manufacturing.

Flexibility: Deleting products eliminates dynamic restrictions, allowing for a wider range of product design alternatives. Sometimes, significant testing may be required for just one dimension of a product (Lee & Bony, 2007). If the firm is deleting certain systems required for manufacturing the deleted product, the production line can become more standardized due to less product variety, despite the improvement in the overall flexibility of manufacturing and operations. Overall, there is a greater

likelihood of improvement in the flexibility of manufacturing and operations activities due to product deletion.

Cost: With the deletion of a product, its associated systems and certifications may no longer be needed for that product. The implication would be lower costs due to the lack of a requirement of certain certifications in operations. Furthermore, associated materials are no longer required in manufacturing, thereby reducing the material variety requirements. This means the focal firm has to manage a narrow range of materials inventory, leading to lessened inventory levels, better control, and thus lower costs (Wan & Sanders, 2017). However, the initial investments in the manufacturing facilities and operational infrastructure development, which are specifically designed and constructed for those products, will no longer be needed. Therefore, restructuring facilities and infrastructure will burden the firm, especially if moving from very different product development and manufacturing directions (Saunders & Jobber, 1994). However, overall, there is a greater likelihood of cost reduction in manufacturing and operations activities due to product deletion.

Quality: Quality increase may occur in the product portfolio due to slack resources from the deleted product and focus on remaining product quality specifications (Anderson, 2001; Avlonitis et al., 2000). Furthermore, product deletion leads to inventory reduction, which also improves overall product quality (Ton & Raman, 2010). With a more rationalized product portfolio, companies will be more focused in their product management strategic development; thus, the quality of overall market offerings will increase in the long run. Overall, product deletion is expected to improve quality in operations and manufacturing activities.

Time: Low efficiency in the manufacturing and operations processes, at least in the short run, results in longer time due to shifting product characteristics and worker retraining (Harness and Marr, 2004). However, the product manufacturing process might be shortened since fewer internal auditing activities will occur, resulting in fewer delays (Edwards, 2003) depending on the occurrence and frequency of internal auditing for a variety of products' operations and processing. In general, product deletion is likely to result in longer manufacturing and operations processes.

Based on the above discussion, in general it is posited that: *Product deletion will likely lead to (a) greater flexibility, (b) lower cost, (c) higher quality, and (d) longer time; and result in (e) greater economic sustainability, (f) worse social sustainability, and (g) worse environmental sustainability in operations and manufacturing processes.*

2.5.3 Distribution and Logistics

Activities in distribution and logistics are influenced by product deletion. These activities include deciding and managing distributing channels, warehouses, packaging partners, retailers, third-party logistic providers, and labor involving sorting and collecting inventory (Zhu and Shah, 2018). The more complex a product portfolio, the more strategic criteria will be needed in organizational logistics selection. Product deletion, when reducing and rationalizing the product portfolio, will lead to fewer logistics partners, fewer quantity of delivery trips, fewer warehouses and lessened packaging requirements, due to reduced product lines, categories, and other variants (i.e. SKUs). Due to compact distribution networks and fewer logistics varieties, the overall supply chain performance in distribution and logistics of the remaining products is likely to improve in the long term perspective, such as delivery quality and time reliability. Rationalization across the supply chain provides profound waste reduction opportunities.

Distribution and logistics include managing activities related to distribution channels, warehousing, packaging, retailing, logistics, transportation, and the sorting and collection of end-of-life products (Franchetti et al., 2017). These downstream processes can be quite extensive, with significant uncertainties. These influences are depicted next with respect to four competencies (flexibility, cost, quality, and time) that play an important role in distribution and logistics.

Flexibility: Packaging design typically utilizes materials using checklists for specific products (Holdway et al., 2002). If certain products are deleted, the associated packaging limitation is no longer a constraint; therefore, more packaging can be associated with aesthetics and marketing, which means more

flexibility in packaging alternatives (Lee & Xu, 2005). The delivery and transportation selection process after product deletion will also allow for greater choices of warehouses and transportation modes (Dekker et al., 2012). However, loss of knowledge in certain packaging designs and transportation modes may reduce experience and expertise (Holan & Phillips, 2004). Overall, there is a greater likelihood of improvement in distribution and logistics flexibility due to product deletion.

Cost: There is a hierarchy of most to least environmentally efficient delivery modes when it comes to energy usage and emissions per unit. Typically, air transportation has been viewed as the least ecologically efficient, while maritime shipping as the most efficient on a per unit delivery basis (Rondinelli & Berry, 2000). If the product candidate is introduced with a pro-environmental purpose, with its deletion, there will be a lessened need to find the most ecologically efficient transportation mode. Wider choices of modes may facilitate major cost reduction depending on the availability of logistics alternatives. In addition, the interaction between packaging and transportation might also have cost implications. Product deletion may decrease wasteful packaging for aesthetic purposes. Wasteful packaging leads to greater packaging and transportation costs (Prendergast & Pitt, 1996). At this stage, supply chain activities work more closely with both organizational and individual customers, as deleting products may risk the company losing customers (retailers) who are loyal to that product (Homburg et al., 2010; Vyas, 1993). Greater potential costs are incurred to seek new markets and customers. Therefore, overall, there is a higher likelihood of an increase in distribution and logistics costs due to product deletion.

Quality: Delivery reliability is an important quality measure for this stage. Greater distribution and logistics alternatives and decreased product portfolio complexity can improve scheduling and delivery reliability; thereby, the quality of the remaining product portfolio will increase (Bello et al., 2003; Jap et al., 1999). With product deletion, similar to other supply chain processes, organizations could switch emphasis and slack resources to other quality-oriented factors. Overall, there is a higher likelihood of improvement in distribution and logistics quality due to product deletion.

Time: Time consuming regulations are not necessary when associated products are removed from the product portfolio. For example, if the product candidate was under regulatory policy, such as Waste Electrical and Electronic Equipment (WEEE) (Ebrahimpour & Johnson, 1992), after its deletion, regulatory compliance with that policy is not required. Therefore, a shorter lead-time cycle is expected, as compliance with environmental product regulations is no longer required post product deletion. Reverse logistics and closed-loop supply chain activities are not necessary any more, thus saving time resources that can be dedicated to other business processes. Overall, there is a greater likelihood of saving time in distribution and logistics activities due to product deletion.

In general, it is proposed that: *Product deletion will likely result in (a) greater flexibility, (b) higher cost, (c) higher quality, and (d) shorter time; and result in (e) worse economic sustainability, (f) worse social sustainability, and (g) better environmental sustainability in distribution and logistics activities.*

2.5.4 Product Usage and Service

Consumer usage and organizational after-sales oriented activities contribute to downstream SCM. These functions are also influenced by product deletion decisions. For products that are not designed for take-back or return, supply chain activity ends with a product purchase transaction. If products are deleted, the associated after-sales service will eventually not be needed. Returns, exchanges, restock, and resale are influenced through inventory management, retailer's responsiveness, and customer relationship management. If there are product stewardship activities in after-sales activities it will mean that product recycling, waste management, reclamation, and remanufacturing will no longer be useful.

After product delivery, individual end users use and consume the product. Product usage and service activities are downstream supply chain processes and are thus closer to individual consumers and product end-users. Here consumers expect after-sales service from focal firms. Product deletion affects

the product usage and service activities with respect to four competencies (flexibility, cost, quality, and time) that are discussed below.

Flexibility: With a product deletion, it is expected that an organization's supply chain responsibilities will end after a consumer's purchase transaction. Organizations may no longer have the responsibility of product recycling and resource reclamation, unless required by law. The implications for the focal firms will be more flexibility within the overall supply chain processes due to additional resources released from discontinued product end-of-life activities that could be redeployed to other supply chain activities. Recycling is an example of product end-of-life activity, which will no longer be required when an associated green product is deleted. One may argue that the focal firm will lose its "recycling flexibility"; however, on the other hand, it is also gaining "labor flexibility" (Bai and Sarkis, 2017). Therefore, overall, usage and service process flexibility improve with product deletion.

Cost: End-of-life activities are adopted by focal firms to acquire less expensive materials and/or components (Guide et al., 2000). With product deletion, costs could potentially increase, since waste reduction emphasis is lessened, resource reclamation is not required, and close-loop resource reallocation is not necessary for that product. Therefore, overall, there is a higher likelihood of increase in usage and service cost due to product deletion.

Quality: Extended producer responsibility (EPR)[1] is an important aspect of close-loop supply chain designs. When a product is deleted, organizations may not necessarily need to attach the after-sales service required by that product's EPR practices. This lack of service may result in consumers perceiving the product to be of lower quality, and may eventually affect consumers' satisfaction levels and perceived brand reputation, both of which are quality measures (Brodie et al., 2009; Sengupta et al., 2015). In general, the quality of usage and service activities is expected to be reduced due to product deletion.

[1] EPR is defined as an organization's responsibility for a product that emphasizes the post-use stage of a product's life cycle. Two primary dimensions of EPR include the producing organization: (1) being at least partially responsible for a product's end-of-life, physically and economically; and (2) incorporating environmental considerations in product design (Lifset et al., 2013).

Time: If focal firms engage in EPR activities, such as offering rebates and deposit-refunds to have consumers return their used products, the product life cycle time is shortened because it is likely that consumers will return products in a relatively shorter time (Souza, 2013; Taylor, 2000). With the deletion of the selected products, its associated EPR incentives are no longer needed; resulting in increased product life cycle time. In addition, in the long run, EPR dissolution would potentially hurt firm image and perception (Albino et al., 2009); thus, more time would be needed to establish firm market standing and to acquire new customers. In general, product deletion is likely to result in longer times in usage and service activities.

Considering the above discussion, it is proposed that: *Product deletion will likely result in (a) greater flexibility, (b) higher cost, (c) lower quality, and (d) longer time; and result in (e) worse economic sustainability, (f) better social sustainability, and (g) better environmental sustainability in usage and service activities.*

2.5.5 Reverse Logistics and a Circular Economy

In addition to the SCOR model, this work considers environmental sustainability as a major supply chain performance metric. A reversed loop can provide additional sustainability implications. Reverse logistics activities relate to after-service supply chain functions and represent the reverse supply chain flow of used materials and products. They are also critical to warranty and takeback functions. Lately, there has been interest in circular economy development in many countries and organizations (Kirchherr et al., 2017). The circular economy is dependent on reverse logistics (Potting et al., 2017). Organizations are encouraged to delete those products not capable of material repurposing including recovery and recycling, repairing, reusing, and refurbishing. If these products are deleted, there will be a decrease in resources required for the entire product portfolio. The freed resources may be channeled to fortify the remaining products in the portfolio. This repurposing can yield a higher resource efficiency, resulting in more sustainable development and less waste.

Many countries and organizations have an economy development agenda (Kirchherr et al., 2017). Product level changes can impact and be impacted by the strategic implementation of reverse logistics and a circular economy. From the linear economy to circular economy, a revolution can be made to products and their associated materials, from the application of essential materials to the extended lifespan of products and its parts, to smarter product usage and manufacturing (Potting et al., 2017). For this purpose, organizations are encouraged to delete those products that not capable of material repurposes including recovery and recycling, repairing, reusing and refurbishing. In return, if these products are deleted, there will be a decrease in the total amount of resources required for the entire product portfolio, or the freed resources and the saved natural resources may be channelized to fortify the remaining products in the portfolio. This situation results in higher resource efficiency and repurpose, resulting in more sustainable development and less waste to the land, air, and ocean.

In this study, all three dimensions including environmental sustainability, are introduced to product deletion and supply chain performance for a more complete picture of the managerial concerns and theoretical development. This addition links stakeholder theory and nature resource-based view conceptualizations to RBV and RV to firm competitive advantage. For example, product deletion helps firms to reallocate resources from underperforming products to better performing products. When the product portfolio is rationalized by deleting underperforming products, there will be a decrease in the total amount of resources required for the entire product portfolio, or the freed resources may be channeled to fortify strong products in the portfolio. As a result, the overall supply chain practices will consume fewer natural resources while creating less waste that flows into the natural environment (Zhu and Shah, 2018).

Table 2.2 summarizes the relationships of product deletion and their potential impact on an organization's supply chain processes, competencies, and sustainability. It is a 4 x 7 matrix, with columns representing the four strategic supply chain performance competencies (flexibility, cost, quality and time) and sustainability performance (economical sustainability, social sustainability, and environmental sustainability), and rows representing supply chain processes (sourcing, operations and manufacturing,

distribution and reverse logistics, and usage and service). Within each cell, the overall consequences and sustainability performance of product deletion are shown for each supply chain process with regard to a specific competency. The upward facing arrow represents an increase in each competency within a specific supply chain process, and the downward facing arrow represents a decrease. A grey arrow represents a negative impact such as increase in cost or time, and a reduction in quality or flexibility. The general propositional relationships are derived from literature and practice.

2: Table 2.2: Relationships between Product Deletion on Supply Chain Processes and Competencies

	Flexibility (a)	**Cost (b)**	**Quality (c)**	**Time (d)**	**Economic Sustainability (e)**	**Social Sustainability (f)**	**Environmental Sustainability (g)**
Sourcing							
Operations and Manufacturing							
Distribution and Logistics							
Usage and Service							

Note: The upward facing arrow represents an increase in each competency within a specific supply chain process, and the downward facing arrow represents a decrease. A grey arrow represents a negative impact such as increase in cost or time, or reduction in quality or flexibility. A white arrow represents a positive impact such as decrease in cost or time or increase in quality or flexibility.

Across every cell, the common drawback of product deletion is lessened social responsibility for associated jobs and customer segments. The strategic concerns include not meeting the needs and expectations of a broader stakeholder community, beyond business partners. Other advantages of supply chain strategies include maintaining business continuity in the supply chain, having a license to operate, additional revenue generation, and improved company image (Sarkis, 2013). It is likely that some or all of

these advantages, known for ‘making the business case’ and not considered amongst the operational performance competencies and process activities, will be lost. However, the critical positive business consequences of product deletion in terms of a company adopting a leaner and more rationalized product portfolio should not be underestimated.

2.6 Research Objectives and Questions

Despite a flurry of attention during the early 1980s and occasional publications thereafter, the topic of product deletion still suffers from research neglect. This lack of research is surprising, given its role in aiding product management that is central to organizational competitive survival.

Based on a joint literature review on product deletion and SCM (Table 2.3), a number of major research gaps are identified.

These research gaps include: (1) no linkage has been established between product deletion and SCM; (2) no systematic product deletion decision making processes including supply chain dimensional factors have been considered; and (3) there has been no investigation indicating a product deletion’s impact on organizational sustainability, especially environmental sustainability.

This work attempts to answer the following research questions:

Research question 1: What are the organizational processes and routines for product deletion? What is the role of the supply chain in these processes?

Research question 2: Will supply chain dimensional factors impact product deletion decisions? How influential are these supply chain factors when compared to other organizational factors, such as marketing, sales, and financial factors?

3: Table 2.3: Positions and Contributions

	THEMES / FOCUS										
	SUPPLY CHAIN MANAGEMENT										
PRODUCT DELETION LITERATURE	***Competencies***				***Processes***				***Sustainability***		
	Flexibility	Cost	Quality	Time	Sourcing	Operations and Manufacturing	Distribution and Logistics	Usage and Service	Economic	Social	Environmental
(Avlonitis, 1983a)						√					
(Avlonitis, 1983b, 1985)									√		
(Avlonitis, 1987)		√							√		
(Avlonitis, 1993)	√					√			√		
(Avlonitis, 1984)								√	√		
(Banville and Pletcher, 1974)	√						√		√		
(Weckles, 1971)		√					√	√	√		
(Evans, 1977)		√						√			
(Hamelman and Mazze, 1972)	√	√							√		
(Hart, 1988)	√				√	√				√	
(Ashayeri wt al., 2015)									√		
(Kent and Argouslidis, 2005)								√			
(M. Mitchell et al., 1997; 1998)		√			√	√			√		
(Muir and Reynolds, 2011)			√	√	√	√	√		√		
(Rothe, 1970)		√							√		
(Shah, 2015)							√	√	√		
(Zhu and Shah, 2018)					√	√	√	√	√	√	√
(Zhu et al., 2018)	√	√	√	√					√	√	√
THIS WORK	**√**	**√**	**√**	**√**	**√**	**√**	**√**	**√**	**√**	**√**	**√**

Research question 2a: What are the supply chain dimensional factors that impact product deletion?

Research question 2b: How does product deletion impact the supply chain?

Research question 3: Can a predictive model/choice model be developed for product deletion decisions? This model would help arrive at decisions such as:

Research question 3a: Which one(s) to delete? When and how many?

Research question 3b: What are the model characteristics and its practical usefulness; and how can the model be improved?

This study: (1) challenges the traditional view that adding products is preferable for firm performance; (2) posits that product deletion would directly impact supply chain performance; (3) applies supply chain theories to help explain and predict product deletion decisions and processes; (4) lays both a conceptual and practical foundation for the further investigation of the linkages between product deletion, marketing, and SCM; and (5) is one of the early endeavors to integrate environmental supply chain sustainability into the product deletion decision-making process.

CHAPTER III: METHODOLOGY

This chapter provides sufficient detail about the methodology used so that the study could be replicated. Little is known on product deletion both in academics and in practice. Qualitative and quantitative methodologies together contribute to the findings of strategic product deletion management.

Most contributions to the existing literature on product deletion have been theoretical (Avlonitis et al., 2000b; Zhu et al., 2018a). In consequence, well-founded knowledge is limited in this research area for managerial application. The overall aim of this work is to acquire and present empirical data about product deletion decision-making behavior in companies and their practical supply chain implications. In addition, organizational historical data will be collected and further analyzed using Bayesian analysis. Bayesian analysis is used for purposes of statistical inferencing, prediction, and potentially as a decision-making model. As a predictive forecasting tool, the model can identify which product candidate can be deleted depending on the business context.

This work aims to use evidence from a diverse industry set, also diverse international locations, when examining product deletion decisions and the decision making process influences on the supply chain. The qualitative research was conducted in a number of countries, both developed and developing ones, respectively, Australia, China, India and Iran. The population subjects are include medium (500-1000 employees) and large sized (1000 - 7000) companies engaged in the manufacturing process of the product candidates.

The study has two main stages: (1) an interview survey which includes 16 in-depth company one-on-one interviews ranging from two days to one week in duration per company; and (2) company historical data acquired to provide insights about interview data. A qualitative evaluation was completed from the initial case study evaluation and is discussed in Chapter 4. The resulting outcome is a theoretical framework for strategic product deletion management. Bayesian analysis was used to analyze the integrated data sets as a quantitative evaluation discussed in Chapter 5. The two main outcomes include:

(1) to evaluate proposed decision making and influencing factors as part of theory building and evaluation; (2) to develop inferencing and predictive models to help determine product deletion candidacy and forecast implications incorporating performance matrices of marketing, finance, supply chain and sustainability.

3.1 Qualitative Study

Qualitative research includes a variety of research methods that use language-based data are clustered (Denzin and Lincoln, 2008; Patton, 1990). Such research methods are oriented towards understanding meanings and experiences; often used in neglected investigated areas, seeking new insights and context discovery (Bowers et al., 1990). Limited research has been conducted in product deletion decision making antecedents and processes, even more neglected in supply chain management and sustainability research; yet this is a complex and important strategic planning phenomenon. On top of the inadequate existing literature, knowledge of it can be best arrived at by conducting interpretive qualitative research by generating practical experiences from industries, managers, decision makers of products.

Grounded theory (Corbin and Strauss, 1990) using case study interviews (Eisenhardt and Graebner, 2007) is utilized to explore the antecedents and processes for this strategic decision making. These in-depth interviews are designed to provide practical insights of what, how, and why organizations make product deletion decisions; specifically what determines a product will be deleted, what factors are considered in the decision, what product deletion process is used, and what cross-functional teams are involved (Campbell et al., 2013).

Qualitative research consists of three critical elements, including data, procedures and reports (Denzin and Lincoln, 2008). Qualitative data can be in the forms of observations, case studies documentations, transcriptions of interviews, and audio or recorded files. Procedures include transcribing if necessary, conceptualizing, reducing, elaborating, interpreting, integrating, and relating. In this study, procedures are conducted through analytic processes in Nvivo 12 of sampling, coding, analyzing and

diagramming (Richards, 1999). The detailed data gathering, and procedures and reports categories are stated in sections 3.1.1. and 3.1.2.

3.1.1 Case Study Method

The theoretical foundation including theories and framework primarily draws from previous literature, common sense, and subject matter of expertise. Whereas, the tie to actual data in the topics of product deletion and supply chain management has been tenuous. Case study methodology as an inductive and exploratory oriented process is comparatively appropriate for new topic areas. Frame breaking insights, tests of related theory, and convincing grounding in practical evidence are key criteria for evaluating this type of research.

Glaser and Strauss (B. Glaser and A. Strauss, 1967) and Strauss (Strauss, 1987) have detailed how case study develops grounded theory based on continuous comparison and relation of data and theory. The iterative case selection and data gathering compose an incremental approach for exploring emergent research questions. Yin has established a systematic typology of case study designs as a research strategy (Yin, 2011); and developed and reasoned the replication logic which allows for multiple case study analysis (Yin, 2017). The validity and reliability of case study methodology as an empirical research method has gained importance in business and management research (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Riege, 2003; Yin, 1994).

3.1.2 Case Study Design and Procedure

The proposed case study procedure is adopted and designed according to Yin and Noor (Noor, 2008; Yin, 1994). There are major four stages of the case study, including a preliminary stage, fieldwork and data collection stage, data analysis stage and conclusion stage (Table 3.1).

4: Table 3.1: In-Depth Case Study Procedure and Steps

Stages	**Steps**	**Activities**
Preliminary stage	Getting Started	a) Clarify the research question b) Shortlist some propositions c) Possibly a priori constructs
	Selecting Cases	a) Purposive theoretical sampling b) Snowball sampling
	Crafting Instruments and Protocols	a) Multiple data collection methods: a. In-depth interviews b. Archival documentations b) Qualitative and quantitative data combined c) Interdisciplinary investigators
Fieldwork and data collection stage	Entering the field	a) In-depth case studies b) Flexible data collection methods
Data analysis stage	Analyzing data	a) Within-case analysis b) Cross-case pattern search using divergent techniques
	Shaping hypotheses	a) Iterative tabulation of evidence for each construct b) Replication, not sampling, logic across cases c) Search evidence for "why" behind relationships for each research questions
	Enfolding literature	a) Comparison with conflicting literature b) Comparison with similar literature
Conclusion stage	Reaching closure	a) Theoretical saturation b) Grounding theory

Preliminary Stage

Three steps are included in the preliminary stage. First and foremost is to clarify the research question, shortlist propositions and constructs. The research questions for this study are generalized to be:

1) Have organizations been aware of or experienced product deletion decisions?

2) Is there a systematic working process to facilitate product deletion decision making?

3) What departments are involved in product deletion decisions? Which department has greater power?

4) What factors are considered when deciding which product candidate to delete?

5) Is there a need for a decision making tool/model to assist in making product deletion decisions? What are the expected characteristics of such a tool?

Owing to the limited literature linkage between product deletion and supply chain management, the research questions are comparably broad and generic. Therefore, in this study, there is no set specification for organization type, industry, country, or data type.

A prior specification of propositions and constructs are critical but essential for the initial case study designs. The general propositions will help shape the broad logic of the in-depth interview protocol. In this study, the propositions are listed in the following:

(1) Product deletion, as a regular product management activity, is a critical and complex decision that influences various aspects of firm performance, including supply chain management.

(2) Product deletion impacts supply chain processes -- from sourcing to manufacturing, delivering to usage and end-of-life -- and competencies -- flexibility, quality, cost, and time.

(3) Product deletion decision making should incorporate cross-functional factors, and supply chain dimensional factors play a major role in making a sound product deletion decision.

(4) There is a need for a systemic and analytical tool or model to facilitate organizational product deletion decisions.

(5) Sustainability is a novel dimension that should be incorporated into product deletion decision making. There may likely be tradeoffs amongst the economic performance of a product versus its social and environmental performance.

Constructs development and relationships are also important for conducting case studies. With continuous case studies, if these constructs prove important in the data collection processes, there is firmer empirical grounding for the relevant theories including RBV and RV. In this study, the interview protocol is designed around related constructs from both product deletion, supply chain management and sustainability literature streams. From the product deletion literature streams, possible constructs include position on PLC, product portfolio size, market trends, market share and competition, correlations with other products in the portfolio and potential organized intervention, customer demand and loyalty. From the supply chain management literature, possible constructs include flexibility, cost, and quality, time of

supply chain processes from sourcing activity to usage and end-of life. From the sustainability literature stream, constructs include the triple bottom line, respectively economic, social and environmental dimensions. These constructs will be explicitly and implicitly measured within the interview protocol. When several of these constructs did merge as related to the product deletion decision making process, there was strong evidence on which to ground the theory; meanwhile, more constructs might arise from the case study processes as well.

The second step is to select cases. Case selection is an important aspect of case study research. The case, in this study, the organization and interviewee, composes the concept of population. The determination of population is critical because it defines the research sample from whom to draw research findings. In this study, the case selection follows purposive theoretical sampling and snowball sampling. There is no demographic criteria for the sample except for: (1) fulltime employee of the interviewed organization; (2) respondent working closely with products or have experienced product management activities; and (3) in each cross-functional department, at least one senior level (e.g. manager/director) will be interviewed. Snowball sampling is also applied. Participants were recruited by email. The referral amongst the interviewees was allowed and expected.

The third step is crafting instruments and interview protocols. Qualitative researchers often combines multiple data collection methods. Such methods include interviews, focus groups, surveys and questionnaires, as well as archival sources such as organizational annual reports (Neuman, 2014; Patton, 1990). In this study, both qualitative (in-depth interviews) and quantitative data (archival documentation, e.g. CSR report) were integrated. Interdisciplinary investigators in this study also bring more validity to the interview processes. In this study, an investigator(s) knowledgeable in both marketing and supply chain domain conducted the company interviews. The convergence of observations from different angles enhances confidence in the overall findings.

Fieldwork and Data Collection Stage

The next stage is entering the field. Participants are interviewed by the investigators for approximately 2 hours. They are first informed about the study and informed consent is explained to them. After they sign the consent form, they are asked about some demographic information including gender, age, education level, as well as their position titles and roles in their respective companies. Second, they will be given a definition of product deletion, followed by a series of questions about what product deletion associated activities they have experienced regarding their tenure within the company. Third, participants will be asked questions on how product deletion decisions are managed and their influences, benefits and opportunities in their organizational strategic development. The interviews will end with open-ended questions about their understanding and suggestions for product deletion decision making and product development.

One of the characteristics of the case study research is the frequent overlap of data collection and data analysis. After an interview is completed the recordings are transcribed. The transcriptions are then imported to NVivo analysis software for further data coding and analysis. The interpretations of the results then be completed. The data analysis proceeds simultaneously with interviews. The purpose is to count and report the frequency and occurrence of themes and constructs involved in content analysis. Data collection and analysis are interrelated with simultaneous constant comparison and contrast in the fieldwork stage. The data collection methods are flexible depending on the interviews and interviewees. The participation level, number of respondents, in the data collection process will depend on thematic saturation.

Data Analysis Stage

There are three major steps in the data analysis stage: analyzing data, shaping hypotheses and enfolding literature. Analyzing data is core for case study evaluation. In this study, data analysis will include within-case analysis and cross-case pattern search using divergent techniques. Within case and cross-case tactics aim at going beyond the literature and propositions initial impressions. Using the structured and diverse lenses on the data will enhance trustworthiness with credibility, transferability,

dependability and confirmability, from data collection to data interpretation and reporting. In this study, four cross-functional teams or members were interviewed to generate their opinions on product deletion both within their own department standpoint but also outside their own department concerning to the correlations to other departments. For each cross-functional role, a set of survey questions was designed (see Appendix A). For example, the interviewee from the marketing department is asked more about product activity questions than an interviewee from a finance department. The finance department respondent is questioned more on financial performance. Also, each department will be asked about their current and expected power to make or influence product deletion decisions, as well as their comparative power amongst other departments. These tactics eventually improve the likelihood a more accurate and reliable theory with best fit to the data collected. The greater depth of the interview protocol, the more likely novel findings can be captured within the data.

Built upon the within-case and cross-case analysis, tentative themes, constructs, as well as relationships amongst variates will arise to shape the hypotheses. The critical iterative process step of relating the data evident to the propositions allows for systematic comparison and alignment of the proposed framework with each case study. It allows for assessment of fit for the case data, and evaluating the accuracy of the proposed framework and general propositions. The purpose of this iterative process is to yield an empirically valid grounded theory.

Shaping theories and enfolding literature involves refining the selection and definition of constructs; clarifying the measurement for each construct and validating relevant theories. In this study, the selected possible constructs are drawn from the product deletion, supply chain management and sustainability literatures based on the propositions and associations with RBV and RV. Since the interviews were conducted across functions, it is anticipated that some of the constructs will found to be significant. The collective case studies will help refine the constructs with measurements, as well as relevant theories. This step is critical because it verifies the fit between proposed relationships amongst constructs and collected evidence from the cases. A proposed relationship will be retained for further

discussion until it is confirmed or supported by the case evident data; otherwise it will needs revision, or even abandon owing to insufficient fit. The detailed interview results and refining process are introduced in Chapter 4 with a series of both theoretical and practical findings.

Conclusion Stage

The issue of when to stop adding cases depends on reaching theoretical saturation. Saturation has attained widespread application as a validation of methodological trustworthiness in qualitative research such as case studies and grounded theories. In broad terms, saturation is used as a criterion for indication that, on the basis of the qualitative data has been collected and analyzed hitherto, no further data collection, analysis, and theorizing is needed to draw conclusions.

Theoretical saturation is defined when there is limited incremental learning that can be drawn from the case studies (B. Glaser and A. Strauss, 1967; Sandelowski, 1995); such as achieving the necessary repeated similarities and contrasts required. Failure to reach saturation challenges the quality of the qualitative research conducted.

The realization and implications for how and when saturation will be sought can be different. Instead of using a standardized formation of saturation, saturation should be operationalized in a way that is consistent with the research question(s) of the work, and the theoretical position and analytic framework obtained, but also constricted to the research scope, so as not to risk saturation losing its coherence and potency if the conceptualization is given too broadly. The detailed saturation formation of this qualitative study appears in Chapter 4.

3.1.2 Grounded Theory

The origins of saturation lies in grounded theory (B. Glaser and A. Strauss, 1967; Strauss and Corbin, 1998). Grounded theory was developed as an argumentation to extreme positivism of seeking scientific truth and ultimate belief. Grounded theory seeks to reveal preexisting and universal explanations of social behavior.

Glaser and Strauss proposed grounded theory as a practical method for qualitative research focusing on the interpretive processes by analyzing the "the production of meanings and concepts used by social actors in practical settings" (Gephart Jr, 2004). The conceptualization of grounded theory emphasizes identifying contrasts amongst practical phenomena through interpretive analysis to form a theoretical framework and foundations.

Grounded theory is an inductive research methodology (Corbin and Strauss, 1990). The reasons and purposes of applying grounded theory in this dissertation include:

(1) The lack of standard definitions, constructs, conceptual frameworks in the field of product deletion;

(2) To ground the emergent theoretical conceptualization detailing the product deletion operationalization from perspectives and practices of industrial represents;

(3) Lack of systematic routines and antecedents as decision making facilitator;

(4) To develop a grounded theoretical framework that could guide future research and practical application.

The trustworthiness of grounded theory methodology lies in the analytic power of knowledge enhancement (Bowen, 2006; Rolfe, 2006): First, The data analysis procedure starts with simultaneous data collection and analysis. Second, open coding, analytic codes, categories, and themes from the data is completed. These two steps do not use predetermined theories and hypotheses. Third, analytic codes are compared as coding continues through the analysis processes. Fourth, developing theoretical conceptualization along with data collection and analysis. Fifth, review the literature post analysis.

Grounded theory does not start with a predetermined theoretical framework. The sampling data is sorted and managed through microanalyses. Such microanalyses in this dissertation has 5 steps:

Step 1: Audio recorded interviews

Step 2: Transcriptions and inputs into Nvivo 12

Step 3: Data coding. The data is carefully scrutinized line by line and word by word through open coding. Amongst all open codes, relationships are drawn through axial coding as context discovery.

Step 4: Interpretation. Based on properties of identified concepts and relationships, categories and themes are developed. These interpreted categories and themes form the fundamental basis for the emergence for theoretical development. Step 4 is most critical as it opens novel avenues of theoretical directions and enhances the in-depth understanding of product deletion.

Step 5: Develop the case study. Summaries are derived from multiple countries, companies, managerial roles, gender, race and personal working experience and beliefs. Diversified while consensus opinions can be arrived with vivid conceptualizations and theoretical saturations.

The working flow and an example of open coding and axial coding appears in Chapter 4. Overall, grounded theory, as an inductive method, fits the purpose of this dissertation in terms of identifying the roots and roles in context discovery and theory building. Perspectives from individuals who directly implement product deletion decisions are more appropriate and reliable, compared to limit deductive reasoning from literature streams.

3.1.4 Critical Analysis of Case Study Research

There are advantages and limitations of conceptualizing case studies as qualitative research methodology (Bryman, 2017; Johnston et al., 1999). One of the strengths of theory building from cases is its likelihood of generating novel conceptualizations through its iterative processes. This advantage is greater when it comes to an under-investigated research area. Since there is little evidence that could be generated from the existing works, exploratory field studies are one of the best ways to collect data that close to the practical phenomenon (Bonoma, 1985). The other strength is that the emergent theory is more likely to be testable and measurable with refined list of constructs that can be readily reflected from the case data. The resulting hypotheses are more likely to be concluded for the same reason. The third

strength is that the resultant theoretical framework is likely to be empirically valid. The iterative processes data collection and analysis contributed s to the consistency with the empirical observation.

Limitations also exist in case study qualitative methodology. Contrary to the strength that drawing theoretical foundations from case studies align more with the reality, the dependence on empirical evidence might also yield the conceptualizations to be overly complex. Compared to analytical methodologies such as regression, case studies lack quantitative gauges that may result in challenges in determining the significant relationships away from those are idiosyncratic to particular cases (Qu and Dumay, 2011). This further reveals another weakness that building conceptual foundations from case study methodology will likely result in narrow and idiosyncratic theory. The case analysis process is a bottom-up approach that seeks generalized theories. The risks lie in the certainty and difficulty in reaching the level of generality of a specific theory. Thus, the combination of qualitative and quantitative evaluations will result in both sound theoretical foundation and statistical validation.

3.2 Quantitative Study

The greatest voids in both the literature and practical case studies on product deletion are: first, limited knowledge about the factors affecting the business outcome, formality, individual involvement and other important aspects of the product deletion process; and second, no predictive model that could be used to facilitate a sound product deletion decision.

Organizations have at their disposal a number of performance measures and tools for strategic decision making in general. Strategy and management literature streams also have broader sets of tools (David, 1986; Scott and Westbrook, 1991). The existing measurements and possible tools that could be applied to the product deletion decision are summarized in Table 3.2.

Frequentist and machine learning approaches have much to add to the endeavor. Compared to these listed possible tools, in this study we chose an under applied tool, Bayesian analysis (Berger, 2013; Ferguson, 1973; Geweke et al., 1992).

5: Table 3.2 Existing Applicable Quantitative Methodologies and Tools

Financial/Economic Models	Checklist Scoring Model	Probabilistic Models	Behavioral Approaches	Optimization	Decision Support Systems	Generalized Linear Models
Payback period	Fit with corporate objectives	Bayesian Analysis	Modified Delphi Method	Mathematical programming	Project Analysis and Support Systems (PASS)	Linear Regression
Break even analysis	Competitive advantage	Decision Tree Analysis	Q-sort method	Statistical decision theory	Mapping Approaches / Bubble Diagrams	Multivariate
ROI	Market attractiveness	Options Pricing Theory	Paired Comparison models	Game theory		ANOVA
Discounted cash flow				Markov processes		
Net Present Value						
Internal rate of return						
Financial ratios						

Bayesian analysis has been a tool for evaluating the probability of outcomes for centuries (Gelman et al., 2013). Bayesian analysis is named after Thomas Bayes. This statistical field is based on utilizing previous knowledge and probabilities of occurrences to predict future outcomes. Unlike its popular statistical cousin which can best be termed as a frequentist and correlative approach to statistical analysis and inferencing, Bayesian analysis has seen relatively few applications in the operations and supply chain management literature (Berger et al., 1994).

Bayesian analysis can be used as an inferencing tool, which: (1) works well for small data sets, both qualitative and quantitative; (2) flexibly represents uncertainty, parameters and noise of the data sets; (3) does not rely on null hypothesis testing; (4) automated and adaptive; and (5) exhibits robustness. Bayesian analysis can also be applied as a predictive tool, identifying the product deletion candidate and predicting the outcome of a deletion activity. With its simulations and sensitivity analysis, Bayesian can also utilize longitudinal data to estimate the frequency of deletion and predict when to delete. An

overview of the methodology is now presented using a variety of sources (Berger, 2013; Berger et al., 1994; Ferguson, 1973; Gelman et al., 2013; Geweke et al., 1992; West and Harrison, 2006).

3.2.1 Bayesian Analysis

One of the most important issues in statistical science is the construction of probabilistic models that explain or predict the true generating mechanism of a phenomenon under research investigation.

Bayesian analysis is a statistical method that answers research questions about unknown parameters using probability statements. Bayesian analysis will help arrive at an intuitive interpretation of credible intervals as possibility distributions of parameters of interest and actual probability range to hypothesis.

Compared to classical frequentist analysis, the parameter estimation is not a fixed value but a distribution of estimated values. Posterior distributions of parameters of interest are the final Bayesian analysis results, which is also the major distinction of Bayesian analysis from classic frequentist statistical solutions.

Bayesian analysis incorporates prior distributions into parameter estimation. Prior distribution is based on prior knowledge.

The major results from Bayesian analysis can be two fold. One is Bayesian inference and the other is Bayesian prediction. Bayesian inference forms summaries of model parameters including statistics of the posterior distribution such as its means, medians, intervals, as well as probability distributions of the parameters themselves. Bayesian methods are data analytic tools that are derived from the principles of Bayesian inference. In general, Bayesian analysis helps to determine:

i. Bayesian parameter estimates with sound statistical properties
ii. Descriptions and frequency analysis of observed data and events
iii. Predictions for future data
iv. Modelling methodology for model estimation, selection and validation

3.2.2 Bayes Rule

Bayesian analysis does not aim to tell the true belief, but an adjusted belief change given new information.

Statistical induction is the process of understanding the general characteristics of a population from sampling of the population. The values of population characteristics are represented as θ, and the sampling data set is y. Before giving any information and computation, θ and y are both uncertain. When y is obtained or simulated, the information will be used to decrease the uncertainty about the entire population characteristics. Bayesian inference is one of the tools that could be used as quantifying this change in uncertainty.

The sampling data space Y stands for the set of all possible datasets of a population. Θ represents the set of possible parameter values. Θ will help to identify the value that best fits the true population characteristics. The Bayes rule states the idealized form of Bayesian analysis, beginning with a numerical formulation of joint belief expressions of y and θ, in terms of the probabilities distributions of Y and Θ.

There is relationship between probability and information. Bayes' rule (expression 3.1) provides a rational method for updating beliefs providing new information.

$$P \text{ (belief | sampling data)} = \frac{P\,(sampling\ data\,|belief)\ P\ (belief)}{P\ (sampling\ data)} \tag{3.1}$$

Where

- | means "event conditional on", or "given";
- Sampling data corresponds to new data that were not used in computing the prior probability;
- Assuming any hypothesis whose probability may be affected by sampling data, $P\ (belief)$ stands for prior probability and P (belief | sampling data) represents posterior probability.

A prior belief or knowledge will be noted as θ and sampling data as y. Then we can rewrite the Bayes rule as expression 3.2:

$$P(\theta \mid y) = \frac{P(y \mid \theta)\, P(\theta)}{P(y)} \tag{3.2}$$

Where

- $P(y \mid \theta)$ represents the likelihood of θ;
- $P(\theta)$ is the prior probability of θ;
- $P(\theta \mid y)$ is the posterior of θ given y.

For each $\theta \in \Theta$, the prior distribution $P(\theta)$ describes the prior belief that θ represents the true population characteristics. And for each $\theta \in \Theta$ and $y \in Y$, the sampling model $P(\theta \mid y)$ represents our belief that y would be the outcome given θ is true.

In this dissertation work, case studies and grounded theory from the previous chapter as well as the follow-up archival product level data of the interviewed companies will contribute to form likelihood distributions in Bayesian analysis. Markov chain Monte Carlo (MCMC) methods and a Gibbs sampler will help to generate posterior distributions. WinBugs, software, is utilized in this work to facilitate Bayesian analysis. R studio is applied to complete convergence checks for the posterior distribution.

3.2.3 The MCMC Algorithms

Applying Bayesian models became practical for management research with the development of an MCMC method called Gibbs Sampler. The algorithms are used to arrive at the posterior distributions in Bayesian analysis.

Before the emergence of MCMC, there are two major techniques to compute the posterior distributions; they are grid approximation and quadratic approximation. But both are subject to poor scaling in high dimensions with many parameters and not tractable for most problems. The idea of MCMC is that, with sound sampling strategy, researchers can feel confident that the sample distribution is representative of the true posterior distribution for statistical inferences. There are different ways to implement MCMC, including Metropolis, Hamiltonian and Gibbs. Gibbs sampling is one of the most popular MCMC algorithms.

3.2.3.1 Gibbs Sampling

The Gibbs sampling or Gibbs sampler algorithm is defined as the parameter vectors of interest. Each iteration in a Gibbs sampler will go through the parameter vectors. Within the sampling processes, one parameter is selected from the n-dimensional parameter space. The parameters are selected in turn creating an ordered cycle, $\theta_1, \theta_2, ..., \theta_n$. When a parameter is selected, say θ_i, a new value this parameter is arrived by assuming conditional posterior distribution of that parameter given the values of the other parameters and the sample data, $p(\theta_i \mid \theta_{j\neq i}$, sampling data). The conditional sampling process then continues through all the parameters , $\theta_1, \theta_2, ..., \theta_n$ to form a complete cycle and then the cycle is repeated a number of assigned times.

Gibbs sampling is an efficient algorithm that does not require tuning, but it has some limitations. The Gibbs algorithm can be conceptualized as a random walk through the parameters where we start the walk at an arbitrary point and where the next step only depends on the current position.

The goal of Gibbs sampling is that sampling upon the conditional posterior distribution across all parameters best represent the joint posterior distribution. The joint posterior distribution becomes the conditional posterior distribution for parameters as the algorithm converges. Values from early iterations are transient values since the Markov chain has not reached a steady state and may not be representative of the posterior distribution. Therefore, the initial values from Gibbs sampler are discarded. In this study the first 4000 values are abandoned. Another limitation is that values generated by the Gibbs algorithm tend to be autocorrelated. In this study, within the Gibbs sampling process, only every 20th iteration of each cycle is selected to be included in the sample to avoid auto-correlation and ensure posterior distribution convergence.

3.2.3.2 MCMC Diagnostics

The goal of MCMC is to achieve posterior distributions that best represent the true distribution through simulation. In order to ensure the simulation process is progressing correctly, a set of diagnostics

are utilized to evaluate convergence of the distribution. These include trace plots, auto correlation plots, and CODA (convergence diagnosis and output analysis) including Geweke, Gelman and Rubin, Raftery and Lewis, Heidelberger and Welch and Cross-Correlations.

Trace Plots

Trace plots represents the multiple chain of parameters plots showing the values of each chain against the sample number of the sampling processes, typically on the same set of axes. The ideal situation of the plotting is that assuming all chains are representative of the posterior distribution, there should be an overlap amongst all chains while being unrelated to their random starting values. The method of plotting the race plots is through simulating multiple chains with 10,000 samples each and observe their convergence depending on the model complexity. If any of the chains are apart from the others there might be potential issues such as model fit, implementation method or input data.

Autocorrelation Plots

Within-chain samples are correlated since the parameter value will influence the distribution of the next parameter. Autocorrelation plot aims to visualize parameter correlations through sampling iterations. The autocorrelation plot doesn't explicitly indicate the representativeness of the posterior distribution, but it shows the efficiency of the selected MCMC algorithm, in this study (Chapter 5) is the Gibbs Sampler. If any chain's autocorrelation plot is significantly different from the other chains, there might be some issues of the sampling processes. Thinning intervals until two successive observations become independent is one solution to these issues.

The Geweke Diagnostic

The Geweke diagnostic checks the convergence of the mean of each parameter against the sampled values of a single chain (Geweke et al., 1992). The test evaluates a time series set of simulated values obtained from the MCMC output. The diagnostic constructs a Z test to check if the estimated mean significantly differs from a subsample of the total MCMC output. These subsamples can be from the start

and the end of the simulated chains. If the estimated mean from the beginning and the end of the total MCMC output are rejected, the convergence of the chain cannot be supported.

By default, CODA compares the initial 10% and the last 60% of the entire iterations. Assuming a set of generated values from WinBugs out is: $\theta_1^1, \theta_1^2, \theta_1^3, \ldots, \theta_1^n$. θ is the parameter of interest, and $\bar{\theta}$ is the sample mean. The standard error of the mean equals to $\sqrt{\frac{S_\theta}{N}}$, N stands for the corresponding sample sizes. Hence, Z diagnostic is calculated by (3.3):

$$Z = \frac{\bar{\theta}^1 - \bar{\theta}^2}{\sqrt{\frac{S_\theta^1}{N_1} + \frac{S_\theta^2}{N_2}}} \tag{3.3}$$

$\bar{\theta}^1$ and $\bar{\theta}^2$ represents the means of two subsamples. N_1 and N_2 are two subsamples' size. $\frac{S_\theta^1}{N_1}$ and $\frac{S_\theta^2}{N_2}$ stand for the corresponding variances of the sample means. If Z score falls between (-2, 2), then convergence is achieved.

The Gelman-Rubin Diagnostic

The Gelman-Rubin Diagnostic checks for convergence by examining if two or more samples generated are in parallel (Gelman and Rubin, 1992). This test is very similar to an ANOVA diagnostic by calculating $\hat{R}$, a shrinking factor of R. $\hat{R}$ compares variances between chains and provides estimate of how much variance could be eliminated by running longer chains. Assuming the model generates n independent chains, then $\hat{R}$ is calculated by (3.4):

$$\hat{R} = \sqrt{\frac{\hat{V}ar\,(\theta)}{\frac{1}{n}\sum_1^n s^2}} \tag{3.4}$$

If $\hat{R}$ is close to 1 it indicates convergence. $\sum_1^n s^2$ stands for the total-sequence interval variances.

The Raftery-Lewis Diagnostic

The Raftery-Lewis Diagnostic focuses on the single chain and it evaluates a certain degree of accuracy of specific quantiles instead of the convergence of multiple chains. The default CODA measurement is 2.5% percentile estimated with accuracy of 0.005 and probability of 0.95. CODA reports N_{min}, *M*, *B* and *I*.

- *N* is the total number of iterations
- N_{min} stands for the minimal number of iterations for quantile of interest estimation with the specified accuracy level;
- *M* is the number of burnin iterations necessary for the model
- *I* is the dependence factor, meaning the relative increase of the total sample due to autocorrelations.
- $I = \frac{N}{N_{min}}$, if *I* equals to 1, then the simulated values are independent.

High *I* values (> 5) are worrisome and may result from starting values issues, high correlations amongst coefficients, or poor mixing.

The Heidelberger-Welch Diagnostic

The Heidelberger-Welch Diagnostic checks for single chain analysis using univariate observations. This diagnostic is derived from Brownian bridge theory (Aldous and Pitman, 1994). It calculates a test statistic to accept or reject the null hypothesis (MCMC output) indicating the chains are from a stationary distribution. The test has two parts, in the first part, researchers need to calculate the test statistic on the whole chain based on selected N iterations and a defined α level, then to decide whether accept or reject the null hypothesis. If the null hypothesis is rejected, then discard the first 10% of the chain and do the same calculation again. If the null hypothesis is still rejected, discard the next 10% of the chain again. Repeat the same procedure until the null hypothesis is accepted. If the test still rejects the null hypothesis with 50% of the chain removed, then the chain failed and a longer chain needs to be calculated. The second part calculates the width of the (1-α) % credible interval to the mean, and

compares the result with a value ε, the desired relative half-width for confidence intervals; if it is lower then the test passes. Heidelberger and Welch aims at detecting and eliminating an initial transient, generating confidence intervals, and controlling run length.

The convergence checks are important for correct estimation of the parameter posterior distributions. A limitation of MCMC methods is that the convergence is not always revealed by checks as clearly as other methodologies such as optimization. The researcher has to specify the length of the burn-in period and the size of the MCMC output including the number of iterations and number of thinning intervals. All these diagnostics have been applied to Bayesian models in Chapter 5 using WinBugs and R Studio. The detailed reports appear in Chapter 5.

3.2.4 A Critical Analysis of Bayesian Statistics

Statistics has argued for a century over the issue of whether the Bayesian and frequentist paradigm is superior. The debate is ongoing and far from consensus is reached since there are fundamental philosophical issues involved. At the statistical methodology level, the debate has ceased owing to the recognition that both approaches contribute to statistical learning and practical inferencing. Both approaches provide significant insights to broader development of other existing and emergent methodologies.

Social science research tends to seek statistical significance without challenging if the statistical significance value answers the wrong question. The probability of the observing data due to random sampling is given only by assuming a null-hypothesis is true. But no probability statements exist for the occurrence of both null-hypotheses and alternative hypotheses being true.

When the question of interest is the probability of a proposed hypothesis being true given the observed data, Bayesian analysis will be one of the better methodologies to answer this question. Bayesian statistics offer established methodology for drawing inferences and assessing plausibility of theories.

Bayesian methods provide a rigorous analysis to the statistical results in terms of the following aspects:

Bayesian analysis includes prior information that takes into consideration previous research findings; findings that cannot be systemically embedded using classical methods. In the operations and supply chain management research field, the prior could be derived from existing established literature in the relevant fields, previous studies of related research projects, or evidence from industries and organizations. Incorporating priors will arguably provide significant variance to the model, which seeks to yield more accurate and reliable results.

Bayesian methods provide comparably exact inferences without concluding to asymptotic approximations. There will be no point estimation with set confidence levels but distribution mappings. The results make more sense and are easier to interpret than fixed p values and confidence intervals and of the model fit. Bayesian findings provide discussions in many initiative ways that are not strictly subject to true or false argumentation. There is no need for p-values or α levels as measurements of statistical evidence as Bayesian analysis can directly provide the probability of plausible values for the parameter estimation of interest and the corresponding likelihood of occurrence.

Bayesian analysis is generally straightforward in making predictions. Bayesian predictive models, or Bayesian forecasting is a product of Bayesian inferencing. Predictions involve the use of existing information of both models and data, to make forecasting about the likely occurrence of future events. Bayesian predictive models can be derived from two principles: one is the principle of explicit formulation using the formal probability statements about the posterior distribution of future events of interests. The other is the principle of conditionally arriving at the distribution of future occurrence based on observed relevant events. Bayesian prediction tends to deliver valid information concerning the involvement of prior information and relevant conditions (West and Harrison, 2006).

Bayesian analysis, for both inferencing and predictive model development purposes, best fit the research questions and dataset of this dissertation work. Other techniques may also applicable. But concerning to the research interest of likelihood estimation and prediction, we utilize Bayesian analysis to add to the foundation of theoretical development and empirical observations from case studies. This dissertation, as the first systematic initiative of integrating product deletion decisions on supply chains, the nature of this work focus on exploratory and context discovery. The existing dataset for deleted products are sensitive to companies, resulting in small and in-balanced generated dataset. Bayesian exhibit robustness in this data environment.

CHAPTER IV: QUALITATIVE STUDY: A GROUNDED THEORY APPROACH

The methodology for the qualitative study is grounded theory through in-depth semi-structured interviews. The in-depth case study interviews are designed to provide practical insights into how organizations make product deletion or associated decision making processes; specifically what causes a product to be deleted, what factors are considered, and the typical product deletion process.

The case studies have been conducted in different countries and cultures. The industry types have been spread across food beverage, manufacturing, clothing, and technology companies. The different characteristics of the individual organizational supply chain will impact the decision-making process and execution. For instance, the maturity of a supply chain might determine the willingness and flexibility of a product deletion decision. Therefore, this work conducts a qualitative analysis of the product deletion decision by investigating, evaluating, and comparing from multiple dimensions and perspectives. The control variable of the supply chain comparison is that all selected companies own/control their own manufacturing processes. Retailing companies are not included in this study. Retailers consider product deletion as product assortment, which is different from this paper's perspective of product portfolio management and rationalization.

4.1 Data Collection

Participants are a convenience sample of several managers from the selected companies. There are no exclusion criteria based on demographics. Participants were recruited by email. Sample characteristics, data collection procedure and theoretical saturation are detailed in sections 4.1.1, 4.1.2, and 4.1.3.

4.1.1 Sample

The overall interview sample number is 16 from 7 companies of 4 countries including India, Iran, Australia, and China; and industries including food and beverage, pharmaceuticals, clothing and textile, home appliances, and computer software. There is a balanced outlet of public, private, and limited

liability companies. In terms of the company size according to the number of employees, 4 are large, 2 are medium, and 1 is a small company. The majority of the sample has global business and supply chain networks. Only GOODIO (China) focuses on domestic market segments.

Detailed company sample descriptions including company type, size, industry, and financial information is shown in Table 4.1.

Managers from various organizational cross-functions were selected as the sample. These cross-functions include marketing, product design, supply chain, manufacturing, finance, sales, and sustainability. The reason for including a wide range of organizational functions is because all functions contribute to product deletion decision-making and managers from these departments work closely with products as an important strategy in their managerial toolkit. Therefore, they are the key informants for the in-depth case study purpose concerning their knowledge about the research investigation and their accessibility and capability to communicate with the investigator (Campbell, 1955).

Existing research has explored the key input from marketing and finance functions in product deletion decisions. However rarely has the question of whether supply chain and sustainability functions are related to product deletion, been studied. This study is one of the first to include supply chain and sustainability professionals as key informants because they are prime decision-makers in all operational activities that source, make, and deliver products to end-users. Specifically, product deletion or retention is the focal point of this study. Only one manager had no direct experience with product deletion; but he is personally involved in product deletion discussions on a regular basis. However, both direct and indirect decision makers were recruited as participants. The findings will be strengthened if the shared knowledge and interactions with other perspectives in terms of obtaining or deleting concerns can be better understood. Key informants and their aggregated information, including their organizational properties, personal attitudes, and behavioral experiences, are summarized in Table 4.2.

6: Table 4.1: Case Study Company Sample Descriptions

COMPANY	ANNUAL REVENUE	COUNTRY	FIRM TYPE	INDUSTRY	MARKET	NUMBER OF EMPLOYEES	PRODUCT LINES	PRODUCT PORTFOLIO SIZE (SKU)
C1	US$ 5.6 billion	Australia	Subsidiary	Food and beverage	Worldwide	7,000	Beer, wine, dairy/juices, RTDs and spirits	NA
C2	US$10 million	China	LLC	Clothing and textile	Domestic	5,000	Men's wear, home textile and children's garment	NA
C3	US$ 23 billion	China	LLC	Clothing and textile	Worldwide	16000	Men's wear, home textile and children's garment	260
C4	Not Applicable	China	Private	Computer software	Worldwide	1000	Artificial Intelligence, computer software, consumer electronics	NA
C5	US$ 15.7 billion	China	LLC	Clothing and textile	Worldwide	5,000	Men's wear, home textile and children's garment	3000
C6	US$ 2 billion	India	Public	Pharmaceuticals	Worldwide	23,524	Generics and OTCs	200
C7	Not Applicable	Iran	Public	Home appliances	Worldwide	NA	Heaters, air-conditioners, vacuum cleaners, Home appliances and small appliances	209

Note: "NA" stands for "Not Available". "Worldwide" means that the investigated company serves international markets besides its origin country. The companies are organized in alphabetical order on country.

Theoretical sampling was applied to form the major cases for this study, which is more appropriate when investigating unexplored areas for maximum theoretical return; product deletion is one such unexplored research topic (Strauss and Corbin, 1998). Sampling in quantitative methodologies, focus on population representativeness, sample fit, or statistical generalizability, and validation, theoretical sampling aims to integrate sample data that collectively contributes to categorizations and conceptualizations for theoretical framework development.

7: Table 4.2: Case Study Key Informants Characteristics

KEY INFORMANTS	COMPANY	ROLE IN THE COMPANY	DEPARTMENTS	GENDER	INDUSTRY	YEARS OF WORKING EXPERIENCE
P1	C6 – India	Director	Top management	Male	Pharmaceuticals	5-10 years
P2	C6 – India	CFO	Finance	Male	Pharmaceuticals	> 10 years
P3	C6 – India	CMO	Marketing	Male	Pharmaceuticals	> 10 years
P4	C6 – India	CMO	Marketing	Male	Pharmaceuticals	20 years
P5	C2 – China	CEO	Top management	Male	Clothing and textile	> 10 years
P6	C3 – China	CEO	Top management	Male	Clothing and textile	> 10 years
P7	C7 – Iran	Manager	Customer relationship management	Male	Home appliances	17 years
P8	C7 – Iran	Manager	Operations and supply chain management	Male	Home appliances	23 years
P9	C7 – Iran	Manager	Sales	Male	Home appliances	> 10 years
P10	C1 – Australia	Manager	Operations and supply chain management	Male	Food and beverage	> 10 years
P11	C4 – China	Manager	Operations and supply chain management	Male	Computer software	3-5 years
P12	C5 – China	Manager	Product management and design	Female	Clothing and textile	< 3 years
P13	C5 – China	Director	Product management and design	Female	Clothing and textile	< 3 years
P14	C5 – China	COO	Marketing	Male	Clothing and textile	5-10 years
P15	C5 – China	Manager	Product management and design	Female	Clothing and textile	5-10 years
P16	C5 – China	Manager	Customer relationship management	Female	Clothing and textile	5-10 years

4.1.2 Procedure

The key informants were sampled through convenience and snowball sampling. Such sampling processes are also called chain sampling or chain-referral sampling. This approach is a nonprobability sampling technique where sampling initiates with acquaintances and future subjects are recruited through existing sample subjects. Thus, the sample group is expected to grow like a rolling snowball. The detailed workflow of data collection procedures is presented in Figure 4.1.

Step 1: The base group of subjects were recruited to the investigator's personal network via email. The expanded subjects were acquired from the base group's referrals. As the sample built up, sufficient data were gathered to be useful for research knowledge. As sample subjects are not selected from a sampling framework (exclusive criteria i.e., demographics), snowball samples tend to subject to numerous biases. For example, people who have direct experience with research topics are more likely to be recruited into the sample. However, concerning the research question characteristics, such biases might even be preferred in this study. A variation of snowball sampling in this study is called respondent-driven sampling, which allows researchers to make asymptotically unbiased analyses.

Step 2: Since this study included human subjects and certain risks and concerns were involved, we filed a Human Subjects Research Exemption Application to the Worcester Polytechnic Institute Institutional Review Board (IRB) for approval. The approval period covers the length of data collection for this study. Every sample subject signed an informed Consent Agreement for participation in this research study. Appendix B details the informed consent agreement, including the purpose of the study, procedures to be followed, risks and benefits to the sample subjects, recording keeping, and confidentiality.

Step 3: The in-depth interview began with the subject's demographic information including company role, gender, age, and education. Following the interview protocol, the investigator asked the subject to express upon and share his or her working experiences in the investigated phenomenon. The vividness of the subjects' responses are subject to the development of the interview protocol (Appendix

A). The interview protocol can be designed with different levels of investigation, ranging from a loosely-guided conversation to semi-structured questions (Charmaz, 2014). The interview protocol of this study followed semi-structured instructions. A series of open-ended questions were asked to help generate qualitative data. The interview began with the subject's tenure in the company, their product management experience, and the structure of his department and team. The interview protocol of this study has four sub-protocols for different managerial roles; respectively, marketing, supply chain, finance, and sustainability.

Step 4: All subjects interviewed followed the data collection procedure in Figure 3. They were then asked about their detailed product deletion experience. Questions included "What is product deletion" "Has the company discontinued or deleted any product under a specific brand/product line?" If yes, which brand (s)/product (s)? When and why? How? If not, why do you think product deletion was never required? These questions served as grand tour questions and set the directions for the interview and extended knowledge of the investigated research questions.

Step 5: As the key informants were sharing product deletion experiences, the investigator proceeded to follow the protocol with questions such as "what antecedents result in product deletion in your company?" and "What influencing factors play a role in determining a product's deletion candidacy?" These questions were included to better understand and interpret the situations in which a product was deleted or was considering deletion; and help to predict what prevents a product from being deleted; further deriving performance measurement for the benchmarking of deletion or retention.

Step 6: The next section of questions focused on the decision-making processes of the past product deletion decisions from recognition, evaluation, and decision formation to implementation. Questions included "What role does your department play in product deletion activities?", "What other departments were involved in the decision making?", "How was the power and role of each cross-functional department weighed in this process?", "How was the power and role of each stakeholder

weighed in this process?", and "Who made the final decision?" These questions were included to help the investigation into the systems and routines of product deletion decisions in organizations.

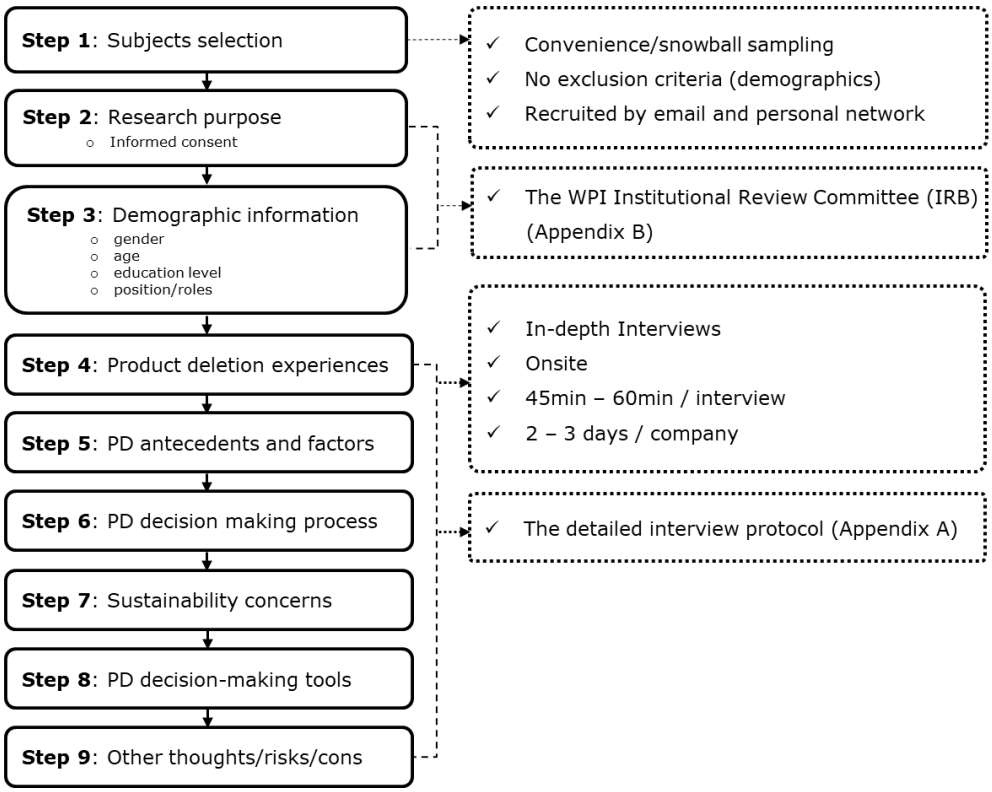
Step 7: Concerning the context and theoretical contribution of this study to the identified research gaps, the interviewees were also asked about sustainability concerns in product deletion decisions. Questions included "will you consider sustainability/CSR issues in product deletion decisions?" Some of the firms have sustainability values in their organizational culture that might consider sustainability issues in product deletion shortlisting. This question provided additional value to the context and theoretical contribution of this work.

Step 8: The next question focused on whether there is any (statistical) tool to facilitate product deletion decision making. If yes, the interviewer asked what the characteristics and expectations of this tool were. This question was designed to validate the necessity of model development in this dissertation.

Step 9: The interview protocol was concluded by asking interviewees for any relevant information (up to them) that was not covered in the interview but might provide additional understanding for the investigation. The author of this study has a master degree in marketing and an ABD doctorate degree in supply chain management with industrial experience in product management, which enhances their understanding of the business environment and management strategies.

The interviews of China and Australia were conducted on site, and the interviews of Iran were completed by email, and the interviews of India accomplished through Skype and Zoom (video conferencing software applications). These open-ended and exploratory questions emphasized in-depth case studies take 45-60 minutes each, and on-site interviews take 2-3 days per company. All interviews were recorded and transcribed (16 interviews transcriptions, 213 KB, 218,684 bytes, 65 pages, 24,567 words and 1,166 lines) and imported into NVivo 12, a software that facilitates systematic qualitative data coding and analyzing for gaining insights from qualitative research.

3: Figure 4.1: Case Study Data Collection Procedure



4.1.3 Theoretical Saturation

The initial case study sampling provides a base for the grounded theory approach; and further sampling serves the need for theoretical elaboration and refinement, until saturation.

In this study, the sample size of 16 helped to arrive at theoretical saturation as the study progressed. A sample size of 16 might appear to be relatively small. However, according to the saturation definition and formation in Chapter 3, there is no critical quantity level of sample size to achieve saturation.

In this study, theoretical saturation was achieved through: (1) no new data surfacing pertaining to any category; (2) the properties and categories and themes becoming repetitive as the data analysis proceeds; (3) the identification of a well-established pattern of relationships among categories; (4) no

need for additional data for new theoretical insights (Strauss & Corbin, 1998). When proceeding with the data analysis processes, comparing and contrasting the open codes and relationship patterns in the early 13 transcripts had the most valence in terms of content and knowledge. The last 3 transcripts indicated that no new codes and properties or categories or themes could be derived, and therefore exhaustive interviews would not have generated novel information that provides additional interpretation and explanation about the research topic.

4.2 Data Analysis

The data analysis was conducted in Nvivo 12. The research method is grounded theory (Glaser and Strauss, 1967; Strauss and Corbin, 1998) introduced in Chapter 3. Data and theory were continuously interpreted and constructed as the data collection and analysis proceeded. The theory is grounded from data categorization, mapping and conceptualization. Grounded theory is widely applied in novel research projects (Charmaz, 2014; Suddaby, 2006).

In terms of coding types, there are three types of coding used in grounded theory in this study; respectively, open coding, axial coding, and selective coding. Open coding were obtained from an initial reading of the data. The coding process should initiate from open coding to more abstract or categorical codes and eventually to conceptual or theoretical codes. However the open coding processes should relate to no interpretive efforts at any stage of the conceptual codes formation. Open coding was done in this study by reading and analyzing the transcriptions line-by-line and word-by-word. This open-coding process is called line-by-line coding, which is essential and critical for the initial stage of data analysis.

After completing the open coding, the later stages of axial coding and selective coding helped to build theories in an inductive process. Axial coding was used to explore the relationships between categories and subcategories. Selective coding was used to inter-relate categories in a theoretical framework. The workflow was generated using NVivo 12. Table 4.3 provides the exemplary coding workflow of this work that enabled a theoretical framework to emerge. The interview transcripts were analyzed through: (1) developing key points as initial codes; (2) grouping codes into similar themes and

generalizing categories; and (3) relating categories in a meaningful way. This approach conceptualizes the bases of a grounded theoretical framework.

8: Table 4.3: Formation of Coding Categories (two examples for each theoretical pattern)

Original transcriptions	Open coding (initial categories)	Axial coding (final coded categories)	Selective coding (conceptualization)
The market performance is not that good and manufacturing is continuing facing issues or we have inventory losses, because backup is so high and [***market demand***] is very low. The profitability of the product is not as great. We took off the product. **- P3** If we are not able to develop the product to meet the [***customer demand***], the product can be dropped. **– P4**	demand	Marketing Factors	ANTECEDENT FACTORS
Then once we launch the product, sometimes the competition will be very high, there will be several companies will launch the product. What happens then is the prices will crush. Prices will continue to reduce. So after sometime, if the product **[*does not have price competitiveness*]**, then I will inform my customer this product I will need to withdraw or discontinue this product from my product portfolio. – **P1** Products at high costs will lead to higher prices and [***a loss of competitive advantage over competitors' products on prices***], and eventually reduce sales. – **P7**	price competitiveness		
Discontinuing products depends on market demand, [***production capability***] and product significance. … If it is [***not possible to produce the product***] …., it is decided to eliminate the product pertinently, therefore the product is deleted and another similar product enters the production line and market. – **P7** If the manufacturing guy might come to us and say their [***manufacturing capacity is getting limited***], and they cannot produce more than these. They might need to build another plant. It will just remain costly. So I need to rationalize and delete the product. – **P4**	limited production capability	Supply Chain Factors	
India side buys a lot of materials from China. Some of the manufacturing facilities have been closed. If we [***cannot get the ingredients from the sources***]. You don't have a choice. We will have to discontinue the product. – **P2** Manufacturing department engages in [***material sourcing and purchasing***]. These supply chain function controls the product deletion by about 80%-90%. Issues in sourcing or purchasing activity will lead to our product deletion. – **P16**	sourcing and purchasing		

4.3 Trustworthiness of Findings

Qualitative research is based on subjective, interpretive, and contextual data, meaning the findings are more likely to be scrutinized and questioned (Altheide and Johnson, 1994). Therefore, it is critical to establish trustworthiness checks and ensure the reliability and validity of the research findings (Kvale, 1989). The trustworthiness of qualitative research findings mainly depends on the rigor of the processes and data quality (Kirk et al., 1986). The criteria for trustworthiness include credibility, transferability, dependability, and confirmability. These criteria ensure the findings are believable, consistent, applicable, and credible.

Credibility

Credibility is often called internal validity (Onwuegbuzie and Leech, 2007). It refers to the believability of the qualitative findings. This criteria focus more on the richness of the data than the quantity of the data gathered. The participants of the study need to be representative and reflective; and they are the ones to validate if the research results explain the phenomena studied. Therefore, it is critical to share the research findings with the informants and receive their approval that the findings and discussions are truthful and accurate. Cross-validation is a commonly applied method to verify the accuracy of the results (Smith, 2015). Since the study involves a number of informants from different countries, industries, companies, and departments, and they also come from different educational backgrounds and managerial levels, the information cross-checking amongst them would provide validation for the research findings given multiple perspectives.

T*ransferability*

Transferability is often referred to as external validity, standing for the degree of the qualitative findings that can be transferred to other contexts by the readers (Whittemore et al., 2001); simply put, generalizability. Such generalization includes other similar research settings, populations, samples, and

other contingent situations. The description of the research procedure including data acquisition, coding, and analysis should be transparent and detailed to ensure the procedure is replicable and applicable.

Dependability

Dependability represents the reliability of the findings. It refers to the consistency with which the findings can be repeated and arrive at the same results. Dependability is related to the legitimacy of the qualitative methods. Considering the characteristics of qualitative research, subject to changing contexts and settings, it is critical to have the possibilities of all unexpected occurrences and combinations of scenarios documented as contingents to the research findings.

Confirmability

Confirmability is a measure to evaluate the objectivity in the process of drawing conclusions from the qualitative findings. In terms of the qualitative research procedure, the results are likely subject to the researchers' own perspectives on both the research processes and data interpretations. This evaluation can be conducted by generating actual data as support for qualitative findings. Another approach is through cross-confirmation from others who can examine the data and analysis. Either way, it will help reduce the subjective inappropriate biases.

Table 4.4 entails the exact approaches taken in this study to ensure the trustworthiness criterion.

9: Table 4.4 Approaches of ensuing trustworthiness in this study

Trustworthiness Criterion	Approaches in this study
Credibility • Internal validity • Believability • Representativeness and reflectiveness • Data richness	○ Snowball sampling till theoretical saturation ○ Member checks ○ Appropriate interviewing techniques applied ○ Cross-validation in countries, industries, company types and managerial roles ○ Weekly debriefing sessions with experts in grounded theory and qualitative research ○ Post findings evaluation by the key informants
Transferability • External validity • Generalizability • Replicable and applicable	○ Theoretical sampling ○ Systematic research procedure ○ Diverse sample characteristics (i.e.: country, industry, firm type, company size, managerial role, managerial levels, experience, etc.)
Dependability • Reliability • Consistency • Method legitimacy	○ Detailed interview protocol and research procedure ○ Informants' experience works closely with research topic, coving recent and past events ○ Contingent situations ○ Various business scenarios
Confirmability • Objectivity (Whittemore et al., 2001)	○ Interpretations and summary of findings reviewed by experts of qualitative research and grounded theory ○ Quantitative study in the next chapter is used to confirm the findings of the qualitative study

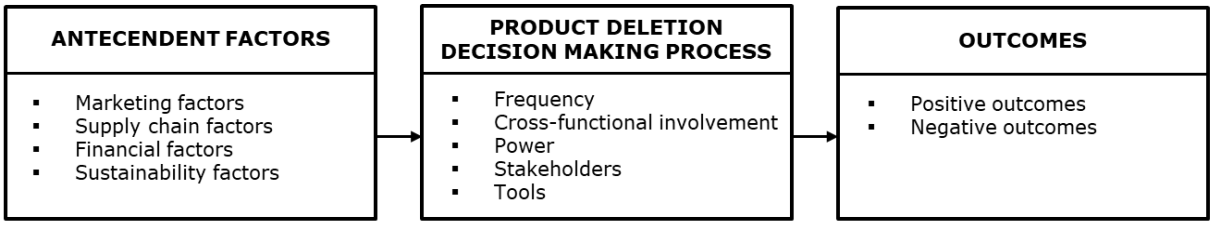
4.4 Findings

The finding of this section are based on grounded theory. The objective is to sensitize ideas that are insightful, repeatedly mentioned by the key informants (Bowen, 2006), and that span across companies, industries, and countries. According to the informants, product deletion is an equally crucial but a more complex decision on strategic product portfolio management.

The overall findings align with the literature that describes how companies invest vast money and time in launching new products, leveraging product portfolios, and acquiring rivals, all the while maintaining competitive advantage. In summary, a systematic analysis of the interview transcripts helps

arrive at the theoretical framework, which helps to understand the antecedents, routines, and outcomes of product deletion in organizations. The data revealed that the routine starts from problem recognition (product deletion antecedent factors), to analysis and evaluation (product candidates' shortlisting and revitalization), to implementation (deletion procedure and department involvement), and finally to outcomes (post deletion). The routine can be brought together in a conceptual framework, as depicted in Figure 4.2.

4: Figure 4.2: A Grounded Theoretical Framework of Product Deletion



The interviewed managers are busy with product line extensions and proliferations, and also channel extensions and supplier extensions, seeking to cater to as many customer segments as possible. However, they all realize and report that complex and broad product portfolio strategies do attract customers but do not necessarily sustain profitability. Over the past decade, they have examined their product portfolio and doubted whether they might be housing too many products. Product deletion or killing is a less appealing perspective when it comes to product portfolio management. However, they all confirmed the critical significance of this decision making.

The overall qualitative findings employ a continuum of conceptualizations, ranging from the very specific and identifiable to a generic set of practical experience-related processes. Additionally, the antecedent factors were analyzed as both internal and external to the focal firm; some of the antecedent factors have been demonstrated in the existing literature, but most are neglected, especially those in terms of supply chain and sustainability functions. The conceptual framework served as a product deletion

mechanism, and how that leads to performance outcomes was further found to be an unsolved issue in empirical research.

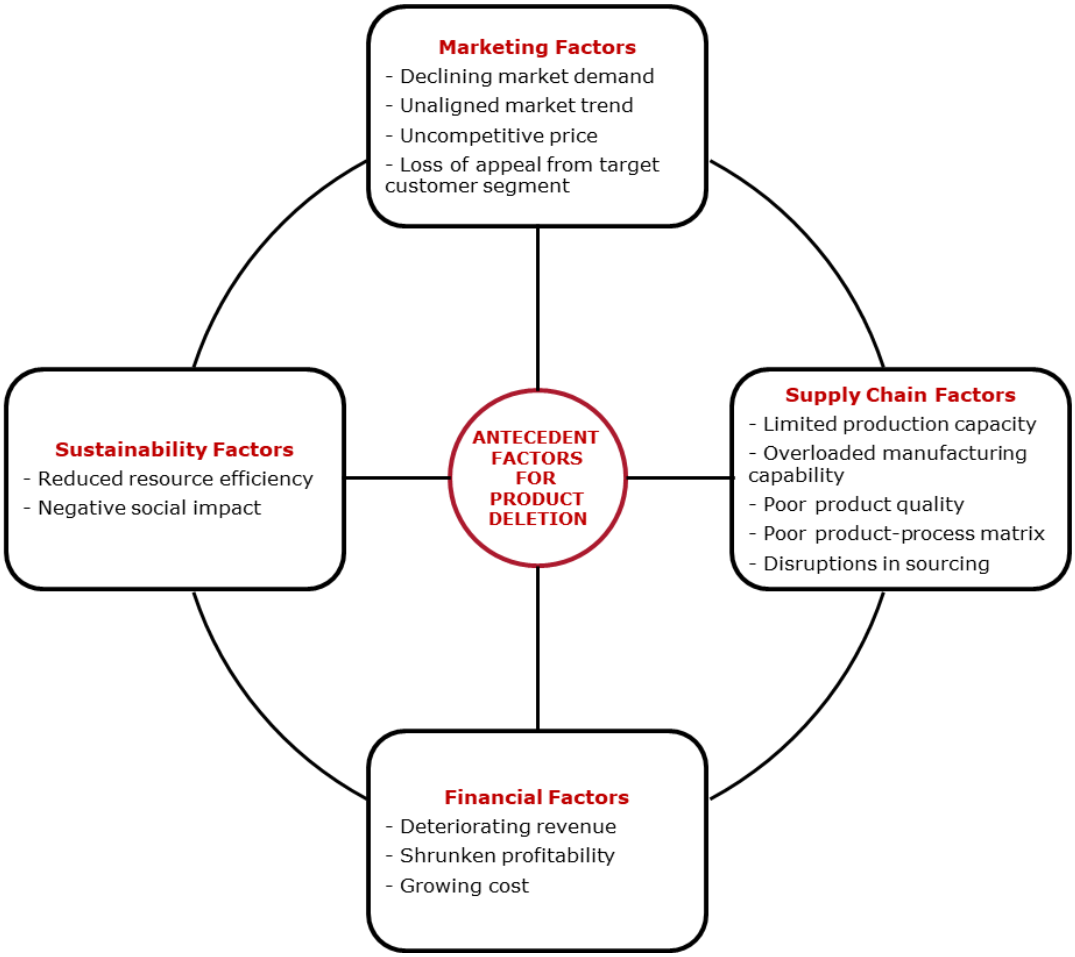
4.4.1 Antecedent Factors

Antecedents refer to the factors that affect the emergence of product deletion decisions (Eriksson, 2014). Antecedents factors are generated as the major qualitative study findings: they are factors or conditions that lead to product deletion decisions, based on the past experience of the informants.

Overall there are 17 antecedent factors identified from the case studies. They have been categorized into 4 major dimensions market, supply chain, financial, and sustainability factors. Marketing factors include: (1) declining market demand, (2) unaligned market trend, (3) noncompetitive price, and (4) loss of appeal from the target customer segment. Supply chain factors include: (1) slackened production capacity, (2) burned manufacturing capability, (3) poor product quality, (4) lethargic processes, and (5) disruptions in sourcing and procurement. Financial factors include: (1) deteriorating revenue/sales, (2) shrunken profitability, (3) lessened financial return and (4) growing cost. Sustainability factors include: (1) accumulating resources waste, (2) improved reclamation and remanufacturing value, and (3) extending stakeholder relations/involvement. Dimensions and antecedent factors are presented in Figure 4.3.

The antecedents may be internal and external to the focal firms. The next sections elaborate on the qualitative evidence from case study informants for each dimension and factor.

5: Figure 4.3: Product Deletion Antecedent Factors



4.4.1.1 Marketing Factors

The majority of the product deletion literature has been identified in the marketing field. Marketing factors are many and varied. Most companies have their portfolio of products scattered across all marketing segments. However, the main goal of the product portfolio strategy should be to maintain marketing competitiveness.

In reality, according to the informants, only a limited number of products are market leaders within a portfolio and because most markets do mature, most of the products, more or less, encounter some marketability issues, such as declining market demand, and unaligned market trend. The deletion will occur depending on in-depth analysis and a market factors matrix of advantages, risks, costs and returns, both short-term and long-term.

Strategic product portfolio management attempts to utilize the market matrix for product deletion decisions, ensuring resource allocation for a high growth business and the need to maintain competitive advantages in the marketplace. In this qualitative case study, a list of situations where product deletion occurs is provided as follows:

Declining Market Demand

Many products have been dropped in practice because they were obsolete. Loss of market demand may cause a product to be deleted. For instance, older versions of the iPhone have been dropped because newer versions have been developed with more functions; hence, customers shifted their demand from the old model to the new model. The obsolescence of old models results in complete deletion from the company product portfolio. Market demand might also come from customer needs. The change of customer need varies across products. Although those products may still have lasting loyalties that could potentially generate revenue, the manufacturers may evaluate whether these benefits would cover the expense of keeping the product in their product portfolio. Example statements from respondents supporting this observation include:

> P1: *There will be a product review. And there you will bring the issue up. You know what, this is what the problems are and this is what our market are, our market demand is probably going down. It is the marketability or anything else.*

> P5: *Customer needs are the major driver of product deletion. If there is obvious decrease in market demand, we will delete the product.*

P5: *When we have better products to replace the old ones, we will consider if we will need to delete the old ones. The one aspect that we will have to make sure is that the customer need of the replacement should be much larger than the customer need of the old one; and the replacement should cater to the overall market demand.*

P7: *Discontinuing products depends on market demand, production capability (cost of production) and product significance. There is no specific instruction to product elimination, but if it is not possible to produce or import the product or decreasing the product demand in the market and sales decreasing, or [there are] customer complaints of inappropriate performance and poor quality, it is decided to eliminate the product pertinently, therefore the product is deleted and another similar product enters the production line and market.*

Unaligned Market Trend

Positioning is a critical concern for product management. Market forecasting helps position products more precisely. Marketers use trend curves as an aid to market forecasting (Harrison and Pearce, 1972). A market trend curve is designed to direct market strength while guiding the firm toward growth opportunities. For example, the GE/McKinsey Company Position/Industry attractiveness screen is a method for determining a product's position in terms of the attractiveness to the overall market trend.

Decline in market potential has been identified as a situational variable for product deletion (Avlonitis et al., 2000b). Keeping pace with market trends is critical in maintaining and increasing a product's market potential. In product development, it is important to acknowledge that the market is ever-changing and in order to stay ahead of the trend curve and avoid competitors passing you by, you need to be able to move with the times for the benefit of long-term business planning. When a product loses track of the market trend, not reacting to the market along an emerging trend, the viability of the product will become challenging.

According to the informants, product deletion has occurred because of unaligned market trends.

P7: We gather data and analyze the sales trend of product. The sales trend from the market provides important prediction of product demand. The overall trend analysis helps the senior manager to decide on product deletion.

P13: There can be three major reasons for deletion. First, fit, when a product doesn't align with the market fashion trend or product positioning, or the theme of the entire brand series, or the market demand of the season, or the price positioning…

P15: The deleted products don't fit the market/fashion trend.

Noncompetitive Price

Price is an important element of the marketing mix that contributes to brand equity. Brand equity is the incremental utility or value added to a product by its brand name, for example, Coke and Nike (Aaker, 2009; Keller, 1993). Consumers view price as an important extrinsic indicator of product value or effectiveness. Higher priced products are often perceived to be of higher quality and less vulnerable to competitive price (Yoo et al., 2000).

However, prices also affect customers' willingness to pay. Customers often relate products to other products within the same product line, internal or external to a brand house. When companies introduce products to a market, research on price positioning will be conducted at the introduction stage, ensuring the product is competitive in price. However, the price effectiveness may decline over time. When products don't necessarily sustain price competitiveness, consumers' willingness to pay will be negatively affected. According to the informants, products have been deleted because of noncompetitive price.

P2: Once we launch the product, sometimes the competition will be very high, there will be several companies who will launch the product. What happens then is the prices will crash. Prices will continue to reduce. So after some time, if the product is not viable in price

competitiveness and it declines along the competition, then I will inform my customer that I will need to withdraw or discontinue this product from my product portfolio.

P4: Product deletion happens at multiple levels. At the consumer level, every product has a target customer profile. When the target consumer is not willing to pay more to cover cost for product development, then we cannot develop it anymore, and the product will be dropped.

P4: Sometimes customers are not willing to pay more for the product, because it is very similar to the other less-expensive products, without offering a very superior characteristic.

Loss of Appeal from Target Consumer Segment

Market segmentation, especially regarding target consumer segment, consists of viewing a heterogeneous market, as to a number of smaller homogenous markets in response to differing consumer preferences amongst target segments. Segmentation has been identified as a marketing strategy that involves a substantial emphasis on target consumer recognition. Market segmentation is fundamentally a merchandising strategy for products. Companies are suggested to make an adjustment of products to cater to their identified target consumer segment for optimal market returns (Shostack, 1977).

When a product loses appeal from its core target consumer segment, companies might modify its characteristics and attributes to sustain its attractiveness (Green and Krieger, 1991). Product deletion occurs in such modification processes, when a major characteristic or a key attribute is removed or replaced. The original SKU will be viewed as a deletion decision. Target consumer segment has been referred to as benefit segments in literature. Targeting only benefit segments, those most interested in specific products, has proven to be the most effective marketing strategy. Product deletion based on target consumer segmentation helps companies develop products in a more tailor-made manner.

P4: *The marketing team and product development team work together and make a target product profile. When R&D comes back and says, sorry we cannot develop it, and the product will be dropped if it cannot meet the target customer requirement, the product can be dropped.*

P1: *The characteristics of target market segments also play a role in product deletion. … Consumers have their market-wise specific differences and we have to adjust our product portfolio to follow them.*

4.4.1.2 Supply Chain Factors

Companies are striving to achieve the best possible performance from their supply chains by many different means such as increased supply chain efficiency, manufacturing capacity planning tools, collaborative forecasting, and replenishment with supply chain partners (Selldin and Olhager, 2007). All these efforts work on and with three fundamental flows: material, capital, and information (Zhao and Fang, 2002). Products are the ultimate carrier of these flows. Ill-performing products create a burden on supply chains with hidden cost and heavy demands on management time and production capacity on short runs.

Based on the informants, all of the interviewed companies expressed the view that product deletion in their product portfolio was eradicated owing to several operational problems. The most frequently mentioned ones include limited production capacity, restricted manufacturing capability, poor product quality, and lethargic processes, as well as disruptions in sourcing and procurement.

Limited production capacity

Capacity planning is a strategic issue of major importance in supply chain management. The problem is maximizing the focal firm's expected profit by determining the capacity planning within a certain product portfolio, subject to a capacity constraint (Shi et al., 2011).

Product deletion also, in turn, impacts capacity planning as the product return, recycling, and reclamation patterns of deleted products could affect the capacity expansion and contraction of collection and remanufacturing capacities (Georgiadis et al., 2006).

According to the informants, product deletion has occurred owing to the slackening of production capacity on supply chains:

> *P4: The manufacturing department once came to us and said their manufacturing capacity is getting limited, and they cannot manufacture this product for us. They might need to build another plant. That case will just remain costly. So I need[ed] to rationalize and finally we decided to delete this product from the product portfolio.*

> *P7: Product deletion occurs when we are not able to produce finished products to consumers, for example, because of high production costs and capacity. The product will be deleted.*

> *P4: Because at the end of the day, if you talk about everybody's time and capacity limitations, people's time and manufacturing plants' capacity is limited. So all you look at the profitability sense, the jobs also the company can only maximize the returns within the capacity of what we have. So from that perspective, product deletion and rationalization are part of every company's exercises that will help for strong products to fall into places.*

Overloaded manufacturing capability

Manufacturing capability development is an emergent topic due to the continuing pressure on manufacturers from rising industry expectations and the growth of global competition. Developing a manufacturing strategy of building up capability has been identified as a key driver for gaining competitive advantage (Corbett and Van Wassenhove, 1993).

The term "capabilities" is primarily derived from the manufacturing strategy literature in business strategy field, particularly following the development of the "resource-based" view of the firm (Hayes and Pisano, 1996). Capabilities form the foundation for competition amongst firms. In supply chains, manufacturing capabilities focus on the selection and growth of unique and sufficient operating capabilities. Capabilities and competencies are interrelated in supply chains. Restricted capabilities will

hurt the supply chain competencies (Swink and Harvey Hegarty, 1998). Hence, when products create a burden on supply chain capabilities, such as manufacturing capability, the product will become problematic on supply chains.

According to the informants, product deletion has occurred because of burned manufacturing capability.

> *P2: Second reason of product deletion is manufacturing capability. We outsource part of the manufacturing to another party. For example, China has some issues of getting their manufacturing process done. India side depends a lot on their job. Because of the delay and limited internal manufacturing capacity of India side, some manufacturing facilities have been closed and associated major products have been deleted as well.*

> *P3: Product deletion, from a supply chain department point of view, we shortlist product deletion candidates based on firm capabilities, such as manufacturing capabilities. If we are not capable to make the product to meet the market demand and need, we will decide [to] not work on the product at all.*

Poor product quality

Quality is a widely applied assessment and benchmark for product performance measurement (Allen, 1984). Quality is also an important supply chain competency (Kuei et al., 2008). Product quality in the supply chain dimension does not focus on perceived quality amongst customers and market (Estampe et al., 2013). Here, poor product quality includes poor product performance (i.e. poor functionality), and product issues of defects and recalls; as well as the service portion attached to the product, such as the post-purchase service.

When a product has been reported with constant quality concerns, a product deletion decision might be taken immediately or externally, to improve organizational reputation and customer satisfaction;

and internally to transfer the resources (people and space) to products with better and more stable performance (Hart, 1988a).

> *P1: There are more product drops because of quality issues. Quality stands for product performance, i.e., effectiveness and safety.*

> *P6: If customers have complaints of inappropriate performance and poor quality, we then will decide to eliminate the product permanently. … For example, the meat & vegetable grinder was deleted 3 years ago because of customer complaints on undesirable quality.*

> *P15: The voices for the products are mainly from the middle management groups, the head of each retailing stores. They provide the majority feedback on whether customers like a product or not and by how much. They will let us know what products involve quality issues, such as the material durability.*

Poor product-process matrix

Leveraging the product-process matrix is a critical dimension in supply chain design (Hayes and Wheelwright, 1979). The dynamics of process life cycles also impacts product management strategies, because process structure (process life cycle) and the corresponding stages that the products go through (product life cycle) are interrelated. The fit issue between product and process has been widely recognized and investigated in the supply chain management literature (Ahmad and Schroeder, 2002; Safizadeh et al., 1996; Spencer and Cox, 1995).

Companies seek the best process for their products. Consequently, when the supply chain process fails to match certain products, especially when the established process is proven to be not robust for certain products, they will make a decision regarding process adjustment or product modification, or simply product deletion (Weckles, 1971).

P2: A second operational factor is the process. If the process of the product is not robust. Process robustness means supposing I am continuously manufacturing this product, but I am not able to get the results what I submitted to the FDA (Food and Drug Agency). Then if it cannot meet the expectation, certainly, we will discontinue this product. Then sometimes, if we feel this is a very good product, we may redo the manufacturing process, and then we will resubmit the new process to FDA. If FDA doesn't give approval, then we will delete the product. So the factors are viability, technical issue, supply chain issues, and process issues.

P1: What we [are] saying is as we invest into new processes, typically in pharmaceuticals, the process development cycle is at least 5 years. So from that time we establish that product till the time the product hit the market, it is already 5 years. After 5 or 6 years, as the product reach the commercial stage, by that time, we will have more mature manufacturing in our plants. We need to understand that in the practical world of pharmaceuticals, any process change has to involve a lot of interval changes. Say if we decide to make a change, the new process need to respond to whatever we have new. It takes more efforts than making a change to or delete problematic products.

Disruptions in sourcing and procurement

Supply chain disruptions have proven to be risky. Disruptive risks tend to have a domino effect on the supply chain (Chopra and Sodhi, 2014); that is, one disruption in one area - for example, a material not being available from the suppliers - ripples into other operational areas, in this case, the manufacturing of a product.

Sourcing and procurement is critical to manufacturing companies. A number of interviewed companies deleted a product when issues arose from sourcing activities, for example, the price of a major component increased to such an extent that the increased cost could not be offset by an equivalent increase in price; or the sourcing party failed to respond to the transactions for later operational activities.

P2: Plants in India outsource materials from China. Some of the China suppliers' manufacturing facilities are closed. If we cannot get the ingredients from the sources, we don't have a choice; we will have to discontinue the product.

P3: Some supply partners, such as suppliers, impact product deletion. If you can't get access to certain materials, because it is constricted in supply chain, I think that can drive us to delete the product in the marketplace.

P4: Every year the cost of raw material is increasing. We have finance team within manufacturing department. This finance team and manufacturing put together a list of products. When I have the list I will consider those products are not valuable to sell, because the price increase in the material sourcing won't be able to make the profit margin for our business.

4.4.1.3 Financial Factors

At the end of the day, business runs on profits. Product portfolio management best practice is realized not by competitive advantage and the efficient allocation of resources, but more explicitly financial returns (Collis and Montgomery, 1995).

Financial returns are core resources for firms (Broadbent and Cullen, 2012). Company responsiveness to market dynamics including risks and opportunities are very limited due to financial resources. One direct source of financial resources come from product offerings. When a product is identified with limited contribution margin to the overall financial return of the company, the product might be considered a deletion candidate. The financial factors that are frequently mentioned by the informants include declining revenue and sales and profitability, as well as growing cost.

Deteriorating revenue

The bottom line of product value lies in revenue generation. If the overall revenue of products has fallen below acceptable levels, the product will be phased out.

P4: We talk about the product is now launched, if the revenue does not pick up or in the first 9 months to 24 months, we consider to dropping the product. The situation is that the revenue does not reach the expectations of the company, for me, what happens is that I will look at marketing expenses, every year, the marketing expenses keep increasing, if the market share of the product is not increasing and the sales are not increasing. If the product remains non-valuable to revenue generation. I will drop the product.

P2: For our company, right now, revenue is the most significant factor. So, simply, if the revenue of the product doesn't meet the KPI (key performance indicator) goal, we will delete it.

P7: Channel Partners such as retailers look at their revenue too. If they are not satisfied with their revenue, they won't buy and distribute the product for us, and as a result, due to unpleasant sales, our company has to eliminate the product.

However, product managers also consider product lifecycle in the revenue analysis. Revenue correlates to the life cycle of a product. Careful analysis of the interview transcriptions reveals that managers have reported that product deletion should involve taking the maturity of the product within its own lifecycle into consideration, which will help to determine whether "poor revenue" is associated with the performance of an established product versus a growing product or an infant product.

P5: Intimacy clothing are fast consumable products. From their introduction time to the market, the lifecycle of product management is 3 years. Our company will add or adjust product portfolios within the 3-year cycle. We usually maintain [a] 50% new products to old products ratio as the product turnover rate. The major reason for product deletion during the adjustment period is due to financial performance in terms of revenue. But we still keep in mind the revenue amount for products at different stages of their lifecycle will be very different. We consider life cycle in revenue assessment.

P4: During a product's mature stage, the revenue is declining. We know that the declining revenue is not because of the others but it reached maturity and we feel no one is really interested in promoting this product and the product is already being there in the market, so we need to milk the product, then we will gradually drop the product.

Shrunken profitability

Strategy scholars have investigated the relationships between products, strategy, and the persistence of superior profits (Roberts, 1999). Sustained high profitability may result from a firm's strategic management of products, while the profitability from each product may erode over time. When the profitability of a product shrinks below the minimum acceptable level, the product might be shortlisted as a deletion candidate.

P1: Permanent deletion happens because of portfolio management. For example, if a product has very limited financial outcomes and we have to spend more money in manufacturing and marketing to realize sales. The profitability of the product is very small and there is expectation of increase. We will delete that immediately.

Profitability is a different factor from sales. Products can have a high sales volume but low profitability; such products can also be deleted.

P1: For example, I will have a product which is very high sales in Russia. And we are making less money out from it. Now obviously, you cannot stop only because it is making less money. In this case, we will keep the high volume product and let's increase the efficiency for that product with lower profitability. How we can maximize the overall value. However, if the profitability cannot improve after all, no matter how much high sales volume we sell, we still will have to delete it.

Growing cost

In order to make sound decisions concerning the product development, managers need to know what their products cost (Niazi et al., 2006). Product decisions including product deletion decisions are influenced by the anticipated cost to predict the product profit margin. When the profit margin is predicted to decrease, the question of product discontinuation will be raised, while cost is the major player in determining profit margin. For example, the low-cost product producer often achieves competitive advantage by sustaining a high profit margin by serving a broader range of customer base; in the long term, those companies can utilize the generated profit margin on innovation, which will further help to reduce costs. Hence, when cost keeps growing for a certain product without a yielding positive profit margin, the product might be deleted.

P2: We use SAP to do the data management and analyses. The software will show product cost over a period of time and profit margin trend. When we identify a growing cost pattern for certain products with a given level of profit margin, the product will be deleted eventually.

P4: The other reason of product deletion is internal to the management. If overall costs for products, including operational processes and management, are increasing. The growing cost will become a financial constraint for us to do a lot for things to the product development. Growing cost leaves no room for expansion. Then we will delete the product.

However, strategic cost management consists of a cost driver analysis and revenue stream analysis. From the revenue stream perspective, even though a given product may have been identified with increasing cost issues, it still generates complementary sales from the remaining transactions of its product portfolio; in the short run, companies may still decide to keep them for revenue-generating purposes (Vyas, 1993).

P2: Sometimes, even though we are not making profit in this product because of growing cost, but because of this product, we are getting profits from other products. We might not

discontinue despite [the fact] we are losing money here but I am earning from other portfolio products.

4.4.1.4 Sustainability Factors

Values and knowledge of sustainability also impact product and product portfolio management. Sustainability from the triple bottom line includes three major dimensions: economical sustainability (profit), social sustainability (people) and environmental sustainability (planet). Companies focus on product strategies and operations to address effectively and efficiently the sustainability issues, such as involving sustainable values in product design. Eco-design and design for environment principles are some of the environmental strategies for sustainability-driven companies (Albino et al., 2009).

Sustainable development priorities start to be integrated within their organizational product development agenda (Brones et al., 2014), but not particularly in product deletion strategic management. According to the informants, sustainability factors have been applied to the product deletion decision making, and the most frequently mentioned ones include reduced resource efficiency and extending the stakeholder's relations/involvement.

Reduced resource efficiency

Resources contribute to core organizational competitiveness. The foundational idea of strategic resources to comparative advantage comes from, first, resource scarcity in terms of heterogeneous, imitability, and substitutability; second, dynamism in terms of how organizations utilize their resources considering capacity, efficiency, and flexibility (Wernerfelt, 1984). Efficiency is critical when resources are subject to constraints. Given the certain amount of resources allocated to products, when resource efficiency for a product becomes low, it is more likely that organizations will decrease the manufacturing quantity of this product, gradually phasing it out or implementing immediate deletion.

P12: Some products waste a lot of resources in its manufacturing processes; which results [in] risks in the overall operations. We decide to cut its quantity.

Lean philosophy is an emergent topic along with lean manufacturing, it has been initiated by Toyota and focuses on the streamlining of value added activities and eliminating waste within the processes, with the goal of better servicing market needs. This waste reduction philosophy has been applied to product management (Morgan and Liker, 2006). Eco-efficient product development is a strategy that involves resource efficiency and waste reduction in product design. Companies have been developing eco-efficient products to replace the old products and contribute to environmental sustainability.

> *P15: In recent years, sustainability has been one of our design philosophy right now. We consider the resource waste a product will incur from its sourcing, to manufacturing, to delivering, and the end of usage. We, in this year, prefer to choose materials that produce less waste as operational output, so as to decrease pollution to the ocean. We delete the products that consumed a lot resources as well as a lot waste.*

Negative social impact

The social dimension of sustainability and corporate social responsibility are interchangeable when it comes to organizational strategic management. Advocates of organizational social responsibility are convinced that it "pays off" for the firm as well as for the organization's stakeholders and society (Burke and Logsdon, 1996). Companies often convey their social concern in their market offerings; tangibly, products.

Based on the informants, products will also be deleted when they cause negative social problems.

> *P4: yes even though it is profitable to me, I don't bother; if it creates issues or problems, creating sustainability issues, for society, probably I might not look at its profits. I will delete the product no matter how much money I can generate from this product as long as it has social concerns.*

P4: No matter how much it sells, it doesn't matter to us. It concerns the product sustainability and the patient safety part of it. Anything happens to these, we will stop manufacturing. We don't comprise on these two things. Patient safety is top in our mind.

The antecedent factors of four dimensions that are derived from the qualitative case studies are triggers for product deletion in most situations. However, sometimes, even though a product may be detected with a critical issue and deletion seems to be the rational decision for companies, the decision maker may still decide to retain the product for strategic reasons.

For example, companies with full-line strategies attempt to enhance product portfolio depth by carrying a high number of variations on similar products in order to satisfy a wide range of different customer desires. Firms with a market share growth strategy might seek to offer their full-line products in order to capture many consumer segments, keeping a larger market share. Line extensions have a much higher chance of survival than brand-new products. Some marketing executives defend line extensions as the best way to build a business (Kotler, 2000). Therefore, some companies when pursing full line strategy may retain a poor performer, just to be able to keep a full line variety.

P12: Product deletion decisions will have a negative impact on the product portfolio variety and destroy the product portfolio composition, and further hurts the sales/profit. Sometimes, we won't delete some products just to have that product line/type in our product portfolio.

4.4.2 Product Deletion Decision Making Process

Companies in a competitive environment need to visit their product portfolio and rationalize it on a regular basis. The routine to do this has systematically been referred to as a product deletion decision making process, according to the informants. The findings on the product deletion decision making process can be illustrated in terms of product deletion frequency, product deletion decision initiating,

cross-functional and individual power play, stakeholder involvement, final decision making, and facilitating tools.

Frequency

Frequency of product deletion is defined as the rate at which product deletion usually occurs in organizations. The informants have varied experiences in product deletion occurrence frequency. The reported feedback ranges from *very often, once in 3-5 years, annual, six months, seasonal, quarterly, occasional*, to *rarely*. The variations may come from the characteristics in culture, firm type and size, industry, and the product specific.

Informants also mentioned product deletion occurred on a regular organizational agenda, including annual budgeting meeting, internal product audit meeting, annual board of directors meeting, and seasonal workshops with business clients. Open discussions and voting is the most widely utilized format for such decision making.

Some informants also indicated that complete deletion might not always happen. Changes or modifications to either product components or supply chain aspects such as supplier alteration are more feasible and preferred solutions in reality. Complete deletion involves risks in cost and uncertainties in post-deletion performance prediction.

> P2: *Every year, at least, once in six months, the supply chain team, manufacturing, marketing team will meet and discuss [if] a product is viable or not viable. They decide if any product we want to discontinue, how to remove from the market.*

> P4: *We do this every year during the budgeting exercises. Which starts around April, and we review this during like February. And in the month of February, we will let internal know that we are not budgeting the products that have been decided to be deleted.*

> P1: *Product deletion might not always happen. It will be changes to manufacturing or other aspects.*

P5: *Because of the product characteristics, we will do the product deletion upon the seasonal change, autumn to winter and spring to summer.*

P13: *Product deletion occurs every season in our company. It is necessary and important. The retain rate of product[s] is 30% to 40%.*

P7: *Products in the company are rarely deleted because of the high cost of making molds and supplying materials.*

Cross-functional Involvement

Product deletion occurs for various reasons. The antecedent factors are possible causes for product deletion. Antecedent factors affect performance of organizational functions. The emergence of cross-functional departments has outpaced our understanding of the collaborative working flow (Jassawalla and Sashittal, 1999). Committing to a common agenda, initiating collaborations, and interpersonal interactions and communications are essential to enhancing cross-functional collective performance.

It seems that companies will seek the root of product issues based on the identified antecedent factor and its associated department; the department should be directly affected by the antecedent factor performance; hence, it makes sense for that department to initiate the product, detecting, and validating for deletion considerations. However, what happens in reality is that financial numbers, in most cases, are still the first and commonly used characteristics for problem identification.

According to the informants product deletion initiatives are often initiated by the finance department.

P10: *So that is I guess finance is the first lens. The financial gave us the D list. They will put out the list to the sales team to get feedback from marketing department.*

P11: *The finance department usually led and initiated the processes, and marketing department should provide data to facilitate the decision-making.*

Because of its complexity, this decision involves many cross-functional departments at different levels. Companies also differ. To summarize, these issues include supply chain, manufacturing, marketing, finance, product design, and R&D.

According to the informants, the most frequently mentioned departments are marketing, supply chain, product design, and the finance department.

> *P2: So every year, at least, once [every] six months, the supply chain team, manufacturing, marketing team will meet and discuss [if] a product is viable or not viable. They decide if any product we want to discontinue, how to remove from the market. Three department heads will take the decision from the marketing team, manufacturing, and supply chain. The three guys will discuss and make the decision.*

> *P3: So part of the teamwork exercise, business bureau will generate input from supply chain, from finance, and marketing. From each, finance we will look at probability, supply chain we will look at manufacturing ability and logistics stand point and marketing we will come from the ability to invest the product or not. So all three will provide the input and the rest [of] the business bureau will decide on whether the product will be deleted or stopped to be manufactured again or stop commercializing. So when that list is given, then the cross-functional teams then meet and the final decisions is made by the marketing team based on the communications with supply chain and finance teams. If there is still some issues, then the decisions will go to the business bureau. They will decide on the deletion of the product.*

> *P4: The departments involved are supply chain, finance, packaging, demand planning and manufacturing, marketing.*

> *P5: marketing team and product development team work together and make a target product profile. And put it to R&D for development. When R&D comes back and say, sorry we*

cannot develop it, and the product will be dropped if it cannot meet the target customer requirement.

When it comes to the final product deletion decision making, according to the informants, often the top management team will finalize the decision. Members of the top management team include the Chief Marketing Officer (CMO), Chief Executive Officer (CEO) and Chief Operating Officer (COO).

P3: The cross-functional teams then meet and the final decision is made by the marketing team based on the communications with supply chain and finance teams.

P1: [The] COO makes the final call. The heads of marketing will report to the COO.

P4: The final call is actually taken by [the] CEO. In most of times the business head of all department will all together make a final decision. If there is any disagreement, they will come to [the] CEO.

Power

Any organizational decision making involves power play. Power in organizations may be vertical or horizontal. It may also engage in interpersonal relations between organizational units (Klein, 2017). Power play in product deletion can involve both the department level and individual level. Department power is found to be most highly correlated with the department's strategic importance within the firm, as well as the department decision maker's power sources (Salancik and Pfeffer, 1974).

According to the informants, finance and supply chain departments are reported to have 30% to 40% power on product deletion decisions; the marketing department, in terms of marketing strategy and branding aspects, has 60%-70% power; the sales department has been stated as the most important and influential (80%); and the design department also has roughly 15% power over product deletion decision making.

P2: Marketing department will take 60%-70%. Supply chain and manufacturing is 40%.

P3: In general, 60% to the marketing, and 30% to finance.

P13: In order to avoid future problems of some products, the design department hold a separate 15% power on the product deletion finalizing.

Power play also involves individuals. Six major sources of individual power have been investigated in this study; respectively, legitimate power, reward power, coercive power, expert power, information power, and referent power (Klein, 2017). According to the informants, expert power and legitimate power are the frequently mentioned power sources.

Legitimate power is power that comes from one's organizational role or position. For example, when a product manager believes the deletion should occur for certain products, others in the department would comply with the requests to make the changes accordingly because they accept the legitimacy of the position, whether they personally like or agree with the product deletion decision or not.

P8: Government has the legitimate power regarding the different standards and regulation for products; it is not whether you want to delete it or not, you have to delete [it] in some cases because of some regulations.

P7: When cross-functional teams cannot reach agreement on whether or not to delete the product, there is a department in our company called business bureau. Business bureau has the authority to make a call regardless of any cross-functional conflicts or disagreement.

Expert power originates from subject matter of expertise, such as knowledge or skills. Others who have expert power in an organization include long-time employees or business partners. For example, when a procurement manager reports that the sourcing cost for a product cannot guarantee a sufficient profit margin. Deletion might be a better choice compared to adjusting to survival from a limited profit margin. Many of these interviewed firms, owing to the globalization characteristics, utilize a mixed structure in which clear lines of legitimate power become blurred as employees communicate regardless

of position. Open discussions and voting has been reported as a standard format of product deletion meetings.

> P9: *Product deletion is a controversial decision amongst departments, which is mainly expert power involved. We rely on experiences and data analysis reasoning.*

> P12: *Based on the recommendations from all departments, we conducted internal open discussion, decision and implementation amongst all cross-functional departments.*

Stakeholders

Stakeholders play a critical role in product deletion decisions. Products might hurt relationships in supply chain networks. According to the informants, channel partners, customers and government, and regulators seem to be the most influential stakeholders involved in product deletion decision making.

Channel partners including retailers and distributors might demand higher prices or better terms for servicing products to customers; after deletion of the weak product, this might adversely impact the partnership with other products in the product portfolio. Involving channel partners and customer in decision making and announcing helps strengthen the relational rents amongst supply chain actors. According to one of the managers, deleting products is not deleting business.

> *P4: Product deletion should land at least 6-9 months in advance. And you also need to inform all the stakeholders which includes pharmacies, doctors, and employees. And in case of certain products, we also need to inform that we are stopping it, but if someone needs it, we still have inventory to supply. You need to inform all the stakeholders because that actually improves the trust portion for the company. Instead of suddenly disappearing all from the market, you are deleting only a product, not the entire company, you have to go back to the same customers for other products.*

> *P7: Customers have an important role to play, because if the customers do not buy the product, the company has to delete the product. The employees at the managerial and expert*

levels in marketing, sales, R & D, supply, production and finance, due to the preparation of specialized reports and analyzing on demand, market, costs, etc., effect on product deletion decision. Investors can provide enough money for supplying product parts, finished product importing and producing at high-cost production. Therefore, they can [have an] effect on product elimination decision. Suppliers can [have an] effect on product elimination decision by the possibility of providing product part at the right time and right price with acceptable quality. Channel Partners (Retailers, Distributors), if they are not satisfied with the profit margin, they won't buy and distribute the product, and as a result, due to sales decreasing, the company has to eliminate the product. The high costs of product promotions in the media can [have an] effect on product elimination, because one of the most important factors in product deletion decision is the unwillingness of customers to buy it.

As for some interviewed companies, their product policy is under the restricted guidance of government and regulations. Government serves as an important stakeholder in their product portfolio development. A public large-sized company distilling pharmaceutical products (Company C1) operates internationally. Before the company launches products to an international market, they would need to meet the requirements of the local government.

P2: We have to follow the process of U.S FDA. Then FDA will give us an approval. The general process will take us two years on average. Once we get approved from FDA then we launch the product to the U.S. market. If the product doesn't meet the results what I submitted to FDA, certainly, we will discontinue this product. Then sometimes, if we feel this is a very good product, we may redo the manufacturing process, and then we will resubmit the new process to the FDA. Once the FDA gives approval, then we will relaunch the product, but it will be a different product in our product portfolio.

P3: Usually, the supply chain, we have only buy materials from these three sources. I cannot buy from any other sources. If we buy from any of the sources, it means that I have to resubmit the document for sourcing to the FDA.

P4: The FDA decides if the product is worthy enough. I don't think we have any choice in this aspect for sure. If FDA takes the call of deletion. We don't have any control. We have to do it. The regulators have the supreme power.

Company C1 also reported operating various price systems in different markets, considering local manufacturing prices including material sourcing and labor, as well as price of willingness to pay. When certain products don't fit with one market, deletion might only occur in the problematic market. Inventories will be deleted but consumers can still access the product from other markets.

P4: Because what happens is in every market, the regulations are very specific to that market. The language, the packaging and registration, everything is particular to that market. So when you are deleting a product, it is not like you decide today and you stop it tomorrow. Because there is a lot of loss inventory as well. And deletion should land at least 6-9 months in advance. And you also need to inform all the stakeholders which includes pharmacies, doctors, and employees. And in case of certain products, we also need to inform that we are stopping it, but if someone needs it, we still have inventory to supply.

Tools and Techniques

The product life cycle concept has been commonly used as a diagnostic technique for product deletion. Products that were identified in the decline stage in terms of marketability, profitability, and production capability become likely candidates for deletion, significant change, or modification. However, there is no specific tool to facilitate product deletion decision making. Arguments have increasingly been made that the lifecycle concept of eliminating products at or after its decline stage is

misleading and not always the optimum solution of deletion. Product deletion decision making tools are contingent to industry-, company-, brand- and product-specific characteristics.

Based on the case studies, 85.7% of the sampled companies reported that no tool has been utilized to facilitate their product deletion decision making.

> *P7: Unfortunately there are no decision making tools/processes to help you manage product deletion decisions.*

Most of the companies resort to open discussions and a voting process to finalize the decision making. The only tools that involve multiple cross-functional antecedent factors are the scorecard and stage-gate model.

> *P14: The decision makers include key clients and KOL (Key Opinion Leader) of associated departments. The process is through [a] scorecard. It will be product display, then take the comments from the audience. Audience will allocate points/scores for each product. The scorecard system depends on the stakeholder itself. For example, some department or the business partner, they have their own impacting factor to consider. Because the designers cannot be very rational about the scores. So the factors consist of fixed factors assigned by their department head or organizational head; and some soft factors are with the individuals' personal preferences. So there is no such a cross-room standard for score rules.*

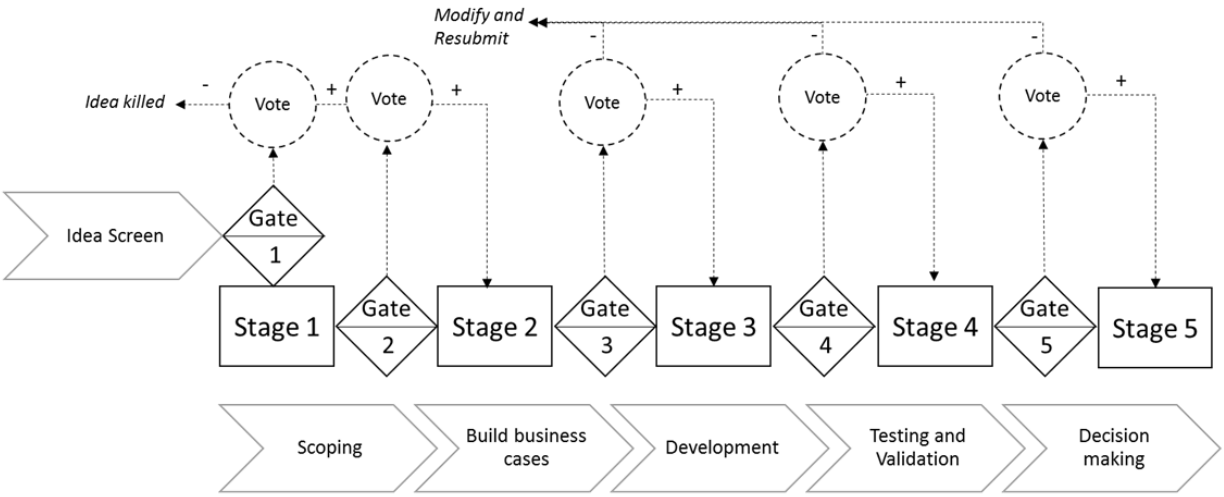
The stage-gate model, as another tool, has been reported as being utilized in the product deletion associated decision making process. The model originates from Cooper (Cooper, 1990) as effective tools to assist organizational new product programs. The interviewed company has revised the model to better fit its business environment and apply the model in product strategic decisions.

> *P10: We use a stage-gate model to manage this process, which [is] adopted by many other organizations around the world, best practice for managing your product life cycle from NPD (new product development) to deletion or rationalization.*

P10: It is a model where you have a cross-functional leadership team, probably go through 5 gates. Each time, basically, it starts with an idea, the idea for product deletion. That idea will go to, basically the cross-functional leadership team to vote on it, involving marketing director, sales director, supply chain director, and financial director. The process continues on through each gate till the fifth gate. Basically it is the logic if a product can be deleted or not.

Based on the interview, the reported modified stage-gate model is summarized in the figure below:

6: Figure 4.4: Product Deletion Decision Making Tool – Stage-gate Model



Note: All vote processes will be conducted by four cross-functional leadership teams, respectively marketing director, sales director, supply chain director, financial director

Product deletion decisions are complex and can be risky for companies. There is a gap in the research on tool development to facilitate the decision making processes. The stage-gate model might be helpful for some companies in certain situations. However, individuals play a significant role in this model. Individual behavioral factors might bias the decision. Thus, a more sophisticated, systematic and completed objective tool is required to ensure sound decision making. This further validates the contribution of the quantitative study of this dissertation. Chapter 5 develops an inferencing and predictive tool to help companies rationalize product deletion decisions based on Bayesian analysis and MCMC Gibbs sampling.

4.4.3 Outcomes

Like many strategic decisions, product deletion results in both positive and negative outcomes. The coexistence of both positive and negative outcomes make it complex and less appealing to managers. Sound product deletion requires careful evaluation and revitalization on the product portfolio and other strategic characteristics. For future managerial implementations, having possible negative outcomes in mind will help organizations react proactively to potential loss and risks.

Positive outcomes

Overall, according to the informants, generally positive outcomes include a more focused firm strategy, more rationalized product portfolio, opportunities for new product development, and competitive advantage.

P12: Product deletion decides resources management in terms of integration and rearrangement; therefore, after product deletion, it will result in more focused firm strategy in terms of resource planning.

P13: After product deletion, resources are more concentrated and the overall strategic positioning is more solid.

P10: Product deletion ensures every product retained are "effective products". Those products retained have a clear positioning on its product line. For example, some of them are for retailing; some of them are for fashion and show purposes; some of them are for brand image, some of them are for matching purposes, and some of them are simply for showcase.

P11: Product deletion helps free up resources and investment and time for new product development. In terms of advantages, from a financial point of view, it is always a benefit to delete a product to rationalize a product portfolio. It allows new products to fall in place. Because at the end of the day, if you talk about everybody's time and capacity limitations, and the manufacturing, people's time and manufacturing plants' capacity is also limited. Product deletion helps free up resources and

investment and time for new product development. So from that perspective, product deletion and rationalization, are part of every company's exercises that will help for strong products to fall into places.

Negative outcomes

According to the informants, they also experienced unpleasant product deletion as well. The most frequently mentioned negative outcomes include potential sales losses, decreased product portfolio variety, inventory, individual emotions, cross-functional department conflicts, and high costs of implementation.

> *P3: What we fear to happen is that when we take a call on deletion, in the end of the budgeting cycle, usually it should have inventory. The big headache. We try to liquid[ate] the inventory as quick as we have in the last 6 full months. Then we fully delete the product from the market. But the thing is when we take a call on the deletion that 6-9 months of inventory we carry will still in stock. And that is additional cost on the product deletion decisions. It is part of the sales losses as well.*

> *P3: Product deletion is risky often times. So some sales are from these products right? And if your business has to grow by X%, and certainly some percentage of the growth has be to coming out because you are restricting or deleting products right. So with the deleted products or newer products launch, you will have to cover the loss. I think every year, we agree discontinuing products make up to 1% of the sales. That 1% of sales now has to be compensated by the remaining and new products we launch.*

> *P12: The disadvantage is that the product portfolio variety will decrease.*

> *P1: When we aware of product deletion disadvantages, the results become very clear. One cons include the decrease of patients (customers). For manufacturing, that product might still on the shelf. That is one Con. The remained inventory for the deleted product become*

obsolete, and requires even more efforts to manage and liquid them. After all, the inventory is costly and soon become waste.

P7: They are trying to remove that emotions from the decisions. Because they are dealing with the products for years. It could be someone's favorite products. Trying to convince that person to delete it is, you know, not going to happen.

P9: Product deletion involves personal preference. Therefore, product deletion decision making process will go through continuous debating, arguing and fighting. To avoid it from happening, we leave the decision for the research department and rely on the actual data.

P13: Cost of implementing product management/deletion is high and it is very difficult to cover and predict all market demand for a product line/brand.

P15: Sound product deletion decisions will make the product portfolio better fit the market demand. However, this decision consumes too much labor resources and material resources.

Product deletion, compared to product addition and new product development, is still a relatively less appealing decision for most managers. This is partly due to the concerns regarding the negative outcomes. Neither the literature nor the case studies inform effective approaches to offset the potential risks within these negative results. Further research could investigate the roots of the negative outcomes and ways to overcome the embedded risks and concerns.

4.7 Summary and Limitations

The qualitative study in this dissertation focuses on the organizational routine of product deletion management. A conceptual framework is arrived including antecedents, decision making processes, and outcomes. The grounded-theory approach within case studies revealed that product deletion is strategic and critical to organizational strategic management. Product deletion impacts and is also influenced by multiple functions of an organization, not limited to marketing and sales, but also supply chain and

sustainability. However, product deletion is generally a last resort and less appealing strategic alternative in product management.

The grounded theoretical model is not comprehensive and slightly influenced by literature, therefore, there is potential for further refinement and advancement. The framework serves as a generalized business routine for product deletion decisions in organizations, based on 16 interviews. Even though the sample size has indicated theoretical saturation, the findings didn't entail differences in product deletion management regarding to perspectives of country, industry, firm type and individual. Archival data and actual observations can also be collected to validate the results of existing interviews.

CHAPTER V: QUANTITATIVE STUDY: A BAYESIAN ANALYSIS APPROACH

"After the elimination of the products, almost 20% of our customers terminated the business relationship. To rationalize this decision, a sophisticated tool that incorporates product level situational factors are needed for different business scenarios."

- *Quotes from case study interviews*

Product deletion is a complex decision. Companies often find it hard to predict the outcome and bear the risks involved in the decision making and implementing processes. The risks and concerns surrounding product deletion suggest the need for a more general model that recognizes the unique character of the decision within the firm, a model in which synergies among product portfolios and the performance measurement of all organizational functions are identified and explicitly considered.

The case studies from the qualitative evaluation indicate that joint collaboration from key cross-functional teams is critical in product deletion decision making processes. Operational and sustainability antecedents on supply chains are emergent but neglected in existing research. Managers seek both inferencing and predicative tools to facilitate this strategic decision making.

Overall, 40 factors are identified and synthesized from both literature and qualitative case studies. Three Bayesian statistical models are included in this chapter, incorporating these 40 factors in different dimensions and levels for both inferencing and predictive analysis. Model 1 investigates how each function relates to product deletion decisions; respectively marketing, supply chain, finance and sales, and sustainability; including 4 dimensions and a total of 40 factors. Meanwhile, Model 2 examines how supply chain management factors play a role in determining product deletion decision making; incorporating 3 dimensions and 15 factors. Model 3 examines how sustainability relates to product deletion; categorizing 4 dimensions and 18 factors.

Some of the dimensional categorizations cannot be separated from one another; for example, data in the finance department relates closely to measurements within sales department. Therefore, these two

departments are grouped together for model 1 and model 3. In addition, since economic sustainability belongs to one determinant in the overall sustainability function and most of the economic data are generated from finance and sales, the sustainability categorization of economic sustainability is therefore included within the finance and sales grouping, whereas the sustainability grouping only accounts for social and environmental sustainability. The quality measurement in the supply chain dimension has been removed for two reasons, one is that quality is widely defined in the literature relating to customer satisfaction, customer feedback, and market performance, which have been included in the marketing dimension; the second is that quality concerning the product defect rate and recall rate is inaccessible in the selected companies. To summarize, the major dimensions introduced in these three models are exploratory and the list of selected factors does not aim for exhaustive in-depth inclusion. Future studies will incorporate more data categories for further investigation.

There might be other factors that could play a role in product deletion decisions and there are arguably other ways to group these factors. These three models are among the first initiatives as exploratory investigation. The proposed quantitative evaluation and its findings are expected to open up new avenues for further extensions.

5.1 Data Sources

Datasets on the defined factors and dimensions are derived from 9 Chinese companies. The company information is summarized in Table 5.1, including company name, industry, portfolio size, annual revenue, and the evaluated product line name, product name and the overall annual sales volume at the product level. All data collected are at the product level. The data is historically stored from the year 2015 - 2018. The data of deleted products are filed as the information of the year of deletion; and the data of retained products are filed as the information of average number spanning from 2015-2018.

10: Table 5.1: Data Sources: Company and Product Information

Industry	***Product Portfolio Name***	***Product Name***	***Product Portfolio Size***	***Annual Revenue (millions)***	***ROI***	***Annual Sales Volume (millions)***
Textile	Daily articles	Ultra-fine fiber cleaning towels	27000000	30	0.285714	25
Apparels	Baby textiles	Baby blanket	650	28	0.3	4
Apparels	Baby textiles	Baby pillow	650	28	0.3	5
Apparels	Baby textiles	Snoopy (urine pad)	650	28	0.3	0.8
Maternal and infant industry	Infant child toys	Mopee (magic pen)	150	6	1.333333	0.2
Mechanical	Castor	Control/central Castor	2600000	26	0.074074	8
Textile	Baby textiles	Children's sweater	320	8	0.5	1.2
Green plant	Green plant	Fleshy green plant	80	3	1.5	0.5
Textile	Baby textiles	Baby romper	4000	2800	0.2	2
Textile	Four-piece set	Feather quilt	260	369	0.857143	3
Textile	Undergarment	Hibra	260	369	0.857143	4
Textile	Menswear	Hodo Causal Suits	10300	60	0.133333	17
Apparels	Women clothing	Jeans	3000	50	0.26	5
Apparels	Women clothing	Ladies blouses	3000	50	0.26	3
Apparels	Women clothing	Sweaters	3000	50	0.26	3.5
Apparels	Women clothing	One-piece dresses	3000	50	0.26	8
Apparels	Women clothing	Jackets	3000	50	0.26	8
Apparels	Women clothing	Tshirt	3000	50	0.26	2
Apparels	Women clothing	Skirts	3000	50	0.26	5
Apparels	Women clothing	Capri pants	3000	50	0.26	2

The entire dataset exhibit 20 products from 9 companies; 15 of them were once shortlisted for deletion but retained and the remaining 5 products were removed from their product portfolio. These products have been investigated on 40 identified factors (Section 5.2). The data collection procedure is as follows:

Step 1: The researcher recruits the company to participate in this research study (snowball sampling via personal networks); the company is restricted to OEM (Original equipment manufacturing);

Step 2: The researcher designed a data acquisition dictionary (Appendix C) for company executives as a reference for respondents to provide the required information (major data sources include ERP system, Excel database);

Step 3: For missing information such as sourcing cost for a certain product, the collected data might be at the product line or brand level, the researcher will generate firsthand information from the targeted department, the targeted worker and the targeted product through WeChat (Chinese instant messaging application) and overseas phone calls.

Step 4: The researcher revisits the dataset and presents the collected dataset to CEO of the selected companies to confirm and validate.

Step 5: The researcher computes the Bayesian analysis to summarize preliminary analysis and findings.

Step 6: The researcher presents the initial results to the selected companies and company executives and check for fit and accuracy. With sound evaluation and further approval, the studies will proceed using MCMC simulations and Gibbs sampler to increase the sample size while exhibit robustness.

5.2 Factor Selection and Description

This section introduces each factor in the order of: (1) definition and its strategic importance in product or firm success within the literature; (2) review of this factor as to the product deletion literature; and (3) practical inferencing in the identified companies, and its measurement and boundaries. The order is marketing, supply chain, finance and sales, and sustainability factors.

These factors are derived from both the literature review of related literature streams including product management, strategy management, supply chain management, and sustainable supply chain management; as well as evidence and findings from the qualitative case studies in Chapter 4.

5.2.1 Marketing Factors

Market Share (MS)

Market share is defined as the percentage of a market in terms of either units or revenue accounted. Market share is a critical measurement for product performance because it closely monitors the signs of change in the competitive landscape (Rust and Zahorik, 1993). Increasing market share is among the top objectives for any business. Market share is categorized as a key indicator of market competitiveness. Such competitiveness demonstrates how well a firm and its offerings satisfy the market against existing competitors (Buzzell et al., 1975). Considering the firm size and industry differences, this study focuses on product-level market share (the product candidate within the product portfolio). This factor, responded by changes in sales revenue, informs managers both primary and selective demand in the target markets.

Research indicates that market share affects product management decisions. Market share gives the strongest indication of a product's advantage relative to competing products (Robinson, 1990). Market share, customer satisfaction, and customer retention are the identified three indexes for the total quality level of a product (Rust and Zahorik, 1993). When market share goes up consistently, the cost associated with acquiring new customers and seeking product improvement goes down. There is a tradeoff between expanding market share of the company and expanding product lines and products. Many companies introduce new products to boost sales and market share without full consideration of product fit. These new products easily turn out to be a failure at the expense of long-term profits. Therefore, market share is a critical factor affecting a product’s retention and abandonment decisions, which needs to be considered with caution.

The data is collected through archival product data, indicating the overall market share of this product within the entire product portfolio in terms of total annual sales. The data type is numerical, noted as a percentage from 0 to 100%. It is hypothesized that the larger the market share a product has, the less likely it will be deleted.

Competition (C)

In business, competition in general stands for rivalry between two or more companies (Hotelling, 1990). Competition is a major tenet of market economies and business. Competition is usually a stimulus to cope with the higher purposes of meeting and reaching better products that the company may produce or develop to meet broader markets. Porter's five forces framework is the most recognized tool for analyzing the competition of a company (Porter, 2008). Porter refers to these forces as the microenvironment.

In this study, economic competition is selected to indicate the competitiveness of the product candidate representing its firm in the microenvironment. There are three levels of economic competition (Hunt, 1999), including direct competition (brand/category competition), substitute competition, and budget competition associated with a consumer's willingness to purchase.

This data is collected through archival product data, which helps to categorize the product candidate into three groups: "most competitive product," "medium competitive product," and "least competitive product." Therefore, the data type used in Bayesian evaluation is ordinal, "1" (lowest), "2" (medium) and "3" (highest). It is hypothesized that the more competitive a product is, the less likely it will be deleted.

Differentiation (D)

Differentiation is an important marketing strategy in product development and management research (Dickson and Ginter, 1987). Product differentiation posits that companies can gain competitiveness by distinguishing a product or service from competing counterparts (Smith, 1956); and the level of differentiation will help arrive at the attractiveness within target customer segmentations. Differentiation influences substitutability. Decisions of product introduction and development are often closely related to the substitutability between the products, depending on the degree to which one firms' product are differentiated from the substitutes in the market.

In this study, differentiation involves the company level, which is product similarity to superior competitor offerings (*PC*) (Bressler, 2012); and the product level, which is the differentiation of product design/characteristics amongst its product portfolio (*PD*) (Ulrich, 2003). Both data sets were collected through interviews with top management with regard to helping to categorize the product candidate into three groups: "most differentiated," "slightly differentiated," and "least differentiated." Therefore, the data type used in Bayesian evaluation is ordinal: "1" (highest), "2" (medium) and "3" (lowest). It is hypothesized that the more differentiated a product is, the less likely it is to be deleted.

Customer Attachment (CA)

Customers are the ultimate recipient of products. Customers can be industrial customers or business-to-business customers (e.g.: retailers, organizational purchasers) or individual customers (end-users) (Gupta et al., 2004). Customer segmentation or target market segments are of critical significance in the product management and marketing strategy literature (Grönroos, 1989). A target market segment is defined as including a group of consumers who contribute to the core revenue streams for which a company aims to dedicate resources and efforts (Rosenberg and Czepiel, 1984). The level of customer preference/demand and target customer product loyalty are all incorporated into this study under customer attachment.

Attachment is a boarder term standing for the emotional connection between customers and products (Park et al., 2013). In this study, we use customer demand (*CD*) (Prabhaker, 2001) and customer loyalty (*CL*) (Innis and La Londe, 1994) to measure customer attachment to a certain product. Customer demand was traced in selected firms' archival historic data in terms of the annual amount of target market demand level. Customer loyalty was scaled by interviewing head of marketing/customer relationship management. Both data are ordinal with scale of "1" to "3"; where "3" represents the lowest attachment, and "1" stands for the highest attachment. It is hypothesized that the higher the customer attachment, the lower the likelihood of deletion.

5.2.2 Financial Factors

Companies generate profits from products; developing and managing products requires significant financial investment. If a product no longer positively contributes to the overall financial performance of the firm, it might be reasonable for managers to consider it for deletion in order to minimize the financial loss (Shah, 2017a). The finance function directly impacts product deletion decisions. Better financials enable companies to pay workers better. Increased pay boosts employee morale and commitment, as employees stay longer, their productivity goes up, and training costs fall; employees' overall job satisfaction, combined with their experience, helps them manage products better. There are a number of identified financial factors from the qualitative case studies. The following three factors are selected for Bayesian model development because of the significant mentions from the interviewed managers.

Profit Margin (PM)

Profit margin, net margin or net profit margin, or new profit ration are all mentioned in different ways in case studies interviews. All these are profitability measurements. The profit margin is used as a key performance indicator for products within a portfolio, mostly for internal comparison (Stahl et al., 2012). In product performance management, the profit margin predicts a company's pricing strategies and cost-benefit analysis. Profit margin is selected in the existing literature to measure the performance of new product development, product improvement, and competitor product performance (Cohen et al., 1996).

In this study, profit margin is calculated as a percentage of annual net profit over revenue. Numbers of revenue and the cost of each product were collected from the firm's archival database. When importing the data into the Bayesian model, the data point was converted to an ordinal type, with a scale of "1" to "3"; where "3" represents the lowest profit margin across all collected product data, and "1" stands for the highest profit margin. It is hypothesized that the higher the profit margin, the lower the likelihood of deletion.

Contribution Significance (CS)

When the share and contribution of each of the products are jointly considered, the evaluation of a product's sales contribution to the entire portfolio considering its share within the portfolio emerges (Devinney and Stewart, 1988). According to Day (Day, 1977), a product portfolio can be diagnosed with the following characteristics: (1) products with low contribution but dominant share are called cash cows, these products are the most profitable and least considered for deletion; (2) products with high contribution and dominant share are star products. These products are market leaders and are also least considered for deletion; (3) products with high contribution and low share are problem children. The high contribution growth and poor sales scale creates an enormous demand for investment and efforts. If companies have investment and other resources concerns, these products will reveal themselves as deletion candidates; (4) products with low contribution and low share are usually at a cost disadvantage and have little potential to be boosted in the market. These products are the first to be considered for deletion.

Retaining the products with high contribution can help the company to use scarce cash and managerial resources of maximum long-run gain (Guenzi and Troilo, 2007). In this study and finance related models, contribution to the product portfolio is selected as a factor focusing on the financial contribution of a product to its product portfolio. The data is generated at the product level from the companies' ERP system; it is calculated by the sales percentage of the product candidate within the sales volume of the entire portfolio. When importing the data into the Bayesian model, the data point has been converted to ordinal type, with a scale of "1" to "3"; where "3" represents the lowest contribution significance to its product portfolio, and "1" stands for the highest contribution significance. It is hypothesized that the higher the contribution significance, the lower the likelihood of deletion.

Management Support (MS)

There has been growing interest in incorporating financial planning in product budgeting and product selection techniques (Brooks and Mukherjee, 2013). Financial support is the essential driver for organizational decision making and implementing. Management support in product deletion literature has focused on emotional and behavioral dimensions, with little focus on the financial dimension (Young and Jordan, 2008).

In this study, management support in financing for product deletion decision making, processes, and implementation is included in the Bayesian model (Badell et al., 2004). The data is generated from the top management on every product, indicating the overall attitude of the top management team toward the product candidate's deletion decision making and implementation. The data type is ordinal with a scale of "1" to "3," where "3" represents the lowest support and "1" stands for the highest support. It is hypothesized that the higher the financial support, the greater the likelihood of deletion.

5.2.3 Supply Chain Factors

Supply chain performance is measured by flexibility, time, quality, and cost according to the supply chain core competencies in Chapter 2. One limitation of this model is that, as one of the core supply chain competencies, quality is not included in this model for the major reason that companies have various ways of defining quality. Some refer to product quality in terms of return rate or defeat rate or even recall rate, while some may use customer retention, satisfaction, and loyalty, and some may use time responsiveness and lead time as measurements. The different definitions make it difficult to compare amongst the dataset; besides, some of the measurements might be covered in the marketing dimension such as customer satisfaction or in supply chain time dimension. Involving various quality measurements may cause noise in data management while producing repeated information. Quality issues are more concerned with product and service perspectives. The quality of supply chain has been reflected by the mixture of flexibility, cost, and time dimensions. The Bayesian models in this study will only focus on these three dimensions for supply chain performance.

Flexibility (FLEX)

Flexibility is an organization's ability to incur uncertainties with little penalty in time and cost (Upton, 1994). Flexibility has been identified to have a contingency influence on firm performance of market offerings. Most of the previous literature on flexibility has focused on internal manufacturing flexibility (D'Souza and Williams, 2000; Vokurka and O'Leary-Kelly, 2000). Manufacturing flexibility is a multi-dimensional construct. In general, there are 15 flexibility measures including machine, material handling, automation, labor, process, routing, product, delivery, innovation, and expansion and market flexibility (Beamon, 1999).

The manufacturing complexity (MC) of a product portfolio impacts the dynamics on supply chain flexibility. In this study, the manufacturing complexity of each investigated product will be generated in a scale of 1-3 based on the subjective judgement from managers from supply chain and manufacturing functions. "1" represents "lowest complexity" and "3" means "highest complexity." Higher complexity in manufacturing processes is likely to lead to more willingness to delete the product with the trend of manufacturing standardization.

Practical trends of outsourcing and mass-customization are forcing firms to seek flexibility, to meet customer demand and guarantee internal supply chain delivery (Barratt, 2004). Sourcing strategy enables firms to respond to the changing environment when uncertainty occurs. The percentage of internal supply chain versus external supply chain (ISC) and level of unique parts developed in house (LU) indicate the internal manufacturing capability of a company. The large percentage of external supply chain versus internal supply chain directly translates to lessened control on the overall supply chain system, thus less mobility for decision making such as product deletion. The higher level of unique parts developed in house ensures more power in supply chain process changes including product design and manufacturing; further giving the focal firm more power in product deletion decisions when needed.

Gaining and maintaining flexibility also contributes to the competitive advantage for companies. Strategic flexibility is composed of two other critical aspects in product competition according to Sanchez (Sanchez, 1995): resource flexibility and coordination flexibility. Resource flexibility extends to

resources arrangement with product alternatives, especially the costs and difficulties related to switching from one resource to anther for different products (Lambe et al., 2002). In this study, the correlations (in terms of resources) of product deletion candidates to other products in the same portfolio (COR) are recorded for investigation. When the product candidate has a high level of correlations in resources with other products candidates, meaning that a high similarity in shared resources and potential suppliers exist, it is easier to make a deletion decision when necessary, since a lower switch cost in terms of resources and suppliers is required.

On top of the operations flexibility (mainly manufacturing flexibility), there is also organizational flexibility involved in strategic decisions such as product deletion. Organizational intervention (OI) (Harrison, 1970) represents the level of transformation in the workforce and the organizational structure within a firm to compensate for a decision such as product deletion. The higher the organizational intervention level, the lower the likelihood is of product deletion.

Cost (C)

One of the predominant supply chain performance measures is cost and a combination of cost and time responsiveness (Cohen and Lee, 1988; Cohen and Moon, 1990). Costs involve operating costs in major supply chain processes, including cost in sourcing activity (CSA), manufacturing activity (CMA), delivering activity (CDA), retailing activity (CRA) and warehouses and inventory management (CWI).

The cost number was collected from historical data in terms of the overall cost at each stage of operational activity, such as collecting the overall purchasing cost from the purchasing and procurement department. One limitation is that not all investigated companies filed cost in terms of separate activities. For those companies who could provide the exact cost of a specific activity and the total operating cost at the product level, we used a percentage ration of activity cost on overall cost as the final data for the cost of that activity. For those companies who could not provide the exact historical cost of specific activities, we approached product managers or managers from each department to provide the estimated ratio of cost

percentage of a specific activity cost over the overall product operating cost. All data were finally coded in percentage format from (0, 100%).

Time (T)

A product can be evaluated by comparing supply chain lead time in manufacturing, delivering, and inventory arrangement. Time measurements in this study include:

The total product order lead time (OLT) represents time consumed between the receipt of customer order and the delivery of the finished products to the customers (Gunasekaran et al., 2004). The decrease in the order cycle time indicates improved performance in supply chain response time, which is another source of competitive advantage if time is critical in the market demand. Product order lead time directly impacts on customer satisfaction and market feedback and also associates with other operational activities performance on supply chains. OLT is collected from product historical data, with categories of "within a week" ("1"), "within a month" ("2"), and "beyond a month" ("3"). A longer lead time is hypothesized to lead to a greater likelihood of product deletion.

On top of the speed aspect of time performance, delivery reliability (DR) is also critical for product performance measurement on supply chains. Delivery reliability represents the ability to meet quoted or anticipated make-to-stock dates and quantities. Delivery reliability also has critical significance on supply chain performance. Existing research indicates that delivery reliability is a source of potential competitive advantage (Sarmiento et al., 2007; Szwejczewski et al., 1997; Ward et al., 1998). In this study, we use the manager's level of confidence that delivery of an investigated product will occur on an agreed date to present delivery reliability. The data is collected from the top managers of the supply chain department, including manufacturing and logistics with a measure of a 1-5 scale: "1" represents "most reliable" and "5" represents "least reliable." It is hypothesized that higher reliability results in a reduced likelihood of product deletion.

Inventory holding also impacts time performance on supply chains. It deals with the make-to-order versus make-to-stock question, which directly impacts the lead time of a product. If firms compete on the speed of delivery or the reliability of delivery, then reducing production lead time may necessitate holding inventory. If shortening the delivery speed, then the early estimation of sales may become a trigger of having inventory with more quantity and longer storage. If the delivery reliability is increased, then the anticipated backorder may become the other reason to have inventory of safety amount. In this study, there are two measures selected for inventory holding. One is inventory holding time (IHT) (Ben-Daya and Raouf, 1994; Roy, 2008), estimating the average time of storing a product inventory in the warehouses. It is a categorical data point with "1" (0-30 days), "2" (30-60 days), "3" (60-120 days), "4" (120-365 days) and "5" (beyond 365 days). The other is inventory turnover rate (ITR) (Gaur and Kesavan, 2015), which is calculated by overall sales on the average inventory amount. The turnover rate for each product is collected through product historical data. It is reported as a percentage between 0-100% and further recoded as an ordinal variable on a 1-3 scale: "1" represents "highest turnover rate" and "3" represents "lowest turnover rate" by comparing product candidates to other products within the same product portfolio. A quick turnover indicates the viability of a product, which is hypothesized to determine a lower likelihood of product deletion.

Managerial or labor time freed-up (LTF) is another factor that greatly impacts product deletion candidacy. Firms invest several human and time resources in developing and managing products. When making a product deletion decision, managers will have to decide what, when, and how the dedicated resources from the deleted product could be released to various other business activities and other products within the organization. This consideration will include releasing management and employee time devoted to the deleted products to other products (Avlonitis, 1984, 1985a). Therefore, LTF is generated in this study to help evaluate product candidacy for deletion purposes. The data is collected from top management in supply chain departments. The ordinal values are coded on a scale of 1-3, where "1" represents "lowest level of time freed-up", and "3" means "highest level of time freed-up." Highest

level of released time can be devoted to other functions of organizational activities and eventually improve the performance of the remaining product portfolio. Hence, a higher LTF is hypothesized to result in an increased likelihood of deletion.

5.2.4 Sustainability (social and environmental) Factors

By definition of triple bottom line, sustainability has three major dimensions including economic, social and environmental. Economic sustainability relates to marketing performances and financial returns. To avoid repetition, social and environmental factors are primarily focused in sustainability dimension. Informed by the qualitative study, stakeholders' benefits, 5Rs, emissions and waste, resources consumption efficiency are included as sustainability measurements.

Stakeholders Benefits (SB)

Pressures from stakeholders are triggers for organizations to make certain levels of social sustainability commitment (Hassini et al., 2012). Similarly, several stakeholders such as customers, employees, suppliers, competitors, government, and the mass media can also influence product deletion and make the decision more difficult and complex (Shah, 2015).

Customers are the end users of products and therefore customer adoption and final purchase contribute to an organization's revenue stream (Kumar, 2008). Deleting products that are ingrained in customers' lives can negatively influence customer satisfaction, firm reputation, and evaluation, and customer loyalty (Shah, 2017), thereby creating a challenge for managers. Competitors are one of the direct influencers for a company to adopt a change, such as mimetic behaviors. Business partners include suppliers, retailers, distributors, and all other third-party business partners that engage and facilitate inter-organizational supply chain operations. The power of channel partners may enforce or impede a firm's product deletion decisions. Governmental policies and regulations set and modify industrial standards. These standards influence organizational decisions related to sustainable supply chain management and product deletion. Mass media influences individual attitudes toward a firm and its brands and products

(Carroll and McCombs, 2003; Kiousis et al., 2007). Deleting a popular or in-demand product could create negative publicity or media criticism that could in turn generate unfavorable firm reputation and further opposition from other stakeholders (Kiousis et al., 2007; Shah, 2015).

Effect on stakeholders' perspectives might impact product deletion decisions. The data was collected from top managers of the investigated companies, estimating the effect of the product candidate on each stakeholder perspective. Data has been generated as categorical: "1" represents "positive", "2" means "negative," and "3" means "same/uncertain." Relationships with stakeholders contribute to the relational rents for focal firm relational competitive development. If a product has great value in enhancing stakeholder beneficial relations, it decreases the likelihood of deletion.

5Rs

Level of 5Rs (reduce, reuse, recycle, reclamation, and remanufacturing) are critical sustainability antecedent factors that could affect product deletion; this can be representative of a product's environmental sustainability criterion. Reduce stands for the reduction of resource usage in sourcing or manufacturing processes, in this case it represents the reduction of waste in end-of-life or post-purchase service stages. Reuse represents the reuse of resource and material input in a product's manufacturing and remanufacturing processes and the reuse of a product or its components after its life cycle. Recycle includes the process of converting output waste to applicable input in product manufacturing and remanufacturing processes, especially after consumption. Reclamation involves the process of recovering and reasserting both materials and products or components for reproduction purposes in subsequent product life cycles. Finally, remanufacturing represents the collecting, sorting, reassembling, and reprocessing of used products and components and converting them into new product forms for resale purpose without losing their original functionality (Scur and Barbosa, 2017).

These 5Rs might have an impact on determining which product to delete in terms of how much the product influences the reduce, reuse, recycle, reclamation, and remanufacturing of corporate

environmental sustainability management. For example, some products may have used design for the environment (DfE) principles (Jackson et al., 2016). DfE principles focus on designing products with the 5Rs in mind. Deleting one of these products can significantly affect the 5Rs. When a product has a high level of reclamation and remanufacturing value, it makes easier to delete and convert them to input for other manufacturing activities; and further solves post deletion risks such as inventory and waste in materials and finished parts of deleted products.

These 5Rs consist of factors within corporate environmental sustainability management dimension that might influence which product to delete based on the level of reduce, reuse, and recycle of a product and its components on supply chains. These 5Rs are evaluated by level assessment on a scale of 1 to 3, where 1 represents lowest level and 3 the highest level, and are utilized by actual data from managers in supply chain function and sustainability. It is hypothesized that the higher the 5R values, the greater the likelihood of deletion.

Waste and Emissions (EW)

Three major outputs from product supply chains include solid waste (Beamon, 1999; Zhu and Geng, 2013) (i.e., landfilled material), air emissions (Srivastava, 2007; Zhu and Geng, 2013) (i.e., CO2), and water emissions (i.e., ocean pollution).

Waste and emissions can come from both upstream activities such as sourcing and production, and downstream activities including delivering and consumption. Waste and emissions are important environmental sustainability factors (Omer, 2008). For companies that are concerned about environmental issues, products with high level of waste and emissions may be the prime candidates for deletion.

All of these outputs are measured by weights allocation and are represented on a scale of 1 to 3, where 1 means very little waste and emissions involved and 3 means a very high level of waste and emission resulting in the production, distribution, and consumption process. It is hypothesized that high waste and emissions lead to a high likelihood of deletion.

Resources Consumption Efficiency (RCE)

Efficient resource management is critical to long term profitability. Energy input represents energy required and consumed in the product usage process, both by the product providers and end users (Lenzen, 1998; Young et al., 2010). The categories of waste and emissions output are similar to the production and distribution supply chain, but focus on the input for developing and managing products, and also include those consumed in product usage activities.

Energy costs are those garnered in the product's manufacturing, distribution, and usage processes. For example, electricity consumed in the factories and petrol used in transportation and delivery. Material cost includes costs associated with acquiring raw material resources, intermediate materials, and semi-finished products necessary for the production process of a product (Beamon, 1999; Min and Zhou, 2002; Mirhedayatian et al., 2014). Non-energy materials may include wood, metals, chemicals, crude oil, and cotton.

The amount of resources including material and energy in a product's supply chain activities take away the entire core organizational resources. Optimization issues in resources allocation within a product portfolio is of great significance for organizational competitiveness. Hence, resources consumption efficiency needs to be considered when making product deletion decisions. Firms may alter resources from low resources efficiency products to high resources efficiency products. Freed up resources from the deleted products, with slack capacity alongside, may contribute to a more rationalized product portfolio with optimized resources consumption efficiency.

Consumption efficiency in both material resource (MR) and energy resources (ER) were collected from top managers for the products under investigation. The data has scaled in 1-3: "1" represents a high level of consumption efficiency and "3" represents a low level of consumption efficiency. It is hypothesized that a higher consumption efficiency will result in a reduced likelihood of deletion.

All selected factors in marketing, finance, supply chain, and sustainability are summarized in Table 5.2, including their data type, descriptions, sources, and scales.

There are many other performance measures that exist in the literature for each functional performance measurement, such as information flow in supply chain management dimension and risk management in finance dimension, but are not included in this study due to their wide application in relevant literature streams and data accessibility reasons. Although those measures may represent important characteristics in each organizational functions, their application in Bayesian models is challenging, since the qualitative nature of those measures makes them difficult to incorporate. Furthermore, data accessibility limitations is also an issue in terms of including many more measurements into the model.

11: Table 5.2: Data Dimensions, Factors, Sub-Factors and Descriptions

Dimensions	Factors	Subfactor	Literature Sources	Data Type	Measurement
MKT	MS		(Robinson, 1990), (Rust & Zahorik, 1993), (Buzzell et al., 1975)	Numerical	Percentage from (0, 100%)
	C		(Hotelling, 1990), (Porter, 2008), (Hunt, 1999)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
	D	PC	(Dickson & Ginter, 1987), (Smith, 1956), (Bressler, 2012)	Ordinal	"1" (few) "2" (medium) "3" (many)
		PD	(Dickson & Ginter, 1987), (Smith, 1956), (Ulrich, 2003)	Ordinal	"1" (highest) "2" (medium) "3" (lowest)
	CA	CD	(Gupta et al., 2004), (Prabhaker, 2001), (Rosenberg & Czepiel, 1984)	Ordinal	"1" (highest) "2" (medium) "3" (lowest)
		CL	(Park et al., 2013), (Innis & La Londe, 1994), (Grönroos, 1989)	Ordinal	"1" (highest) "2" (medium) "3" (lowest)
FIN	PM		(Shah, 2017a), (Cohen et al., 1996), (Stahl et al., 2012)	Numerical	Percentage from (0, 100%)
	CS		(Day, 1977), (Guenzi & Troilo, 2007), (Devinney & Stewart, 1988)	Numerical	Percentage from (0, 100%)
	MS		(R. Young & Jordan, 2008), (Brooks & Mukherjee, 2013), (Badell et al., 2004)	Ordinal	"1" (lowest) "2" (median) "3" (highest)
SCM	FLEX	MC	(Upton, 1994), (D'Souza & Williams, 2000), (Vokurka & O'Leary-Kelly, 2000)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		ISC	(Barratt, 2004)	Numerical	Percentage from (0, 100%)

Dimensions	Factors	Subfactor	Literature Sources	Data Type	Measurement
		LU	(Sanchez, 1995)	Numerical	Percentage from (0, 100%)
		COR	(Lambe et al., 2002)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		OI	(Harrison, 1970)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
	C	CSA	(Cohen & Lee, 1988), (Cohen & Moon, 1990)	Numerical	Percentage from (0, 100%)
		CMA		Numerical	Percentage from (0, 100%)
		CDA		Numerical	Percentage from (0, 100%)
		CRA		Numerical	Percentage from (0, 100%)
		CWI		Numerical	Percentage from (0, 100%)
	T	OLT	(Gunasekaran et al., 2004)	Categorical	"1" (within a week) "2" (within a month) "3" (beyond a month)
		DR	(Sarmiento et al., 2007), (Szwejczewski et al., 1997), (Ward et al., 1998)	Scale	1-5 "1": most reliable "5": least reliable
		IHT	(Roy, 2008), (Ben-Daya & Raouf, 1994)	Categorical	"1" (0-30 days) "2" (30-60 days) "3" (60-120 days) "4" (120-365 days) "5" (beyond 365 days)
		ITR	(Gaur & Kesavan, 2015),	Ordinal	"1" (highest) "2" (medium) "3" (lowest)
		LTF	(Avlonitis, 1984), (Avlonitis, 1985)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
SUS	SB	EER	(Hassini et al., 2012), (Shah, 2015), (Kumar, 2008), (Shah, 2017), (Carroll & McCombs, 2003), (Kiousis et al., 2007)	Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
		ECR		Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
		ESR		Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
		CRA		Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
		GR		Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
		M		Categorical	"1" (positive) "2" (negative) "3" (same/uncertain)
	5Rs	RD	(Scur & Barbosa, 2017), (Jackson et al., 2016)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		RE		Ordinal	"1" (lowest) "2" (medium) "3" (highest)

Dimensions	Factors	Subfactor	Literature Sources	Data Type	Measurement
		REC		Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		RECL		Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		REM		Ordinal	"1" (lowest) "2" (medium) "3" (highest)
	EW	SW	(Beamon, 1999), (Zhu & Geng, 2013)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		AE	(Srivastava, 2007), (Zhu & Geng, 2013)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
		WE	(Omer, 2008)	Ordinal	"1" (lowest) "2" (medium) "3" (highest)
	RCE	MR	(Lenzen, 1998), (W. Young et al., 2010)	Ordinal	"1" (highest) "2" (medium) "3" (lowest)
		ER	(Beamon, 1999), (Min & Zhou, 2002), (Mirhedayatian, et al., 2014)	Ordinal	"1" (highest) "2" (medium) "3" (lowest)

5.3 Model 1: Product Deletion and Organizational Cross Functions

The major purpose of this model is to investigate which cross-functional role impacts the product deletion decision and what is the predictive relationship between each functional performance and product deletion. These four key cross-functional departments were identified from the literature review as well as supported and validated by the qualitative in-depth case studies in the previous chapter. These cross-functional dimensions include marketing, supply chain, finance and sales, and sustainability. All the factors within each dimension are derived from the qualitative evaluation (case studies) and supported by the associated literature streams.

5.3.1 Model Development

Whether a product is deleted concerns the overall performance in marketing, supply chain, finance and sales, and sustainability. The dependent variable has two responses and these are coded as shown below. We use subscript k to denote different nominal levels of the dependent variable hence $k = 1, 2$.

Delete	*Keep*	Levels of the dependent variable
No	Yes	k = 1
Yes	No	k = 2

This model is an analysis of a variance type model (rather than linear regression because the independent and dependent variables are nominal variables). We calculated the frequencies of occurrence of each level of the dependent variable for each independent variable combination. The interpretation is, based on historical data observations, that the dependent variable of the model represents the number of occurrence of two product decisions (delete or keep) under all different/various business scenarios. This model involves all four cross-functions and all 40 factors selected.

Raw data were generated from selected companies' archival product level data and one-on-one interviews with top management for those categorical and ordinal factors concerning the important input of subjective judgement. The raw data is shown in the table below (Table 5.3).

All factors will be normalized by making the data stochastic. The normalization is needed to have all the values between 0 to 1. The normalization occurs by dividing each data point by the maximum number of that data column (Equation 1).

$$x' = \frac{x_i}{x_{max}} \tag{5.1}$$

In the above equation (5.1), x' stands for the normalized data value, x_i is the original data value from archival data and interview data. x_{max} represents the maximal value of each data column. Normalized table is presented in Table 5.4.

12: Table 5.3: Model 1 Raw Data

Product ID	DV	MKT										SCM										
		MS	C	PC	PD	CD	CL	ISC	MC	COR	SCI	LU	CSA	CMA	CDA	CRA	CWI	OLT	LTF	DR	IHT	ITR
1	0	0.25	3	3	1	2	2	0.9	2	2	2	0.89	0.08	0.01	0.01	0.01	3	2	2	1	2	2
2	0	0.25	2	3	3	2	1	0.3	2	2	3	0.83	0.02	0.08	0.05	0.02	1	3	2	1	3	1
3	0	0.3	2	3	3	2	1	0.3	1	3	3	0.84	0.02	0.02	0.1	0.02	1	3	2	1	3	1
4	1	0.03	2	3	3	2	1	0.3	1	3	3	0.67	0.01	0.2	0.1	0.02	1	3	2	3	2	1
5	0	0.03	3	3	1	1	1	0.1	3	3	3	0.6	0	0.03	0.35	0.02	1	3	2	4	1	1
6	0	0.3	3	2	2	2	2	0.9	2	1	2	0.9	0.06	0.01	0.02	0.01	3	2	3	1	2	2
7	1	0.8	2	3	3	2	1	0.7	1	3	3	0.62	0.01	0.25	0.1	0.02	1	3	2	3	2	1
8	1	0.15	2	3	3	2	1	0.8	1	3	3	0.65	0.02	0.01	0.3	0.02	1	3	1	1	3	1
9	1	0.01	3	3	3	2	1	0.5	1	3	3	0.35	0.25	0.08	0.3	0.02	2	3	2	3	2	2
10	0	0.2	3	3	1	2	2	0.1	2	3	2	0.5	0.08	0.02	0.15	0.25	1	3	2	3	2	2
11	0	0.3	3	2	2	2	2	0.1	2	2	1	0.6	0.05	0.2	0.05	0.1	2	3	2	3	2	2
12	0	0.06	3	2	2	2	2	0.65	3	3	2	0.28	0.29	0.05	0.29	0.09	3	3	2	2	3	2
13	0	0.01	3	2	2	2	2	0.7	2	2	3	0.1	0.11	0.01	0.22	0.01	2	3	2	3	2	2
14	0	0.01	3	2	2	2	2	0.7	2	2	3	0.1	0.11	0.01	0.22	0.01	3	2	1	3	3	2
15	0	0.01	3	3	2	3	2	0.7	2	2	3	0.13	0.08	0.01	0.22	0.01	1	2	3	3	3	2
16	0	0.01	3	2	2	3	3	0.7	2	3	3	0.1	0.11	0.01	0.22	0.01	3	2	3	3	3	2
17	0	0.01	3	2	2	3	2	0.7	3	3	3	0.1	0.11	0.01	0.22	0.01	3	3	2	4	2	3
18	0	0.01	3	2	2	2	2	0.7	1	1	2	0.13	0.08	0.01	0.22	0.01	2	2	1	3	3	2
19	0	0.01	3	2	2	2	2	0.7	2	2	2	0.1	0.11	0.01	0.22	0.01	2	2	2	3	3	2
20	1	0.009	3	2	2	1	2	0.7	2	3	3	0.1	0.22	0.01	0.22	0.01	2	2	1	3	3	2

Product ID	DV	FIN								SUS										
		MS	CS	PM	EER	ECR	ESR	CRA	GR	M	RD	RE	REC	RECL	REM	SW	AE	WE	MR	ER
1	0	3	0.83	0.12	2	2	3	3	3	3	1	1	1	1	1	1	1	1	2	1
2	0	3	0.14	0.28	2	2	3	1	3	3	1	1	1	1	1	1	2	2	2	1
3	0	3	0.18	0.48	2	2	3	1	3	3	1	1	1	1	1	1	2	2	2	1
4	1	3	0.03	0.53	3	3	3	3	3	3	1	1	1	1	1	1	2	2	2	1
5	0	3	0.03	0.57	3	3	3	3	3	3	1	1	1	1	1	1	2	2	2	1
6	0	3	0.31	0.12	2	2	3	3	3	3	1	1	1	1	1	1	1	1	2	1
7	1	3	0.15	0.55	3	3	3	3	3	3	1	1	1	1	1	1	2	2	2	1
8	1	3	0.17	0.47	2	2	3	1	3	3	1	1	1	1	1	1	1	1	1	1
9	1	3	0.00	0.66	3	2	2	3	3	3	1	1	1	1	1	1	2	2	2	1
10	0	3	0.04	0.95	3	3	2	2	3	3	2	2	1	1	1	1	1	2	1	2
11	0	3	0.06	0.85	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1
12	0	1	0.63	0.54	3	3	2	3	3	3	2	1	1	1	1	2	1	1	2	2
13	0	3	0.10	0.5	3	2	2	3	3	3	1	1	1	1	1	1	1	1	1	1
14	0	3	0.06	0.5	3	2	3	3	3	3	1	1	1	1	1	1	1	1	1	1
15	0	3	0.07	0.5	3	2	3	3	3	3	1	1	1	1	1	1	1	1	1	1
16	0	3	0.16	0.5	2	2	2	1	3	3	3	1	1	1	1	1	1	1	1	1
17	0	3	0.16	0.5	2	2	2	1	3	3	1	1	1	1	1	1	1	1	1	1
18	0	3	0.04	0.5	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1
19	0	3	0.10	0.5	3	3	2	3	3	3	1	1	1	1	1	1	1	1	1	1
20	1	3	0.04	0.5	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1

13: Table 5.4: Model 1 Normalized Data

PRODUCT ID	DV	MKT												SCM								
		MS	C	PC	PD	CD	CL	ISC	MC	COR	SCI	LU	CSA	CMA	CDA	CRA	CWI	LT	LTF	DR	IHT	ITR
1	0	0.33	1.00	1.00	1.00	0.67	0.67	1.00	0.67	0.67	0.67	0.99	0.28	0.04	0.03	0.04	1.00	0.67	0.67	1.00	0.67	0.50
2	0	0.33	0.67	1.00	0.33	0.67	1.00	0.33	0.67	0.67	1.00	0.92	0.07	0.32	0.14	0.08	0.33	1.00	0.67	1.00	1.00	1.00
3	0	0.33	0.67	1.00	0.33	0.67	1.00	0.33	0.33	0.33	1.00	0.93	0.07	0.08	0.29	0.08	0.33	1.00	0.67	1.00	1.00	1.00
4	1	0.67	0.67	1.00	0.33	0.67	1.00	0.33	0.33	0.33	1.00	0.74	0.03	0.80	0.29	0.08	0.33	1.00	0.67	0.60	0.67	1.00
5	0	0.67	1.00	1.00	1.00	1.00	1.00	0.11	1.00	0.33	1.00	0.67	0.00	0.12	1.00	0.08	0.33	1.00	0.67	0.40	0.33	1.00
6	0	0.33	1.00	0.67	0.67	0.67	0.67	1.00	0.67	1.00	0.67	1.00	0.21	0.04	0.06	0.04	1.00	0.67	1.00	1.00	0.67	0.50
7	1	0.33	0.67	1.00	0.33	0.67	1.00	0.78	0.33	0.33	1.00	0.69	0.03	1.00	0.29	0.08	0.33	1.00	0.67	0.60	0.67	1.00
8	1	0.33	0.67	1.00	0.33	0.67	1.00	0.89	0.33	0.33	1.00	0.72	0.07	0.04	0.86	0.08	0.33	1.00	0.33	1.00	1.00	1.00
9	1	1.00	1.00	1.00	0.33	0.67	1.00	0.56	0.33	0.33	1.00	0.39	0.86	0.32	0.86	0.08	0.67	1.00	0.67	0.60	0.67	0.50
10	0	0.33	1.00	1.00	1.00	0.67	0.67	0.11	0.67	0.33	0.67	0.56	0.28	0.08	0.43	1.00	0.33	1.00	0.67	0.60	0.67	0.50
11	0	0.33	1.00	0.67	0.67	0.67	0.67	0.11	0.67	0.67	0.33	0.67	0.17	0.80	0.14	0.40	0.67	1.00	0.67	0.60	0.67	0.50
12	0	0.67	1.00	0.67	0.67	0.67	0.67	0.72	1.00	0.33	0.67	0.31	1.00	0.20	0.83	0.36	1.00	1.00	0.67	0.80	1.00	0.50
13	0	1.00	1.00	0.67	0.67	0.67	0.67	0.78	0.67	0.67	1.00	0.11	0.38	0.04	0.63	0.04	0.67	1.00	0.67	0.60	0.67	0.50
14	0	1.00	1.00	0.67	0.67	0.67	0.67	0.78	0.67	0.67	1.00	0.11	0.38	0.04	0.63	0.04	1.00	0.67	0.33	0.60	1.00	0.50
15	0	1.00	1.00	1.00	0.67	0.33	0.67	0.78	0.67	0.67	1.00	0.14	0.28	0.04	0.63	0.04	0.33	0.67	1.00	0.60	1.00	0.50
16	0	1.00	1.00	0.67	0.67	0.33	0.33	0.78	0.67	0.33	1.00	0.11	0.38	0.04	0.63	0.04	1.00	0.67	1.00	0.60	1.00	0.50
17	0	1.00	1.00	0.67	0.67	0.33	0.67	0.78	1.00	0.33	1.00	0.11	0.38	0.04	0.63	0.04	1.00	1.00	0.67	0.40	0.67	0.33
18	0	1.00	1.00	0.67	0.67	0.67	0.67	0.78	0.33	0.67	0.67	0.14	0.28	0.04	0.63	0.04	0.67	0.67	0.33	0.60	1.00	0.50
19	0	1.00	1.00	0.67	0.67	0.67	0.67	0.78	0.67	0.67	0.67	0.11	0.38	0.04	0.63	0.04	0.67	0.67	0.67	0.60	1.00	0.50
20	1	1.00	1.00	0.67	0.67	1.00	0.67	0.78	0.67	0.33	1.00	0.11	0.76	0.04	0.63	0.04	0.67	0.67	0.33	0.60	1.00	0.50

(Table 5.4 continued)

PRODUCT ID	DV	FIN			SUS														
		MS	CS	PM	EER	ECR	ESR	CRA	GR	M	RD	RE	REC	RECL	REM	SW	AE	WE	RU	EU
1	0	1.00	0.33	1.00	1.00	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00	0.50
2	0	1.00	0.67	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
3	0	1.00	0.33	0.33	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
4	1	1.00	1.00	0.33	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
5	0	1.00	1.00	0.33	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
6	0	1.00	0.33	1.00	1.00	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00	0.50
7	1	1.00	0.67	0.33	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
8	1	1.00	0.67	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
9	1	1.00	1.00	0.33	0.50	1.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
10	0	1.00	1.00	0.33	0.50	0.50	1.00	0.67	1.00	1.00	0.67	0.67	1.00	1.00	1.00	0.50	0.50	1.00	0.50	1.00
11	0	1.00	1.00	0.33	0.50	0.50	0.50	0.33	1.00	1.00	0.67	0.67	0.67	0.67	0.67	0.50	0.50	0.50	0.50	0.50
12	0	0.33	0.33	0.33	0.50	0.50	1.00	0.33	1.00	1.00	0.67	1.00	1.00	1.00	1.00	1.00	0.50	0.50	1.00	1.00
13	0	1.00	1.00	0.67	0.50	1.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
14	0	1.00	1.00	0.67	0.50	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
15	0	1.00	1.00	0.67	0.50	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
16	0	1.00	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
17	0	1.00	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
18	0	1.00	1.00	0.67	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
19	0	1.00	0.67	0.67	0.50	0.50	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
20	1	1.00	1.00	0.67	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50

14: Table 5.5: Model 1 Summation Data of Cross-functions' Overall Performance

PRODUCT ID	DV	MKT	SC	FC	ST
1	0	4.667	8.87	2.33	12.8
2	0	4	9.2	2.67	14.5
3	0	4	8.45	1.67	14.5
4	1	4.333	8.21	2.33	12.8
5	0	5.667	8.04	2.33	13.5
6	0	4	9.51	2.33	12.8
7	1	4	8.8	2	12.8
8	1	4	8.99	2.67	13
9	1	5	8.83	2.33	13.8
10	0	4.667	7.88	2.33	12.5
11	0	4	8.06	2.33	9.67
12	0	4.333	10.4	1	13
13	0	4.667	8.41	2.67	12.3
14	0	4.667	8.41	2.67	11.8
15	0	4.667	8.34	2.67	11.8
16	0	4	8.74	2.33	12.8
17	0	4.333	8.38	2.33	13.5
18	0	4.667	7.34	2.67	11.3
19	0	4.667	8.08	2.33	11.8
20	1	5	8.12	2.67	11.3
AVERGAE		*4.467*	*8.55*	*2.33*	*12.6*

The independent variables are categorized into four dimensions based on organizational cross-functions, respectively marketing, supply chain, finance and sales and sustainability. Independent variable levels are arrived by the summation of the selected data value within each dimension (Equation 5.2).

$$X_{total} = \sum_{i=1}^{n} x_i' \tag{5.2}$$

In the above equation (2), X_{total} stands for the overall value of each cross-functional dimension, and x_i' is the normalized value of the data point value within its dimension. n represents the number of selected factors within its dimension. For example, the marketing dimension has 6 factors, in this case, n = 6. The summations table is presented in Table 5.5.

Model 1 has four independent variables, respectively $\beta_{m,k}$, $\gamma_{sc,k}$, $\delta_{f,k}$, $\delta_{f,k}$, and $\zeta_{st,k}$.

Variable $\beta_{m,k}$ stands for, amongst all identified products, the question of whether the performance in the marketing dimension has resulted in a product being deleted or kept. Marketing

performance response has been recoded to 1 or 2[2] by comparing it to the average number of all products performance. If $m > AVG(X_{total})$, then $m = 1$, indicating a higher value of performance, otherwise, $m = 2$, meaning lower value of performance.

Variable $\gamma_{sc,k}$ represents, amongst all identified products, the question of whether the performance in supply chain dimension has resulted in a product being deleted or kept. Supply chain performance response is coded high, $sc = 1$, or low, $sc = 2$.

Variable $\delta_{f,k}$ states, amongst all identified products, whether the performance in finance and sales dimension has resulted in a product being deleted or kept. Financial and sales performance response is coded high, $f = 1$, or low, $f = 2$.

Variable $\zeta_{st,k}$ indicates, amongst all identified products, whether the performance in the sustainability dimension has resulted in a product being deleted or kept. Sustainability performance response coded high, $st = 1$, or low, $st = 2$.

The independent variables are summarized below:

IV	$\beta_{m,k}$	$\gamma_{sc,k}$	$\delta_{f,k}$	$\zeta_{st,k}$
	Amongst all identified products, has the performance in marketing / supply chain / finance and sales / sustainability dimension resulted in a product to be being deleted?			
levels	$m = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$sc = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$f = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$st = \begin{cases} 1, & high \\ 2, & low \end{cases}$

The recoded table and input data for Bayesian analysis is presented in Table 5.6.

[2] By coding them as 1, 2 instead of 0, 1 we can use the coded value also as a subscript, which will help us remember the level of the variable from its subscript. Note the subscript k refers to the level of the dependent variable.

15: Table 5.6: Model Recoded Table (a) for Bayesian Analysis Input (b)

(a)

PRODUCT ID	DV	MKT	SC	FC	ST	0 - KEEP	1 - DELETE
1	0	1	1	2	1	1	
2	0	2	1	1	1	1	
3	0	2	2	2	1	1	
4	1	2	2	2	1		1
5	0	1	2	2	1	1	
6	0	2	1	2	1	1	
7	1	2	1	2	1		1
8	1	2	1	1	1		1
9	1	1	1	2	1		1
10	0	1	2	2	2	1	
11	0	2	2	2	2	1	
12	0	2	1	2	1	1	
13	0	1	2	1	2	1	
14	0	1	2	1	2	1	
15	0	1	2	1	2	1	
16	0	2	1	2	1	1	
17	0	2	2	2	1	1	
18	0	1	2	1	2	1	
19	0	1	2	2	2	1	
20	1	1	2	2	2		1

(b)

MKT	SC	FC	ST	DV SCENERIO	FREQUENCY
1	1	1	1	0	0
1	1	1	1	1	0
1	1	1	2	0	0
1	1	1	2	1	0
1	1	2	1	0	1
1	1	2	1	1	1
1	1	2	2	0	0
1	1	2	2	1	0
1	2	1	1	0	0
1	2	1	1	1	0
1	2	1	2	0	2
1	2	1	2	1	0
1	2	2	1	0	1
1	2	2	1	1	0
1	2	2	2	0	0
1	2	2	2	1	1
2	1	1	1	0	1
2	1	1	1	1	1
2	1	1	2	0	0
2	1	1	2	1	0
2	1	2	1	0	3
2	1	2	1	1	1
2	1	2	2	0	0
2	1	2	2	1	0
2	2	1	1	0	0
2	2	1	1	1	0
2	2	1	2	0	2
2	2	1	2	1	0
2	2	2	1	0	2
2	2	2	1	1	1
2	2	2	2	0	3
2	2	2	2	1	0

5.3.2 Model Statement

The binomial logistic model with nominally measured variables needs a baseline value of the dependent variable from which the impact of other levels of the dependent variable are measured. For model 1, the baseline level of the dependent variable is 0 which corresponds to, from the above table, no decision has been made regarding the product. For ANOVA type models, we need to define one of the

levels of all independent variables as a reference level. We define level 1, for each of the four independent variables as the reference levels from which level 2 effect is measured. Model 1 is presented below in Equation (5.3):

$$y_{m,sc,f,st,k} = \propto_k + \beta_{m,k} + \gamma_{sc,k} + \delta_{f,k} + \zeta_{st,k} \quad (5.3)$$

$$where\ m = 1,2;\ \ sc = 1,2;\ \ \ f = 1,2;\ \ \ st = 1,2;\ \ \ \ k = 1,2.$$

The odds ratio model is a multiplicative model defined by equation (5.4):

$$\frac{p(m,sc,f,st,k)}{p_{1,1,1,1,1}} = \ e^{\propto_k} e^{\beta_{m,k}} e^{\gamma_{sc,k}} e^{\delta_{f,k}} e^{\zeta_{st,k}} \quad (5.4)$$

Amongst all the investigated companies, those involved in the product deletion decision making process belongs to level 2 ($k = 2$). This assumes a product candidate has a high marketing performance ($m = 1$), such as large market share; and high supply chain performance ($sc = 1$), such as high manufacturing processes complexity and high operational cost; and a low finance performance ($f = 2$), such as low profit margin; as well as a high sustainability performance ($st = 1$), such as the high environmental performance and high stakeholder benefits. This business scenario (data event) is represented in model 1 by equation (5.5):

$$y_{1,1,2,1,2} = \propto_2 + \beta_{1,2} + \gamma_{1,2} + \delta_{2,2} + \ \zeta_{1,2} \quad (5.5)$$

$\beta_{1,2}\ \gamma_{1.2}\ and\ \zeta_{1,2}$ are both 0 because level 1 of all independent variables is used as the reference level. In fact, all $\beta_{1,k},\ \gamma_{1,k},\ \delta_{1,k},\ \epsilon_{1,k}$ for $k = 1\ and\ 2$ are 0 because they are the reference level of the independent variables and $\propto_1,\ \beta_{m,1},\ \gamma_{sc,1},\ \delta_{f,1},\ \zeta_{st,1}\ \epsilon_{j,1}$ for $m, sc, f, st\ = 1, 2$ are all set at zero because it is the baseline level (level 1) of the dependent variable. Every product in the existing dataset will be identified with a single event of unique business scenarios. Overall, in model 1, there are 32 (2^5) events since each dependent value and independent value has two dimensions.

5.3.3 Results and Discussions

After importing the conducted model into WinBugs, with 1,000,000 iterations with 10,000 refresh for each chain, an initial 4000 samples were discarded and thinned at 20th interval; the Winbugs results are presented in Table 5.7. The specified percentiles are 2.5% to 97.5%.

16: Table 5.7: Model 1 Coefficients Statistics

node	mean	sd	mc error	2.5%	median	97.5%	start	sample
alpha[2]	-0.3601	0.8118	0.004027	-2.098	-0.3252	1.15	4001	49800
beta[2,2]	-0.5194	0.7866	0.003891	-2.192	-0.4775	0.9466	4001	49800
delta[2,2]	0.09218	0.7637	0.003806	-1.382	0.07923	1.678	4001	49800
gamma[2,2]	-0.5967	0.8827	0.004237	-2.542	-0.5274	0.9864	4001	49800
zeta[2,2]	-0.6187	0.9878	0.004549	-2.845	-0.527	1.114	4001	49800
aprob[2]	0.332	0.4709	0.002171	0.0	0.0	1.0	4001	49800
bprob[2,2]	0.2512	0.4337	0.002095	0.0	0.0	1.0	4001	49800
dprob[2,2]	0.5447	0.498	0.002349	0.0	1.0	1.0	4001	49800
gprob[2,2]	0.2451	0.4302	0.001927	0.0	0.0	1.0	4001	49800
zprob[2,2]	0.2605	0.4389	0.002092	0.0	0.0	1.0	4001	49800

5.3.3.1 Bayesian Inferencing Estimates and Posterior Distributions

According to Table 5.7, the coefficient estimates for level 2 ($m = 2; sc = 2; f = 2; st = 2; k = 2$) give us $\propto_2 = -0.3601$, $\beta_{2,2} = -0.5194$, $\gamma_{2.2} = 0.09218$, $\delta_{2,2} = -0.5967$, $\zeta_{2,2} = -0.6187$. When examining the coefficients estimates alone (row 1-5 in Table 5.7), the negative coefficient mean estimation indicates the negative effect on product deletion, meaning a decrease in the odds of product deletion; while a positive coefficient mean estimation indicate the positive effect on product deletion, meaning an increase in the odds of product deletion. The coefficients posterior distribution and likelihood of deletion or keeping of sampling data is shown in Figure 5.1.

$\propto_2 = -0.3601$ stands for the mean (average) influence of all independent variables on product deletion. Incorporating the $\propto_2$ distribution and the likelihood of occurrence of negative effect, we can conclude that when all independent variables are at a high level, there is a 63.99% chance that it will decrease the odds of product deletion; on average the odds of deletion go down by a factor of 0.7 ($e^{-0.3601}$)

Similarly, $\beta_{2,2} = -0.5194$ indicates that if a product has an improved performance in marketing characteristics, then there is a 74.88% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by a factor of 0.59 ($e^{-0.5194}$).

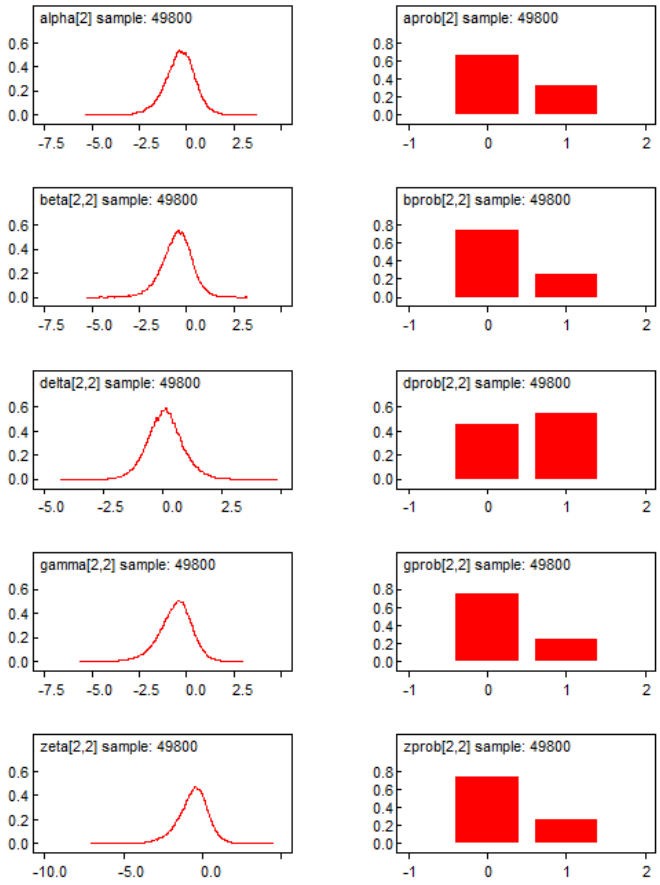
$\gamma_{2.2} = 0.09218$ means that if a product has an improved performance in finance and sales characteristics, then there is a 54.47% chance that it will increase the odds of product deletion; on average the odds of deletion go up by a factor of 1.10 ($e^{0.09218}$).

$\delta_{2,2} = -0.5967$ signifies that if a product has an improved performance in supply chain characteristics, then there is a 75.49% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by a factor of 0.55 ($e^{-0.5967}$).

$\zeta_{2,2} = -0.6187$ specifies that if a product has an improved performance in sustainability characteristics, then there is a 73.95% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by 0.54 ($e^{-0.6187}$).

Amongst all coefficients, $\delta_{2,2}$ has the highest percentage of discriminant occurrence (75.49%), which shows a higher level of statistical confidence, further indicating that supply chain characteristics are better predictors for product deletion. Improved performance in the supply chain dimension will result in a reduced likelihood of deletion by 55%.

7: Figure 5.1: Model 1 Posterior Distributions



5.3.3.2 Results and Outcomes

Given $\propto_2 = -0.3601$, $\beta_{2,2} = -0.5194$, $\gamma_{2.2} = 0.09218$, $\delta_{2,2} = -0.5967$, $\zeta_{2,2} = -0.6187$ and the baseline ($m = 1; sc = 1; f = 1; st = 1; k = 1{,}2$) are all equal to 0. Hence, the y values have very different interpretation compared to linear regression. The y values are (natural) logs of the odds. For example, $p(m, sc, f, st, k)$ is the probability of the event where independent variable 1 has coded for value *k*. The last value denoted by *k* is taken by the dependent variable. Odds for that event are then computed against the probability, $p(1{,}1{,}1{,}1{,}1)$, which is the probability of the baseline category. Therefore the odds ratio for specified event of (1, 2, 2, 1, 2). Odds is the ratio $p(1, 2, 2, 1, 2)/p(1{,}1{,}1{,}1{,}1)$ so:

$$y_{1,2,2,1,2} = \ln\left(\frac{p(1,2,2,1,2)}{p(1,1,1,1,1)}\right) = \propto_2 + \beta_{1,2} + \gamma_{2,2} + \delta_{2,2} + \zeta_{1,2} = -0.86$$

There are 32 numbered events/business scenarios. The events represent all the possible combinations of alpha, beta, gamma, delta and zeta; that is, all combinations of levels of independent and dependent variables: 2x2x2x2x2=32. Table 5.7 presents the Bayesian outcomes for all 32 events/business scenarios.

The table of outcomes provides the log of odds in the column titled total. All of these log odds in the table are computed against $p(1,1,1,1,1)$, as we see from the above formula; it is in the denominator, considering event 1,1,1,1,1 serves the baseline event, so the odds for events may be computed with it. The choice of baseline depends on the scenario, for results interpretations, designating the event 1,1,1,1,1 as baseline makes comparisons easier; that is, all cross-functional performance is high. However, we can use any row as the baseline for the other row, which indicates the influence of a change in one dimension on the function of odds for product deletion.

The subscripts to four independent variables are shown in the left half of the table; the right half of the table shows their corresponding values after running the model stated above. For example, row 23 indicates that alpha has subscript 2, beta has 1, gamma 2, delta 2 and zeta has 1. Their corresponding values for the model and the data from WINBUGS software are given in the same row but in the right-hand part. They are $\propto_2 = -0.3601,\ \beta_{1,2} = 0,\ \gamma_{2.2} = -0.597,\ \delta_{2,2} = 0.09218,\ \zeta_{1,2} = 0$. That is $y_{1,2,2,1,2} = -0.3601 + 0 - 0.597 + 0.09218 + 0 = -0.86$. This total is shown in the column titled total in the table. To get actual odds instead of log of odds, we can do the following simple calculation:

Use the total as an exponent to e, the base of natural logs; in the above case we have:

$$e^{-0.86} = 0.42$$

17: Table 5.8: Model 1 Bayesian Predicative Outcomes

Subscripts						Value of coefficients							
sequence number	m	sc	f	st	k	[k] alpha	[m,k] beta	[sc,k] gamma	[f,k] delta	[st,k] zeta	ln(p#x / p#1) total	odds e^total	Prob
1	1	1	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
2	1	1	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
3	1	1	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
4	1	1	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
5	1	2	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
6	1	2	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
7	1	2	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
8	1	2	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
9	2	1	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
10	2	1	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
11	2	1	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
12	2	1	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
13	2	2	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
14	2	2	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
15	2	2	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
16	2	2	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5%
17	1	1	1	1	2	-0.3601	0.00	0.00	0.00	0.00	-0.36	0.70	3%
18	1	1	1	2	2	-0.3601	0.00	0.00	0.00	-0.6187	-0.98	0.38	2%
19	1	1	2	1	2	-0.3601	0.00	0.00	0.09218	0.00	-0.27	0.76	4%
20	1	1	2	2	2	-0.3601	0.00	0.00	0.09218	-0.6187	-0.89	0.41	2%
21	1	2	1	1	2	-0.3601	0.00	-0.5967	0.00	0.00	-0.96	0.38	2%
22	1	2	1	2	2	-0.3601	0.00	-0.5967	0.00	-0.6187	-1.58	0.21	1%
23	1	2	2	1	2	-0.3601	0.00	-0.5967	0.09218	0.00	-0.86	0.42	2%
24	1	2	2	2	2	-0.3601	0.00	-0.5967	0.09218	-0.6187	-1.48	0.23	1%
25	2	1	1	1	2	-0.3601	-0.5194	0.00	0.00	0.00	-0.88	0.41	2%
26	2	1	1	2	2	-0.3601	-0.5194	0.00	0.00	-0.6187	-1.50	0.22	1%
27	2	1	2	1	2	-0.3601	-0.5194	0.00	0.09218	0.00	-0.79	0.46	2%
28	2	1	2	2	2	-0.3601	-0.5194	0.00	0.09218	-0.6187	-1.41	0.25	1%
29	2	2	1	1	2	-0.3601	-0.5194	-0.5967	0.00	0.00	-1.48	0.23	1%
30	2	2	1	2	2	-0.3601	-0.5194	-0.5967	0.00	-0.6187	-2.09	0.12	1%
31	2	2	2	1	2	-0.3601	-0.5194	-0.5967	0.09218	0.00	-1.38	0.25	1%
32	2	2	2	2	2	-0.3601	-0.5194	-0.5967	0.09218	-0.6187	-2.00	0.13	1%
										Total	-18.90	21.57	1.00

The results table provides odds for all events with a baseline event of 1,1,1,1,1. Probabilities (based on odds) calculations are calculated in the last column in the table, representing the likelihood of the specific business scenario/data event that occurred in the collected sampling data. We can conclude from the data that, within the sampling dataset, 4% of product deletion occurred in event 1,1,2,1, when $m = 1; sc = 1; f = 2; st = 1$; that is, when marketing, sustainability, and supply chain characteristic remain the same, a single reduction in finance performance resulted in a product being deleted. Four percent is the highest occurrence rate within the sampling data. This event also has the highest total log odds, 0.76. The second highest event is 1,1,1,1,, which has log odds of 0.70. We compare these two events against each other by making baseline category to 1,1,1,1,2 :

$$ln(\frac{p_{1,1,2,1,2}}{p_{1,1,1,1,2}}) = \alpha = (-0.3601) - (-0.3601);\ \beta = 0 - 0;\ \gamma = 0 - (0);\ \delta = 0 -$$

$$0.09218; \quad \zeta = 0 - 0$$

$$\ln\left(\frac{p_{1,1,2,1,2}}{p_{1,1,1,1,2}}\right) = \alpha = 0;\ \beta = 0;\ \gamma = 0;\ \delta = -0.09218;\ \zeta = 0$$

$$= -0.09218$$

When we ignore all independent variables (marketing, supply chain, finance and sales and sustainability), the log odds are -0.09218. The companies are much less likely to delete the product (k=2) rather than keep the product (k=1). In addition, delta is negative, indicating that if we include the impact of independent variables (a decrease in finance and sales performance separately, in this case only), then it is likely that a company will delete the product candidate. The independent variable with the most impact on the log odds is finance and sales performance in this case. This means that if a company identifies a decrease in finance and sales performance, then it is highly likely that the company will consider the product as a primary deletion candidate.

The next highest percentage is 3% for event 1,1,1,2, indicating that 3% of the investigated products were deleted when being identified high in all cross-functional characteristic, specifically high

marketing and financial returns as well as high cost and investment and high resources consumption. This further indicates that a return aspect of product performance might not play separately to determine whether a product is retained; the investment and risk aspect of other organizational functions may also influence the decision making.

5.3.4 Managerial Implications

Model 1 investigates if cross-functional involvement, including marketing characteristics, supply chain characteristics, finance and sales characteristics and sustainability characteristics, impacts product deletion decision making, both separately and jointly. It further examines the predictive relationships between each cross-function and product deletion shortlisting.

Bayesian estimates indicate that high performance in all investigated organizational functions, specifically marketing, supply chain, finance, sales, and sustainability, is 64% more likely to result in decreased odds of product deletion. Furthermore, for products, if improved performance is identified in every single dimension, it is more likely (greater than 50%) to decrease the likelihood of deletion. Amongst these cross-functions, supply chain characteristics, collectively, form a better indicator (75.49% chance) of a product's candidacy for deletion. The existence of impact and the strength of indication from supply chain characteristics, first supports the proposition in Chapter 2 that supply chain factors and/or operational triggers impact product deletion. Second, it fills a gap in the product deletion literature that, except for the considerations of marketing and finance, the supply chain should be considered, equally or even more significantly, for a sound product deletion decision.

The sampling data under investigation displays the highest probability (4%) of product deletion occurrence when marketing, sustainability, and supply chain characteristic remain the same with a single reduction in finance performance. Certainly, sales and financial perspectives are still the first lenses of this critical issue. However, finance characteristics also involve the investment and operational input. A further investigation of financial return over the operational and stakeholders input is needed for a complete product performance evaluation. Therefore, an in-depth examination of supply chain/operations

dimension as well as sustainability (including social and environmental) will add additional value to sound product deletion decision making.

In addition, 3% of the investigated products were deleted when being identified high in all cross-functional characteristics, specifically high marketing and financial return as well as high cost and investment and high resources consumption. This further indicates that the return aspect of product performance does not always guarantee a product retention. The investment and risk aspect of other organizational functions may also influence the decision making.

Hence, ideally, it is suggested that managers involve both input and output of multiple organizational functions in product deletion decision making. Big data analytics are essential to rationalize this decision, but the subjective portion from professional judgement is also critical. Some subjective considerations can be quantified for decision making, while some cannot. Therefore, a decision making model that incorporates a mixed dataset and imbalanced dataset is recommended for managers to apply more systematic and visualized decision making.

5.4 Model 2: Product Deletion and Supply Chain Management

The major purpose of model 2 is to investigate how supply chain performance relates to product deletion decision making, specifically how each dimension including supply chain flexibility, time and cost, respectively, determines a product's candidacy of deletion. All the factors within each dimension are derived from the qualitative evaluation (case studies) and the dimension categorization is supported by supply chain management literature streams on competencies. Refer to Table 5.2 for data information.

5.4.1 Model Development

The model investigates if supply chain factors resulted in a product being deleted. The dependent variable has the same two levels.

Delete	*Keep*	Levels of the dependent variable
No	Yes	k = 1
Yes	No	k = 2

The model development is similar to Model 1. The interpretation is, based on historical data observations, the dependent variable of the model represents the number of occurrence of two product decisions (delete or keep) under all different/various business scenarios.

Raw data were generated from selected companies' archival product level data (Section 5.1) and one-on-one interviews with top management for those categorical and ordinal factors concerning the important input of subjective judgement (Table 5.9). All factors were normalized by making the data stochastic (Table 5.10). The normalization is conducted by Equation (5.1).

18: Table 5.9: Model 2 Raw Data

PRODUCT ID	**DV**	**FLEX**					**C**					**T**				
		ISC	MC	COR	SCI	LU	CSA	CMA	CDA	CRA	CWI	LT	LTF	DR	IHT	ITR
1	0	0.9	2	2	2	0.89	0.08	0.01	0.01	0.01	3	2	2	4	1	2
2	0	0.3	2	2	3	0.83	0.02	0.08	0.05	0.02	1	3	1	4	1	1
3	0	0.3	1	1	3	0.84	0.02	0.02	0.1	0.02	1	3	1	4	1	1
4	1	0.3	1	1	3	0.67	0.01	0.2	0.1	0.02	1	3	1	4	3	2
5	0	0.1	3	1	3	0.6	0	0.03	0.35	0.02	1	3	1	4	4	3
6	0	0.9	2	2	2	0.9	0.06	0.01	0.02	0.01	3	2	2	3	1	2
7	1	0.7	1	1	3	0.62	0.01	0.25	0.1	0.02	1	3	1	4	3	2
8	1	0.8	1	1	3	0.65	0.02	0.01	0.3	0.02	1	3	1	5	1	1
9	1	0.5	1	1	3	0.35	0.25	0.08	0.3	0.02	2	3	2	4	3	2
10	0	0.1	2	1	2	0.5	0.08	0.02	0.15	0.25	1	3	2	4	3	2
11	0	0.1	2	2	1	0.6	0.05	0.2	0.05	0.1	2	3	2	4	3	2
12	0	0.65	3	1	2	0.28	0.29	0.05	0.29	0.09	3	3	2	4	3	2
13	0	0.7	2	2	3	0.1	0.11	0.01	0.22	0.01	2	3	2	3	2	2
14	0	0.7	2	2	3	0.1	0.11	0.01	0.22	0.01	3	2	1	3	3	2
15	0	0.7	2	2	3	0.13	0.08	0.01	0.22	0.01	1	2	3	3	3	2
16	0	0.7	2	1	3	0.1	0.11	0.01	0.22	0.01	3	2	3	3	3	2
17	0	0.7	3	1	3	0.1	0.11	0.01	0.22	0.01	3	3	2	2	2	1
18	0	0.7	1	2	2	0.13	0.08	0.01	0.22	0.01	2	2	1	3	3	2
19	0	0.7	2	2	2	0.1	0.11	0.01	0.22	0.01	2	2	2	3	3	2
20	1	0.7	2	1	3	0.1	0.22	0.01	0.22	0.01	2	2	1	3	3	2

19: Table 5.10: Model 2 Normalized Data

PRODUCT ID	DV	FLEX						C					T			
		ISC	MC	COR	SCI	LU	CSA	CMA	CDA	CRA	CWI	LT	LTF	DR	IHT	ITR
1	0	1.00	0.67	1.00	0.67	1.00	0.99	0.28	0.04	0.03	0.04	0.67	0.67	0.80	0.25	0.67
2	0	0.33	0.67	1.00	1.00	0.33	0.92	0.07	0.32	0.14	0.08	1.00	0.33	0.80	0.25	0.33
3	0	0.33	0.33	0.50	1.00	0.33	0.93	0.07	0.08	0.29	0.08	1.00	0.33	0.80	0.25	0.33
4	1	0.33	0.33	0.50	1.00	0.33	0.74	0.03	0.80	0.29	0.08	1.00	0.33	0.80	0.75	0.67
5	0	0.11	1.00	0.50	1.00	0.33	0.67	0.00	0.12	1.00	0.08	1.00	0.33	0.80	1.00	1.00
6	0	1.00	0.67	1.00	0.67	1.00	1.00	0.21	0.04	0.06	0.04	0.67	0.67	0.60	0.25	0.67
7	1	0.78	0.33	0.50	1.00	0.33	0.69	0.03	1.00	0.29	0.08	1.00	0.33	0.80	0.75	0.67
8	1	0.89	0.33	0.50	1.00	0.33	0.72	0.07	0.04	0.86	0.08	1.00	0.33	1.00	0.25	0.33
9	1	0.56	0.33	0.50	1.00	0.67	0.39	0.86	0.32	0.86	0.08	1.00	0.67	0.80	0.75	0.67
10	0	0.11	0.67	0.50	0.67	0.33	0.56	0.28	0.08	0.43	1.00	1.00	0.67	0.80	0.75	0.67
11	0	0.11	0.67	1.00	0.33	0.67	0.67	0.17	0.80	0.14	0.40	1.00	0.67	0.80	0.75	0.67
12	0	0.72	1.00	0.50	0.67	1.00	0.31	1.00	0.20	0.83	0.36	1.00	0.67	0.80	0.75	0.67
13	0	0.78	0.67	1.00	1.00	0.67	0.11	0.38	0.04	0.63	0.04	1.00	0.67	0.60	0.50	0.67
14	0	0.78	0.67	1.00	1.00	1.00	0.11	0.38	0.04	0.63	0.04	0.67	0.33	0.60	0.75	0.67
15	0	0.78	0.67	1.00	1.00	0.33	0.14	0.28	0.04	0.63	0.04	0.67	1.00	0.60	0.75	0.67
16	0	0.78	0.67	0.50	1.00	1.00	0.11	0.38	0.04	0.63	0.04	0.67	1.00	0.60	0.75	0.67
17	0	0.78	1.00	0.50	1.00	1.00	0.11	0.38	0.04	0.63	0.04	1.00	0.67	0.40	0.50	0.33
18	0	0.78	0.33	1.00	0.67	0.67	0.14	0.28	0.04	0.63	0.04	0.67	0.33	0.60	0.75	0.67
19	0	0.78	0.67	1.00	0.67	0.67	0.11	0.38	0.04	0.63	0.04	0.67	0.67	0.60	0.75	0.67
20	1	0.78	0.67	0.50	1.00	0.67	0.11	0.76	0.04	0.63	0.04	0.67	0.33	0.60	0.75	0.67

The independent variables are categorized in three dimensions based on supply chain competencies, respectively flexibility, time and cost. Independent variable levels are arrived at by the summation of the selected data value within each dimension according to Equation (5.2). The summation table is presented in Table 5.11.

Three independent variables are as follows:

Variable $\beta_{flex,k}$: Amongst all identified products, has the performance in supply chain flexibility dimension resulted in a product being deleted? The value for flexibility has been recoded to 1 or 2 by comparing it to the average number of all products performance in flexibility. If higher than average, then $flex = 1$, indicating high flexibility; otherwise, $flex = 2$, low flexibility.

Variable $\gamma_{c,k}$: Amongst all identified products, has the performance in supply chain cost dimension resulted in a product being deleted? Supply chain cost performance response coded high, $c = 1$, or low, $c = 2$.

Variable $\delta_{t,k}$: Amongst all identified products, has the performance in supply chain time dimension resulted in a product being deleted? Supply chain time performance response coded high, $f = 1$, or low, $f = 2$.

IV	$\beta_{flex,k}$	$\gamma_{c,k}$	$\delta_{t,k}$
levels	Amongst all identified products, has the performance in supply chain flexibility / cost / time dimension resulted in a product being deleted?		
	$flex = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$c = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$t = \begin{cases} 1, & high \\ 2, & low \end{cases}$

20: Table 5.11: Model 2 Summation Data of Supply Chain Dimensional Overall Performance

PRODUCT ID	DV	FLEX	C	T
1	0	4.33	1.4	3.05
2	0	3.33	1.5	2.72
3	0	2.5	1.4	2.72
4	1	2.5	1.9	3.55
5	0	2.94	1.9	4.13
6	0	4.33	1.3	2.85
7	1	2.94	2.1	3.55
8	1	3.06	1.8	2.92
9	1	3.06	2.5	3.88
10	0	2.28	2.3	3.88
11	0	2.78	2.2	3.88
12	0	3.89	2.7	3.88
13	0	4.11	1.2	3.43
14	0	4.44	1.2	3.02
15	0	3.78	1.1	3.68
16	0	3.94	1.2	3.68
17	0	4.28	1.2	2.9
18	0	3.44	1.1	3.02
19	0	3.78	1.2	3.35
20	1	3.61	1.6	3.02
AVERAGE		3.47	1.6	3.36

The recoded table and input data for Bayesian analysis is presented in Table 5.12.

21: Table 5.12: Model 2 Recoded Table (a) for Bayesian Analysis Input (b)

(a)

PRODUCT ID	DV	FLEX	C	T	0 - KEEP	1 - DELETE
1	0	1	2	2	1	
2	0	2	2	2	1	
3	0	2	2	2	1	
4	1	2	1	1		1
5	0	2	1	1	1	
6	0	1	2	2	1	
7	1	2	1	1		1
8	1	2	1	2		1
9	1	2	1	1		1
10	0	2	1	1	1	
11	0	2	1	1	1	
12	0	1	1	1	1	
13	0	1	2	1	1	
14	0	1	2	2	1	
15	0	1	2	1	1	
16	0	1	2	1	1	
17	0	1	2	2	1	
18	0	2	2	2	1	
19	0	1	2	2	1	
20	1	1	2	2		1

(b)

FLEX	C	T	DV SCENERIO	FREQUENCY
1	1	1	0	1
1	1	1	1	0
1	1	2	0	0
1	1	2	1	0
1	2	1	0	7
1	2	1	1	1
1	2	2	0	1
1	2	2	1	0
2	1	1	0	2
2	1	1	1	4
2	1	2	0	1
2	1	2	1	0
2	2	1	0	3
2	2	1	1	0
2	2	2	0	0
2	2	2	1	0

5.4.2 Model Statement

The binomial logistic model with nominally measured variables needs a baseline value of the dependent variable from which the impact of other levels of the dependent variable are measured. Similar to Model 1, the baseline level of the dependent variable is 0, which corresponds to, from the above table, no decision being made for the product. Level 1, for each of the four independent variables as the reference levels from which the level 2 effect is measured. The function is summarized in equation (5.6):

$$y_{flex,c,t,k} = \propto_k + \beta_{flex,k} + \gamma_{c,k} + \delta_{t,k} \tag{5.6}$$

$$where\ flex = 1,2;\ \ c = 1,2;\ \ \ t = 1,2;\ \ \ \ k = 1,2.$$

The odds ratio model is a multiplicative model is shown in equation (5.7):

$$\frac{p(flex,c,t,k)}{p_{1,1,1,1}} = \ e^{\propto_k} e^{\beta_{flex,k}} e^{\gamma_{c,k}} e^{\delta_{t,k}} \tag{5.7}$$

Similar to Model 1, $\beta_{1,2}\ \gamma_{1.2}\ and\ \delta_{1,2}$ are both 0 because level 1 of all independent variables is used as the reference level. In fact, all $\beta_{1,k},\ \gamma_{1,k},\ \delta_{1,k},\ \epsilon_{1,k}$ for $k = 1\ and\ 2$ are 0 because they are the reference level of the independent variables. Every product in the existing dataset will be identified with a single event of unique business scenarios. Overall, in Model 2, there are 16 (2^4) events since each dependent value and independent value has two dimensions.

5.4.3 Results and Discussion

After importing the conducted model into WinBugs, with 1,000,000 iterations with 10,000 refresh for each chain, an initial 4000 samples were discarded and thinned at the 20th interval; the Winbugs results are presented in Table 5.13. The specified percentiles are 2.5% to 97.5%.

22: Table 5.13: Model 2 Coefficients Statistics

node	mean	sd	mc error	2.5%	median	97.5%	start	sample
alpha[2]	-0.4552	0.7798	0.003504	-2.109	-0.4195	0.9891	4001	49800
beta[2,2]	0.3267	0.7822	0.003684	-1.143	0.2947	1.989	4001	49800
delta[2,2]	-1.194	2.648	0.02084	-6.591	-0.6863	1.236	4001	49800
gamma[2,2]	-1.601	1.093	0.005232	-4.065	-1.476	0.1837	4001	49800
aprob[2]	0.276	0.447	0.002049	0.0	0.0	1.0	4001	49800
bprob[2,2]	0.6613	0.4733	0.002077	0.0	1.0	1.0	4001	49800
dprob[2,2]	0.2501	0.4331	0.001891	0.0	0.0	1.0	4001	49800
gprob[2,2]	0.04327	0.2035	8.637E-4	0.0	0.0	1.0	4001	49800

5.4.3.1 Bayesian Inferencing Estimates and Posterior Distributions

According to table 5.13, the coefficients estimates for level 2 ($flex = 2; c = 2; t = 2; k = 2$) give us $\propto_2 = -0.4552,\ \beta_{2,2} = 0.3267,\ \gamma_{2.2} = -1.194,\ \delta_{2,2} = -1.601$. The possibility of coefficients being positive is respectively, 27.6%, 66.13%, 25.01% and 0.4327%. The interpretations are:

When a product is identified with high value in supply chain characteristics, namely high flexibility, high cost and high time responsiveness, there is a 72.4% chance that it will decrease the odds of product deletion; on average the odds of deletion fall by a factor of 0.634 ($e^{-0.4552}$).

If a product has decreased flexibility, then there is a 66.13% chance that it will increase the odds of product deletion; on average the odds of deletion go up by a factor of 1.386 ($e^{0.3267}$).

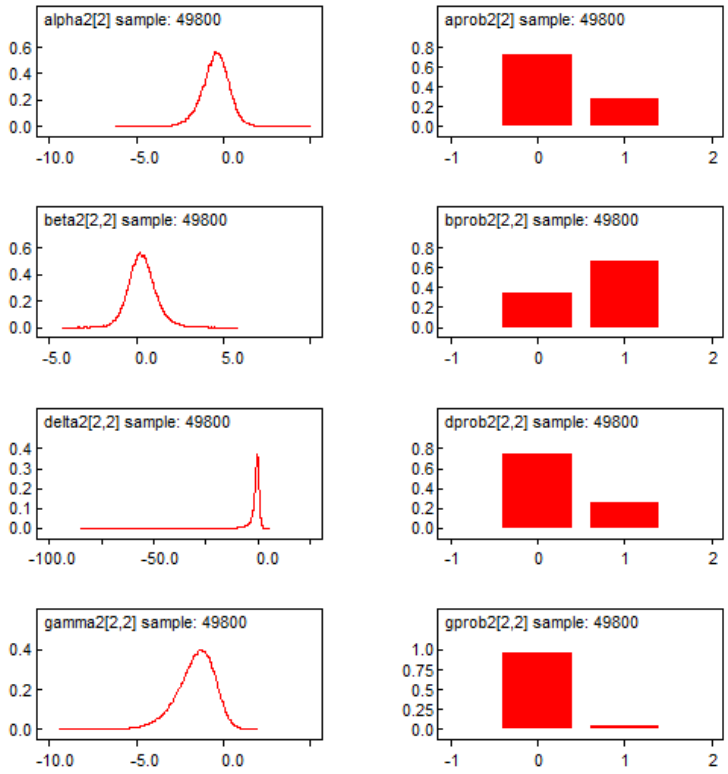
If a product has better lead time characteristics, then there is a 74.99% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by a factor of 0.303 ($e^{-1.194}$).

If a product has decreased supply chain activity cost, then there is a 95.673% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by a factor of 0.202 ($e^{-1.601}$).

Amongst all coefficients, $\delta_{2,2}$ has the highest percentage of discriminant occurrence (95.673%), which shows a higher level of statistically confidence, further indicating that cost factors in supply chain major activities are better predictors for product deletion. Decreased cost in supply chain activities will result in a reduced likelihood of deletion by 20.2%.

The coefficients for posterior distribution and likelihood of deletion or keeping of sampling data are shown in Figure 5.2:

8: Figure 5.2: Model 2 Posterior Distributions



5.4.3.2 Results and Outcomes

There are 16 numbered events/business scenarios in Model 2. The events represent all the possible combinations of alpha, beta, gamma, and delta that is all combinations of levels of independent and dependent variables: 2x2x2x2=16. Table 5.14 presents the Bayesian outcomes for all 16 events/business scenarios of Model 2.

Table 5.14 provides odds for all events with a baseline event of 1,1,1,1. Probabilities (based on odds) calculations are calculated in the last column in the table, representing the likelihood of the specific business scenario/data event occurring in the collected sampling data. The table of outcomes provides the log of odds in the column titled total. All of these log odds in the table are computed against $p(1,1,1,1)$. It is in the denominator, considering event 1,1,1,1 serves the baseline event so the odds for events may be

computed with it. The choice of baseline depends on the scenario, for results interpretations, designating the event 1,1,1,1 as baseline makes comparisons easier, that is all supply chain characteristics are high. However, we can use any row to be the baseline for the other row, which indicates the influence of a change in supply chain characteristics on the odds of product deletion.

23: Table 5.14: Model 2 Bayesian Predicative Outcomes

Subscripts					**Value of coefficients**						
sequence number	flex	c	t	k	[k] alpha2	[flex,k] beta2	[c,k] gamma2	[t,k] delta2	ln(p#x / p#1) total	odds e^total	Prob
1	1	1	1	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
2	1	1	2	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
3	1	2	1	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
4	1	2	2	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
5	2	1	1	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
6	2	1	2	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
7	2	2	1	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
8	2	2	2	1	0.000	0.000	0.000	0.000	0.000	1.000	10%
9	1	1	1	2	-0.455	0.000	0.000	0.000	-0.455	0.634	6%
10	1	1	2	2	-0.455	0.000	0.000	-1.601	-2.056	0.128	1%
11	1	2	1	2	-0.455	0.000	-1.194	0.000	-1.649	0.192	2%
12	1	2	2	2	-0.455	0.000	-1.194	-1.601	-3.250	0.039	0%
13	2	1	1	2	-0.455	0.327	0.000	0.000	-0.129	0.879	8%
14	2	1	2	2	-0.455	0.327	0.000	-1.601	-1.730	0.177	2%
15	2	2	1	2	-0.455	0.327	-1.194	0.000	-1.323	0.266	3%
16	2	2	2	2	-0.455	0.327	-1.194	-1.601	-2.924	0.054	1%
								Total	-13.51	10.37	1.00

Amongst all the 16 events of various combinations of supply chain characteristics, (2,1,1,2) has the highest possibilities of occurrences (8%) for product deletion in the investigated sampling dataset, where the product has identified with a decrease in flexibility while time and cost remaining the same. Since the log odds in this case is -0.129, the negative relationship indicates that the companies are much less likely to delete the product (k=2) rather than keep the product (k=1). Flexibility has a larger influence on product deletion compared to cost. Decreased value in flexibility might come from less manufacturing complexity, or a higher percentage of the external supply chain, or a lower level of unique parts

developed in house, or decreased resources correlations with other products in the same portfolio, or lessened organizational intervention. Either situation is identified with a product candidate, the results shows that 8% of times companies are more willing to keep the product than to delete it.

The second highest percentage is 6% where all independent variables (flexibility, cost, time) are identified at a high level and the log odds are -0.455. This indicates that if a product is very flexible in terms of manufacturing complexity or substitutability, and very expensive to make, and has a longer lead time, it is common for companies to delete this product. Both cost and time have a negative effect on product deletion (decreased cost and time results in a reduced likelihood of product deletion), while flexibility has a positive effect on product deletion (decreased flexibility results in a greater likelihood of product deletion). The independent variable with the most impact on the log odds is flexibility (odds ratio = 1.386). This is further indicated by the internal supply chain capability and capabilities playing the most powerful role in product deletion. However, by examining the likelihood of occurrence, cost is the best indicator (95.673% confidence), which further demonstrates that the cost aspect of strategic decision making including product deletion is still most explicit and prime trigger.

5.4.4 Managerial Implications

Model 2 investigated if supply chain characteristics, respectively supply chain flexibility, cost, and time, impact the product deletion, and what the predictive relationships are between each supply chain characteristic and product deletion candidacy.

Bayesian estimates indicate, amongst all supply chain characteristics, that flexibility has the largest influence in predicting a product deletion. A product's flexibility on supply chains largely determines its deletion candidacy. Flexibility should be included in the product evaluation with the highest weights. Companies should focus on a product's manufacturing complexity, its outsourcing percentage, level of unique parts developed in house, and resources correlations with other products in the same portfolio, as well as organizational intervention from product change activities. For target products, managers should invest efforts in maintaining their manufacturing complexity as simple and lean, and

keep the core manufacturing processes and unique parts developed in house. Managers also might consider conducting a resources planning strategy, in order to establish high correlations on resources amongst products. In this way, firms can further develop long-term resources acquaintance partnership and eventually achieve an optimized supply chain network by cutting those lagged products with lessened flexibility and wasted cost and time.

Cost, overall, is the best predictor in the sampling dataset. It is recommended to managers that the supply chain cost allocated to each product is critical for constituently product performance measurement. Through annual budgeting cycles, it is suggested that a cost breakdown analysis is conducted, not limited to supply chain level, but also to the product line and product level. If a product occupies too many capital resources, they might be shortlisted as prime candidates of product deletion.

5.5 Model 3: Product Deletion and Sustainability

The major purpose of model 3 is to investigate how sustainability (primarily social and environmental) performance relates to product deletion decision making, specifically how each dimension - including the effect on stakeholders, 5Rs, emissions and waste and resource usage efficiency, respectively - determines a product's candidacy for deletion. All the factors within each dimension are derived from the qualitative evaluation (case studies), and the dimension categorization is supported by the sustainable supply chain management literature.

5.5.1 Model Development

This concerns whether a product is deleted concerning the overall sustainability of performance. The dependent variable has two responses and are coded as shown below. We use subscript k to denote different nominal levels of the dependent variable hence $k = 1, 2$.

Delete	*Keep*	Levels of the dependent variable
No	Yes	k = 1
Yes	No	k = 2

The model setup is similar to the previous two models. The interpretation is, based on historical data observations, that the dependent variable of the model represents the number of occurrence of two product decisions (delete or keep) under all different/various business scenarios of sustainability characteristics.

Raw data are generated from selected companies' archival product level data (Section 5.1) and one-on-one interviews with top management for those categorical and ordinal factors concerning the important input of subjective judgement (Table 5.15). All factors will be normalized by making the data stochastic (Table 5.16). The normalization is conducted by Equation (5.1).

The independent variables are categorized in four dimensions based on sustainability characteristics, respectively the effect on stakeholders, 5Rs, emissions and waste and resource usage efficiency. Independent variable levels are arrived at by a summation of the selected data value within each dimension according to Equation (5.2). The summation table is presented in Table 5.17.

The four independent variables are as follows:

Variable $\beta_{e,k}$: Amongst all identified products, has the sustainability performance concerning the effect on the stakeholders dimension resulted in product being deleted? Effect on stakeholders performance response is coded high, $e = 1$, or low, $e = 2$.

Variable $\gamma_{r,k}$: Amongst all identified products, has the sustainability performance concerning to 5Rs dimension resulted in a product being deleted? 5Rs performance response is coded high, $r = 1$, or low, $r = 2$.

Variable $\delta_{w,k}$: Amongst all identified products, has the sustainability performance concerning to emissions and waste dimension resulted in a product being deleted? Emissions and waste performance response is coded high, $w = 1$, or low, $w = 2$.

Variable $\zeta_{u,k}$: Amongst all identified products, has the sustainability performance concerning resources usage efficiency resulted in a product being deleted? Resources usage efficiency performance response is coded high, $u = 1$, or low, $u = 2$.

IV	$\beta_{e,k}$	$\gamma_{r,k}$	$\delta_{w,k}$	$\zeta_{u,k}$
	Amongst all identified products, has the performance in sustainability concerning effect on stakeholders, 5Rs, emissions and waste, and resources usage efficiency resulted in a product being deleted?			
levels	$e = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$r = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$w = \begin{cases} 1, & high \\ 2, & low \end{cases}$	$u = \begin{cases} 1, & high \\ 2, & low \end{cases}$

The recoded table and input data for Bayesian analysis is presented in Table 5.18.

24: Table 5.15: Model 3 Raw Data

PRODUCT ID	DV	ES								5RS				EW		RU	
		EER	ECR	ESR	CRA	GR	M	RD	RE	REC	RECL	REM	SW	AE	WE	RU	EU
1	0	2	2	1	1	1	1	3	3	3	3	3	1	1	1	2	1
2	0	2	2	1	3	1	1	3	3	3	3	3	1	2	2	2	1
3	0	2	2	1	3	1	1	3	3	3	3	3	1	2	2	2	1
4	1	1	1	1	1	1	1	3	3	3	3	3	1	2	2	2	1
5	0	1	1	1	3	1	1	3	3	3	3	3	1	2	2	2	1
6	0	2	2	1	1	1	1	3	3	3	3	3	1	1	1	2	1
7	1	1	1	1	1	1	1	3	3	3	3	3	1	2	2	2	1
8	1	2	2	1	3	1	1	3	3	3	3	3	1	1	1	1	1
9	1	1	2	2	1	1	1	3	3	3	3	3	1	2	2	2	1
10	0	1	1	2	2	1	1	2	2	3	3	3	1	1	2	1	2
11	0	1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1
12	0	1	1	2	1	1	1	2	3	3	3	3	2	1	1	2	2
13	0	1	2	2	1	1	1	3	3	3	3	3	1	1	1	1	1
14	0	1	2	1	1	1	1	3	3	3	3	3	1	1	1	1	1
15	0	1	2	1	1	1	1	3	3	3	3	3	1	1	1	1	1
16	0	2	2	2	3	1	1	1	3	3	3	3	1	1	1	1	1
17	0	2	2	2	3	1	1	3	3	3	3	3	1	1	1	1	1
18	0	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	1
19	0	1	1	2	1	1	1	3	3	3	3	3	1	1	1	1	1
20	1	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	1

25: Table 5.16: Model 3 Normalized Data

PRODUCT ID	DV	ES				5RS							EW		RU	
		EER	ECR	ESR	CRA	GR	M	RD	RE	REC	RECL	REM	SW	AE	WE	RU	EU
1	0	1.00	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00	0.50
2	0	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
3	0	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
4	1	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
5	0	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
6	0	1.00	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00	0.50
7	1	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
8	1	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
9	1	0.50	1.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
10	0	0.50	0.50	1.00	0.67	1.00	1.00	0.67	0.67	1.00	1.00	1.00	0.50	0.50	1.00	0.50	1.00
11	0	0.50	0.50	0.50	0.33	1.00	1.00	0.67	0.67	0.67	0.67	0.67	0.50	0.50	0.50	0.50	0.50
12	0	0.50	0.50	1.00	0.33	1.00	1.00	0.67	1.00	1.00	1.00	1.00	1.00	0.50	0.50	1.00	1.00
13	0	0.50	1.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
14	0	0.50	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
15	0	0.50	1.00	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
16	0	1.00	1.00	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
17	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
18	0	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
19	0	0.50	0.50	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50
20	1	0.50	0.50	0.50	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50

26: Table 5.17: Model 3 Summation Data of Sustainability Dimensional Overall Performance

PRODUCT ID	ES	5RS	EW	RU
1	4.833	5.000	1.500	1.500
2	5.5	5.000	2.500	1.500
3	5.5	5.000	2.500	1.500
4	3.833	5.000	2.500	1.500
5	4.5	5.000	2.500	1.500
6	4.833	5.000	1.500	1.500
7	3.833	5.000	2.500	1.500
8	5.5	5.000	1.500	1.000
9	4.833	5.000	2.500	1.500
10	4.667	4.333	2.000	1.500
11	3.833	3.333	1.500	1.000
12	4.333	4.667	2.000	2.000
13	4.833	5.000	1.500	1.000
14	4.333	5.000	1.500	1.000
15	4.333	5.000	1.500	1.000
16	6	4.333	1.500	1.000
17	6	5.000	1.500	1.000
18	3.833	5.000	1.500	1.000
19	4.333	5.000	1.500	1.000
20	3.833	5.000	1.500	1.000
AVERAGE	4.675	4.833	1.850	1.275

27: Table 5.18: Model 3 Recoded Table (a) for Bayesian Analysis Input (b)

(a)

PRODUCT ID	DV	ES	5RS	EW	RU	0 - KEEP	1 - DELETE
1	0	1	1	2	1	1	
2	0	1	1	1	1	1	
3	0	1	1	1	1	1	
4	1	2	1	1	1		1
5	0	2	1	1	1	1	
6	0	1	1	2	1	1	
7	1	2	1	1	1		1
8	1	1	1	2	2		1
9	1	1	1	1	1		1
10	0	2	2	1	1	1	
11	0	2	2	2	2	1	
12	0	2	2	1	1	1	
13	0	1	1	2	2	1	
14	0	2	1	2	2	1	
15	0	2	1	2	2	1	
16	0	1	2	2	2	1	
17	0	1	1	2	2	1	
18	0	2	1	2	2	1	
19	0	2	1	2	2	1	
20	1	2	1	2	2		1

(b)

ES	5Rs	EW	RU	DV SCENERIO	FREQUENCY
1	1	1	1	0	2
1	1	1	1	1	1
1	1	1	2	0	0
1	1	1	2	1	0
1	1	2	1	0	2
1	1	2	1	1	0
1	1	2	2	0	2
1	1	2	2	1	1
1	2	1	1	0	0
1	2	1	1	1	0
1	2	1	2	0	0
1	2	1	2	1	0
1	2	2	1	0	0
1	2	2	1	1	0
1	2	2	2	0	1
1	2	2	2	1	0
2	1	1	1	0	1
2	1	1	1	1	2
2	1	1	2	0	0
2	1	1	2	1	0
2	1	2	1	0	0
2	1	2	1	1	0
2	1	2	2	0	4
2	1	2	2	1	1
2	2	1	1	0	2
2	2	1	1	1	0
2	2	1	2	0	0
2	2	1	2	1	0
2	2	2	1	0	0
2	2	2	1	1	0
2	2	2	2	0	1
2	2	2	2	1	0

5.5.2 Model Statement

The binomial logistic model with nominally measured variables needs a baseline value of the dependent variable from which the impact of other levels of the dependent variable are measured. Similar to Model 1 and 2, the baseline level of the dependent variable is 0 which corresponds to, from the above table, no decision being made regarding the product. And level 1, for each of the four independent variables as the reference levels from which level 2 effect is measured; as shown in equation (5.8).

$$y_{e,r,w,u,k} = \propto_k + \beta_{e,k} + \gamma_{r,k} + \delta_{w,k} + \zeta_{u,k} \tag{5.8}$$

$$where\ e = 1,2;\ \ r = 1,2;\ \ \ w = 1,2;\ \ \ u = 1,2;\ \ \ \ k = 1,2.$$

The odds ratio model is a multiplicative model as shown in Equation (5.9):

$$\frac{p(e,r,w,u,k)}{p_{1,1,1,1}} = \ e^{\propto_k} e^{\beta_{e,k}} e^{\gamma_{r,k}} e^{\delta_{w,k}} e^{\zeta_{u,k}} \tag{5.9}$$

Similar to Model 1 and 2, $\beta_{1,2}$, $\gamma_{1.2}, \delta_{1,2}\ and\ \zeta_{1,2}$ are both 0 because level 1 of all independent variables is used as the reference level. In fact, all $\beta_{1,k},\ \gamma_{1,k},\ \delta_{1,k},\ \zeta_{1,k}\ \ \epsilon_{1,k}$ for $k = 1\ and\ 2$ are 0 because they are the reference level of the independent variables. Every product in the existing dataset will be identified with a single event of unique business scenarios. Overall, in Model 3, there are 32 (2^5) events since each dependent value and independent value has two dimensions.

5.5.3 Results and Discussions

After importing the conducted model into WinBugs, with 1,000,000 iterations with 10,000 refresh for each chain, an initial 4000 samples were discarded and thinned at the 20th interval; the Winbugs results are concluded in Table 5.19. The specified percentiles are 2.5% to 97.5%.

28: Table 5.19: Model 3 Coefficients Statistics

node	mean	sd	mc error	2.5%	median	97.5%	start	sample
alpha[2]	-0.4626	0.6837	0.003118	-1.901	-0.4346	0.8076	4001	49800
beta[2,2]	0.07697	0.7507	0.003519	-1.399	0.07204	1.616	4001	49800
delta[2,2]	-0.8781	1.031	0.005716	-3.165	-0.7666	0.8259	4001	49800
gamma[2,2]	-1.926	3.559	0.03305	-8.744	-1.191	0.6873	4001	49800
zeta[2,2]	-0.0816	0.9702	0.005399	-1.97	-0.09603	1.879	4001	49800
aprob[2]	0.2471	0.4313	0.001998	0.0	0.0	1.0	4001	49800
bprob[2,2]	0.5403	0.4984	0.002298	0.0	1.0	1.0	4001	49800
dprob[2,2]	0.1779	0.3825	0.001712	0.0	0.0	1.0	4001	49800
gprob[2,2]	0.1278	0.3339	0.001513	0.0	0.0	1.0	4001	49800
zprob[2,2]	0.4534	0.4978	0.002355	0.0	0.0	1.0	4001	49800

5.5.3.1 Bayesian Inferencing Estimates and Posterior Distributions

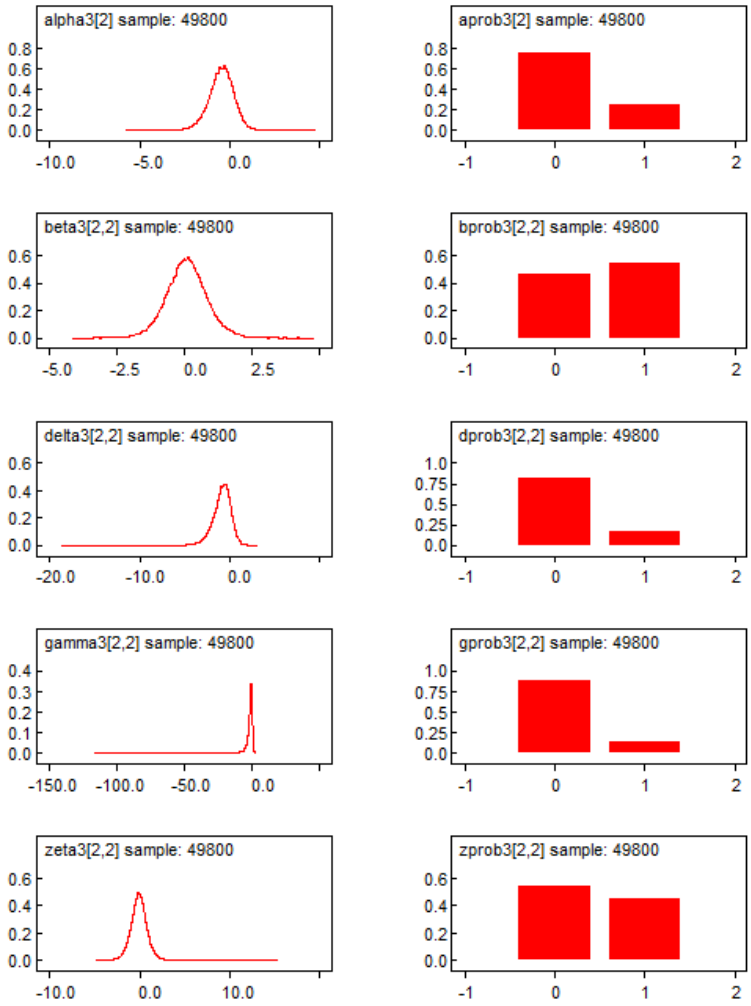
According to the table above, the coefficients estimates for level 2 ($e = 2; r = 2; w = 2; u = 1,2; k = 2$) give us $\propto_2 = -0.4626,\ \beta_{2,2} = 0.07697,\ \gamma_{2.2} = -0.8781,\ \delta_{2,2} = -1.926,\ \zeta_{2,2} = -0.0816$. The possibility of coefficients being positive is respectively, 24.71%, 54.03%, 17.79%, 12.78% and 45.34%.

The coefficients posterior distribution and likelihood of deletion or keeping of sampling data are shown in Figure 5.3.

When all sustainability characteristics are identified at a high value, specifically high stakeholders benefits, high emissions and waste, high 5Rs value, and high resource usage, there is a 75.29% chance that it will decrease the odds of product deletion; on average the odds of deletion go down by 0.63 ($e^{-0.4626}$).

If a product has been identified with a lower contribution to stakeholder benefits including suppliers, customers, employees and government, then there is a 54.03% chance that it will increase the odds of product deletion; on average the odds of deletion go up by 1.08 ($e^{0.07697}$). Improved social sustainability decrease the odds of product deletion. Considerations of various perspectives including customers, suppliers, and other business partners are significant for sound product deletion decision making.

9: Figure 5.3: Model 3 Posterior Distribution



If a product has lower emissions and waste, then there is an 82.21% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by 0.42 ($e^{-0.8781}$). Improved environmental sustainability decreased the odds of product deletion.

If a product has a lower 5Rs value, then there is an 87.22% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by 0.15 ($e^{-1.926}$).

If a product has a reduction in resources usage, then there is a 54.66% chance that it will decrease the odds of product deletion; on average the odds of deletion will go down by 0.92 ($e^{-0.0816}$).

Amongst all coefficients, stakeholders' benefit is the most influential dimension (1.08) for product deletion. In addition, $\gamma_{2,3}$ has the highest percentage of discriminant occurrence (87.22%), and the second highest is emissions and waste (82.21%), which shows a higher level of statistically confidence, collectively indicating that environmental sustainability, overall, is a better predictor for product deletion.

5.5.3.2 Results and Outcomes

There are 32 numbered events/business scenarios in Model 3. The events represent all possible combinations of alpha, beta, gamma, delta and zeta; that is, all combinations of levels of independent and dependent variables: 2x2x2x2x2=32. Table 5.20 presents the Bayesian outcomes for all 32 events/business scenarios of Model 3.

The results table provides odds for all events with a baseline event of 1,1,1,1,1. Probabilities (based on odds) calculations are calculated in the last column in the table, representing the likelihood of the specific business scenario/data event occurring in the collected sampling data. The table of outcomes provides the log of odds in the column titled total. All of these log odds in the table are computed against $p(1,1,1,1,1)$. It is in the denominator, considering event 1,1,1,1,1 serves the baseline event, so the odds for events may be computed with it. The choice of baseline depends on the scenario; for results interpretations, designating the event 1,1,1,1,1 as baseline makes comparisons easier; that is, all sustainability characteristics are high. However, we can use any row as the baseline for the other row, which indicates the influence of a change in sustainability characteristics on the odds of product deletion.

The outcome table shows that, overall, improved performance on social and environmental factors reduces the likelihood of product deletion. Environmental impact from emissions, waste, and the 5Rs are the best indicators for product deletion. Environmental sustainability should be emphasized in product deletion considerations in addition to monetary concerns. Stakeholder's benefits form a critical factor in product deletion decision making, since product deletion often occurs when stakeholder benefits

are low. Hence, stakeholder inputs are critical and significant for sound product deletion decisions. Decision making tools should involve and quantity stakeholders' perspectives and beliefs into data generating and calculations.

This further enhances the theoretical foundation of this study regarding incorporating the relational view into the resource-based view. The relational view is supported as a core theoretical perspective to investigate product deletion. Managers should view product deletion decisions as relationship enhancement or debilitating decisions.

The resources consumption dimension is also influential. High resource consumption leads to higher odds of deletion. Consumption efficiency in both material and energy should be included in evaluating products.

5.5.4 Managerial Implications

Model 3 investigated if sustainability affects product deletion. Within the sustainability dimension, improved performance on social and environmental factors reduced the likelihood of product deletion. Resource consumption efficiency and social impact are the major findings of both qualitative and quantitative studies. Resource consumption relates to waste, emissions and the 5Rs and social impact involves stakeholder benefits. Bayesian models further demonstrates that resource consumption efficiency forms the best indicator to determine a product deletion decision. High resource consumption leads to higher odds of deletion. Consumption efficiency in both material and energy should be included in evaluating products. And stakeholder's benefits are the most influential dimension for product deletion. These stakeholders represent society, community, social norms, governments, regulators and media and the nature environment.

Sustainability, often a neglected consideration for product deletion, is proven to have an effect on, and also be influenced by, product deletion. Environmental and social sustainability should be emphasized in product deletion on top of economic sustainability. A more comprehensive product

deletion management should also incorporate resource consumption efficiency, waste management, recycle and repurpose value, as well as social impact into product evaluation. Sound product deletion will contribute to organizational sustainability development in terms of long term profitability, corporate social responsibility, and pro-environmental performance in resources consumption and reverse supply chain activities.

This further enhances the theoretical foundation of this study of incorporating relational view into the resource based view. The relational view is supported as a core theoretical perspective to investigate product deletion. Managers should view product deletion decisions as relationship enhancement or debilitating decisions.

29: Table 5.20: Model 3 Bayesian Predicative Outcomes

Subscripts						Value of coefficients							
sequence number	e	r	w	u	k	[k] alpha3	[e,k] beta3	[r,k] gamma3	[w,k] delta3	[u,k] zeta3	ln(p#x / p#1) total	odds e^total	Prob
1	1	1	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
2	1	1	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
3	1	1	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
4	1	1	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
5	1	2	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
6	1	2	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
7	1	2	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
8	1	2	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
9	2	1	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
10	2	1	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
11	2	1	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
12	2	1	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
13	2	2	1	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
14	2	2	1	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
15	2	2	2	1	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
16	2	2	2	2	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.0%
17	1	1	1	1	2	-0.4626	0.00	0.00	0.00	0.00	-0.46	0.63	3.1%
18	1	1	1	2	2	-0.4626	0.00	0.00	0.00	-0.0816	-0.54	0.58	2.9%
19	1	1	2	1	2	-0.4626	0.00	0.00	-0.8781	0.00	-1.34	0.26	1.3%
20	1	1	2	2	2	-0.4626	0.00	0.00	-0.8781	-0.0816	-1.42	0.24	1.2%
21	1	2	1	1	2	-0.4626	0.00	-1.926	0.00	0.00	-2.39	0.09	0.5%
22	1	2	1	2	2	-0.4626	0.00	-1.926	0.00	-0.0816	-2.47	0.08	0.4%
23	1	2	2	1	2	-0.4626	0.00	-1.926	-0.8781	0.00	-3.27	0.04	0.2%
24	1	2	2	2	2	-0.4626	0.00	-1.926	-0.8781	-0.0816	-3.35	0.04	0.2%
25	2	1	1	1	2	-0.4626	0.07697	0.00	0.00	0.00	-0.39	0.68	3.4%
26	2	1	1	2	2	-0.4626	0.07697	0.00	0.00	-0.0816	-0.47	0.63	3.1%
27	2	1	2	1	2	-0.4626	0.07697	0.00	-0.8781	0.00	-1.26	0.28	1.4%
28	2	1	2	2	2	-0.4626	0.07697	0.00	-0.8781	-0.0816	-1.35	0.26	1.3%
29	2	2	1	1	2	-0.4626	0.07697	-1.926	0.00	0.00	-2.31	0.10	0.5%
30	2	2	1	2	2	-0.4626	0.07697	-1.926	0.00	-0.0816	-2.39	0.09	0.5%
31	2	2	2	1	2	-0.4626	0.07697	-1.926	-0.8781	0.00	-3.19	0.04	0.2%
32	2	2	2	2	2	-0.4626	0.07697	-1.926	-0.8781	-0.0816	-3.27	0.04	0.2%
										Total	-29.87	20.08	100.0%

5.6 MCMC Diagnostics

To further validate the models and results, a series of diagnostics are completed to determine if convergence has occurred (see section 3.2.3.2). Markov chain Monte Carlo algorithms are used to test fit issues in Bayesian statistical models where the traditional estimation techniques are difficult to apply. One of the MCMC algorithms is to determine and test the convergence of the algorithm. The convergence checks the convergence of a distribution to another distribution in Gibbs sampling.

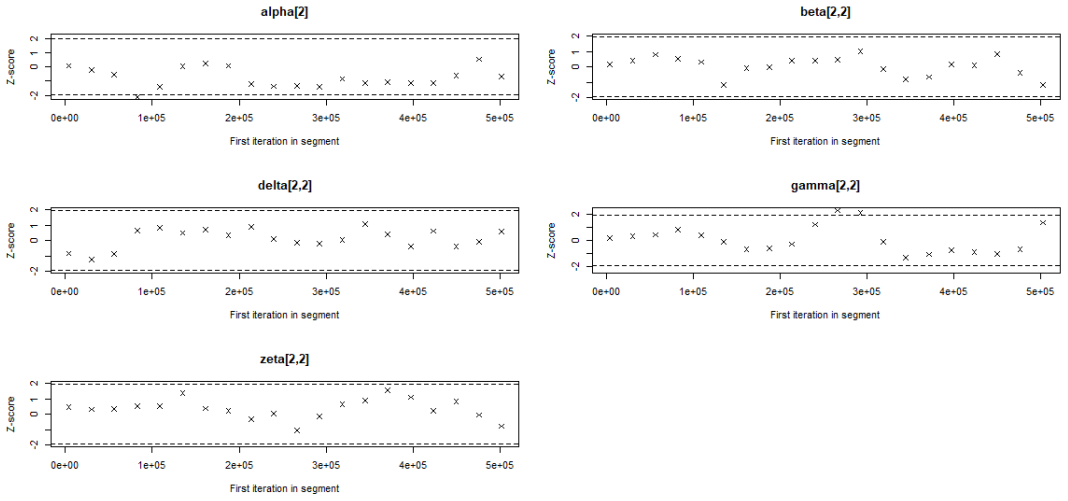
CODA package in RStudio is utilized in this paper to conduct convergence checks.

5.6.1 Model 1 Convergence Tests

5.6.1.1 Geweke Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

Fraction in 1st window = 0.1
Fraction in 2nd window = 0.5

  alpha[2]  beta[2,2] delta[2,2] gamma[2,2]  zeta[2,2]
   0.07814    0.14547   -0.84834    0.17397    0.46218
```

From the output, we observe that all Z values are within -2 and 2, indicating no differences in the means for the first and last sets of iterations. Z-scores plot can be reviewed below.



5.6.1.2 Raftery and Lewis Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800


Quantile (q) = 0.025
Accuracy (r) = +/- 0.005
Probability (s) = 0.95

            Burn-in  Total Lower bound  Dependence
            (M)      (N)   (Nmin)       factor (I)
 alpha[2]   60       84680 3746         22.6
 beta[2,2]  40       77440 3746         20.7
 delta[2,2] 40       78620 3746         21.0
 gamma[2,2] 40       79140 3746         21.1
 zeta[2,2]  40       77700 3746         20.7
```

From this output, we conclude that a larger sample of size equal to 84680 iterations (which is the maximum of all N) is required to obtain the prespecified accuracy for the 2.5% quantile. No additional burnin is needed since M is generally low (here 3999 iterations have been already removed). I for all parameters are high, indicating high autocorrelations for these parameters and that a thinning interval may be required to make observations independent (here we use 20).

5.6.1.3 Heidelberger and Welch Stationarity and Interval Halfwidth Tests

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

Precision of halfwidth test = 0.1

           Stationarity start     p-value
           test         iteration
alpha[2]   passed       1         0.235
beta[2,2]  passed       1         0.854
delta[2,2] passed       1         0.825
gamma[2,2] passed       1         0.668
zeta[2,2]  passed       1         0.701

           Halfwidth Mean    Halfwidth
           test
alpha[2]   passed    -0.4993 0.00770
beta[2,2]  passed    -0.3440 0.00740
delta[2,2] failed     0.0496 0.00826
gamma[2,2] passed    -0.4343 0.00859
zeta[2,2]  passed    -0.7408 0.00962
```

This output indicates that all tests have been passed and convergence has been reached except for delta.

5.6.1.4 Autocorrelations

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

, , alpha[2]

         alpha[2] beta[2,2] delta[2,2] gamma[2,2] zeta[2,2]
Lag 0    1.00e+00  -0.39477  -0.380079   -0.18492 -1.14e-01
Lag 20   1.17e-01  -0.04627  -0.057838   -0.02626 -4.16e-03
Lag 100  2.63e-04  -0.00347  -0.003971    0.00379 -2.54e-04
Lag 200  4.64e-05  -0.00254  -0.000642   -0.00291  6.57e-03
Lag 1000 8.08e-03  -0.00692  -0.002724   -0.00531  8.98e-06

, , beta[2,2]

          alpha[2] beta[2,2] delta[2,2] gamma[2,2] zeta[2,2]
Lag 0    -0.394771   1.00000  -0.277715   0.090298   0.13422
Lag 20   -0.064725   0.06722  -0.013107   0.023079   0.02577
Lag 100   0.004707  -0.00276   0.004072  -0.008001  -0.00359
Lag 200   0.001395   0.00649   0.000259  -0.001488  -0.00846
Lag 1000  0.000471   0.00185  -0.000962  -0.000799   0.00234

, , delta[2,2]

          alpha[2] beta[2,2] delta[2,2] gamma[2,2] zeta[2,2]
Lag 0    -0.380079  -0.27771   1.000000  -0.272266 -0.154661
Lag 20   -0.063375  -0.04043   0.102982  -0.010663 -0.014893
Lag 100  -0.002071   0.00130   0.002071  -0.000347  0.004473
Lag 200  -0.000564  -0.00157  -0.000422   0.009361 -0.005398
Lag 1000 -0.005971   0.00239   0.000805  -0.001275  0.000842

, , gamma[2,2]

          alpha[2] beta[2,2] delta[2,2] gamma[2,2] zeta[2,2]
Lag 0    -0.184924  0.090298  -2.72e-01   1.00e+00 -0.355050
Lag 20   -0.019889  0.043803  -3.85e-02   5.68e-02 -0.017988
Lag 100  -0.002179  0.007017  -6.96e-04   3.50e-03  0.001687
Lag 200  -0.003162 -0.000107   7.34e-05  -4.26e-05 -0.000192
Lag 1000  0.000746 -0.000116  -4.10e-04   1.03e-03  0.006585

, , zeta[2,2]

          alpha[2] beta[2,2] delta[2,2] gamma[2,2] zeta[2,2]
Lag 0    -0.114092   0.13422   -0.15466  -3.55e-01   1.00000
Lag 20    0.000283   0.02287   -0.00886  -3.87e-02   0.04352
Lag 100   0.003235  -0.00652    0.00499  -4.61e-03  -0.00142
Lag 200   0.005001   0.00472   -0.00902  -2.85e-03   0.00237
Lag 1000 -0.002486  -0.00274    0.00684   3.88e-05   0.00078
```

5.6.1.5 Cross-Correlations

	alpha[2]	beta[2,2]	delta[2,2]	gamma[2,2]	zeta[2,2]
alpha[2]	1.000	-0.3948	-0.380	-0.1849	-0.114
beta[2,2]	-0.395	1.0000	-0.278	0.0903	0.134
delta[2,2]	-0.380	-0.2777	1.000	-0.2723	-0.155
gamma[2,2]	-0.185	0.0903	-0.272	1.0000	-0.355
zeta[2,2]	-0.114	0.1342	-0.155	-0.3550	1.000

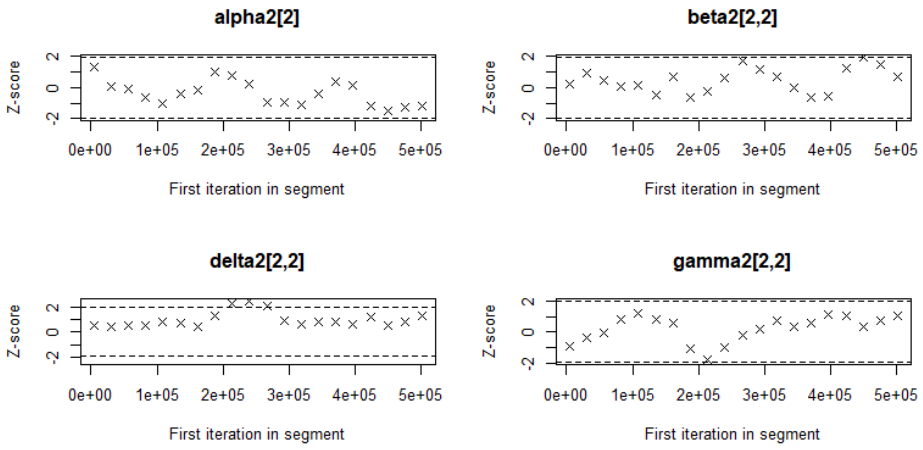
5.6.2 Model 2 Convergence Tests

```
Abstracting alpha2[2] ... 49800 valid values
Abstracting beta2[2,2] ... 49800 valid values
Abstracting delta2[2,2] ... 49800 valid values
Abstracting gamma2[2,2] ... 49800 valid values
Checking effective sample size ...OK
CODA Main Menu
```

5.6.2.1 Geweke Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

$model2codaoutput2.txt

Fraction in 1st window = 0.1
Fraction in 2nd window = 0.5

  alpha2[2]  beta2[2,2] delta2[2,2] gamma2[2,2]
     1.3440      0.1955      0.4948     -0.9547
```

From the output, we observe that all Z values are within -2 and 2, indicating no differences in the means for the first and last sets of iterations. Z-plots are presented below.



5.6.2.2 Raftery and Lewis Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800


Quantile (q) = 0.025
Accuracy (r) = +/- 0.005
Probability (s) = 0.95

             Burn-in  Total  Lower bound  Dependence
             (M)      (N)    (Nmin)       factor (I)
 alpha2[2]   60       87160  3746         23.3
 beta2[2,2]  40       78100  3746         20.8
 delta2[2,2] 120      160600 3746         42.9
 gamma2[2,2] 40       76040  3746         20.3
```

From this output, we conclude that a larger sample of size equal to 87160 iterations (which is the maximum of all N) is required to obtain the prespecified accuracy for the 2.5% quantile. No additional burnin is needed since M is generally low (here 3999 iterations have been already removed). I for all parameters are high, indicating high autocorrelations for these parameters and that a thinning interval may be required to make observations independent (we use 20 as interval in the models of this work).

5.6.2.3 Heidelberger and Welch Stationarity and Interval Halfwidth Tests

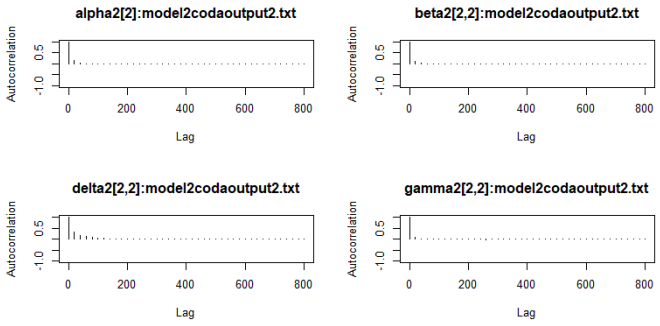
```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

Precision of halfwidth test = 0.1


            Stationarity start     p-value
            test         iteration
alpha2[2]   passed       1         0.765
beta2[2,2]  passed       1         0.841
delta2[2,2] passed       1         0.332
gamma2[2,2] passed       1         0.974

            Halfwidth Mean   Halfwidth
            test
alpha2[2]   passed    -0.512 0.00807
beta2[2,2]  passed     0.434 0.00785
delta2[2,2] passed    -1.211 0.03719
gamma2[2,2] passed    -1.537 0.01056
```

This output indicates that all tests have been passed and convergence has been reached.

5.6.2.4 Autocorrelations within Each Chain

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

, , alpha2[2]

         alpha2[2] beta2[2,2] delta2[2,2] gamma2[2,2]
Lag 0      1.00000  -0.613638    -0.04984    -0.54681
Lag 20     0.14471  -0.112016    -0.01239    -0.10839
Lag 100    0.00128  -0.002288    -0.00608    -0.00148
Lag 200   -0.00540   0.000735     0.00288     0.00237
Lag 1000  -0.00583   0.010527    -0.00602     0.00792

, , beta2[2,2]

         alpha2[2] beta2[2,2] delta2[2,2] gamma2[2,2]
Lag 0    -0.613638    1.00000    -0.03698     0.25037
Lag 20   -0.124880    0.09541     0.00227     0.09057
Lag 100   0.000337    0.00173     0.00362    -0.00373
Lag 200   0.003930   -0.00307    -0.00192    -0.00277
Lag 1000  0.004260   -0.01333     0.00607    -0.00597

, , delta2[2,2]

         alpha2[2] beta2[2,2] delta2[2,2] gamma2[2,2]
Lag 0     -0.04984  -3.70e-02     1.00000     0.00918
Lag 20    -0.00727   3.23e-05     0.32141     0.01073
Lag 100    0.00571  -8.45e-03     0.04696    -0.00570
Lag 200    0.00307  -6.55e-03    -0.00184    -0.00472
Lag 1000  -0.00166  -8.23e-03    -0.00387     0.00232

, , gamma2[2,2]

         alpha2[2] beta2[2,2] delta2[2,2] gamma2[2,2]
Lag 0     -0.54681    0.25037     0.00918    1.000000
Lag 20    -0.11544    0.08692     0.01055    0.090164
Lag 100    0.00351    0.00521     0.00105    0.000294
Lag 200    0.00146    0.00368     0.00100    0.002712
Lag 1000   0.01163   -0.01145    -0.00464   -0.009448
```

5.6.2.5 Autocorrelations



5.6.2.6 Cross-Correlations

```
               alpha2[2] beta2[2,2] delta2[2,2] gamma2[2,2]
alpha2[2]       1.0000     -0.614    -0.04984    -0.54681
beta2[2,2]     -0.6136      1.000    -0.03698     0.25037
delta2[2,2]    -0.0498     -0.037     1.00000     0.00918
gamma2[2,2]    -0.5468      0.250     0.00918     1.00000
```

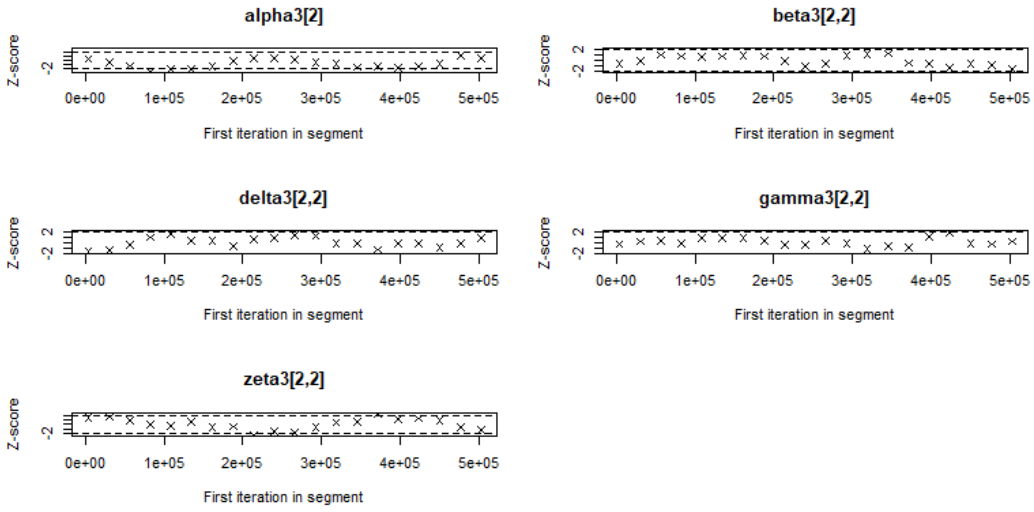
5.6.3 Model 3 Convergence Tests

```
Abstracting alpha3[2] ... 49800 valid values
Abstracting beta3[2,2] ... 49800 valid values
Abstracting delta3[2,2] ... 49800 valid values
Abstracting gamma3[2,2] ... 49800 valid values
Abstracting zeta3[2,2] ... 49800 valid values
Checking effective sample size ...OK
```

5.6.3.1 Geweke Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800


Fraction in 1st window = 0.1
Fraction in 2nd window = 0.5

  alpha3[2]  beta3[2,2] delta3[2,2] gamma3[2,2]  zeta3[2,2]
     0.3209     -0.6433     -1.6937     -0.3015      1.3788
```

From the output, we observe that all Z values are within -2 and 2, indicating no differences in the means for the first and last sets of iterations. Z-plots are provided below.



5.6.3.2 Raftery and Lewis Convergence Diagnostic

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

Quantile (q) = 0.025
Accuracy (r) = +/- 0.005
Probability (s) = 0.95

             Burn-in  Total  Lower bound  Dependence
             (M)      (N)    (Nmin)       factor (I)
 alpha3[2]   40       77200  3746         20.6
 beta3[2,2]  40       75240  3746         20.1
 delta3[2,2] 120      165960 3746         44.3
 gamma3[2,2] 180      263580 3746         70.4
 zeta3[2,2]  40       77380  3746         20.7
```

From this output, we conclude that a larger sample of size equal to 77200 iterations (which is the maximum of all N) is required to obtain the prespecified accuracy for the 2.5% quantile. No additional burnin is needed since M is generally low (here 3999 iterations have been already removed). I for all parameters are high, indicating high autocorrelations for these parameters and that a thinning interval may be required to make observations independent (we use 20 as interval in the models of this work).

5.6.3.2 Heidelberger and Welch Stationarity and Interval Halfwidth Tests

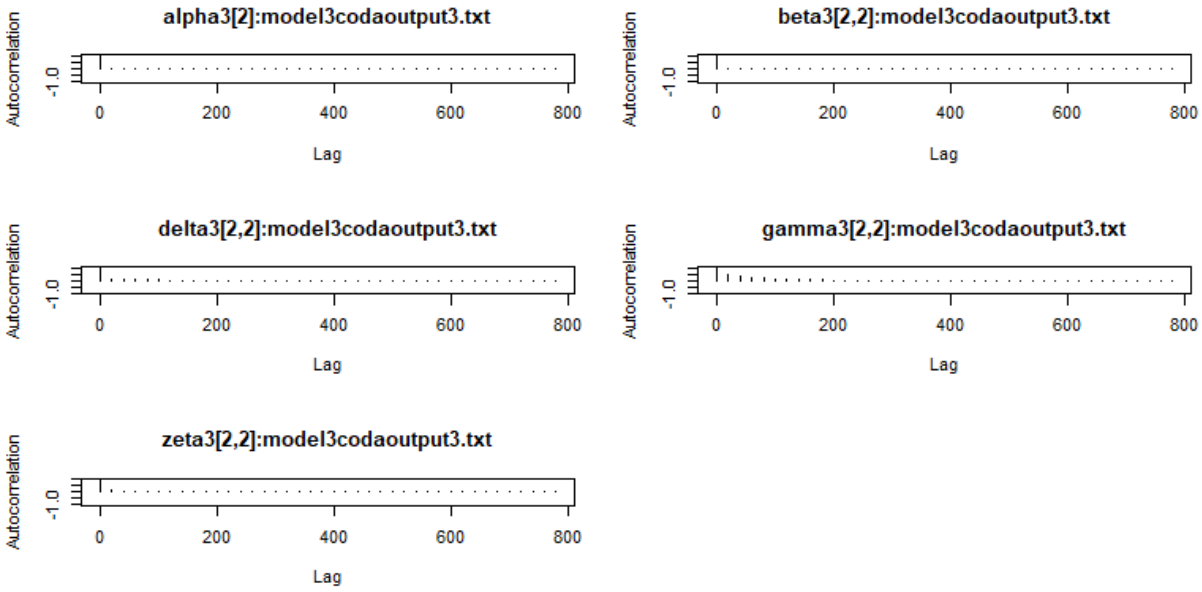
```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

Precision of halfwidth test = 0.1

            Stationarity start     p-value
            test         iteration
alpha3[2]   passed       1         0.282
beta3[2,2]  passed       1         0.768
delta3[2,2] passed       1         0.818
gamma3[2,2] passed       1         0.762
zeta3[2,2]  passed       1         0.787

            Halfwidth Mean    Halfwidth
            test
alpha3[2]   passed    -0.4626 0.00634
beta3[2,2]  passed     0.0770 0.00677
delta3[2,2] passed    -0.8781 0.01142
gamma3[2,2] passed    -1.9258 0.06713
zeta3[2,2]  failed    -0.0816 0.01081
```

This output indicates that all tests have been passed and convergence has been reached except for zeta.

5.6.3.2 Autocorrelations within Each Chain

```
Iterations used = 4000:999980
Thinning interval = 20
Sample size per chain = 49800

, , alpha3[2]

         alpha3[2] beta3[2,2] delta3[2,2] gamma3[2,2] zeta3[2,2]
Lag 0      1.00000  -0.391285   -0.340272   -0.073161   -0.08529
Lag 20     0.05377  -0.027291   -0.038783   -0.021416    0.01509
Lag 100   -0.00295   0.000154    0.004511   -0.006865    0.00267
Lag 200   -0.00341  -0.000599    0.004542    0.005067   -0.00554
Lag 1000   0.00906  -0.004963   -0.000373   -0.000998   -0.00879

, , beta3[2,2]

         alpha3[2] beta3[2,2] delta3[2,2] gamma3[2,2] zeta3[2,2]
Lag 0     -0.39128    1.00000   -0.006034   -0.076612  -0.116559
Lag 20    -0.03896    0.02668    0.023134   -0.014194  -0.006156
Lag 100    0.00311    0.00195   -0.005990   -0.004633   0.002344
Lag 200    0.00603    0.00138   -0.000695   -0.007626   0.000499
Lag 1000  -0.00353   -0.00472    0.006219    0.000356  -0.000572

, , delta3[2,2]

         alpha3[2] beta3[2,2] delta3[2,2] gamma3[2,2] zeta3[2,2]
Lag 0     -0.34027  -0.006034     1.00000     0.02171   -0.55742
Lag 20    -0.05099   0.012170     0.14429     0.00113   -0.11618
Lag 100   -0.00160  -0.002989     0.02301     0.00091   -0.02422
Lag 200    0.00433   0.000469     0.00469     0.00901   -0.00410
Lag 1000  -0.00377   0.002366    -0.00129     0.00439   -0.00052

, , gamma3[2,2]

         alpha3[2] beta3[2,2] delta3[2,2] gamma3[2,2] zeta3[2,2]
Lag 0     -0.07316   -0.07661    0.021708      1.0000  -0.000527
Lag 20    -0.01061   -0.01514    0.006197      0.5040  -0.000662
Lag 100    0.00218   -0.00532   -0.005008      0.1329   0.005321
Lag 200    0.00374   -0.00532    0.000146      0.0146  -0.002087
Lag 1000   0.00420   -0.00345   -0.001816      0.0046   0.001562

, , zeta3[2,2]

         alpha3[2] beta3[2,2] delta3[2,2] gamma3[2,2] zeta3[2,2]
Lag 0    -0.085288  -0.116559    -0.55742   -0.000527    1.00000
Lag 20    0.037724  -0.006267    -0.13912    0.007089    0.12055
Lag 100   0.004626  -0.000841    -0.01934    0.000181    0.02297
Lag 200   0.001945  -0.004837    -0.00654   -0.007745    0.00866
Lag 1000 -0.000163  -0.004242    -0.00254   -0.002577    0.00707
```

5.6.3.3 Autocorrelations



5.6.3.4 Cross-Correlations

	alpha3[2]	beta3[2,2]	delta3[2,2]	gamma3[2,2]	zeta3[2,2]
alpha3[2]	1.0000	-0.39128	-0.34027	-0.073161	-0.085288
beta3[2,2]	-0.3913	1.00000	-0.00603	-0.076612	-0.116559
delta3[2,2]	-0.3403	-0.00603	1.00000	0.021708	-0.557422
gamma3[2,2]	-0.0732	-0.07661	0.02171	1.000000	-0.000527
zeta3[2,2]	-0.0853	-0.11656	-0.55742	-0.000527	1.000000

CHAPTER VI INTEGRATIVE ANALYSIS AND RESEARCH PROPOSITIONS

The integrative results and findings of this dissertation work lead to further research propositions for investigating organizational product deletion management and relationships to sustainable supply chain management.

The following propositions are derived from the literature review (Chapter 2), qualitative (Chapter 4) and quantitative (Chapter 5) study results, using the research questions from Section 2.6 as guidelines. The propositions are exemplary and provide potential directions for further investigation.

6.1 Strategic Product Deletion Management

Research question 1: What are the organizational processes and routines for product deletion? What is the role of the supply chain in these processes and routines?

The resource-based view can inform strategic product deletion management. Increasing technological and market dynamics present companies with both business opportunities and risks which require organizations to develop their capabilities to remain competitive. Greater market dynamics require organizations to develop product portfolios in consonance with their competitive environment. Product and product portfolio development – which is the essence of product management strategy – has led to an interest by both academics and practitioners in product proliferation (Rothwell et al., 1974), innovation and new product development (Cooper, 1979; Zirger and Maidique, 1990).

Only focusing on product addition has led to an incomplete understanding of product portfolio management. Identifying and withdrawing products that no longer contribute to the organizational competitiveness remains a gap in both literature and practical exercises.

This dissertation work builds upon the context of discovery by synthesizing existing ideas and combining unconnected bodies of knowledge (Yadav, 2010). The integrative conceptual framework presented in Chapter 2 attempts to combine marketing, supply chain management, sustainability and

product deletion literatures by explicating the influence of product deletion on supply chain management competencies, processes and sustainability performance.

Product deletion, often a marketing decision, is triggered by consumer needs, and is led by the research and development and/or the product management function (Zhu et al., 2018b). However, the findings of this research indicate that product deletion not only affects the product management function but also influences several aspects of inter-actor relational rents. These actors include customers, distributors, suppliers, and competitors (Ashayeri et al., 2015; Muir & Reynolds, 2011; Shah, 2015). These influences, according to the qualitative findings, government, social norms, and community concerns are integral to product deletion management.

From a supply chain and its network perspective, any elimination from the product line affects various dimensions. Issues include: (1) reactions from and relationships with channel partners (retailers and distributors); (2) manufacturing capacity and capabilities including production runs, product-process matrix (Alexander, 1964; Hamelman & Mazze, 1972); (3) production, sourcing and distribution compatibility with other products of the firm (Banville & Pletcher, 1974), and (4) capacity utilization (Avlonitis, 1993).

From an organizational and individual perspective, a number of observations on organizational routines and individual behaviors are made. Antecedents of marketing and finance are primarily customer driven. Supply chain antecedents derive from suppliers, manufacturers, distributors, and retailers. Sustainability antecedents are societal and community oriented. Individual power is involved in product deletion practices. Expert power and legitimate power are identified in the qualitative study. Decision maker's organizational role or position, as well as their knowledge and expertise, will affect their department's power in the product deletion decision making process. The power play creates uncertainty leading to either positive or negative outcomes. Biases exist when individual power comes into play. Individual personal preference (i.e.: product attachment) to certain products might decrease the rationality of product deletion.

These observations help arrive at the first two general propositions:

Proposition 1: To make sustained product and product portfolio competitiveness, product deletion, equally critical and crucial to product addition, requires investigation from multiple levels of analysis. These analysis levels include macro (institutional), meso (supply chain and network) and micro (organizational and individual) boundaries; and relate to underlying strategic organizational logic and routines.

Proposition 2: For sound strategic product deletion processes and routines, the integration of marketing, finance, supply chain management and sustainability perspectives is needed. Amongst all, supply chain characteristics are important and should receive equal or greater emphasis in determining product deletion candidacy. A comprehensive sustainable supply chain performance matrix including flexibility, cost, quality, time, social and environmental sustainability can be explored, developed and used.

Modern business perspectives state that companies are no longer competing as individual entities in the marketplace, but as supply chains. Among the more vexing problems of a business organization are decisions relating to supply chain collaborations with actors as well as interactions with competitors. Product deletion decisions are made not only within firms but also within supply chain networks, where trade-offs must be made among inter-firm resources and routines (Dyer & Singh, 1998). These inter-firm resources and routines include relation-specific assets, knowledge-sharing routines, complementary resources/capabilities, and effective governance. Integrating the relational view with the resource-based view, product deletion decisions go beyond a decision that enhance or undermine intra-organizational resources capabilities but a decision that gain or lose inter-organizational resources capabilities.

Proposition 3: Product deletion, not only relates to internal resources for competing firms by contributing to internal resources that are rare, valuable, and non-substitutable; but also impacts relational rents that involve multiproduct firms interlocking with shared-resource linkages from supply

chain relationships. Stakeholders should be involved in the decision-making processes including suppliers, clients, customers, government and the environment.

The identified theoretical frameworks and organizational routines for product deletion is critical and subject to supply chain behavior, organizational behavior and individual behavior. The theory development (Chapter 2, see Figure 2.2) and qualitative grounded theory (Chapter 4, see Figure 4.2) in this dissertation helps set the stage for a unifying framework ("middle theory") for product deletion. For this complex and strategically focused decision, multiple theoretical perspectives from strategy, operations, marketing, economics and sustainability may exist and interact.

Proposition 4: A systematic further investigation of the product deletion decision triggering antecedents is required to operationalize an integrative theoretical framework. Assimilating managerial behavior and mind-sets as well as general organizational culture, value and behavior, are necessary.

6.2 Product Deletion and Sustainable Supply Chain Management

Research question 2: Will supply chain and sustainability dimensional factors impact product deletion decisions? How influential are these supply chain and sustainability factors when compared to other organizational factors, such as marketing, sales, and financial factors?

Product deletion typically goes through identification, evaluation, analysis and implementation. Product deletion antecedents can be manifold. Using the qualitative case studies, major antecedent dimensions relate to key organizational functions, specifically marketing, supply chain, finance and sustainability. Marketing antecedents and finance antecedents align with the literature streams. Market performance including sales and financial returns are often the most common aspects for product deletion triggers. Findings also provide evidence that companies also delete products because of operational reasons and sustainability concerns within supply chains. The supply chain and sustainability functions and antecedents are in addition to the existing product deletion literature.

Product deletion routines occur on different time bases for different firms. The finance function often initiates product deletion processes and involves supply chain and marketing functions. The qualitative study shows marketing has the most power in product deletion decision making processes, followed by the supply chain function. Collaboration and communication amongst key functions is based on organizational strategic planning goals. The quantitative Bayesian analysis further supports the qualitative findings that financial performance is still the most common antecedent for product deletion candidate identification. Overall supply chain characteristics form a better indicator to determine a product's candidacy for deletion. Our findings indicate improved supply chain performance helps decrease the likelihood of deletion.

Proposition 5: Product deletion decision making processes involve identification, evaluation, analysis and implementation. Marketing, finance, supply chain and sustainability functions each engage in these four phases. The former two functions often initiate product deletion identification. The latter two functions, supply chain and sustainability, provide better indicators for product deletion analysis and outcome prediction. Integrated organizational cross-functional involvement is needed. Supply chain and sustainability characteristics are significant and should receive equal or greater emphasis than financial and marketing factors.

Within the supply chain dimension, our qualitative findings indicate that product capacity, manufacturing capability, product-process matrix and supply chain disruptions in sourcing activities are the fundamental antecedents. Quantitative findings further strengthen the qualitative findings and show flexibility has the largest influence on product deletion. Internal supply chain capacity and capabilities are the most important flexibility measurements. Managers should focus on keeping low manufacturing complexity -- simple and lean -- and maintaining fundamental manufacturing processes and unique parts developed in house (Zhu et al., 2018a). Supply chain cost is the best indicator for product deletion, which further demonstrates cost triggers are still the most explicit and leading factor. The higher supply chain costs are, the more likely this product will be deleted. Supply chain cost allocated to each product is

critical for good product performance measurement. A cost analysis is needed at the supply chain level and at the product line and product level.

Proposition 6: Critical supply chain dimension factors that affect product deletion involve product capacity, manufacturing capability, product-process matrix and supply chain disruptions in sourcing. Product deletion can free up flexibility to internal organizational capabilities (resource-based view); and intra- and inter- supply chain capacity (relational view). Product deletion can also free up capital resources (supply chain cost) that could be repurposed and reallocated to core product portfolio items.

Within the sustainability dimension, improved performance on social and environmental factors reduce the likelihood of product deletion. Both qualitative and quantitative studies show resource consumption efficiency and social impact are the major antecedents. Resource consumption relates to waste, emissions and the 5Rs, while social impact is associated with stakeholder benefits. Bayesian models further demonstrate that resources consumption efficiency form the best indicator to determine a product deletion decision. High resource consumption leads to higher odds of deletion. Consumption efficiency in both material and energy should be included in evaluating products. Stakeholder benefits are the most influential dimension for product deletion. These stakeholders include society, community, governments, regulators, media and the natural environment.

Proposition 7: Sustainability, often a neglected consideration for product deletion, is proven to effect and be influenced by product deletion. Environmental and social sustainability should be emphasized in product deletion in addition to economic sustainability.

Proposition 7a: Comprehensive product deletion management should incorporate social and environmental sustainability considerations including resource consumption efficiency, waste management, recycle and repurpose value and social impact on stakeholders.

Proposition 7b: Sound product deletion will contribute to organizational sustainability development in terms of long-term profitability, corporate social responsibility, and pro-environmental performance in resources consumption and reverse supply chain activities.

6.3 Product Deletion Decision Making Tool Development

Research question 3: Can a predictive model/choice model be developed for product deletion decisions? This model would help arrive at decisions such as: which one(s) to delete, when and how many, what are the model characteristics and its practical usefulness; and how can the model be improved?

Product deletion was first introduced to the literature focusing on resource allocation concerns. Firms started to realize that proliferation was draining their valuable resources and they needed to shift their focus from proliferation to rationalization by deleting weak products from their product lines (Johnson, 1975).

The existing efforts of tool development focus on resource allocation processes. These efforts have taken two directions. One is a product portfolio approach. At the strategic level a host of conceptual and analytical tools have been suggested for determining the product portfolio mix, its composition and complexity (Devinney and Stewart, 1988; Goli et al., 2019). The second is an investment return approach. At a more tactical level, scoring procedures (Dean and Nishry, 1965), present value computations (Robey et al., 2019), and various process models of technological innovation (Johne, 2018) have been developed. Generic organizational strategic decision methodologies, for example the stage-gate model found in a qualitative case study, are used product deletion decisions. The usefulness of product portfolio models and investment return models are well documented in the literature and have been applied in practice. These models are not without their problems, however. No specific tools for product deletion have been developed, although some specific conceptual models have recently emerged (Bai et al., 2018; Zhu et al., 2018b).

Product deletion is a complex decision for any company. Considering the nature of this decision, product deletion indicates a certain a level of failure in strategic development. Firms are not willing to share much information about product deletion. Limited access to data makes tool development difficult. Product deletion involves many actors at the institutional, supply chain, and individual levels. Historical product data does not represent the complete analysis. Decision maker value, expertise and behavior are also critical to product deletion. A statistical tool that incorporates both subjective and objective factors is needed. Managerial beliefs are valuable for real business application.

Not only is product deletion decision making complex; product deletion implementation is also complex. There are foreseeable implementation risks. One of the direct risks is loss of sales from certain customer bases. One of the quotes in the qualitative case study states *"The removal of products is a huge endeavor that requires considerable resources and often do not meet our expectations."* Therefore, both inferencing and predictive models to simulate business scenarios and predict possible outcomes are needed for managerial implementation support.

Proposition 8: Bayesian analysis, a method of incorporating managerial beliefs with archival data, can be used to develop inferencing and predictive tools for product deletion decision making.

Proposition 9: More comprehensive tools are needed for product deletion decision implementation. The desired tools should be able to facilitate: (1) product deletion implementation for internal and external supply chains; (2) when to inform different supply chain actors; and (3) the degree of product deletion related to products, manufacturing, inventory, transactions amongst business partners; and (4) predict the consequences (positive or negative) of product deletion.

CHAPTER VII DISCUSSION AND CONCLUSION

This concluding chapter summarizes this dissertation, and discusses implications, limitations and future research directions.

7.1 Summary

Organizations' long-term survival depends upon their product portfolio management, including adding new products to the portfolio, replacing existing products with new ones, or modifying existing products (Zhu et al., 2018a). Deleting a product is also a critical decision in product portfolio management. Product deletion may benefit firms across various aspects including organizational, financial, operational, marketing and sustainability dimensions. Resources freed up from the deleted products can be redeployed into stronger products that can deliver greater returns. Although product deletion offers several advantages to a firm, it is a complex strategic choice as multiple factors influence and are influenced by this decision, such as financial performance metrics and drivers, internal and external stakeholders, organization's strategies and goals.

This dissertation alters the traditional perspective that adding new products is always beneficial to firms; product deletion is equally critical to organizational strategic management. The contributions of this dissertation work include: (1) contextually conceptualizing the product deletion decision, an important strategic concern for organizations, based on an integrative theoretical foundation of resource-based view and relational view; (2) filling an important gap by integrating product deletion, supply chain management and sustainability literatures; (3) developing a grounded theory to summarize antecedent factors, decision making routine, and product deletion outcomes through case studies as a qualitative approach; and (4) formulating a product deletion decision-making model using Bayesian analysis, which aids in enhancing organizational performance in marketing, supply chain, finance and sustainability. The development and application of a flexible and replicable Bayesian model provides significant opportunity for future research, model expansion, and practical validation.

7.2 Theoretical Implications

This dissertation work, being one of the first initiatives integrating product deletion, supply chain management and sustainability literatures, is meant to investigate product deletion relationships in supply chain management including sustainability management from a joint perspective of the resource-based view and the relational view. This paper challenges the traditional perspective that marketing and branding objectives drive and initiate all product deletion decisions. Whereas, this study investigates how goals related to broader strategic development including marketing, finance, supply chain and sustainability, can influence product deletion decisions.

Relationships in this study are conceptualized from the product deletion, supply chain management, and sustainability and lean management literature. The conceptualized model serves as a contextual tool to facilitate firms' product deletion decision-making evaluation; and provides both a conceptual and practical foundation for further investigation of product deletion and its impact on organizations. The conceptualizations serve as theoretical foundation for both qualitative grounded theory case studies and quantitative Bayesian analysis.

Another major theoretical implication of this study is that the decision-making exercise is more complex. Complex decision tools, methods, and behavioral theoretical developments are needed. Group decision making tools and relationships play a critical role in effective implementation. The consensus building aspects for these strategic decisions are needed with appropriate study designs. There are a number of directions for future research, outlined later in this section, that need to be further investigated related to some of the modeling and behavioral concerns. In addition to the decision modeling theory, there are application theoretic concerns. Much of the research on product portfolio management is on new product development and product proliferation. The further investigation of product deletion within product portfolio and lean project/product management is thoughtfully required.

7.3 Managerial Implications

Product deletion is a strategic decision for all firms. A strategic decision-making process may become complex and involves both internal and external firm characteristics, such as resources, strategy, marketing performance, financial performance, supply chain processes and performance competencies, and stakeholders including social and environmental concerns.

The integrated strategic decision model of case studies and Bayesian analysis proposed in this dissertation is designed to facilitate the product deletion decision for firms that aim to achieve a broader strategic perspective that involve multiple level of considerations.

The model presented incorporates multiple dimensions of antecedent factors to help structure the decision in a way that guides decision makers. Based on qualitative findings, Bayesian analysis becomes valuable in the model by explicitly considering the interactions amongst the deletion making factors with regard to the likelihood of deletion or retention given all possible business scenarios.

The historical data gathered supported the construction of both inferencing and predictive models. The foundational philosophy of Bayesian analysis is based on belief adjustment. Considering the nature of product deletion decisions, both subjective evaluation and objective observation are necessary and critical to developing a sound decision. Bayesian analysis systematically incorporates subjective evaluation to inform a prior distribution, by adding new information from archival data, the Bayesian rule eventually formulates a posterior distribution; which helps adjust the prior distribution from managerial belief; hence the Bayesian posterior distribution is expected to provide informative value to better facilitate managerial decision rationalization.

Qualitatively and quantitatively, together, the model characteristics help arrive at a strategic and systemic decision on deleting a product and optimizing a product portfolio. The integrated model of grounded theory and Bayesian analysis, in this dissertation, aims to help facilitate the product deletion decision across multiple organizational functions or departments. Managers from marketing, finance,

operations, and environmental sustainability can cooperate under the guidance of this model to make a comprehensive and strategic product deletion decision. The integrated efforts and the decision can meet organizational goals while considering social and environmental sustainability impact. The model is flexible and replicable, i.e., it can be modified to suit different organizational objectives and contexts. Firms and management can involve selected sets of factors within the model development in different business scenarios. Firms with specific organizational goals can simulate different scenarios by creating variations in the sub-factors, factors and dimensions to arrive at a product deletion decision in different business scenarios and situations.

The model presented in this paper can address various strategic and operational concerns. If time, resources, and more detailed evaluations are needed, managers can incorporate many cross-functional department and individual perspectives into the model. Time series can also add additional value when considering longitudinal data into the Bayesian analysis.

Further practical implications relate to how to effectively implement this decision model such as larger secondary data acquisition. The data can be generated in different levels, country level, industry level, firm level, brand level, product line level, product level, and SKU level.

Integration with other methodologies is also applicable for Bayesian models. One potential is integrating with multi-criteria decision making tools such as the Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) for preliminary factor priorities analysis (Zhu et al., 2018a). One of the advantages of the AHP/ANP process is that it provides a comprehensive structure for factor evaluation. In a group setting, discussion around the factors and their relationships and relative importance should occur. It can be a guide for a rich and comprehensive discussion associated with the decision environment. Of course, in a group team decision setting various group dynamics, e.g. power dynamics, may also cause a distortion of the decision. Thus, practical concerns on fair and logically supported inputs in the decision environment is necessary. ANP can also consider the spillover effect of product deletion to other products within the product portfolio.

7.4 Limitations and Future Research Directions

In the model development stage, only certain dimensions and factors were included. They are mainly derived from qualitative case studies and are supported by highly cited works in the literature, but they still may not represent and capture all business situations and practical cases. In various product deletion decision environments, variations in factor incorporation for the Bayesian model might be needed; this study does not provide a required set of factors and models and these will have to be determined.

The Bayesian model with a limited set of characteristics involves the informative prior distributions. Managerial beliefs change has not been integrated in this study. Future studies can possibly trace the change of managerial beliefs by adding a certain amount of new data information at a time.

Only Bayesian analysis is used to construct the model. The application of other methodologies to model development may provide another future research direction from a methodological perspective. Model verification through an actual application and feedback is still needed to determine the feasibility, reliability, accuracy, and validity of the model.

In addition to tool development, strategic product deletion decision making can also benefit from technological innovations on supply chains. Blockchain technology governance structure is a potential key that enhances flow of information in supply chains, which can improve the quality of data available for product deletion specific. Blockchain, as a disruptive innovation, is transforming information sharing governance structures. Accurate information sharing mechanisms enabled by blockchain can provide the required inputs for effective product deletion decision making in every stage of supply chain management. Blockchain technology-supported supply chain information governance advances and enables organizational rationalization in decision-making. Significant opportunities exist for future research to incorporate technological innovation such as blockchain-supported information governance and its implications for product deletion decision making on supply chain dynamics.

Product deletion can also be investigated in the context of the circular economy. The circular economy has a variety of characterizations and definitions (Korhonen et al., 2018). It begins with the idea of materials cycles including recycling, remanufacturing, refurbishment, reuse, and reclamation. The circular economy also includes management practices that help to close-the-loop such as reverse logistics and supply chain activities. Industrial waste minimization also occurs with former wastes transformed into useful, revenue generating, byproducts. The sale of byproducts to other organizations for use in production has also been termed industrial symbiosis (Sarkis and Zhu, 2008). Given this supply chain environment, product deletions have implications on circular economy operations; in turn, circular economy activities and actions can influence product deletion decisions. The traditional linear economy presents a "make and dispose" model of product production. Within this mode, when a product is deleted, its inventory will immediately become obsolete and transform into a waste. It may be disposed, sometimes to third parties for resale purposes; or disposed of in a traditional fashion into landfills.

In a circular economic system, deleted product inventory and their finished components may be reclaimed as input in resource, energy and material loops through remanufacturing, refurbishing, reusing and recycling (Shah and Zhu, 2018). Product deletion may become, in the short-term, profitable not only from more rationalized product portfolio management, but also from the utilization of freed up resources, and materials as closed-loop input (Bai et al., 2018a).

The investigations of product deletion in a circular economy can focus on product design thinking, systems thinking, and product lifecycle extensions. Circular economy practices help to minimize resource inputs into and the waste and emission leakage out the supply chain and production system. Resources in a circular economy environment may arise from recycling approaches, efficiency improvements, and product use extensions.

7.5 Concluding Remarks

This investigation and thesis represents an initiative introducing strategic product deletion management to supply chain management. We challenge a traditional view of product portfolio growth as always beneficial to organizational competitive advantage. We also sought to introduce product deletion decisions to a broader business and organizational community include supply chain organizational actors, internal stakeholder, and societal players. Our goal was to integrate several literature streams including marketing, supply chain and sustainability disciplines and fields. This goal is meant to contribute to theory development and empirical evaluation at the nexus of these phenomenon with respect to product deletion. Our hope is that this work opens new avenues for further investigation expanding the research context and potential technological and methodological applications.

The integration of grounded theory – a qualitative methodology -- and Bayesian analysis –a quantitative methodology -- helps enrich the practical validation to this underexplored research topic. This mixed methods investigation serves to cross-validate, strengthen, and synergize. We believe that this is only the beginning of a fertile research field to help businesses, managers, scholars, and society.

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APPENDICES

Appendix A: Interview Protocol

Hello XXX, thanks for agreeing to participate in this research project. Your opinions and experiences will help build our knowledge on product management and supply chain management. Your time and patience is highly appreciated. I assure you the information you provide will be kept anonymous and confidential. Do I have the permission to audio record this conversation for future reference?

Thank you. (Continue recording if the participant agrees. Otherwise stop recording and take notes).

Please tell me something about yourself and your role in this company.

I. Age, work experience, education
II. Tenure in the company, role in the company
    A. Marketing role (e.g., brand manager)
        i. Which brand (s) and product(s) do you manage?
        ii. How long have you been managing them?
        iii. What are the different levels in the hierarchy of the marketing department?
            1. Who reports to you?
            2. Whom do you report to?
            3. Who is responsible for what activities and decision-making?
    B. Supply chain role
        i. Which brand (s) and product(s) do you manage?
        ii. How long have you been managing them?
        iii. What are the different levels in the hierarchy of the supply chain department?
            1. Who reports to you?
            2. Whom do you report to?
            3. Who is responsible for what activities and decision-making?
    C. Finance role
        i. How long have you been working in this department?
        ii. What are the different levels in the hierarchy of the Finance department?
            1. Who reports to you?
            2. Whom do you report to?
            3. Who is responsible for what activities and decision-making?
    D. Sales role
        i. Which brand (s) and product(s) do you work with?
        ii. How long have you been working with them?
        iii. What are the different levels in the hierarchy of the sales department?
            1. Who reports to you?
            2. Whom do you report to?
            3. Who is responsible for what activities and decision-making?

A. MARKETING QUESTIONNAIRE:

1. What is the structure of the marketing team in this company?
2. Please describe the company's brand portfolio and product lines.

3. How are brands and products managed in this company?
    a. Like adding and managing products, does this company also discontinue products as a part of product management? If yes, why? If not, why not?
    b. As a marketing professional, what is the role and importance of product deletion in product management?
    c. What are the pros and cons of product deletion?
    d. What factors influence the product deletion decision or are considered while deciding which products to delete?
4. How is the success of a brand measured in this company?
5. How is the success of a product measured in this company?
6. Has the company discontinued or deleted any product under a specific brand/product line?
    a. Yes. Would you please tell me more about it?
        i. Which brand (s)/product (s)?
        ii. When and why?
        iii. How? What procedure was followed to plan and implement product deletion? Please tell me more about it.
        iv. Do you think product deletion impacts marketing?
        v. What role does marketing play in product deletion activities?
            1. Major or Minor - Why do you think so?
            2. Have you or will you consider factors outside of marketing department to make product deletion decisions? Such as related to supply chain or others?
        vi. Who was involved in the decision making? (Ask about Cross functional as well as stakeholder involvement)
        vii. How was the power and role of each cross-functional department weighed in this process?
            1. Sales
            2. Finance
            3. Supply Chain
            4. Any other
        viii. Is product deletion a controversial decision which involves conflicts among departments?
            1. Do you think there is power play involved?
                a. Legitimate Power
                b. Reward Power
                c. Coercive Power
                d. Expert Power
                e. Information Power
                f. Referent Power
            2. Do you think it is an emotional decision for managers?
            3. Any other…
        ix. How was the power and role of each stakeholder weighed in this process?
            1. Customers
            2. Employees
            3. Investors
            4. Suppliers
            5. Channel Partners (Retailers, Distributors)

6. Media
7. Government
8. Any other

x. Who made the final decision? (Ask about Top Management involvement)
xi. What were the outcomes of the product deletion decision?
xii. According to you, was the deletion successful? If yes, how did you measure the success of the deletion decision? If no, why not?
xiii. How often does product deletion activity occur in this company?
xiv. Do you have any decision making tools/processes to help you manage product deletion decisions?
    1. If yes, what are they?
    2. If no, what according to you should the tool be like? What should it measure? What factors should it consider?
    3. I know of a tool but we don't use it… WHY?

b. No.
    i. Why do you think product deletion was never required?
    ii. Do you think it is important to discontinue products? If yes, Why or for what reasons? If not, why not?
    iii. What are the pros and cons of product deletion?
    iv. According to you, what factors could be considered while making the product deletion decision?
    v. According to you, what are some outcomes of discontinuing products?
    vi. According to you, how can a company measure the success of a product deletion decision?
    vii. Do you think cross-functional departments are involved in product deletion decision making? Why or Why not?
    viii. According to you, which department of these plays a vital role in the product deletion decision?
    ix. According you, who are the stakeholders that will directly or indirectly be impacted by product deletion and/or will influence the decision?
    x. According to you, if this company were to adopt product deletion, what process should it follow?
    xi. Do you know of any tool that could be used in product deletion decision making?

7. Will you consider sustainability/CSR issues in product deletion decisions?
8. Is there anything else important that you would like to share with me that we have not discussed yet?
9. Thank you so much for your time and sharing this information with me. It will be very helpful for my research.

B. SUPPLY CHAIN QUESTIONNAIRE:

1. What is the structure of the supply chain team in this company?
2. Please describe the company's brand portfolio and product lines.
3. Please tell me about major supply chain processes/activities in your company?
4. How many product lines, products, and SKUs is your company managing?
5. Does each product have a separate supply chain?

6. In making a typical product, how much of its components are outsourced and how much is made in house?
7. How does the company measure the performance of its supply chains?
    a. Competencies
    b. Sustainability
    c. Others
8. How are brands and products managed in this company?
    a. Like adding and managing products, does this company also discontinue products as a part of supply chain activity? If yes, why? If not, why not?
    b. As a supply chain professional, what is the role and importance of product deletion in product management?
    c. What are the pros and cons of product deletion?
    d. What factors influence the product deletion decision or are considered while deciding which products to delete?
9. Has the company discontinued or deleted any product under a specific brand/product line?
    a. Yes. Would you please tell me more about it?
        i. Which brand (s)/product (s)?
        ii. When and why?
        iii. How? What procedure was followed to plan and implement product deletion? Please tell me more about it.
        iv. Do you think product deletion impacts your department?
        v. What role does your department play in product deletion activities?
            1. Major or Minor - Why do you think so?
            2. Have you or will you consider factors outside of your department to make product deletion decisions? Such as related to marketing or others?
        vi. Who was involved in the decision making? (Ask about Cross functional as well as stakeholder involvement)
        vii. How was the power and role of each cross-functional department weighed in this process?
            1. Sales
            2. Finance
            3. Marketing
            4. Any other
        viii. Is product deletion a controversial decision which involves conflicts among departments?
            1. Do you think there is power play involved?
                a. Legitimate Power
                b. Reward Power
                c. Coercive Power
                d. Expert Power
                e. Information Power
                f. Referent Power
            2. Do you think it is an emotional decision for managers?
            3. Any other…
        ix. How was the power and role of each stakeholder weighed in this process?
            1. Customers
            2. Employees

3. Investors
4. Suppliers
5. Channel Partners (Retailers, Distributors)
6. Media
7. Government
8. Any other

x. Who made the final decision? (Ask about Top Management involvement)
xi. What were the outcomes of the product deletion decision?
xii. According to you, was the deletion successful? If yes, how did you measure the success of the deletion decision? If no, why not?
xiii. How often does product deletion activity occur in this company?
xiv. Do you have any decision making tools/processes to help you manage product deletion decisions?
1. If yes, what are they?
2. If no, what according to you should the tool be like? What should it measure? What factors should it consider?
3. I know of a tool but we don't use it… WHY?

b. No.
i. Why do you think product deletion was never required?
ii. Do you think it is important to discontinue products? If yes, Why or for what reasons? If not, why not?
iii. What are the pros and cons of product deletion?
iv. According to you, what factors could be considered while making the product deletion decision?
v. According to you, what are some outcomes of discontinuing products?
vi. According to you, how can a company measure the success of a product deletion decision?
vii. Do you think cross-functional departments are involved in product deletion decision making? Why or Why not?
viii. According to you, which department of these plays a vital role in the product deletion decision?
ix. According you, who are the stakeholders that will directly or indirectly be impacted by product deletion and/or will influence the decision?
x. According to you, if this company were to adopt product deletion, what process should it follow?
xi. Do you know of any tool that could be used in product deletion decision making?

10. Will you consider sustainability/CSR issues in product deletion decisions?
11. Is there anything else important that you would like to share with me that we have not discussed yet?
12. Thank you so much for your time and sharing this information with me. It will be very helpful for my research.

C. FINANCE QUESTIONNAIRE:

1. What is the structure of the finance team in this company?
2. What product-level activities affect a firm's overall financial performance?

3. How is a brand's and product's performance measured in this company?
4. What impacts a product's financial performance?
5. What will finance department usually do to improve a product's financial performance?
6. What is the relationship between a product's financial performance and its overall performance? In other words, will you consider a poorly financially performing product a poorly performing product overall and should be discontinued?
7. Has the company discontinued or deleted any product under a specific brand/product line?
    a. Yes. Would you please tell me more about it?
        i. Which brand (s)/product (s)?
        ii. When and why?
        iii. How? What procedure was followed to plan and implement product deletion? Please tell me more about it.
        iv. Do you think product deletion impacts your department?
        v. What role does your department play in product deletion activities?
            1. Major or Minor - Why do you think so?
            2. Have you or will you consider factors outside of your department to make product deletion decisions? Such as related to marketing or others?
        vi. Who was involved in the decision making? (Ask about Cross functional as well as stakeholder involvement)
        vii. How was the power and role of each cross-functional department weighed in this process?
            1. Sales
            2. Supply chain
            3. Marketing
            4. Any other
        viii. Is product deletion a controversial decision which involves conflicts among departments?
            1. Do you think there is power play involved?
                a. Legitimate Power
                b. Reward Power
                c. Coercive Power
                d. Expert Power
                e. Information Power
                f. Referent Power
            2. Do you think it is an emotional decision for managers?
            3. Any other…
        ix. How was the power and role of each stakeholder weighed in this process?
            1. Customers
            2. Employees
            3. Investors
            4. Suppliers
            5. Channel Partners (Retailers, Distributors)
            6. Media
            7. Government
            8. Any other
        x. Who made the final decision? (Ask about Top Management involvement)
        xi. What were the outcomes of the product deletion decision?

xii. According to you, was the deletion successful? If yes, how did you measure the success of the deletion decision? If no, why not?
xiii. How often does product deletion activity occur in this company?
xiv. Do you have any decision making tools/processes to help you manage product deletion decisions?
    1. If yes, what are they?
    2. If no, what according to you should the tool be like? What should it measure? What factors should it consider?
    3. I know of a tool but we don't use it… WHY?

b. No.
    i. Why do you think product deletion was never required?
    ii. Do you think it is important to discontinue products? If yes, Why or for what reasons? If not, why not?
    iii. What are the pros and cons of product deletion?
    iv. According to you, what factors could be considered while making the product deletion decision?
    v. According to you, what are some outcomes of discontinuing products?
    vi. According to you, how can a company measure the success of a product deletion decision?
    vii. Do you think cross-functional departments are involved in product deletion decision making? Why or Why not?
    viii. According to you, which department of these plays a vital role in the product deletion decision?
    ix. According you, who are the stakeholders that will directly or indirectly be impacted by product deletion and/or will influence the decision?
    x. According to you, if this company were to adopt product deletion, what process should it follow?
    xi. Do you know of any tool that could be used in product deletion decision making?

8. Will you consider sustainability/CSR issues in product deletion decisions?
9. Is there anything else important that you would like to share with me that we have not discussed yet?
10. Thank you so much for your time and sharing this information with me. It will be very helpful for my research.

D. SALES QUESTIONNAIRE:

1. What is the structure of the sales team in this company?
2. How do brand and product management activities affect sales performance in this company?
3. What factors influence the overall sales performance of a brand and product portfolio?
    a. Do you think the number of products within a product portfolio plays a role in overall sales performance?
    b. Do you think reducing the number of products within a portfolio will improve the sales performance?
4. Has the company discontinued or deleted any product under a specific brand/product line?
    a. Yes. Would you please tell me more about it?
        i. Which brand (s)/product (s)?

ii. When and why?
iii. How? What procedure was followed to plan and implement product deletion? Please tell me more about it.
iv. Do you think product deletion impacts your department?
v. What role does your department play in product deletion activities?
    1. Major or Minor - Why do you think so?
    2. Have you or will you consider factors outside of your department to make product deletion decisions? Such as related to marketing or others?
vi. Who was involved in the decision making? (Ask about Cross functional as well as stakeholder involvement)
vii. How was the power and role of each cross-functional department weighed in this process?
    1. Supply chain
    2. Finance
    3. Marketing
    4. Any other
viii. Is product deletion a controversial decision which involves conflicts among departments?
    1. Do you think there is power play involved?
        a. Legitimate Power
        b. Reward Power
        c. Coercive Power
        d. Expert Power
        e. Information Power
        f. Referent Power
    2. Do you think it is an emotional decision for managers?
    3. Any other…
ix. How was the power and role of each stakeholder weighed in this process?
    1. Customers
    2. Employees
    3. Investors
    4. Suppliers
    5. Channel Partners (Retailers, Distributors)
    6. Media
    7. Government
    8. Any other
x. Who made the final decision? (Ask about Top Management involvement)
xi. What were the outcomes of the product deletion decision?
xii. According to you, was the deletion successful? If yes, how did you measure the success of the deletion decision? If no, why not?
xiii. How often does product deletion activity occur in this company?
xiv. Do you have any decision making tools/processes to help you manage product deletion decisions?
    1. If yes, what are they?
    2. If no, what according to you should the tool be like? What should it measure? What factors should it consider?
    3. I know of a tool but we don't use it… WHY?

b. No.
    i. Why do you think product deletion was never required?
    ii. Do you think it is important to discontinue products? If yes, Why or for what reasons? If not, why not?
    iii. What are the pros and cons of product deletion?
    iv. According to you, what factors could be considered while making the product deletion decision?
    v. According to you, what are some outcomes of discontinuing products?
    vi. According to you, how can a company measure the success of a product deletion decision?
    vii. Do you think cross-functional departments are involved in product deletion decision making? Why or Why not?
    viii. According to you, which department of these plays a vital role in the product deletion decision?
    ix. According you, who are the stakeholders that will directly or indirectly be impacted by product deletion and/or will influence the decision?
    x. According to you, if this company were to adopt product deletion, what process should it follow?
    xi. Do you know of any tool that could be used in product deletion decision making?

5. Will you consider sustainability/CSR issues in product deletion decisions?
6. Is there anything else important that you would like to share with me that we have not discussed yet?

Thank you so much for your time and sharing this information with me. It will be very helpful for my research.

Appendix B: IRB Approval and Informed Consent Agreement

WORCESTER POLYTECHNIC INSTITUTE

Worcester Polytechnic Institute IRB# 1
HHS IRB # 00007374

17 January 2018
File: 18-0200

Re: IRB Expedited Review Approval: File 18-0200 "Organizational Product Deletion Decision Making"

Dear Prof. Sarkis,

The WPI Institutional Review Committee (IRB) approves the above-referenced research activity, having conducted an expedited review according to the Code of Federal Regulations 45 (CFR46).

Consistent with 45 CFR 46.116 regarding the general requirements for informed consent, we remind you to only use the **attached stamped approved consent form** and to give a copy of the signed consent form to your subjects. You are also required to store the signed consent forms in a secure location and retain them for a period of at least three years following the conclusion of your study. You may also convert the completed consent forms into electronic documents (.pdf format) and forward them to the IRB Secretary for electronic storage.

The period covered by this approval is 17 January 2018 until 16 January 2019 unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific approval must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this approval.

Sincerely,

Kent Rissmiller
WPI IRB Chair

Informed Consent Agreement for Participation in a Research Study

Investigator:
This study is under supervision of Foisie Business School doctoral program within Worcester Polytechnic Institute. Dr. Joseph Sarkis is the Principal Investigator (PI) and Dr. Purvi Shah is the co-PI. The student investigator, Qingyun Zhu is a PhD candidate within Foisie Business School.

Contact Information:
Dr. Joseph Sarkis
Phone: 508.831.4831
Email: jsarkis@wpi.edu

Title of Research Study:
Organizational Product Deletion Decision Making

Introduction
You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study:
You are invited to participate in a research project about organizational decisions on product deletions conducted by researchers at WPI.

This study, aims to investigate product management activities in this organization and how they influence or are influenced by supply chain management.

Procedures to be followed:
You will be asked to answer several questions regarding your opinions and experiences about products and supply chains. Additionally, you will be asked to share your demographic information such as gender, age, work experience, and education level. The interview would be approximately 45 minutes long.

Risks to study participants:
The reduction of risk in association with your participation has been taken very seriously. With any research study, like this one, there can be a risk of a loss of confidentiality. To minimize this risk, your responses will be kept confidential and only associated with a randomly generated participant ID. All identifying information will be separated from the interview information. This means that your name will never appear on any of the results found without your permission. We do not expect any risks to occur; however, every precaution that is necessary will be taken to prevent them. Protocols have been developed to prevent data management errors. Data will be stored in a password protected electronic storage device or a locked location, such as in a locked office.

Benefits to research participants and others:

Your participation in this research will be most helpful in understanding how organizations manage products and supply chains. We can also share the research findings with your organization.

Record keeping and confidentiality:
If you permit, we would like to use the company name, your title, and your name in the research paper resulting from this interview. However, if you do not permit this, complete anonymity and confidentiality will be maintained.

Efforts will be made to keep this personal information private. We cannot guarantee absolute confidentiality. If required by law, your personal information will be disclosed. Organizations that may inspect and / or copy your research records for quality assurance and data analysis include groups such as the investigators and their research associates, and the WPI Institutional Review Board (IRB) or its designees.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: (Fill in your contact information or make reference to information provided at top of page. In addition, include the contact information for the IRB Chair (Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu) and the University Compliance Officer (Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu). This section is required.)

Your participation in this research is voluntary.
Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits.
By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement. May I audio record our conversation for future reference?

_____ Date: _____
Study Participant Signature

APPROVED
WPI IRB 1
1/17/18 to 1/16/19

_____
Study Participant Name (Please print)

_____ Date: _____
Signature of Person who explained this study

Appendix C: Product Archival Data Dictionary

Factors	*Description*
Company Name	Name of the interviewed company
Industry	Industrial sector the interviewed company belong
Competition	The level of competition of the firm in its industry
% of Internal Supply Chain	Percentage of the internal supply chain out of the entire supply chain of the focal firm
% of External Supply Chain	Percentage of the external supply chain out of the entire supply chain of the focal firm
Product Portfolio Size	Number of products and SKUs of the firm's product portfolio
Annual Sales Volume	The overall annual sales volume of the entire company's product portfolio
Annual Revenue	Annual revenue earned of the entire company's products portfolio
Net Profit	Net profit earned of the entire company's products portfolio
Overall Investment	Overall investment of the entire company's products portfolio
Total Assets	Total assets of the entire company's products portfolio
Market Share (of the overall industrial market)	Market share of the focal firm within the entire market within its industrial sector
Management financial support for PD decision making	Overall attitude of the top management team towards to PD decision making
Product Portfolio Name	Name of the product portfolio or product line
Product Name	Name of the product candidate
Annual Sales Volume	Annual amount of products sold
Overall Cost	Overall cost occurred of making one unit of the finished product candidate
Unit Selling Price	Price sold of one unit of the product candidate
Profit per unit	Profit per unit of product candidate
Profit Margin	The percentage of selling price that is turned into profit
Position on PLC	The product candidate's current stage on its life cycle
Market trends	The overall market trend of the product deletion candidate
Market Share (of this product amongst the portfolio)	The market share of the product deletion candidate amongst the entire product portfolio revenue
Manufacturing complexities	The level of complexity to manufacture the product deletion candidate
Correlations with other products in the portfolio	The correlation and influence of the product deletion candidate on other products within the product portfolio
Potential organized intervention	The level of organization intervention in response to the product deletion decision and process
% of cost in sourcing activity	Cost percentage occurs in sourcing activities of the entire product deletion's overall cost
% of cost in Manufacturing Activity	Cost percentage occurs in manufacturing activities of the entire product deletion's overall cost
% of cost in Delivering Activity	Cost percentage occurs in delivering activities of the entire product deletion's overall cost
% of cost in Retailing Activity	Cost percentage occurs in retailing activities of the entire product deletion's overall cost
% of cost in Warehouses and inventory holding	Cost percentage occurs in warehouses and inventory management activities of the entire product deletion's overall cost
Product similarity to superior competitor offerings	The number of competing market offerings
Differentiation of product design/characteristics	The level of differentiation amongst the competing market offerings
Customer demand	The amount of market demand
Customer loyalty	The level of customer loyalty to the product deletion candidate
Level of unique parts developed in house	The amount of components that developed within the focal firm apart from its suppliers
Lead time	Time spent from shipping to arriving to end-users
Delivery reliability	Reliability of products on-time delivery
Inventory holding time	Average time to hold inventory of the product deletion candidate
Inventory turn-over rate	Speed of turning over inventory

Managerial time freed-up	Time saved after deleting the product candidate that could be freed up and reallocate to other duties
Profit Margin	The percentage of selling price that is turned into profit
Effect on employee relations	Product deletion's influence on employees
Effect on customer relations	Effect on customer relations
Effect on supplier relations	Product deletion's influence on suppliers
Competitor reaction	The reaction from competitors on product deletion decision
Media	Product deletion's influence on the media
Government regulations	Product deletion's response to governmental policy
Reduce	The amount of product components that can reduced
Reuse	The amount of product components that can reused
Recycle	The amount of product components that can recycled
Reclamation	The amount of product components that can reclaimed
Remanufacturing	The amount of product components that can remanufactured
Solid Waste	The overall level of solid waste produced by the product candidate's entire supply chain
Air emissions	The overall level of air emissions produced by the product candidate's entire supply chain
Water emissions	The overall level of water emissions produced by the product candidate's entire supply chain
Resource usage	The overall level of resources usage used on the product candidate's entire supply chain
Energy usage	The overall level of energy usage used on the product candidate's entire supply chain