Energy and Carbon Dioxide Impacts from Lean Logistics and Retailing Systems:

A Discrete-event Simulation Approach for the Consumer Goods Industry

by

Gustavo Marco Antonio Ugarte Irizarri

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved November 2011 by the
Graduate Supervisory Committee:

Jay Golden, Co-Chair
Kevin Dooley, Co-Chair
Christopher Boone
George Basile

ARIZONA STATE UNIVERSITY

December 2011

ABSTRACT

Consumer goods supply chains have gradually incorporated lean manufacturing principles to identify and reduce non-value-added activities. Companies implementing lean practices have experienced improvements in cost, quality, and demand responsiveness. However certain elements of these practices, especially those related to transportation and distribution may have detrimental impact on the environment. This study asks: What impact do current best practices in lean logistics and retailing have on environmental performance?

The research hypothesis of this dissertation establishes that lean distribution of durable and consumable goods can result in an increased amount of carbon dioxide emissions, leading to climate change and natural resource depletion impacts, while lean retailing operations can reduce carbon emissions. Distribution and retailing phases of the life cycle are characterized in a two-echelon supply chain discrete-event simulation modeled after current operations from leading organizations based in the U.S. Southwest.

By conducting an overview of critical sustainability issues and their relationship with consumer products, it is possible to address the environmental implications of lean logistics and retailing operations. Provided the waste reduction nature from lean manufacturing, four lean best practices are examined in detail in order to formulate specific research propositions.

These propositions are integrated into an experimental design linking annual carbon dioxide equivalent emissions to: (1) shipment frequency between supply chain partners, (2) proximity between decoupling point of products and final customers, (3) inventory turns at the warehousing level, and (4) degree of supplier integration. All propositions are tested through the use of the simulation model.

Results confirmed the four research propositions. Furthermore, they suggest synergy between product shipment frequency among supply chain partners and product management due to lean retailing practices. In addition, the study confirms prior research speculations about the potential carbon intensity from transportation operations subject to lean principles.

DEDICATION

This dissertation is dedicated to my parents Patricia and Marco, and my sister Gisela. They have witnessed this entire journey from Mexico and Canada respectively, while supporting me in each step of the way. I want to thank God and Saint Jude Thaddeus for allowing me to undertake this endeavor and provide me with the strength and health to build a life away from home. It is also in memory of my dear friend Alfonso Rodríguez Reyes who watches over me from heaven.

ACKNOWLEDGMENTS

My most sincere appreciation to each one of my graduate committee members for their patience, wisdom, and support along the development of this dissertation; Drs. Golden, Dooley, Boone, and Basile, thank you so much for your interest in this research, for all the time and resources provided for its completion, and for making my time at Arizona State University a life changing and fulfilling experience.

This research was possible thanks to grants, fellowships, and research assistantships provided by: The Sustainability Consortium, the National Center of Excellence on SMART Innovations, The School of Sustainability, Tec de Monterrey, The Mexican Council of Science and Technology (CONACYT), and APICS, The Association for Operations Management.

TABLE OF CONTENTS

Page

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

1 INTRODUCTION 1

1.1 Introduction 1

1.2 Flow of the Dissertation...8

2 LITERATURE REVIEW 10

2.1 Overview of Sustainability 10

2.1.1 Definition of Sustainability 10

2.1.2 Critical Issues of Sustainability 12

2.1.3 Consumer products and Sustainability 15

2.2 Sustainable Logistics and Retailing 19

2.2.1 Relative impact of logistics and retailing on consumer product sustainability.. 19

2.2.2 Previous research in sustainable logistics........................22

2.2.3 Previous research in sustainable retailing.....................24

2.3 Lean logistics and retailing...26

2.3.1 Lean manufacturing as waste reduction..........................26

2.3.2 Just-in-Time 32

2.3.3 Postponement 38

2.3.4 Cross-Docking 43

2.3.5. Vendor Managed Inventory 49

CHAPTER Page

3 THEORY 60

3.1 Introduction 60

3.2. Impact of Just-in-Time delivery 61

3.3 Impact of Postponement 67

3.4 Impact of CrossDocking........... 72

3.5 Impact of Vendor Managed Inventory 77

4 METHODOLOGY 84

4.1 Introduction..84

4.2 Experimental Design for process modeling....................................89

4.3 A discrete-event simulation model....................................93

5 MODEL RESULTS 105

5.1 Model validation 105

5.2 Regression modeling 111

6 DISCUSSION 116

7 CONCLUSIONS.................................... 126

REFERENCES 133

APPENDIX

A EXPERIMENTAL DESIGN FACTORS AND LEVELS PER INVENTORY MANAGEMENT METHOD 178

B GEOGRAPHICAL DESCRIPTIONS OF SUPPLY CHAINS 184

C INDUSTRY CALL FOR PARTICIPATION 190

D A DISCRETE-EVENT SIMULATION MODEL FOR LEAN LOGISTICS AND RETAILING....................................194

BIOGRAPHICAL SKETCH.................................... 197

LIST OF TABLES

Table Page

1. Environmental considerations from supply chain stages 25

2. Sources of waste according to lean manufacturing 28

3. Prior research on lean applications in the supply chain 31

4. Lean-oriented inventory management methods defined 32

5. Simulation-based research overview 86

6. Experimental design factors and levels for process configurations ... 92

7. Experimental levels for control variables 92

8. Durable goods supply chain locations 97

9. Consumable goods supply chain locations 98

10. Model parameters by operational domain 100

11. Transportation time parameters by supply chain type 101

12. Experimental levels for process configurations 102

13. Experimental levels associated with control variables 103

14. Sensitivity analysis of carrier fuel economy 107

15. Correlations for model variables 112

16. Model parameter estimates 114

A.1 Economic Order Quantity 179

A.2 Just-in-Time 180

A.3 Postponement 181

A.4 Cross-docking 182

A.5 Vendor Managed Inventory 183

LIST OF FIGURES

Figure | Page

1. General structure for research propositions 61

2. Integrated view of research propositions 83

3. System boundary for lean logistics and retailing model 93

4. Operational domains and model processes 94

5. Lean logistics and retailing model 96

6. Simulation model overview.. 99

7. Traditional and improved product packaging 103

8. Supply chain emissions by operational domain 108

9. Two-factor model outcomes... 110

10. Three-factor model outcomes 111

11. Four-factor model outcomes... 111

B.1 Regional description of durable goods supply chain 185

B.2 Routing detail description for durable goods supply chain............... 186

B.3 Local routing detail description for durable goods supply chain 187

B.4 Regional description of consumable goods supply chain................. 188

B.5 Local routing detail description for consumable goods supply chain..189

D.1 Retailing domain submodel... 195

D.2a Warehousing domain sub-model 195

D.2b Warehousing domain sub-model 196

D.3 Transportation domain sub-model 196

CHAPTER 1

INTRODUCTION

1.1 Introduction

In October of 2005, Lee Scott then President and Chief Executive Officer from Walmart, the largest employer in the United States and one of the most influential global retailers, launched their sustainability program having three long-term goals: be supplied by 100 percent renewable energy, create zero waste, and sell products that sustain people and the environment (Walmart, 2011).

The operationalization of these overarching imperatives set Walmart into a transformational journey of epic proportions encompassing more than 8,900 retail units and more than 100,000 suppliers worldwide. By 2006, a Packaging Scorecard aimed at their supplier base was launched and one year later the organization committed to exclusively offer concentrated liquid laundry detergents in the United States.

By 2009, under the tenure of Mike Duke, current President and CEO of the organization, seed funding has been awarded for the development of the Sustainability Consortium (Walmart, 2011). This multi-stakeholder organization brings together leading global Universities, Corporations, and Non-Governmental Organizations to develop science-based measurement and reporting systems accessible to producers, retailers, distributors, and consumers (TSC, 2011).

At the same time, Walmart launched their Sustainability Index initiative encompassing three main phases: a Supplier Sustainability Assessment, the development of a Lifecycle Analysis Database, and the implementation of Simple Tools for Customers. Currently, Walmart, the Sustainability

Consortium, and their global partners have joined efforts to develop the lifecycle analysis database (Walmart, 2011).

The emergence of transparent supply chain metrics able to accelerate the adoption of best practices and drive product innovation from a sustainability standpoint requires the active engagement of suppliers, manufacturers, distributors, and retailers. Furthermore, a focused examination of critical supply chain stages such as logistics and distribution has become critical given the volume and variety of consumable and durable goods flowing from manufacturers to retailing stores.

Currently, economically normalized open input-output models based on aggregated manufacturing processes, tend to assign climate change impacts due to distribution processes equivalent to 23% of the total product life cycle under a cradle through consumer scope (TSC, 2011b). However, as 85% to 95% of total inventory from global leading retailers is managed through lean logistics practices such as Cross-Docking (Simchi-Levi et al, 2003, Sheu et al, 2006), the increased demand for such practices has been followed by corresponding infrastructural developments over the last two decades.

The resulting manufacturing, warehousing, and retailing facilities currently shape contemporary supply chains across the globe. At the same time, process refinements in logistics and distribution operations have taken place during the quality movement of the 1980's. Further improvements resulting from the adoption of lean principles aimed at the systematic reduction of non-value-added activities during the 1990's, have provided substantial evidence of the inherent economic performance from lean operations, while missing a closer examination from an environmental standpoint.

For instance, Just-in-Time (JIT) consumer goods procurement, where products are only supplied after actual consumer demand takes place ideally moving one unit at a time; is heavily associated with the overall notion of lean and therefore generally assumed as a sustainable way of conducting business.

However, when lean practices are assessed across different downstream supply chain stages such as distribution and retailing, they could potentially result in more resource intensive practices than traditional procurement methods having a direct impact in the environment. Specifically, the guiding research question for this dissertation is: **Do current best practices in lean logistics and retailing lead to increased environmental performance?**

Given the significant adoption of lean-oriented practices across multiple industries over the last twenty-five years (Kraemer et al., 2000; Simchi-Levi et al, 2003; Tyan and Wee, 2003; Brown et al., 2005), leading global organizations that currently issue annual reports addressing their Corporate Sustainability performance and develop Carbon Neutrality Plans (Wheeler and Elkington, 2001; Adams, 2004; Lovell et al., 2009); can improve strategic decision making processes across their supply chains by assessing the environmental performance of best practices associated with lean logistics and retailing operations.

In order to address the guiding research question, the following hypothesis is presented: **Lean distribution of durable and consumable goods (i.e. lean logistics) can result in an increased amount of carbon dioxide emissions, while lean retailing operations can reduce process emissions.**

Distribution and retailing phases of the life cycle are characterized in a two-echelon supply chain discrete- event simulation model in conjunction with empirical analysis in order to examine the hypothesis. Because of the number and complexity of environmental impacts associated with these operations, this research specifically focuses on the quantification of carbon dioxide equivalents resulting from warehousing, transportation, and retailing operations. This overarching process metric has been supported by modeling, allocation, and reporting frameworks such as the PAS-2050 specification and the Carbon Disclosure Project (Kolk et al., 2008; Weidema et al., 2008; Sinde, 2009).

This line of scientific inquiry is relevant as supply chain environmental performance information such as energy consumption and pollutant emissions associated with lean practices and their supporting infrastructure (Porter and Van der Linde, 1995; O' Brien, 1999; Woensel, et al., 2001; Childerhouse et al., 2002; Hesse, 2002; Marlow and Paixao, 2003; Kleindorfer et al., 2005; Motwani et al., 2009; Busch, 2010; Fliedner and Majeske, 2010), represent critical elements towards the development of transparent reporting addressing firm and product sustainability in multiple industries.

By focusing on contemporary lean-oriented product procurement models, specific process variables can be identified and modeled into a supply chain simulation in order to provide a deeper understanding of their environmental implications within state-of–the-art consumer goods supply chains. A simulation-based research of this nature can be flexible enough to incorporate different families of consumer goods, while uncovering process dynamics from lean practices that are currently underrepresented in scientific literature (Dubelaar et al., 2001; Van Hoek, 2001; Fiksel, 2003; Ramdas, 2003; Appelqvist et al., 2004; Gupta et al., 2006).

As Enterprise Resource Planning systems (Ragowski and Somers, 2002; Simchi-Levi et al., 2003; Arnold and Chapman, 2004; Heizer and Render, 2004) expand their scope from internal enterprise optimization to collaborative commerce and supply network management, supporting systems are expected to become more intelligent. Furthermore, data mining and intelligence tools including expert systems will increasingly be used to suggest and make critical business decisions. Particularly, process simulation capabilities are expected to become increasingly important for integrated enterprise planning and execution systems as they are fully adopted across supply chains (Jacobs and Wetson, 2007; Ilic et al., 2009).

From a broader perspective, this research is needed as the increasing demand for sustainable products in the marketplace, more stringent pollution regulations set forth by government, and sustainability-oriented business management suggested the importance of assessing the environmental performance of downstream supply chain processes beyond manufacturing (Wu and Dunn, 1995; Beamon, 1999; Hall, 2000; Simpson and Power, 2005; Linton et al., 2007; Seuring and Muller, 2008; McKinnon, 2010).

Provided that an increasing number of leading organizations from the consumer goods industry closely monitor the environmental performance of their operations (Michelsen et al., 2006; Goetschalckx et al, 2007; Quariguasi et al., 2009; Busch, 2010), product distribution stages are not considered in isolation, but rather as functional links between operational domains that could support the timely identification of important decarbonization opportunities across the supply chain (McKinnon, 2010).

For instance, transportation-related activities represent 9.5% of U.S. Gross Domestic Product, petroleum consumption due to transportation activities in the United States accounts for almost 15 million barrels per day (RITA, 2010). According to the U.S. Bureau of Transportation Statistics (2007), home electronics and office equipment are transported on average 815 miles between manufacturing facilities, regional warehouses, and retailers before reaching their intended customers. Distribution, logistics, and retailing operations significantly support the performance of the electronic sector with annual sales of $87B (US) (U.S. Census, 2007).

At the same time, transportation is considered the single largest source of environmental hazards in the logistics system (Wu and Dunn, 1995; May et al., 2003), while most scenarios on the future of world trade and freight transport rest on multimodal infrastructure sharing limited resources prone to increased energy consumption (Rodrigue et al., 2001, Woensel, et al., 2001; Motwani et al., 2009). Particularly, product transportation by truck accounts for more than 70% of total product shipments in the United States over rail, water, and air modes.

The average travel distance per shipment due to this transportation mode is 203 miles (U.S. DOT, 2007). In 2006, light duty trucks and passenger cars represented 62% of total carbon dioxide emissions within the transportation end-use sector in the United States. Provided that product transportation accounts for at least 10-15% of a company's total operation cost (Christensen, 1996; Hesse and Rodrigue, 2004), the examination of these operations became strategic for several organizations.

The emerging demand for environmentally friendly products required the examination of their supporting supply chain operations. Although initial assessments relied on voluntary standards and codes of conduct adopted by proactive organizations (Schot et al., 1997; Michaelis, 2003), government regulations have been developed to address the objective evaluation of processes including procurement activities (Weidema et al., 2008).

With annual sales of $4.4B (US) (U.S. Census, 2007), the logistics operations from the retail and food services sector in the United States are subject to Presidential Executive Order 13514. This mandate establishes sustainability goals for transportation activities in the country, including reduction targets in greenhouse gas emissions, increase in energy efficiency, waste reduction, and general support for environmentally-responsible products and technologies (U.S. DOT, 2010).

Further down the supply chain, widely used inventory management methods supporting the procurement of consumable goods are of utmost importance for the retail grocery business, as they account for more than 50% of the $400B (US) annual turnover of the US retail grocery industry (Ilic et al., 2009). Emerging research in product sourcing (Rizet et al., 2010) has identified the significance of environmental impacts due to consumer goods transportation and retailing environments.

According to the U.S. Energy Information Administration (2010) 20% of total energy consumed by commercial buildings is associated with retail and service facilities. Lighting, refrigeration, heating, ventilation, and air conditioning account for 65% of commercial building emissions (Milian, 2010).

Considering the environmental impacts of this kind of facilities, in 2007 the U.S. Green Building Council piloted its Leadership in Energy and Environmental Design (LEED) program exclusively for Retail. This program provides measurable guidelines to validate the design, construction, and operation of retailing facilities (USGBC, 2009).

1.2 Flow of the Dissertation

The second chapter is divided in three main sections. First, an overview of sustainability is presented including the definition of the concept, critical sustainability issues and its relationship to consumer products. Second, previous research on sustainable logistics and retailing is reviewed. And third, the concept of lean manufacturing and its relationship with waste reduction provide a platform to address specific processes under the umbrella of lean logistics and retailing operations.

Chapter three builds upon the level of detail provided by the four lean practices described to develop a set of propositions fully aligned with the overarching research hypothesis of the study. Each proposition identifies a critical process variable associated with the adoption of lean practices that can influence the outcomes from consumer goods procurement processes.

The fourth chapter presents the methodology developed for this research. The first part of the chapter provides an introduction and outlines the experimental design able to integrate the propositions developed to examine the research hypothesis. The second part of the chapter describes the development of a two-echelon supply chain discrete-event simulation model in order to conduct the research.

Chapter five presents the results from the supply chain discrete-event simulation model. Elements such as model validation and the relevance of linearity testing are covered at the beginning of the chapter. The rest of the chapter is devoted to the corresponding regression modeling approach to test the research hypothesis.

The sixth chapter discusses the results from the research. Encompassing how current findings confirm speculations from prior research, while addressing the synergy found between process variables associated with lean logistics and retailing operations and their corresponding environmental performance. In addition, model generalization potential into upstream supply chain operations and current retailing trends based on local product sourcing and the gradual servitization of the consumer goods industry are covered at the end of the chapter.

Finally, chapter seven presents the overall conclusions from the research and identifies future work on lean logistics and retailing systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Sustainability

2.1.1 Definition of Sustainability

Although the concept of sustainability appeared for the first time in the Oxford English Dictionary during the second half of the 20th century, historical accounts about the emergence and evolution of the concept claim that it has been used for centuries. The term sustainability was first used in German forestry circles in 1713 (Du Pisani, 2006).

Other works during the 18th century addressing population growth and resource consumption due to food production conveyed the notion of progress and sustainability. During the 19th century, the focus shifted to coal as the most important source of energy and the concern of potentially exhausting its deposits. Similar observations about the drastic increase in oil consumption and its potential supply limitations appeared during the first half of the 20th century (Von Wright, 1997; Hopwood et al., 2005; Du Pisani, 2006).

The concept of sustainability emerged again from research on agricultural sciences during the late 1970's (Orr, 2002), Lester Brown's work on building a sustainable society (1980) and elements from The World Conservation Strategy (Allen, 1980) generally shaped the concept. Particularly, the publication of Our Common Future (1987) from the United Nations World Commission on Environment and Development often referred as the Brutland Report, defined sustainable development as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

Since then, several principles of sustainable development have arisen in order to suit different industries, interests, and views. For instance, research developed during the initial implementation of the Earth Summit's Agenda 21 argues about four dimensions to sustainability: social, economic, environmental, and institutional. Here the environmental dimension can be defined to be the sum of al bio-geological processes and their supporting elements, whereas the social dimension consists of the intra-personal qualities of human beings: their skills, dedication, and experiences (Spangenberg and Lorek, 2002).

The economic dimension includes the formal economy as well as all kinds of informal activity that provide service to individuals and groups increasing the standard of living beyond traditional monetary valuations. Institutions are the result of inter-personal processes, such as communication and co-operation, resulting in information and systems of rules governing the interaction of members and society (Spangenberg, 2002). However, in general terms sustainability addresses three interrelated areas of concern: environmental stewardship, economic issues, and social equity and justice.

From a broader perspective, additional approaches to the concept consider the views of weak and strong sustainability. Weak sustainability sees natural and manufactured capital as interchangeable with technology able to fill human produced gaps in the natural world (Daly and Cobb, 1989). Conversely, strong sustainability argues that human-made capital cannot replace the vast array of natural systems, biodiversity, and vital processes to human existence such as the ozone layer, photosynthesis or the water cycle (Haughton and Hunter, 1994). Nonetheless, these views are heavily focused on environmental issues leaving aside socio-economic consequences.

By integrating the economic, environmental, and social dimensions of sustainability, the notion of sustainable development can rest upon five equity-based principles: futurity – inter-generational equity; social justice – intra-generational equity; transfrontier responsibility – geographical equity; procedural equity – people treated openly and fairly; and inter-species equity – importance to biodiversity (Haughton; 1999; Dasgupta et al., 2000).

A more contemporary definition provided by the Forum for the Future (2009) defines sustainable development as a dynamic process which enables all people to realize their potential and to improve their quality of life in ways which simultaneously protect and enhance the Earth's life support systems.

2.1.2 Critical Issues of Sustainability

Since the 1960's the publication of Rachel Carson's Silent Spring (1962), raised public awareness of the environmental cost of widespread pesticide use. The Club of Rome was formed in 1968 and their report titled The Limits of Growth (1972) explored a number of scenarios while stressing the choices open to society in order to reconcile sustainable progress within environmental constraints.

The energy crisis of the early 1970's associated with the embargo on oil exports placed by OPEC countries raised awareness about energy use and led to developments in energy conservation and the consideration of alternative energy sources, such as wind power. In 1970, the U.S. Environmental Protection Agency (EPA) starts operations in order to protect human health and the environment (EPA, 2011). Two years later the United Nations Stockholm Conference on the Human Environment marked the first international meeting focused on how human activities were impacting the environment putting humans at risk (Sohn, 1973).

The notion of environmental protection in the self-interest of human species gained additional momentum when the United Nations Environmental Program and the International Union for the Conservation of Nature developed the 1980 World Conservation Strategy (IUCN, 1980). The publication of Our Common Future (1987) from the United Nations World Commission on Environment and Development often referred as the Brutland Report developed the most generally accepted definition for the concept of sustainable development.

In 1992, the United Nations Conference on Environment and Development held in Rio de Janeiro developed Agenda 21, a comprehensive plan of action addressing biodiversity, forestry, and climate change pressing issues at global, national, and local levels (Selman, 2000). As recommended in Chapter 40 of the document, the Commission on Sustainable Development (CSD) undertook the development of a set of sustainability indicators as a tool for assessing and communicating the progress towards sustainability (UNDPCSD, 1995). Moreover, the local implementation or Local Agenda 21 (LA 21) has been orchestrated by the International Council for Local Environmental Initiatives (ICLEI).

In Europe alone, approximately 4,000 cities and municipalities have been actively involved during the first ten years of program implementation (Evans and Theobald, 2003). During the World Summit on Sustainable Development in 2002, several agreements were reached including: the reduction of the number of people without access to clean drinking water supplies from over 1 billion to

500 million by the year 2015; reducing the number of people without proper sanitation to 1.2 billion; and increase the use of sustainable energy resources (Green et al., 2005; Spalding-Fecher et al., 2005).

Several contemporary issues of sustainability have been identified by global assessments such as the United Nations Millennium Development Goals (2011). The eight ambitious goals from this document include: the eradication of extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria and other diseases; ensure environmental sustainability; and develop a global partnership for development.

These goals are interrelated with several global challenges involving: peace and security; population, migration, and urbanization; affluence and poverty; production, consumption, and technology; globalization, governance, and institutions; and global environmental change (Kates and Parris, 2003). The latter has been addressed by The United Nations Framework Convention on Climate Change (UNFCC) and their Kyoto Protocol developed in 1997.

This document in international climate change policy set new targets for the reduction of greenhouse gases. By 2012, emissions of six major greenhouse gases must be reduced below 1990 levels. In February 2005, the protocol entered into force encompassing implementation instruments such as emission trading, joint implementation, and the clean development mechanism (Stewart and Wiener, 2003; Santilli et al., 2005).

At the same time, rapid urbanization of the planet has been occurring at an unprecedented pace resulting in 80 million new urban dwellers every year during a transition that is allowing humans to truly live in an urban society for the first time in history (Golden et al., 2007). In addition, the sharp increase in human population during the 20th century has significantly contributed to the imminent milestone of reaching 7 billion habitants in the planet by the first quarter of 2012 (Costanza et al., 2007; U.S. Census, 2011).

These global challenges form an interlinked system where population increase results in rising consumption of products and services supported by global supply chains that heavily contribute to climate change. A critical element that flows across the system can be represented by the vast array of consumer products available in the global market. Therefore, it is necessary to understand their connection to sustainability.

2.1.3 Consumer Products and Sustainability

Gradually, an increasing number of business organizations from multiple industries such as electronics, chemical intensive products, and apparel acknowledged the interdependence between their industrial activities and the natural environment (Hart, 1995; Porter and Van der Linde, 1995b, Wu and Dunn, 1995; Ekins, 2005; Fliedner and Majeske, 2010; Subramanian et al., 2010). Moreover, these organizations promptly realized that operational improvements in manufacturing operations can represent significant cost reductions while decreasing their corresponding environmental impacts. Along these critical opportunities, new frameworks and fields of study have emerged over time.

Industrial Ecology, defined as the study of technological organisms, their use of resources, their potential environmental impacts, and the ways in which their interactions with the natural world could be restructured to enable global sustainability (Graedel and Allenby, 2003); found synergy with other approaches such as: Total Material Flow based on economic and geographical activities over time; the Factor 10 concept as a direct benchmark for the dematerialization of industrialized countries needed to achieve sustainability; The Natural Step Framework designed for qualitative problem analysis, community building, and for the development of investment-programs in business corporations and municipalities; the Zero Emissions concept developed by the United Nations University considers total material cycles from intake to emissions from a holistic approach; the Cleaner Production concept developed by the United Nations Environment Program that relies in the continuous application of an integrated preventive strategy to process products and services to reduce risks for humans and the environment (WRI, 1997; UNEP, 1998; Robert et al., 2002).

Beyond these organizational initiatives and tools, overarching business paradigms towards firm sustainability emerged and were incorporated by global manufacturers of consumer goods. Among these progressive approaches we can find the Triple Bottom Line concept. Initially developed by the management think-tank AccountAbility, found wider acceptance through the work of John Elkington titled Cannibals With Forks: The Triple Bottom Line of 21st Century Business (1997).

This approach establishes that the ultimate success of a corporation can and should be measured not just by the traditional financial bottom line, but also by its social/ethical and environmental performance (Graedel and Allenby, 2003; Norman and MacDonald, 2004; Foran et al., 2005; Hacking and Guthrie, 2008).

As significant improvements were taking place in process resource efficiency across operations with their corresponding economic outcomes, the social dimension of business performance have been extensively documented in the form of Corporate Social Responsibility reports (Carroll, 1999; McWilliams and Siegel, 2001; Matten and Moon, 2004).

Provided that multiple consumer goods organizations have been developing their own reports, the corresponding content and focus have been significantly diverse compared to those documents developed under strict reporting guidelines focused on process, product, and environmental quality (Corbett and Kirsch, 2001; Heizer and Render, 2004; ISO, 2006). Therefore, an increasing need for a reporting standardization scheme across companies emerged over time (UNEP, 1994; Wheeler and Elkington, 2001; Adams, 2004).

Consequently, the Global Reporting Initiative was established in 1997 by a number of companies and organizations belonging to the Coalition for Environmentally Responsible Economies (CERES), with the mission of developing globally applicable guidelines for reporting on economic, environmental, and social performance.

Initially for corporations and eventually for any business or governmental or non-governmental organization, these guidelines recommend that sustainability reports should include six main elements: (1) an statement of the organization's Executive Officer; (2) a profile of the reporting organization; (3) executive summary supported by key indicators; (4) vision and strategy coupled with the three dimensions of sustainability; (5) policies, organization, and management systems; and (6) economic, environmental and social performance (Hussey et al., 2001; Hedberg and Malborg, 2003; Laufer, 2003).

Considering the significant improvement opportunities associated with transparent sustainability reporting across industries, critical stakeholders such as governments and multi-national corporations have been supporting the development of specific benchmark instruments in order to build momentum around this new approach. In September of 1999, a partnership between the Dow Jones Global Indexes and the Swiss-based SAM Sustainability Group launched the first family of global indexes for tracking the performance of sustainability – driven corporations worldwide (Cerin and Dobers, 2001).

The Dow Jones Sustainability Group Index (DJSGI) contains five corporate sustainability principles: (1) innovative technology in products and services; (2) corporate governance including organizational capability and stakeholder relations; (3) shareholder relations based on sound financial returns and long-term economic growth; (4) commitment to industrial leadership; and (5) social well-being (Knoepfel, 2001).

The DJSGI consists of a family of 20 different indexes; five of them are geographical in character among them we can find: the World Index, Europe, North America, the Asia-Pacific region, and the U.S. Each region considers a subset of indexes that exclude stock associated with corporations involved in tobacco, gambling or alcohol (Cerin and Dobers, 2001).

Particularly, the DJSGI address the top 10% of leading sustainability companies in the Dow Jones Global Index universe encompassing 2,000 organizations in 64 industry groups from 34 different countries. Four market-driven DJSGI attributes have been instrumental for making it a benchmarking tool including its global representation, rational assessment method involving a weighting system; consistent method including analysis of company policies and stakeholder relations; and design flexibility (Cerin and Dobers, 2001; Knoepfel, 2001; Lopez et al., 2007).

Other market-based approaches mainly focused on industry-wide environmental performance were carbon-tax (Pearce, 1991; Ekins, 1996; Hoel, 1996) and Cap-and-trade schemes (Colby, 2000; Hovi and Holtsmark, 2006; Murray et al., 2009). Their fundamental calculations are strongly influenced by core processes environmental performance operating within an increasingly ecologically conscious marketplace demanding consumer goods able to incorporate economic, environmental, and social considerations throughout the complete product's life-cycle (Bhate and Lawler, 1997; Minton and Rose, 1997; Laroche et al., 2001; Howard and Allen, 2006).

2.2 Sustainable Logistics and Retailing

2.2.1 Relative impact of logistics and retailing on consumer product sustainability

In principle, global manufacturers of consumer goods had different drivers to integrate sustainability into their strategies and tactics. Some organizations have been guided by a compliance approach focused on reducing the risk of sanctions for failing to meet minimum standards in their respective fields. Here companies aim to provide a safe, healthy workplace while avoiding economic, environmental, and social abuses that could lead to litigation or strong community action towards the firm (Clarke and Varma, 1999; Gates, 2004; Drew et al., 2006).

Compliance with governmental regulations is considered a reactive approach, while the increasing adoption of co-regulatory and voluntary practices (Corbett and Kirsch, 2001; Hussey et al., 2001; Hedberg and Malborg, 2003; ISO, 2006) concurrently developed through multi-stakeholder processes including non-governmental organizations, industry partners, and academic institutions are considered proactive approaches. The latter can provide a platform for industry self-regulation schemes able to anticipate potential governmental interventions (Gunningham and Rees, 1997; King and Lenox, 2000; Heritier and Eckert, 2008).

Another driver has been found in the form of peer pressure among competing organizations. To some extent, this kind of pressure fostered the rapid adoption of early quality and environmental company wide programs (Green et al., 1996; Corbett and Kirsch, 2001; King and Lenox, 2001). More recently, a similar dynamic fostered the development of corporate environmental and sustainability reports (UNEP, 1994; Wheeler and Elkington, 2001; Adams, 2004).

Several organizational initiatives have been instrumental in transitioning from strategic imperatives into actual process implementation in order to understand the sustainability performance of consumer goods companies. Manufacturing operations have been pivotal to advance this understanding. These operations provided a platform based on Total Quality Management (TQM) initiatives supported by international frameworks such as the ISO 9000 quality standard (Corbett and Kirsch, 2001; Heizer and Render, 2004).

This structure able to document process-based metrics has been instrumental to support the incorporation of environmentally related initiatives such as Total Quality Environmental Management (TQEM) programs and their supporting international standards contained in the ISO 14000 series (Flynn et al., 1995; Hendricks and Singhal, 1997; Sakakibara et al., 1997; Ytterhus et al., 1999; Angell, 2001; Corbett and Klassen, 2006).

In consequence, an improved vision of manufacturing operations emerged by measuring the relative environmental performance of facilities based on the development of production functions addressing the relationship between facility sizes and aggregated toxic emissions (Walley and Whitehead, 1994; Lamming and Hampson, 1996; King and Lenox, 2000).

New information resulting from these assessments supported the notion that any product, no matter how environmentally friendly, uses resources and burdens the environment (Wu and Dunn, 1995; Hart and Ahuja, 1996; Kleindorfer et al., 2005). Therefore, further assessments beyond the manufacturing phase were required in order to realize the contribution of other supply chain stages.

Tracking and communicating performance metrics across multiple supply chain stages have been supported by end-to-end solutions such as Environmental Management Systems (EMS) able to integrate logistics and retailing operations (Kitazawa and Sarkis, 2000; Melnyk et al., 2003; Sroufe, 2004). At the same time, these process level assessments have been instrumental in informing product level sustainability.

Life cycle-assessment research focused on chemical intensive products and appliances have identified the use phase as the most resource intensive stage from a functional unit standpoint (Saouter & Van Hoof, 2001; Choi et al., 2006; Eberle et al., 2007; Cullen & Allwood, 2009). Currently, economically normalized open input-output models based on aggregated manufacturing processes, tend to assign climate change impacts due to distribution processes equivalent to 23% of the total product life cycle under a cradle through consumer scope (TSC, 2011b). However, as 85% to 95% of total consumer goods inventory from global leading retailers is managed through lean logistics practices such as Cross-Docking and Vendor Managed Inventory (Simchi-Levi et al, 2003, Sheu et al, 2006), the increased demand for such practices has been followed by corresponding infrastructural developments over the last two decades.

As new regulations are introduced to reduce greenhouse gas emissions from logistics and transportation activities; and improved design and construction schemes for commercial facilities are increasingly adopted. Both, logistics and retailing operations are bound to play a larger role in informing product sustainability in the years to come.

2.2.2 Previous research in sustainable logistics

Suppliers associated with lean logistics and retailing systems are more likely to incorporate environmentally-oriented metrics (Green et al., 1996). The adoption of advanced pollution prevention processes by the supplier base has resulted in reduction of materials usage and avoidance of waste management costs (Rothenberg et al. 2001; Rothenberg 2003).

Company associates supporting lean product procurement processes have developed an increased awareness of environmental effects due to changes in production and distribution processes (MacDuffie, 1995; Hyland et al., 2003). Similarly, a legacy from manufacturing operations performing under quality and environmental standards was the integration of waste reduction initiatives such as pollution prevention to reduce the extent of onsite waste treatment (Womack et al., 1990; Klassen and Whybark, 1999; King and Lenox, 2001; Graedel and Allenby, 2003; Sroufe 2003).

Improved environmental performance in manufacturing settings relied on the elimination of production interruptions, delays, backflows, inventories, and bottlenecks (Milgrom and Roberts, 1995; Hart, 1997; Hawken et al., 1999). Particularly, the systematic reduction of inventory levels at multiple supply chain stages became a guiding waste stream with further implications into facilities and mobile infrastructure (Kitazawa and Sarkis, 2000; Melnyk et al., 2003; Sroufe, 2004).

For instance, the hub-and-spoke warehousing configuration considers a central location where product sorting takes place, and the spokes are outlets serving the destinations related to the hub (O'Kelly, 1998; Lumsden et al., 1999; Rodrigue, 1999). This product distribution array tends to concentrate traffic at a relatively small number of terminals. This concentration exacerbates local environmental problems, such as noise, air pollution, and traffic congestion (Cusumano, 1994; Rodrigue et al. 2001; Woensel et al., 2001; Tripp and Bontekoning, 2002).

Provided the increased number and size of warehouses and distribution centers to support demand responsiveness targets, land usage implications became relevant to surrounding communities (Wu and Dunn, 1995; Rodrigue et al. 2001; Hesse and Rodrigue, 2004). Environmental performance improvement opportunities through the application of lean principles in warehousing operations have been identified in the form of facility design, forklift routing, and fleet utilization (Murphy and Poist, 2000; Fulconis et al., 2007).

Another important waste stream associated with warehousing operations is the amount of materials used for primary, secondary, and shipping packaging. Primary packaging contains the product itself and is considered the minimum required container, while secondary packaging protects the first layer of materials and are usually discarded when the product is about to be used. Shipping packaging materials refers to the necessary elements for storage, identification, and transportation of products. These materials are discarded when products reach their supply chain destination (Wu and Dunn, 1995; Hesse and Rodrigue, 2004; Abukhader, 2008).

2.2.3 Previous research in Sustainable Retailing

Prior research addressing the environmental performance from retailing operations has been focused on the geographical implications of supporting supply chain infrastructure. Guided by improved customer service levels, several retail chains spread their facilities across regions fostering better market segment coverage (Hesse and Rodrigue, 2004; Brown et al., 2005; Quak and De Koster, 2007). In addition, land regulations framework, tax policy, and economic development incentives in the United States have supported the establishment of big-box retailers; conveying the idea that bigger is better and encouraging the development of large scale, space extensive facilities (Goss, 1993; Jacques et al., 2003; Brown et al, 2005; Christopherson, 2007).

Particularly, Walmart, the largest employer in the U.S. with a workforce of over 1.2 million people has expanded its operations by building new stores in rural and suburban areas. By 2003, almost 94% of the American population lived within a 15 miles radio from a Walmart store (Christopherson, 2007).

So far, prior research has identified different sources of waste in multiple supply chain stages including logistics and retailing operations. However, most of the insights tend to describe functionally isolated views resulting in local process improvements (Table 1). An alternative approach to capture the internal dynamics between logistics and retailing processes is to examine the underlying inventory management methods (IMMs) that guide them.

From a traditional standpoint, the Economic Order Quantity (EOQ) approach has been widely used due to its relatively modest differences in total costs as a function of variations in product demand, setup, and holding costs (Goyal, 1985, Chu et al., 1998; Heizer and Render, 2004). Products supplied under this IMM are considered readily available at all times since they are part of larger regional inventories held at distribution centers (Goswami and Chaudhuri, 1992; Pagh and Cooper, 1998; Twede et al., 2000).

Table 1. Environmental considerations from supply chain stages

Stage	Environmental Considerations	Authors
Lean Manufacturing	Environmental performance at the facility level based on toxic emissions.	Walley & Whitehead, 1994; Lamming & Hampson, 1996; King & Lenox, 2000.
	Integration of pollution prevention programs as a legacy from quality programs adoption.	Flynn et al., 1995; Hendricks & Singhal, 1997; Sakakibara et al., 1997; Klassen & Whybark, 1999; Kitazawa & Sarkis, 2000; Corbett & Kirsch, 2001; King & Lenox, 2001; Dunphy et al., 2003; Graedel & Allenby, 2003; Melnyk et al., 2003; Sroufe, 2004.
	Improved environmental performance through reduced: interruptions, delays, inventories, and bottlenecks.	Milgrom & Roberts, 1995; Hart, 1997; Hawken et al., 1999.
	Improved environmental performance from the supplier base.	Green et al., 1996; Rothenberg et al. 2001; Rothenberg, 2003.
Warehousing	Land-use and impacts in surrounding communities.	Wu & Dunn, 1995; Rodrigue et al. 2001; Hesse & Rodrigue, 2004.
	General resources utilization at the facility level.	Murphy & Poist, 2000; Fulconis et al., 2007; Abukhader, 2008.
Transportation	Noise and air pollution.	Cusumano, 1994; Woensel et al., 2001; Tripp & Bontekoning, 2002.
Retailing	Land-use, general resources utilization, and impact in surrounding communities.	Christopherson, 2007; Rizet et al., 2010.

As several organizations consolidated local warehouses into regional facilities, they achieved economies of scale in distribution processes while still serving local catchments in an efficient manner. The increased capacity of these facilities allowed companies to reach distant procurement points beyond regular distribution routes.

Regionally, these facilities were expected to cope with large amounts of time-sensitive consignments (Hesse and Rodrigue, 2004), including safety stocks and inventory buffers for several stock-keeping-units in order to maintain predetermined customer service levels at the retail stores (Eppen and Martin, 1988; Benton, 1991; Arnold and Chapman, 2004). Paradoxically, the increased coverage supported by these infrastructural developments gradually turned into several supply chain challenges due to the emerging flow of information between organizations and additional process flexibility required to accommodate demand responsiveness.

2.3 Lean logistics and retailing

2.3.1 Lean manufacturing as waste reduction

Provided that the guiding research question contains a central element in the concept of lean, it is necessary to acknowledge that several organizations ranging from the airline industry (Hallowell, 1996), fast-food chains (Bowen and Youngdahl, 1998) to higher education institutions (Comm and Mathaisel, 2003), and healthcare service providers (De Koning et al., 2006) have been clearly benefited from the adoption of lean principles. Furthermore, these organizations have a common denominator: the use of quality management systems.

Waste elimination efforts are pursued through continuous improvement events, as well as radical improvement activities (Womack and Jones, 1996; Tan, 2001). Variability reduction opportunities across processes attempt to improve product quality, reduce operations lead time, and increase overhead productivity (Germain et al., 1994; Arnheiter and Maleyeff, 2005; Schroeder et al., 2008). These elements characterize lean principles in operations management.

Lean can be described as a dynamic process of change driven by a systematic set of principles and best practices aimed at the identification and reduction of non-value-added activities within an organization (Womack et al., 1990; Simpson and Power, 2005). The origins of lean can be traced back to the Toyota Production System, a manufacturing philosophy pioneered by Japanese engineers Taiichi Ohno and Shigeo Shingo (Inman, 1999). As a result, the concept of lean has been primarily associated with manufacturing and production environments (Karlsson and Norr, 1994).

According to Arnold and Chapman (2004), lean production is the system-wide philosophical approach used to integrate a manufacturing system toward the ultimate goal of maximized customer service with minimal system waste. Heizer and Render (2004) defined lean production as a way to eliminate waste by focusing on exactly what the customer wants. In addition, lean manufacturers can combine efficient mass production techniques with flexible craft production approaches (Krafcik, 1988), while harnessing several programs such as: focused factory, set-up time reduction, group technology, total preventive maintenance, kanban, total quality control, and quality circles (Philipoom et al., 1990; Davy et al., 1992; Bowen and Youngdahl, 1998; Shah and Ward, 2003).

Due to the intensive material handling nature of manufacturing operations, a general classification addressing sources of waste emerged from the continuous adoption of lean principles (Table 2). These sources are: overproduction, unnecessary inventory, excess motion, waiting time, transportation, over-processing, and operational disruption (Hernandez, 1989; Womack et al., 1990; Monden, 1993; Karlsson and Ahlstrom, 1996; Mason-Jones et al., 2000; Stratton and Warburton, 2003).

These sources of waste are applicable to downstream supply chain processes as the potential for improved operational performance, resource usage, and process quality remained in the interest of organizations using traditional consumer goods procurement techniques.

Independent-demand inventory management approaches such as economic order quantity (Goswami and Chaudhiri, 1992), fixed reorder cycle (Klastorin et al., 2002), and fixed reorder quantity (Chen, 1998), could not incorporate the process flexibility of lean principles without affecting the overall quality and timeliness of their operations (Arnold and Bernard, 1989; Croom et al., 2000).

Table 2. Sources of waste according to lean manufacturing

Sources of waste	Authors
1. Overproduction 2. Unnecessary inventory 3. Excess motion 4. Waiting time 5. Transportation 6. Over-processing 7. Operational disruption	Hernandez, 1989; Womack et al., 1990; Monden, 1993; Karlsson & Ahlstrom, 1996; Mason-Jones et al., 2000; King & Lenox, 2001; Stratton & Warburton, 2003.

Given the proximity to the market from distribution (Ellram, 1991; Lumsden et al., 1999) and logistics (Wu and Dunn, 1995; Murphy and Poist, 2003) processes, most of the waste reduction opportunities were translated into time and economic-based metrics so they can clearly contribute to strategic decision making processes (Rodrigue et al., 2001; Dong et al., 2007). Further down the supply chain, several wholesalers and retailers integrated their physical distribution and logistics functions into the transportation and logistics operations to enhance their competitive advantages (Rodrigue, 1999; Tan, 2001; Hesse and Rodrigue, 2004).

At the same time, multiple supply chain stages experienced a wide spread adoption of technologies such as Electronic Data Interchange, a standardized data-transmittal format for computerized communications between organizations (Carter and Fredenhall, 1990; Mukhopadhyay et al., 1995; Tan, 2001; Arnold and Chapman, 2004; Heizer and Render, 2004; Evans and Harrigan, 2005; Dong et al., 2007). This type of information technology tools supported the close monitoring of key performance indicators associated with actual market activity (Lumsden et al., 1999; Croom et al., 2000).

Consequently, the information collected allowed organizations to coordinate in a timely fashion core processes including product replenishment, transportation, warehouse management, material handling, and product assortment across the supply chain. Walmart stores spearheaded this movement by significantly investing in information technology infrastructure in order to fully streamline their operations (Duclos et al., 1995; Brown et al., 2005). These databases incorporated actual product consumption at the point-of-sale in order to provide accurate information to distribution systems and foster efficient product flow among supply chain partners (Wu and Dunn, 1995).

The challenges associated with product volume and variety configurations at distribution and logistics stages (MacDuffie et al., 1996; Salvador et al., 2002) remain at the retailing level. One approach able to address these challenges is product range management, where product supply is guided by the relative importance of product families at the retail level (Camuffo et al., 2001). This classification method uses traditional product sales volume combined with value judgment from customers in order to coordinate product replenishment processes (Holmstrom, 1997).

The original category management approach based on inventory turns that usually defines store layout and product display is combined with customer-oriented attributes such as convenience an easy access to a product and potential accessories. Product kitting can take place at the store level under this approach, even if it means having the same product displayed in more than one location at the floor. For instance, instead of having a section devoted to diapers, a subset of related products such as lotion, oil, and powder for babies are allocated to the same shelves in order to maximize their cumulative inventory turns. The imminent identification of waste reduction in retailing environments provided room for innovation through the potential adoption of lean principles.

With a similar emphasis on temporal and economic metrics, Lean Retailing is defined as the set of business practices supported by information technology that allow retailers to hold small inventories and timely respond to fluctuations in consumer demand (Handfield, 1994; Evans and Harrigan, 2005). According to Christopherson (2007), successful lean retailing is dependent on cost-effective relationships with suppliers and the ability to minimize labor costs on the distribution and retailing sides of the firms. Lean retailing aims to the development of a truly integrated supply chain where final consumers pull the inventory through the value chain instead of the manufacturers pushing their products to the end users in an attempt to replace inventory with information (Wu and Dunn, 1995; Tan, 2001).

Although most of the benefits from lean logistics and retailing operations have been documented from an economic standpoint (Rodrigue et al., 2001; Dong et al., 2007), the continuous focus on the timely identification and elimination of process-based sources of waste can encompass environmental elements such as energy usage, materials flow, and pollutant emissions associated with core supply chain processes. The quantification of these potential cumulative improvements can advance the understanding of contemporary supply chains from the environmental dimension of sustainability.

The influence of lean philosophy and principles started in an industry with significant manufacturing implications. By expanding its notion of waste and non-value-added activities, lean became applicable not only to downstream stages of the supply chain but to multiple industries and their corresponding product procurement processes servicing local and global markets. Table 3 provides an overview of research addressing lean applications across different stages of the supply chain.

Table 3. Prior research on lean applications in the supply chain

Topic	Authors
Lean Manufacturing	Sugimori et al., 1977; Bagchi et al., 1987; Krafcik, 1988; Philipoom et al., 1990; Womack et al., 1990; Hernandez, 1989; Fandel & Reese, 1991; Davy et al., 1992; Monden, 1993; Germain et al., 1994; Karlsson & Norr, 1994; Bowen & Youngdahl, 1998; Inman, 1999; Walters, 1999; Chang & Makatsoris, 2000; Croom et al., 2000; Mason-Jones et al., 2000; Shah & Ward, 2003; Dong et al., 2001; Arnold & Chapman 2004; Heizer & Render, 2004; Arnheiter & Maleyeff, 2005; Evans & Harrigan, 2005; Kainuma & Tawara, 2006; Dong et al., 2007; Schroeder et al., 2008.
Lean Distribution	Schonberger & Gilbert, 1983; Arnold & Bernard, 1989; Das & Goyal, Ellram, 1991; Carter & Fredenhall, 1990; Savsar, 1996; Holstrom, 1997; Lumsden et al., 1999; Murphy & Poist, 2000; Chan et al., 2002; Heizer & Render, 2004.
Logistics	Carlson, 1989; Ramasesh, 1990; Billesback, 1991; Duclos et al., 1995; Waters-Fuller, 1995; Wu & Dunn, 1995; Murphy & Poist, 2003; Kannan & Tan, 2004; Choi et al., 2006; US Census, 2007; RITA, 2010.
Retailing	Handfield, 1994; Wu & Dunn, 1995; Holmstrom, 1997; Tan, 2001; Simon & Mason, 2003; Evans & Harrigan, 2005; Weil, 2006; Christopherson, 2007.

Consequently, lean-oriented inventory management methods (IMMs) emerged as a set of solutions able to address contemporary challenges within consumer goods supply chains. Specifically, four representative lean best practices have been selected to further understand the process dynamics taking place within integrated lean logistics and retailing systems (Table 4). The following sections will describe each one of these practices.

Table 4. Lean-oriented IMMs defined

Process definition	Authors
Postponement A product design strategy that shifts product differentiation closer to consumer by delaying final configurations such as assembly or packaging, to the last possible supply chain location in order to meet high levels of product customization.	Alderson, 1950; Bucklin, 1965; Heskett, 1977; Shapiro, 1984; Zinn & Bowersox, 1988; Cooper, 1993; Cusumano, 1994; Andries & Gelders, 1995; Holmstrom, 1997; Morash & Clinton, 1997; Lee & Tang, 1998; Pagh & Cooper, 1998; Lumsden et al., 1999; Mason-Jones & Towill, 1999; Naylor et al., 1999; Twede et al., 2000; Van Hoek & Van Dierdonck, 2000; Camuffo, 2001; Lee & Whang, 2001; Rodrigue et al., 2001; Van Hoek, 2001; Yang & Burns, 2003; Yang et al., 2005; Christopherson, 2007.
Just-in-Time The synchronized and timely product flow from supplier to buyer, where materials and finished goods are pulled, ideally one unit at a time, to where they are needed just as they are needed responding to actual customer demand.	Sugimori et al., 1977; Schonberger & Gilbert, 1983; Carlson, 1989; Das & Goyal, 1989; Ramasesh, 1990; Billesbach, 1991; Wu & Dunn, 1995; Waters-Fuller, 1995; Christensen, 1996; Schonberger, 1996; Holmstrom, 1997; Lumsden et al., 1999, 1997; Walters, 1999; Dong et al., 2001; Chan et al., 2002; Arnold & Chapman, 2004; Heizer & Render, 2004; Kannan & Tan, 2004; Arnheiter & Maleyef, 2005.
Cross-Docking The concept of packing products on the incoming shipments so they can be easily sorted at intermediate warehouses or for outgoing shipments based on final destination. The items are carried from the incoming vehicle docking point to the outgoing vehicle docking point without being stored in inventory at the warehouse.	O'Kelly, 1986; Bozer et al., 1988; Cooper, 1994; Wu & Dunn, 1995; Brynzer & Johansson, 1996; St. Onge, 1996; Holmstrom, 1997; Kinnear, 1997; Daniels et al., 1998; Van den Berg et al., 1998; Chew & Tang, 1999; Gue, 1999; Lumsden et al., 1999; Bartholdi & Gue, 2000; De Koster et al., 2002; Levy & Grewal, 2000; Lee & Whang, 2002; Sung & Song, 2003; Petersen & Aase, 2004; Won & Olafsson, 2005; Waller et al., 2006; De Koster et al., 2007; Goetschalckx et al., 2007.
Vendor Managed Inventory When supplier is granted access to customer's inventory data and is responsible for maintaining required customer on-site inventory levels. Consumed, damaged, and outdated products are restocked and correspondingly invoiced to the customer organization.	Goyal & Gupta, 1989; Grieco, 1989; Holmstrom, 1997; Blatherwick, 1998; Holmstrom, 1998; Dow et al., 1999; Lummus & Vokurka, 1999; Vergin 7 Barr, 1999; Waller et al., 1999; Cachon & Fisher, 2000; Croom et al., 2000; Tan, 2001; Cheung & Lee, 2002; Stenzel & Stenzel, 2002; Disney, 2003; Hausman & Stock, 2003; Tyan & Wee, 2003; Simpson & Power, 2005; Danese, 2006; Kainuma & Tawara, 2006; Christopherson, 2007; Dong et al. 2007.

2.3.2 Just-in-Time (JIT)

This practice was developed at the core of the Toyota Production System. This philosophy emphasized that only the necessary products, at the necessary time, in the necessary quantity are manufactured (Sugimori et al., 1977; Schonberger, 1996; Arnheiter and Maleyeff, 2005). The JIT system is driven by final product demand, where each item is procured, manufactured, and delivered in the quantities needed just-in-time to satisfy demand in the next stage of the supply chain system or the marketplace (Snyder et al., 1982; Sadhwani et al., 1985; Billesbach, 1991). In its ideal form, JIT integrates multiple functions from the supply chain such as marketing, distribution, customer service, purchasing, and production into one controlled process (Gomes and Mentzer, 1988; Billesbach and Schniederjans, 1989; Harvey, 1989: Wasco et al., 1991; Silvestro et al., 1993; Canel et al., 2000).

Just-in-time can be defined as an operational approach designed to eliminate waste and foster continuous improvement of productivity (Hernandez, 1989; Chase et al., 1998; Arnold and Chapman, 2004). Waste is defined as anything other than the minimum amount of equipment, materials, parts, space, and human capital time which are absolutely essential to add value to a product or service (Burnham, 1987; Inman and Mehra, 1991; Canel et al., 2000). Specifically, inventory levels are intended to be kept to an absolute minimum, ideally moving one unit a time in response of actual customer orders (Bitran and Chang, 1987; Philipoom et al., 1990; Ramasesh, 1990; Lovell, 1992; Savsar, 1997) while eliminating waste from the process (Frazier et al., 1988; Silver, 1990; Spencer and Guide, 1995).

Top customer service levels heavily rely on time sensitive or just-in-time product procurement techniques which can be subject to traffic congestion, poor weather, or vehicle breakdown (Chapman and Carter, 1990; Kant and Grenoble, 1991; Christensen, 1996; Holmstrom, 1997). Unlike traditional distribution systems where products are pushed into the market, JIT focuses on eliminating any unnecessary product delivery prior to actual demand. Therefore, reducing the amount of safety stock and buffer inventories that sit idle accumulating holding costs (Ansari and Modarress, 1986; McDaniel et al., 1992; Selto et al., 1995).

This strategy adopted key principles from the traditional manufacturing just-in-time philosophy to support stricter quality control and increase customer satisfaction through improved reliability on final product delivery (Levitt, 1976; Lee and Seah, 1988; Arnold and Bernard, 1989; Cusumano, 1994; Walters, 1999).

Similarly, JIT product procurement is defined by high shipment frequency (Schonberger and Gilbert, 1983; Das and Goyal, 1989; Wu and Dunn, 1995; Lumsden et al., 1999; Chan et al., 2002) of reduced lot sizes (Carlson, 1989; Waters-Fuller, 1995; Kannan and Tan, 2004), associated with higher transportation costs (Bagchi et al., 1987; Fandel and Reese, 1991; Dong et al., 2001) and increased carbon emissions (Rodrigue et al., 2001; IBM, 2008).

JIT has been characterized by synchronization and balance of information and work flow, resulting in improved customer service levels (Bagchi et al., 1987; Goyal and Gupta, 1989; Freeland, 1991; Duclos et al., 1995). Constant information sharing between retailers, warehouses, and manufacturing facilities is critical to support JIT purchasing (Lee and Ansari, 1985; Adair-Heeley, 1988; Burton, 1988; Gupta, 1990; Handfield, 1993; Enarsson, 1998), allowing a quick response to the ever-changing demands from customers while decreasing the likelihood of inventory obsolescence and perishability (Duclos et al., 1995; Canel et al., 2000; Kraemer et al., 2000). In essence, JIT is the ultimate time-based pull logistics strategy coupled with total supply chain cost minimization (Stalk, 1988; Germain et al., 1994).

This procurement practice is based on a time-compression strategy that allows companies to effectively compete on waste elimination by taking time and inventory out of the entire system (Hay, 1990; Stalk et al., 1992; Cusumano, 1994; Germain and Droge, 1995; Canel et al., 2000). In consequence, suppliers and carriers are expected to consistently deliver appropriate quantities of products within fixed time frames (Gomes and Mentzer, 1988; Daniel and Reitsperger, 1996) opening the possibility of incurring in less-than-full-truckload shipments (Disney et al., 2003).

Provided that products delivered must conform to customer's specification every time; quality assurance is a critical component of JIT (O'Neal, 1987; Inman, 1990; Lummus and Duclos-Wilson, 1992; Davis, 1993; Spencer and Guide, 1995; Claycomb et al., 1999; Kraemer et al., 2000). Other critical elements for successful JIT product procurement are executive and managerial support (Lee and Ebrahimpour, 1984; Giunipero, 1990; Mehra and Inman, 1992; Chong et al., 2001), and the timely involvement and development of a reduced supplier base (Schonberger, 1982, Hall, 1983; Manoochehri, 1984; Ansari and Modarress, 1987; Ansari and Modarress, 1988; Crawford et al., 1988; Im and Lee, 1989).

JIT supports an inter-company perspective (Arnold and Bernard, 1989; Newman, 1989; Leavy, 1994) that allows the development of key performance indicators focused on the efficient distribution of goods (Bartezzaghi and Turco, 1989; Ramsay and Wilson, 1990; Willis and Huston, 1990) through supplier certification programs (Schonberger and Ansari, 1984; Celley and Clegg, 1986; Macbeth, 1987; Giunipero, 1990b; Nelson and Jambekar, 1990) and dual sourcing practices (Westbrook, 1988; Harrison and Voss, 1990).

Emergent challenges from an operational standpoint consider the evaluation of multi-modal transportation for product delivery and effective fleet utilization when executing backhauling activities (Goetschalckx and Jacobs-Blecha, 1989; Higginson and Bookbinder, 1990; Kelton et al., 2010). Conversely, these same challenges can identify supply chain wide improvement opportunities such as the reduction of intermediaries through the implementation of direct delivery systems (Bookbinder and Locke, 1986; Fieten, 1989; Crawford and Cox, 1990; Goyal and Deshmukh, 1992). Over time, several industries have adopted JIT product procurement due to its vast array of operational benefits.

In 1996, a joint investment between Ford Motor Company and the Government of Spain allowed an assembly plant in Valencia to develop a series of aerial tunnels to support the manufacture of the Ford KA model. These tunnels supported point-of-manufacture delivery from the supplier park into Ford's production floor. By 1997, this process improvement allowed the organization to achieve its full production quota of 1,100 vehicles/day in 8 weeks compared to the 15 weeks required a year before. In addition, 100% of supplier deliveries were completely handled through the aerial tunnels, fully avoiding the operations associated with receiving 250 truck shipments every day as the previous year (Kochan, 1997).

In 1990, after selling through retail outlets such as CompUSA, Circuit City, and Price Club; Dell Inc. withdrew from the retail market and established direct sales to customers. At the same time, it defined their own customer relationship segment focused on Fortune 1,000 companies that purchased at least $ 1M (US) every year. By establishing their Direct Sales Model, Dell increased global net sales from $ 2B (US) in 1992 to $18.2B (US) in 1998;

increased worldwide market share from 3% in 1995 to 9.2% in 1999, and established corporate accounts with Boeing, Oracle, Ford, Microsoft, P&G, and Walmart with corresponding sales increasing from 59% in 1992 to 70% in 1997 in the United States. At the plant level, Dell's days of inventory dropped from 32 in 1994 to just 6 by 1998 with an average total production cycle time per unit of 7 hours and order turnaround time of 7 days (Kraemer et al., 2000).

The virtual store concept introduced by Amazon.com in 1995 gradually required critical supporting infrastructure in order to respond to increased product stock-outs, delayed deliveries, and logistic costs (Van Hoek, 2001b). Demand responsiveness efforts from Amazon resulted in the development of 3 million square feet of dedicated fulfillment and customer service centers in the US between 1996 and 2001 (Ricker and Kalakota, 1999). After becoming the second largest internet retailer with $1.8B (US) in sales in 2001 (Grewal et al., 2002), a strategic partnership was developed with the United States Postal Service. Forty percent of parcel services related to this alliance required expedited shipments all year around (Heizer and Render, 2004). Activities associated with same-day delivery service promise were prone to rapid escalation. For instance, the mobilization of 250,000 copies of a Harry Potter title on publication day required the operation of 100 air-freight planes and 9,000 trucks only in the US (Matthews et al., 2000).

The potential identification and elimination of waste sources remains in the long-term for organizations that fully adopt JIT practices (Romero, 1991; Inman and Mehra, 19993). Resource waste under this IMM is usually associated with supplying organizations as they are responsible for product quality, packaging materials, distribution processes, and inventory levels, while the retailing partners tend to reap most of the overall process benefits (Frazier et al., 1988; Das and Goyal, 1989; Fandel and Reese, 1991).

This perceived functional imbalance between supply chain partners highlights the risk of operational disruption and vulnerability from retailing organizations depending on a reduced supplier base and subject to the complexity associated with any supplier substitution process (Frazier et al., 1988; Wilkinson and Oliver, 1989; Gupta and Heragu, 1991). Therefore, a balanced distribution of risks, benefits, and waste elimination opportunities among supply chain partners remains as a constant challenge for JIT procurement practices (Harbert et al., 1990; Karlsson and Norr, 1994; Waters-Fuller, 1995).

2.3.3 Postponement

The notion of postponement was originally introduced to reduce the risk and uncertainty costs tied to product differentiation (Alderson, 1950). Bucklin (1965) supplemented the concept with the speculation-postponement strategy applied to distribution channels, in order to determiner where, when, and which supply chain partner must hold inventory to reduce cost and risk. Particularly, the concept of speculation relies on product demand forecasts and therefore it is considered a push-approach, while postponement supports the integration of customer requirements impacting product design and production processes guided by consumer demand in a pull-approach fashion (Shapiro, 1984).

Postponement is a product design strategy that shifts product differentiation closer to consumers by delaying final configurations such as assembly or packaging, to the last possible supply-chain location in order to meet high levels of product customization (Pagh and Cooper, 1998; Van Hoek, 2001). The rationale behind postponement is that the delay in final product differentiation leads to improved risk management and reduced product variability as actual costumer requirements become available (Lee and Tang, 1998; Van Hoek, 2000a; Lee and Whang, 2001).

Manufacturing organizations may design and develop standard or generic configurable semi-finished products, and perform individual customization quickly and inexpensively once actual consumer demand is known while reducing inventory carrying and holding costs (Yang et al., 2005). Depending on time, place, and form product customization can encompass light manufacturing, deferred assembly, labeling, and packaging activities during downstream supply chain operations (Cooper, 1993; Pagh and Cooper, 1998).

Multi-national corporations managing several manufacturing facilities, each responsible for a specific product range (Lumsden et al., 1999), face multiple challenges in order to customize final products according to specific regional requirements and market segments (Cusumano, 1994; Holmstrom, 1997; Yang and Burns, 2003; Christopherson, 2007) while coping with the corresponding trade-off between operational cost and customer service (Zinn and Bowersox, 1988; Feitzenger and Lee, 1997; Camuffo et al., 2001). According to Twede (2000), postponement can reduce 30% of inventory carrying costs for manufacturers and as much as 50% for wholesalers and retailers.

Ideally, distribution systems architecture should adapt according to customer demand, product volume, and variety considerations (Lumsden et al., 1999). Products with regular large volumes and little product variety can be shipped directly from factories to retailers, others with medium volumes and high product variety can be subject to seasonal variation and timely handled by a third-party-logistic organization; while stock with low volumes and high product variety can be allocated to distribution centers with final customization capabilities (Van Hoek and Van Dierdonck, 2000). This practice reduces warehouse space requirements for final products until actual customer demand is known (Rodrigue et al., 2001) and emphasizes the importance of quick and reliable transport (Morash and Clinton, 1997).

Theoretically, postponement is located at the push-pull boundary of the supply chain, where undifferentiated product can be built and transported based on long-term forecasts, while final customization addresses actual market demand (Simchi-Levi et al, 2003). It is at this same boundary where the Decoupling Point is located, this is the point where in the supply chain customer orders penetrate and distinguish between product forecast and order-driven activities (Sharman, 1984; Yang and Burns, 2003).

The decoupling point location is intended to respond to volatile downstream demand yet providing product level scheduling in upstream operations (Naylor et al., 1999; Van Hoek et al., 1999). As a result, postponement can move the decoupling point closer to the end user and increase the efficiency and effectiveness of the supply chain (Heskett, 1977; Andries and Gelders, 1995; Mason-Jones and Towill, 1999).

Ernst and Kamrad (2000) classified different types of supply chains depending on the different degrees of product modularization and postponement available within them. Their classification included rigid, modularized, postponed, and flexible supply chains. Product modularization was mainly associated with manufacturing operations, while postponement activities were associated with packaging processes. In addition, the relationship between speculation and postponement was associated with an operational continuum among product customization and standardization (Lampel and Mitzberg, 1996). Along this continuum several supply chain strategies going from make-to-forecast and shipment-to-order were connected to buy-to-order and engineering-to-order practices in order to achieve pure product customization (Hoekstraand Romme, 1992; Van Hoek, 1997).

Logistics postponement keeps finished inventory at a central location and ships products directly on demand. Therefore, it usually involves premium transportation for less-than-truckload (LTL) service and air freight, in order to minimize the time from order to delivery. Accordingly, packages should be small and compact to minimize shipping costs, while at the same time sufficiently robust in structure to withstand repeated handling, conveyors movement, and mixed-load stacking (Bowersox and Closs, 1996; Twede et al., 2000; Yang and Burns, 2003).

In a manufacturing-packaging postponement process, semi-finished products are shipped in bulk to a point near to the market. Final operations, such as light manufacturing, assembly packaging, and labeling are performed once a customer order is received. These differentiating steps take place at a decentralized point close to the market.

Distribution costs are usually low since products are shipped in bulk to regional packing centers or assembly sites. This is especially true if the item can be shipped in a more compact form before final packaging is applied. Inventory risk tends to be low as undifferentiated product can be diverted to another form, location or packing operation according to demand shifts. Conversely, production and packaging costs may be higher in this strategy due to similar operations taking place at multiple locations (Twede et al., 2000).

The reduction of non-value added activities while increasing product variety and customer focus resulting from product postponement, clearly resonates with the notion of mass customization. According to Hart (1995), mass customization is the use of flexible processes and structures to produce varied and even individually customized products and services at the lowest cost possible. This kind of environment combines individual product customization with manufacturing economies of scale (Bowen and Youngdahl, 1998).

Postponement has been significantly adopted by the electronics and apparel industries (Lee and Tang, 1998; Pagh and Cooper, 1998; Camuffo et al., 2001). Particularly, computer manufacturers entered into a vertical disintegration trend, in which additional links are integrated into the logistical chain. Intermediate warehouses can conduct final assembly between manufacturers and consumers in order to achieve full product customization (Rodrigue et al., 2001).

In 1990, one of the most successful products from Hewlett-Packard, the Deskjet family of thermal inkjet printers used to be localized at the factory level (Lee et al., 1993; Simchi-Levi et al, 2003; Heizer and Render, 2004). Given the significant amount of final product configurations required in small European markets such as Denmark, the organization decided to delay the localization of power supply components, product labeling, and documentation at the distribution center level (Kraemer et al., 2000; Twede et al, 2000). This change allowed the company to reduce a 7-week finished goods inventory to a 5-week generic inventory, while maintaining a 98% customer service level in the region in 1991. According to Davis (1993), the corresponding inventory savings from 1990 to 1991 accounted for $30M (US).

Following the localization success from the inkjet printers which duplicated its original offering of 138 versions from the six basic models during the early 1990's, the next process improvement for Hewlett Packard leveraged packaging postponement. By avoiding the use of cushioning materials when transporting main printer modules, a pallet space usage reduction was achieved from 4,320 to 2,406 cubic inches in 1992. Original pallets used to carry 32 printers, after space usage improvement each pallet transported 60 printers. By 1994, pallets were substituted by slip-sheets. The additional space allowed for an extra layer of product going from 60 to 75 printers per pallet (Twede et al., 2000).

In 1995, the Casual Wear Division of the Benetton Group consolidated their traditional garment dyeing postponement process and operations reversal practices into a 1.2 million square feet high-tech production facility in Treviso, Italy (Simchi-Levi et al, 2003; Heizer and Render, 2004). The centralized production capacity of 120 million items per year allowed the organization to reduce product customization from 20% in 1995 to 7% in 2001 in order to eliminate waste and develop a standard array of products able to support one overarching brand image across different countries such as Spain, Portugal, Egypt, India, and Korea. The Casual Wear Division accounted for 74% of total annual revenue for the Benetton Group valued at $1.8B (US) in 2000 (Camuffo et al., 2001; Yang and Burns, 2003).

2.3.4 Cross-Docking

This practice has been widely associated with Hub-and-Spoke (H&S) distribution architecture where shipments coming from several originating points are consolidated at major terminals or hubs and redirected to their respective destinations through radial links or spokes where products go through short-term stays defined by little or no order picking needed (Lumsden et al., 1999; De Koster et al., 2007). This approach became relevant as the increasing number of supply chain partners contributed to multi-echelon allocations of inventory (Clark and Scarf, 1960) and their corresponding sources of waste.

Cross-docking handles products delivered from multiple plants to multiple distribution centers, or from multiple distribution centers to multiple retail stores, re-assort and transport them to further destinations without formally staying at warehousing facilities (Kinnear, 1997; Lee and Whang, 2002). Product packaging configurations consider final destinations and ease for re-assortment at intermediate warehouses as products flow from receiving to shipping docks (St. Onge, 1996; Holmstrom, 1997).

In a traditional retail distribution system different shipments of several truckloads from a given item can be received, checked, and moved to backroom storage. Then, incoming orders would be picked from stock, assembled into kits with other items and shipped to the stores. Conversely, in a cross-docking environment, the incoming shipment would be unloaded, broken down and immediately reassembled in outbound shipments to the stores (Cooper, 1994). Since products are not stored in warehouses but rather moved from manufacturers or distributors to wholesalers and retailers, directly crossing their warehouses (Wu and Dunn, 1995; Goetschalckx et al., 2007) maximum process efficiency can be achieved through careful planning and shared information about product sales.

Under this practice warehouses become operational nodes for material handling and information exchange, instead of traditional storage locations for raw materials, work-in-process, and finished products at and between points of origin and consumption (De Koster et al., 2002; Sung and Song, 2003). Therefore, cross-docking warehouses can address natural time and space constraints at lower costs while keeping demand responsiveness towards retailers (Won and Olafsson, 2005; Goetschalckx et al, 2007). Internal dynamics associated with warehouse management can uncover improvement opportunities in resource usage.

Traditional processes such as order picking, the process of retrieving products from storage or buffer areas in response to a specific customer order has been characterized as the most labor-intensive operation in warehouses with manual systems, and a very capital-intensive operation if automated systems are involved.

The cost of order picking is estimated to be as much as 55% of total warehouse operating expense depending on its corresponding order-picking, routing, zoning, order-batching, and sorting policies (Bozer et al., 1988; Brynzer and Johansson, 1996; Daniels et al., 1998; Chew and Tang, 1999; De Koster et al., 2007).

For manual order picking systems, handling costs and travel time within the facility represent important opportunities for process improvement subject to warehouse layout optimization (Petersen, 1999; Roodbergen and De Koster, 2001; Petersen and Aase, 2004); these considerations are dramatically reduced by the implementation of cross-docking.

Usually, products need to be placed into reserve areas or forward storage locations within the warehouse before they can be picked-up to fulfill customer orders (Van den Berg et al., 1998; De Koster et al., 2007). The complexity inherent to storage assignment methods such as random location, closest open storage, dedicated storage, full turnover storage, and class-based storage is significantly reduced by this practice (Heskett, 1964; Hausman et al, 1976; Rosenblatt and Roll, 1984; De Koster, 1994; Petersen, 1997; Van den Berg and Gademann, 2000).

Once inbound trucks arrive into the warehouse yard, they are assigned into a receiving or striping door for unloading; the goods are sorted according to destinations, and then loaded onto outbound trucks at shipping or stack doors. Often, each stack door is designated to a particular destination, and once established, it generally does not change for longer periods of time. Therefore, a significant amount of warehouse operational planning is focused on receiving/departing docks coordination and retail store product allocation scheduling (Federgruen and Zipkin, 1984; Gue, 1999; Bartholdi and Gue, 2000; Goetschalckx et al, 2007). Product flow at the warehouse is usually defined by two common models.

The product sort model allows supplying organizations to dispatch a complete consignment of one product code covering the aggregated demand from final destinations. The cross-docking facility receives these product consignments and breaks them down into common final delivery orders. This post-receipt allocation model supports time and space-constrained supplying organizations unable to sort their products by final destination. Conversely, the final destination sort model requires the supplier to pick and label each consignment for its final destination at the source (Kinnear, 1997; Waller et al., 2006).

Cross-docking facilities bridge traditional inventory management practices at the factory level with marketing-guided retailing inventory management policies (Jonsson and Silver, 1987; Levy and Grewal, 2000). Particularly, when cross-docking takes place at the retailer distribution center, it can impact the amount of shelf space allocated to a product in order to achieve competitive customer service levels (Sabath et al., 2001; Waller et al., 2006).

A typical Hub-and-Spoke system configuration, largely employed by express couriers, is a multiple terminal network scheme based on several hubs at the same hierarchical level (O'Kelly, 1986; Slack, 1990; Kuby and Gray, 1993; Aykin, 1995; Taylor and Hallsworth, 2000). In consequence, products coming from or going to any satellite points require one or more handling operations before reaching their final destinations.

When compared to the single terminal network model, the multiple terminal configuration results, on average, in reduced distances travelled by products but with an overall less efficient utilization of transportation resources (O'Kelly, 1998, Lumsden et al., 1999).

Cross-docking implemented across H&S systems can increase carrier filling rates and travel frequency, while decreasing transportation costs, inventory investment, and storage space requirements (Holmstrom, 1997; Lumsden et al., 1999). Warehouses performing freight consolidation functions and breakbulk operations can improve transportation capabilities, thus minimizing the waste and environmental impact of the facilities and corresponding fleets (Wu and Dunn, 1995; Sung and Song, 2003).

Several mass merchandisers and grocery chains are increasingly adopting this lean practice to reduce their operational costs while reaching an increased number of final delivery points (Kinnear, 1997; Simchi-Levi et al, 2003). Particularly, cross-docking has been widely associated with improved performance of retail distribution environments (Kulwiec, 1994; Blatherwick, 1998; Brown et al., 2005).

Walmart successfully integrated cross-docking operations into its strategy since the early 1990's. This company wide initiative was supported by significant infrastructural investments such as the development of a satellite communication system to enable video link across the whole organization, the establishment of 19 distribution centers, and a company owned transportation fleet of 2,000 trucks (Duclos et al., 1995; Brown et al., 2005).

These capabilities streamlined the management of 85% of its total inventory through cross-docking and provided demand responsiveness based on store replenishments twice a week compared to the industry average of once every two weeks (Stalk et al., 1992). In addition, Walmart's presence in the warehouse clubs industry increased from 30 facilities in 1986 to 180 in 1991. In 1990, the average cross-docking lead time for the organization was approximately 48hrs, ten years later the same operation required only 13hrs (Simchi-Levi et al, 2003).

Another example is the sixth cross-docking facility from JCPenney located in Lathrop, California which is a 436,000 square foot center able to handle 165,000 cartons per day. The process is mainly supported by a high-speed conveyor and sortation system which allows 95% of inventory to pass through the facility from receiving to shipping docks in approximately five minutes, a significant improvement from their traditional distribution facilities that handled on average 44,000 cartons in 7.5 hrs (Witt, 1992). Moreover, the supplier certification program offered to their 20,000 members in 2004, allowed the organization to achieve an incoming inspection rate of 1% compared to the

6% industry standard for supplier shipments (Simchi-Levi et al, 2003; Sheu et al, 2006).

In May 2007, American Eagle Outfitters opened their fourth distribution center in Ottawa, Kansas. The 552,000 square feet facility expandable to 720,000 serves the three apparel business divisions of the company. Equipped with 7 miles of conveyor and sorting systems, the center can handle up to 300,000 Stock Keeping Units a day; enough regional distribution capacity to sustain the $2.7B (US) annual sales of the organization. In addition, 70% of total inventory goes through Cross-Docking with an average lead time per order of 6 minutes. Former distribution centers in their network required 12-24hrs to process a cross-docking shipment. Product-flow operations can pick up 6,200 items per hour during seasonal peak demand (Dematic, 2008).

2.3.5 Vendor Managed Inventory (VMI)

Traditional supplier-customer relationships were usually defined by customer managed inventory practices where suppliers received orders from the customer organization, verified product availability from buffer inventories, and schedule the corresponding shipment (Goyal and Gupta, 1989; Blatherwick, 1998).

In principle, information exchange among organizations used to be very limited and mainly focused on price, quantity, product mix, and due date considerations (Disney et al., 2003). Moreover, the relationships between suppliers and costumers were described as adversarial, since there was always the potential of contrasting goals among supply network members supported by the reluctance of sharing confidential process information (Das and Goyal, 1989; Simchi-Levi et al, 2003; Danese, 2006).

Eventually, supply chain partners realized the importance of developing an approach to address materials management and information flows between one or more customer organizations and their immediate suppliers. As a result, several organizations found profitable the adoption of strategies involving the development of strategic partnerships with major suppliers (Schonberger, 1982, Hall, 1983; Crawford et al., 1988; Youngdahl, 1996). Important elements acknowledged when engaging in this type of partnerships were: the position of the focal firm within the total network, the existence of legal ties between firms, and the length and complexity of the chain (Grieco, 1989; Dow et al., 1999; Croom et al., 2000; Cox, 2001; Tan, 2001; Hausman and Stock, 2003; Simpson and Power, 2005; Christopherson, 2007).

Specifically, the origins of Vendor Managed Inventory (VMI) can be traced back to the early development of Quick Response programs for general merchandized retailers and their suppliers during the early 1980's. A quick response strategy is a system where retailers and suppliers work together to serve consumer needs quickly based on information sharing (Tyan and Wee, 2003). In 1984, due to the intense competition in the textile industry, leaders from the US apparel industry formed the "Crafted With Pride in the USA Council" an adopted quick response practices.

By 1992, leaders from the grocery industry formed a task force called the Efficient Consumer Response working group with significant emphasis on the quick and accurate flow of information within the supply chain (Lummus and Vokurka, 1999). The combined influence of both groups facilitated the concept development of Continuous Replenishment Policy, where vendors receive point of sale data and use it to prepare shipments at previously agreed intervals to maintain specific inventory levels (Vergin and Barr, 1999). VMI emerged as the natural progression from these practices combined with the early adoption of information technologies such as Electronic Data Interchange and Enterprise Resource Planning systems (Holmstrom, 1998).

Vendor Managed Inventory is a supply chain system whereby a supplier assumes responsibility for maintaining inventory levels and determining order quantities for its customers in order to ensure that predetermined customer service levels are maintained at the store level (Disney et al., 2003; Dong et al., 2007). This activity is accomplished by a process in which resupply is done by the vendor through regularly scheduled reviews of the on-site inventory.

This inventory is counted and damaged or outdated goods are removed from the shelves in order to restock inventory to predefined levels (Waller et al., 1999). The vendor obtains a receipt for the restocked items and accordingly invoices the customer organization (Tyan and Wee, 2003).

Provided that suppliers decide on appropriate inventory levels for each of the products, their initial operations need to be approved by the retailer, but the long-term goal of many VMI programs is to completely eliminate retailer oversight from the process (Andel, 1996; Holmstrom, 1998; Simchi-Levi et al, 2003).

Product replenishment in fixed or variable quantities takes place when the stock level at the buyer organization reaches a specified level. Product supplied quantities are based on both the average demand during the transportation lead-time and a safety stock to cover for demand variations (Waller et al., 1999; Kaipia et al., 2002).

By delaying the ownership transfer of goods, VMI fosters an increased replenishment frequency similar to what might be expected from a continuous replenishment program (Stenzel and Stenzel, 2002; Dong et al., 2007). Information sharing practices between supply chain members are critical for VMI development (Cachon and Fisher, 2000; Danese, 2006), as they tend to decrease the average stock level in the supply chain through better supplier visibility (Lancioni et al., 2000; Cheung and Lee, 2002) and reduce the number of stock out occurrences at the retail level (Waller et al., 1999; Kainuma and Tawara, 2006), while providing demand responsiveness (Holmstrom, 1997; Blatherwick, 1998; Smaros, 2000).

According to Disney and Towill (2002), the most significant aspect from VMI is that customer organizations share information rather than orders with suppliers. In fact, supplier delivery plans are decided on the basis of information communicated by customers in the form of product sales data, forecasts, and projected inventory levels (Christopher, 1992). Compared to JIT practices, VMI suppliers are in a better position as they can identify waste reduction opportunities on a timely manner and level product replenishment to address demand peaks in the planning horizon.

In JIT, the supplier must adjust its activities very quickly according to the customer, and may end up keeping unnecessary inventories or extra capacity dedicated to the customer. From a product range perspective, low volume products with reduced replenishment frequencies can achieve increased efficiencies due to the enhanced visibility provided by VMI (Kaipia et al., 2002; Smaros et al., 2003).

At the same time, this kind of visibility minimizes the usual demand distortion coming from downstream supply chain members (Cetinkaya and Lee, 2000; Disney and Towill, 2003) and allows product batching implementation to minimize transport demand without negatively impacting the overall performance of the supply chain (Disney et al., 2003). Several collaborative efforts between manufacturers and retailers have flourished through the adoption of VMI.

For instance, the Walmart and Procter & Gamble strategic partnership initiated in 1985 (Buzzell and Ortmeyer, 1995). Walmart completed a $700M (US) satellite communications network installation connecting all stores to their headquarters in 1987. P&G fully devoted a team of 250 associates to nurture the partnership by locating them in the city of the account's central office (Simchi-Levi et al, 2003). In 1993, the VMI initiative between both organizations allowed an average Walmart store to devote 10% of its square footage to backroom storage, compared to an industry average of 25%. Similarly, operating expenses per store accounted for 18% versus the industry average of 25%. Over time, Walmart became P&G's largest customer, conducting business with them for $3B (US) annually, or equivalent to 10% of P&G's total revenue by 1993. VMI paved the way for further collaboration practices between organizations such as Collaborative Planning, Forecasting and Replenishment (CPFR) and the overarching Voluntary Inter-Industry Commerce Standards (VICS) launched in 1995 and 1996 respectively (Grean and Shaw, 2002; Tyan and Wee, 2003).

Kimberly-Clark Corp. managed the inventory of 44 retailers of their products from 1997 to 1999, saving $200M (US) in supply chain costs. In 1997 it started managing Costco's inventory. Before VMI's roll-out, Costco used to carry one full month of supply from Kimberly-Clark's products as safety stock at each store, this inventory was reduced by 50% in 1998. Product replenishment lead time from the manufacturer to Costco achieved an average of 1 week, instead of multiple bi-weekly shipments per store in 1999. Kimberly Clark's next step was to extend VMI practices into its supplier base. In 1999, it reduced by 50% its diapers' finished product inventory by coordinating production schedules with their leading supplier Velcro USA Inc (Simchi-Levi et al, 2003).

The international pharmaceutical group GlaxoSmithKline (GSK) with global sales of $30B (US) and 108 plants located in 41 different countries, decided to implement VMI in 1995 under their Global Supply Chain Project. Prior to VMI implementation, GSK's supply chain operations were based on an 18-month forecast. By 1997, a 9-month planning horizon jointly-administered by antibiotic manufacturing plants and distribution centers was fully operating. In addition, by managing 65% of its total inventory through VMI, GSK improved its customer service level from 90% in 1995 to 97% in 1997. The original project considered 18 manufacturing plants, while the second stage included 44 additional facilities by 1999 (Danese, 2006).

Vendor Managed Inventory became a clear example of the integrated management of networked entities; initially in supplier-customer dyads but with a feasible extension from suppliers' suppliers to customers' customers for the production and delivery of goods to the end consumers (Disney et al., 2003; Danese, 2006).

Under this approach, companies do not seek to achieve short-term local optimizations due to cost reductions or profit improvements at the expense of their supply network partners, but rather seek to make the supply network more efficient and competitive as a whole in the long-term (Perdue et al., 1986; Sabath, 1995; Duke, 1998; Marien, 2000; Mohanty and Deshmukh, 2000; Dong and Xu, 2002).

The transparent management of VMI partnerships is critical to reduce the complexity associated with processes such as changing purchasing strategies and policies, the jointly development of demand forecasting, identification of inventory and retail management capabilities (Tyan and Wee, 2003). In addition, regular reviews of the partnership must be in place to support the continuous exchange of sales, costs, inventories, information, and knowledge between organizations (Lamming et al., 2001). These periodic assessments can incorporate supporting technologies such as decision support systems (Achabal et al., 2000) able to accommodate future business partners.

Although each inventory management method previously described offers specific process performance advantages, all of them share several waste streams that can contribute to the environmental performance of their supply chains. Some improvement opportunities are: the utilization of transportation fleets, cubic space allocation in warehouses and retailing facilities; fuel and electricity requirements to support warehousing, transportation, and retailing processes; and the overall reduction of inventory across the supply chain.

Given the overarching nature of lean-oriented systems, their corresponding structure and performance might be prone to an increased number of vulnerabilities when compared to traditional consumer goods procurement systems. The latter are usually defined as distributed systems composed of independent yet interactive elements that may deliver equivalent or better functionality with greater system resilience (Fiksel, 2003). Conversely, lean-oriented systems can be conceptualized as complex hierarchically organized systems containing rigid operating parameters. This type of systems is resistant to stress only within narrow boundaries, and may be vulnerable to small, unforeseen perturbations (Jackson, 2000).

For instance, JIT procurement models emphasize that only the necessary products, at the necessary time, in the necessary quantity are procured (Sugimori et al., 1977; Schonberger, 1996; Arnheiter and Maleyeff, 2005). Their corresponding operational dynamics are triggered by outcomes coming from downstream supply chain stages in the form of actual product consumption (Snyder et al., 1982; Sadhwani et al., 1985; Billesbach, 1991).

This demand-driven approach aims to keep product inventory levels to an absolute minimum, ideally moving one unit at a time in response to actual customer orders (Bitran and Chang, 1987; Philipoom et al., 1990; Ramasesh, 1990; Lovell, 1992; Savsar, 1997) while eliminating waste from the process (Frazier et al., 1988; Silver, 1990; Spencer and Guide, 1995).

Provided that upstream processes are deemed ready for the eventual procurement of product requirements (Gomes and Mentzer, 1988; Billesbach and Schniederjans, 1989; Harvey, 1989: Wasco et al., 1991; Silvestro et al., 1993; Canel et al., 2000), each operational domain involved in the process can potentially become a source of performance disruption.

For instance, transportation activities supporting the operations can be subject to elements such as increased traffic congestion, poor weather conditions, narrow delivery window time frames, or vehicle breakdown (Chapman and Carter, 1990; Kant and Grenoble, 1991; Christensen, 1996; Daniel and Reitsperger, 1996; Holmstrom, 1997).

Process disruptions along these supply chain stages can have significant impacts when time-sensitive and perishable products are being handled (Duclos et al., 1995; Canel et al., 2000; Kraemer et al., 2000). The potential use of additional resources represents a constant risk due to the narrow operational process boundaries of the system. Another important source of potential supply chain disruption associated with lean systems is found in supplier streamlining processes.

Similar to the interactions taking place between raw material suppliers and manufacturing organizations (Frazier et al., 1988; Wilkinson and Oliver, 1989; Dubelaar et al., 2001; Childerhouse et al., 2002), certified partners can deliver consumer goods directly into retailing shelves without further inspection. Supplier development programs are essential to lean systems. Practices such as Postponement and Vendor Managed Inventory rely on the proven quality of upstream partner organizations to deliver sub-assemblies and final products at the actual point-of-sale.

An additional outcome from supplier development initiatives is the significant reduction of the supplier base. As long-term partnerships are established with a discrete number of organizations, some can evolve into a sole or unique supplier model (Ansari and Modarress, 1988; Crawford et al., 1988; Im and Lee, 1989). However, such a degree of inter-company dependence can describe a lack of strategic risk distribution from the customer organization.

This organizational array can derive in significant environmental burdens due to the sudden change of suppliers including the time and resources required for developing a new strategic partner. Although the rationale behind the elements previously described aims at the systematic reduction of waste across supply chain functions, their cumulative interactions can also result in a lack of operational flexibility based on a reduced number of alternative processes supporting the timely flow of resources and products in response to actual market demand.

Under a lean perspective, elements such as buffer inventories at several levels of the supply chain or having an expanded supplier base can be considered redundant resource allocations that not necessarily convey immediate value to the procurement process. Nonetheless, having alternative system pathways based on redundant supply chain design are in many cases the basis for overall system resilience.

The resulting decreased level of resilience from critical processes within different operational domains can lead to the sudden break down of larger systems in the face of disturbances that previously could be absorbed by a redundant design (Redman, 2005). The capacity for a system to undergo evolutionary change or self-organization requires that the system must be capable of exercising sufficient direct power to maintain its integrity over time, while possessing a reserve of flexible resources that can be used to meet the exigencies of novel disturbances (Ulanowicz et al., 2009). In consequence, the gradual loss of spare resource capacity, diversity or flexibility may degrade the overall level of resilience from a supply chain, thereby undermining its long term sustainability even as measures of eco-efficiency improve over time (Korhonen and Seager, 2008; Ulanowicz et al., 2009).

The following chapter builds upon the level of detail provided by these lean practices in order to develop a set of propositions fully aligned to the overarching research hypothesis of the study. Each proposition identifies a critical process variable associated with the adoption of lean practices that can influence the outcomes from consumer goods procurement processes.

CHAPTER 3

THEORY

3.1 Introduction

Given the environmental implications associated with the integration of lean principles into logistics and retailing processes across the supply chain, I will develop arguments that lead to the following overarching research hypothesis:

Lean distribution of durable and consumable goods (i.e. lean logistics) can result in an increased amount of carbon dioxide emissions, while lean retailing operations can reduce process emissions.

The following sections describe four research propositions associated with each one of the selected lean-oriented Inventory Management Methods (IMM). The process being modeled is the procurement of a consumer product. The default IMM representing common, "non-lean" practice is the Economic Order Quantity (EOQ) procurement model.

Because of the number and complexity of environmental impacts associated with these procurement processes, outcomes from warehousing, transportation, and retailing operations are quantified in carbon dioxide equivalents. Given a particular lean-oriented IMM, each proposition incorporates operational elements that could impact the energy requirements and carbon dioxide equivalent magnitudes resulting from the consumer goods procurement process.

Figure 1 provides a schematic representation of the consumer goods procurement process and its corresponding outcome. The central arrow connecting these two elements represents the process implementation subject to operational variables associated with the selected lean practices. The following propositions are presented in the same order as lean practices were described in the previous chapter.

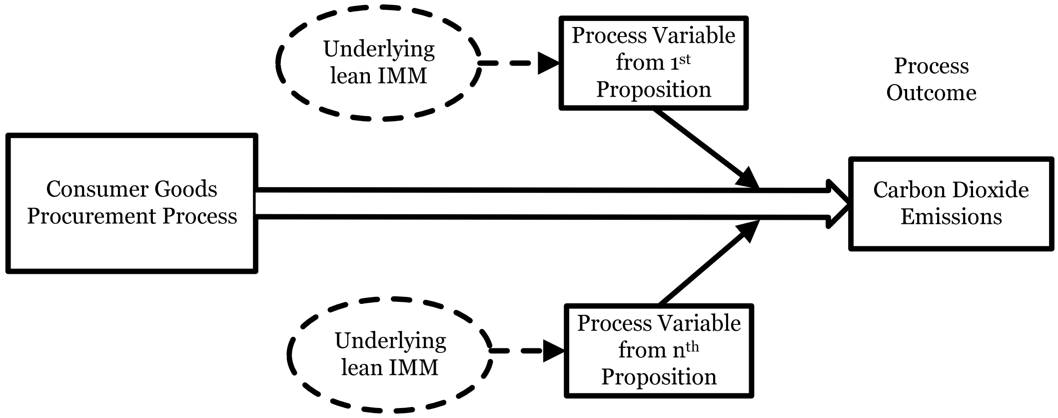


Figure 1: General structure for research propositions.

3.2 Impact of Just-in-time delivery

The objective of inventory management methods is to provide the required level of customer service at the retailing stage of the supply chain (Arnold and Chapman, 2004). This proposition aims to compare the environmental performance between the lean method of just-in-time product procurement and Economic Order Quantity (EOQ) measured in carbon dioxide equivalents.

On the one hand Just-in-Time product procurement can be considered an environmentally responsible practice due to its emphasis on waste elimination (Spencer and Guide, 1995; Canel et al., 2000). From process idle time and packaging material reductions to efficient cubic space utilization at warehouses and motor carriers, the broadened notion of waste as any non-value added activity becomes particularly relevant for this leading practice (Corbett and Klassen, 2006) towards environmental performance. On the other, the inventory management method of Economic Order Quantity has been widely used due to its relatively modest differences in total costs as a function of variations in setup costs, holding costs, and product demand (Goyal, 1985, Chu et al., 1998; Heizer and Render, 2004). This IMM is used primarily to ensure that demand for a product can be immediately fulfilled, since products are inventoried at central distribution centers (Goswami and Chaudhuri, 1992; Pagh and Cooper, 1998; Twede et al., 2000).

JIT embodies the lean principle of demand responsiveness between supply chain partners by allowing product procurement based on single deliveries driven by actual consumer demand regardless of truck filling rate considerations. This kind of deliveries can affect fleet utilization resulting in less-than-truckload (LTL) shipments (Lumsden et al., 1999; Disney et al., 2006). Furthermore, carrier cubic space utilization is also affected by established vehicle size and weight regulations (McKinnon and Woodburn, 1994; Wu and Steve, 1995). Conversely, once an EOQ has been determined for a specific product, stores still can adapt their replenishment orders to available packaging product configurations such as pallet loads, cases, or dozens (Arnold and Chapman, 2004), which make its corresponding retailing deliveries prone to full-truck loads (TL) associated with better utilization of cubic space within product carriers (Wu and Dunn, 1995; Rodrigue, 1999; Fernie et al., 2000).

From a packaging materials handling and space utilization standpoint, product consolidation and containerization before shipment have been suggested by prior research as immediate process improvement opportunities for product procurement activities under both approaches (Wu and Dunn, 1995; McKinnon, 2000; Hesse and Rodrigue, 2004). Specifically, product consolidation and containerization can concentrate packaging materials handling activities in order to manage lower volume flows, while offering economies of scale based on batch flow items and therefore increasing the cubic space utilization and load factors of product carriers (Rodrigue, 1999; Fernie et al., 2000).

The initial trade-offs from integrating such activities into both approaches can be reflected on inventory carrying costs from distribution centers and retailers versus variable transportation costs between supply chain partners. By definition, EOQ is robust against inventory carrying costs (Chu et al., 1998; Heizer and Render, 2004) while JIT aims to reduce overall inventory carrying costs by ideally moving one unit at a time in response to actual customer demand (Bitran and Chang, 1987; Philipoom et al., 1990; Ramasesh, 1990; Lovell, 1992; Savsar, 1997). Moreover, the time required for product consolidation can potentially obstruct JIT's inherent demand-responsiveness-oriented pace in an attempt to gather the exact quantity of needed products expected within a narrow time window (Gomes and Mentzer, 1988).

Besides product demand windows, delivery schedules from warehouses are subject to other spatiotemporal constraints. Timely product delivery to retailers must acknowledge the increasing implementation of specific time-windows or time-access restrictions which force distribution activities to take place within specified periods of the day (Quak and De Koster, 2007) and progressive environmental measures such as the establishment of low emission zones, where air quality is intended to be improved by limiting the circulation of older, high-polluting delivery vehicles from certain urban areas while encouraging the take up of more modern, cleaner vehicles.

Another relevant element are congestion charging schemes in which companies pay a fee in order to enter a particular geographical area at a particular time. These charging schemes aim to reduce road traffic levels and corresponding pollutant emissions in urban areas (Anderson et al., 2005). Consequently, the transportation implications from both inventory management methods emerge as a potential improvement area towards environmental performance.

Although prior research (Rao et al., 1991; Cusumano, 1994; Wu and Dunn, 1995; Murphy and Poist, 2000; Tripp and Bontekoning, 2002) has been describing environmentally responsible transportation modes which operate under fewer and larger shipments at slow velocities, consumer goods industry at the regional and local levels has been defined by the usage of parcel services and ground carriers, either company-owned or provided by third-party logistics organizations (Fernie et al, 2000; Taylor and Hallsworth, 2000; Rodrigue et al., 2001). Both EOQ and JIT rely on this type of motor carriers to conduct product procurement processes. Each one having different shipment frequencies by design since EOQ shipments include product demanded over delivery lead time, resulting in more spaced deliveries compared to JIT.

Given the contemporary emphasis on cycle time compression for order delivery, recent freight flows tend to be of lower volumes with higher frequencies, often taking place over longer distances (Hesse and Rodrigue, 2004). Particularly, the increased frequency of shipments that characterizes JIT product procurement adds pressure to road traffic infrastructure (Wu and Dunn, 1995; Hesse and Rodrigue, 2004) while conveying the notion of increased operational costs and greenhouse gas emissions (Wu and Dunn, 1995; Rodrigue et al., 2001; Woensel et al., 2001; IBM, 2008). Product shipment frequency can enable the quantification of the environmental performance of EOQ and JIT product procurement. Given a specific customer service level for both inventory management methods, each of them can incur in transportation activities with different occurrence frequencies, which in turn can result in different process outcomes measured in carbon dioxide equivalents. Therefore, this proposition establishes that the JIT inventory management method will yield higher carbon dioxide equivalents than the EOQ-based method. In summary I propose that:

H1. The higher the shipment frequency, the greater carbon dioxide equivalents will result due to the adoption of lean distribution of consumer goods.

A contingency element that can further increase the carbon dioxide equivalents due to each inventory management method is the type of product being handled. In principle, it is important to differentiate between durable and consumable goods. Durable goods encompass products that are not subject to perishability concerns in the short-term or require specific temperature-controlled conditions during their transportation, storage, and display across the supply chain. Appliances, electronics, furniture, and clothing are some examples. Conversely, consumable goods are products that require especial attention to their expiration date and usually require special handling due to temperature requirements to conserve the integrity and performance of the product. Food and vaccines are among them.

Durable goods such as electronics and apparel are also time-sensitive goods. Electronic goods face the challenges of product obsolescence due to constant upgrades, competing technologies, and reduced remanufacturing time windows (Twede et al., 2000; Ruyter et al., 2001; Souza, 2009). This kind of products also represent the high value and low weight share of inventory at the warehouse and store levels (Hesse and Rodrigue, 2004), therefore impacting the volume and variety of available items in both locations.

Within extended planning horizons clothes and fashion items follow a similar dynamic in their store replenishment activities (Childerhouse et al., 2002). Product deployment and phase-out processes are subject to market seasonality imperatives and operational time-frames agreed upon designers, manufacturers, and retailers of this kind of products (Camuffo et al., 2001; Simchi-Levi et al, 2003).

Consumable goods such as fresh produce, dairy, and other perishable items have the imminent requirement of point-to-point and direct delivery to retailers (Ytterhus et al., 1999), which is combined with the mandatory requirement of temperature-controlled storage, transportation, and display at the store level (Goodwin et al., 2002; Hyland et al., 2003; Estrada-Flores and Eddy, 2006).

Additional processes such as pre-cooling at the distribution center and backroom storage at the retailer can impact the energy requirement and emissions due to the overall product management of this kind of consumer goods. As a result consumable goods encompass a greater level of complexity since they are simultaneously time and temperature-sensitive. Therefore, I proposed that:

H1a. The more consumable goods transported under a higher shipment frequency, the greater carbon dioxide equivalents will result compared to durables goods transported under the same shipment frequency.

3.3 Impact of postponement

Regional warehousing facilities extended the reach of manufacturing operations through postponement. The functions inside distribution centers gradually became more complex by allowing light manufacturing tasks such as final assembly and specially packaging to take place on-site (Appelqvist and Gubi, 2005). To some extent production and distribution functions got merged with logistical integration processes (Hesse and Rodrigue, 2004).

In principle, postponement implementation reduces final product economies of scale by delivering partially-finished sub-assemblies to several distribution centers able to execute final product customization processes within reduced cycle times for the customers (Yang and Burns, 2003; Appelqvist and Gubi, 2005). As a result, postponement tends to increase the cost of product packaging and final processing, but at the same time improves demand responsiveness through higher levels of product customization (Holmstrom, 1997; Twede et al., 2000; Childerhouse et al., 2002).

Inventory carrying costs for these functionally expanded distribution centers can further increase due to storage requirements for a larger quantity of components necessary for final assembly. Particularly, an above average number of product configurations available for local customers can potentially outweigh the benefits of component modularity and the location of the decoupling point that characterizes this leading practice (Cusumano, 1994, Ramdas, 2003). Families of products subject to a large number of regional and local market-based configurations affecting packaging size or brand identification materials are good candidates for this delayed configuration process (Twede et al., 2000; Hesse and Rodrigue, 2004).

Provided that economies of scale support the mass production and bulk distribution of the standardized semi-finished modules of the product to the regional warehouses where definitive product customization takes place (Pagh and Cooper, 1998; Abukhader, 2008); organizations still need to cope with a final transportation segment either between distribution centers and retailers or between the customization facility and final customers. It is important to acknowledge that products at this stage have reached the maximum value added from a manufacturing and assembly standpoint while complying with specific customer requirements. Consequently, these products incur in additional packaging materials usage and associated distribution costs in order to be safely delivered at the points-of-purchase.

Timely delivery is essential for customized products, especially if customers have partially or fully paid for them in advance (Appelqvist and Gubi, 2005). Although demand responsiveness associated with postponement operations is deemed greater than EOQ approaches, its cumulative demand is unable to achieve economies of distribution at the finished product level. This is a direct result of addressing assemble-to-order type of products relying on final assembly schedules where many end items can be made from combinations of basic components and subassemblies (Song et al., 1999; Arnold and Chapman, 2004; Pil and Holweg, 2004). In consequence, this proposition establishes that the postponement inventory management method will yield less carbon dioxide equivalents than an EOQ-based method.

A contingency element that can further decrease the carbon dioxide equivalents due to final product transportation from postponement operations is the development of product customization capabilities at the store level. Similar to lean ports, retail stores can display specific product assortments and develop an array of tailored services focused on the local requirements of the markets they serve (Rapert and Wren, 1998; Bititci et al., 1999; Dubelaar et al., 2001). The development of such capabilities at the point-of-sale imply the full avoidance of the last distribution segment taking place between product warehouses and retail stores. Therefore, reducing the packaging materials required for shipment and associated carbon dioxide equivalents.

This physical distribution process simplification at the regional warehouse level fosters an expanded operational environment in the retail stores beyond regular activities such as backroom product storage and customer pick-up. In addition, packaging materials usage impact at the store level can be further reduced by selecting environmentally-friendly components to guard the product in its final form, while still providing the required differentiation levels for local customers (Wu and Dunn, 1995; Holmstrom, 1997; Pagh and Cooper, 1998; Murphy and Poist, 2000). However, establishing a postponement operation into a retail location requires specific elements in order to be feasible. The candidate retailing location should require additional space compared to its original layout just to receive and store the standard semi-finished components prior to perform the corresponding final configuration process (Dubelaar et al., 2001).

Candidate products for an operation of this kind should receive the major proportion of its total value added during the final configuration steps (Pagh and Copper, 1998; Hesse and Rodrigue, 2004), at least from the customer's perspective. Similarly, the potential for significant investments in dedicated equipment for on-site integration and testing can make less economically feasible the development of product customization capabilities at the store level (Appelqvist and Gubi, 2005).

Besides machinery investment and space requirement considerations, another important aspect is the complexity associated with the final product configuration process. Limited availability of specialized knowledge from the process could prevent the potential establishment of product customization capabilities at several retail locations (Appelqvist and Gubi, 2005). Product experts can potentially be better leveraged at the regional level of product distribution or at service centers rather than the actual retailing locations (Pagh and Copper, 1998).

Particularly, durable goods such as personal computers can reap the benefits of a retail environment with expanded product customization capabilities due to its modular product architecture (Olhager, 2003; Appelqvist and Gubi, 2005) including attributes such as compatible hardware design and final customization based on basic components and software.

As both, the basic components and software used for final product configuration are very likely to form part of the standard product assortment available at the retail store; inventory turns from these products can potentially increase since they are not only available off-the-shelf for individual purchase, but they can also be used at any given time as part of a specific customer order due to its assemble-to-order nature.

Along the same lines, several retail formats including big-box retailers and membership-based warehouses have gradually incorporated more electronic goods into their total inventory offerings, causing a product assortment overlap with category specialist organizations in the market. Consequently, these stores are devoting more square-footage for the proper storage, maintenance, and display of consumer electronics.

A partial explanation to this product deployment trend is offered by the fierce competition experienced among retailers, which initial value propositions either based on low-price competition or innovative product offerings allowed them to currently converge in the long-term marketplace known as the Big Middle (Brown et al., 2005; Levy et al., 2005).

From the retailer's perspective, logistical and full postponement of consumer electronics provide approximately the same customer service level (Appelqvist and Gubi, 2005). At the same time, manufacturing organizations of this kind of products are aware that their initial investment efforts in modular-oriented product design built into consumer electronics, allows them to reduce their overall inventory carrying costs while providing additional revenue streams for retailers in the form of new business opportunities based on product customization (Dubelaar et al., 2001; Olhager, 2003).

Implicitly, the development of postponement capabilities at the retail level can move the decoupling point of entire families of products, such as personal computers, one step closer to the customer. Therefore, by increasing product variety at the closest possible location to the actual customer, the objectives of manufacturing and logistical postponement (Pagh and Cooper, 1998; Childerhouse et al., 2002) are fulfilled, while reducing the carbon dioxide equivalents along the process. This insight can be formalized as follows:

H2. The closer a product's decoupling point is to final customers, the less carbon dioxide equivalents will result due to lean retailing operations.

H2a. The more durable goods are involved in a decoupling point close to final customers, the less carbon dioxide equivalents will result compared to consumable goods involved at the same decoupling point location.

3.4 Impact of cross-docking

Distribution centers have established themselves as the operational interface between manufacturing and retailing locations across supply chains. As global sourcing is linked to regional distribution through these facilities, their location considers accelerated information transfers between companies, changing consumer preferences, rising competition, and cost efficiency (Hesse and Rodrigue, 2004; Evans and Harrigan, 2005; Dong et al., 2007).

Warehouse planning and development tends to choose suburban sites instead of core urban areas, since the first ones offer larger and cheaper extensions of land, unrestricted transport access, and a flexible environment for round-the-clock operations (Rodrigue, 1999). New facility locations aim for the optimal ratio between lower land acquisition investments and short delivery distances towards final product distribution points (Hesse and Rodrigue, 2004).

Several organizations have consolidated local warehouses into regional ones in an attempt to achieve economies of scale in distribution processes while still serving local catchments in an efficient manner. The increased magnitude of these facilities allowed organizations to reach distant final distribution points beyond traditional terminal sites.

Gradually, the strategy of concentrating freight at hub locations became significantly restricted due to increased urban density, land constrains, and congested traffic arterials. At the same time, these facilities were expected to handle large amounts of time-sensitive consignments (Hesse and Rodrigue, 2004).

This type of facilities was critical for the establishment of Economic Order Quantity as one of the leading inventory management methods across several industries over time. Especially due to the necessity of keeping safety stocks and inventory buffers for several stock-keeping-units in order to maintain predetermined customer service levels at the retail stores (Eppen and Martin, 1988; Benton, 1991; Arnold and Chapman, 2004).

Cross-docking emerged as an operational solution for the limits to expansion faced by organizations developing their hubs and local warehousing networks. The adoption of this lean method allowed this type of facilities to capitalize the scarce hinterland connections available for product distribution (Hesse and Rodrigue, 2004; Brown et al., 2005) while empowering the notion of flexible in-transit and mobile inventories across the supply chain (Childerhouse et al., 2002).

Provided that cross-docking facilities are increasingly designed as a set of flow and throughput-oriented distribution centers, the initial benefit for organizations using them is a significant reduction in holding inventory costs associated with large product volumes held at regional distribution centers. Moreover, organizations using cross-docking acknowledged that the bulk of product synchronization taking place at these facilities could generate critical cycle time reductions at closer locations to final customers (Rodrigue, 1999), while providing a constant flow of commodities in order to ensure product availability and its corresponding customer service levels at the retail stores (Fernie et al., 2000; Hesse and Rodrigue, 2004). This process agility-based value proposition represents a clear deviation from EOQ's customer service levels supported by buffer inventories and fully dedicated distribution centers.

From a facility management standpoint, cross-docking facilities can be considered environmentally superior to traditional warehouses due to its implied reduction in warehouse space utilization, dunnage material requirements, and constant product flow from receiving to shipping docks (Twede et al., 2000; Lee and Whang, 2002).

These facilities have gone a step further in product management applications by combining physical distribution processes with transportation functions (Tan, 2001). As a result, a significant amount of space at each cross-docking facility is devoted to door-to-door product sorting and conveying systems (Cusumano, 1994; Wu and Dunn, 1995; Twede et al., 2000; Rodrigue et al., 2001; Tripp and Bontekoning, 2002).

Eventually, organizations supported by cross-docking facilities faced an operational challenge once encountered in traditional warehousing operations: The notion of increasing the number of facilities of this type in order to provide improved customer service levels, while reducing the average distance traveled by their corresponding product delivery fleets (Wu and Dunn, 1995; Fernie et al, 2000; Levy et al., 2005). In addition, the deregulation of transport markets fostered an important reduction in variable distribution costs which resulted in lower freight rates and allowed several organizations to expand their product delivery capabilities over time (Fernie et al., 2000; Taylor and Hallsworth, 2000; Hesse and Rodrigue, 2004).

As the number of available distribution terminals increased, the frequency of shipments between facilities increased accordingly leading to road congestion and less efficient utilization of transportation resources (Lumsden et al., 1999). The timely product delivery process based on frequent shipments offered by cross-docking operations has been translated into better demand responsiveness when compared against the EOQ approach.

While the traditional product replenishment method takes days to be completed, cross-docking lead times have been characterized as hourly-based processes (Kraemer et al., 2000; Heizer and Render, 2004), therefore incurring in greater carbon dioxide equivalents due to its shipment periodicity. Consequently, this proposition establishes that the Cross-docking inventory management method will yield higher carbon dioxide equivalents than the EOQ-based method.

A contingency element that can further increase the carbon dioxide equivalents due to each inventory management method is the type of product being handled. Specifically, consumable products such as fresh produce, dairy, and meat pose a relevant challenge in supply chain resource utilization due to regular warehouses, cross-docking facilities, transportation carriers, and different retail formats carrying this type of products on a permanent basis.

The market integration of perishable commodities was a result of the development and perfection of mechanical refrigeration. This operational improvement allowed organizations to take control over seasonal patterns of products such as milk and butter in order to establish a continuous flow of goods into the shelves of retailers (Goodwin et al., 2002). The transportation aspect of perishable goods among dedicated distribution centers and retail stores acknowledged the performance implications of temperature-controlled delivery units and their corresponding costs (Wilson, 1996; Estrada-Flores and Eddy, 2006).

For instance, in 1989 Tesco in the United Kingdom had 62% of its total warehouse infrastructure under temperature-controlled conditions with an average warehouse area of 140,000 square feet. By 1992, the temperature-controlled facilities from this organization averaged an area of 250,000 square feet per warehouse just to keep up with demand of temperature-sensitive products (Fernie et al., 2000). A decade later, 35% of United Kingdom's consumer goods distribution compliance programs were devoted to initiatives focused on temperature-controlled operations including the monitoring of storage facilities and transportation units (Bishara, 2006).

The seminal concept of composite distribution whereby temperature-sensitive products are handled by an array of multi-temperature warehousing facilities and transportation carriers (McKinnon and Woodburn, 1994; Wilson, 1996; Fernie et al., 2000); gradually evolved into the current notion of cold chain management which encompasses multiple products including pharmaceuticals.

This type of supply chain aims to ensure that the quality and efficacy of products are not compromised at any point in time, including their corresponding storage and display at the retailing level (Bishara, 2006). Although products spend significantly less time at warehousing facilities, the increased frequency of Cross-Docking operations coupled with their corresponding product management and transportation activities can result in more resource intensive operations. In formal terms:

H3. The higher the inventory turns at the warehousing level, the greater carbon dioxide equivalents will result due to the adoption of lean distribution of consumer goods.

H3a. The higher the inventory turns associated with the lean distribution of consumable goods, the greater carbon dioxide equivalents will result compared to durable goods distributed under the same lean policy.

3.5 Impact of vendor managed inventory

Supplier-customer partnerships provide the foundations for Vendor Managed Inventory. This lean practice faces the challenge of balancing retailers' interest in providing value to the customers with suppliers' objective of developing product category leadership and profit (Holmstrom, 1997). Similarly, the process considers the management of supply chain strategic partnerships involving multiple operational risk levels and trust requirements among organizations (Ring and Van de Ven, 1992; Childerhouse et al., 2002; Tyan and Wee, 2003). Given this multi-objective environment taking place among supply chain partners, the corresponding transactional processes have been characterized by structural tensions partially due to the uneven distribution of power and authority among organizational members (Fernie et al., 2000; Hall, 2000; Taylor and Hallsworth, 2000).

Most of the products addressed by VMI are considered cycle stock, which aims to anticipate demand under increased conditions of certainty such as established product lot sizes and historical product demand (Dubelaar et al., 2001). The EOQ model relies on similar process characteristics such as increased certainty in product demand and delivery lead times (Arnold and Chapman, 2004; Heizer and Render, 2004). However, these inventory management methods significantly differ once they are implemented across supply chain partners.

EOQ product replenishment process requests goods from suppliers in unilaterally fashion. This supply chain dynamic indicates a lack of integration between organizations beyond transactional operations in order to maintain specific customer service levels at retail stores. Conversely, VMI uses supplier development and integration through strategic partnerships as a platform to launch its operations (Dubelaar et al., 2001; Childerhouse et al., 2002).

Although initial product replenishment operations under VMI are supervised by the retailer, each supplying organization develops an autonomous product procurement process as complete ownership of this operation takes place at the retailer's facility over time (Andel, 1996; Holmstrom, 1998; Simchi-Levi et al, 2003). Consequently, goal alignment between the supplying organization and the retailer is essential to establish and improve supplier incentives and performance metrics towards the environmental management associated with lean-oriented product procurement contracts (Tan, 2001; Brown et al., 2005; Simpson and Power, 2005).

Supplier partnerships relying on product demand and inventory information shared through information technology platforms can go even further to the point of establishing field offices in the same city of the organizational account and assign in-house personnel into retailers' facilities on a permanent basis (Rubiano and Crespo, 2003; Simchi-Levi et al, 2003).

The cumulative effect of such organizational activities results in a significantly improved supplier's vision and understanding of retailers' product flow and operations. This increased process knowledge allows VMI-based product delivery schedules to afford economies of distribution able to cope with demand peaks. By leveling product demand requirements based on an extended planning horizon, the utilization of transportation resources can be improved as more full-truck-load shipments can be scheduled towards retailers (Rodrigue, 1999; Kaipia et al., 2002; Kainuma and Tawara, 2006).

Even in cases where additional reductions in transportation distances between retailers and warehouses are available due to the geographical collocation of both supply chain partners in suburban areas (Brown et al., 2005), VMI does not expedite product shipments or increase its delivery frequency in straightforward fashion.

On the contrary, the controlled product replenishment pace of VMI can adequately address low volume items without relying on continuous replenishment shipments triggered by frequent purchasing orders from the retailer (Holmstrom, 1997; Kaipia et al., 2002). In consequence, this proposition establishes that the Vendor Managed Inventory method will yield less carbon dioxide equivalents than an EOQ-based method.

A contingency element that can further decrease the carbon dioxide equivalents due to the implementation of VMI is the retail format being supported (Rizet et al., 2010). The concept of cubic space utilization from warehouse facilities and motor carrier capacity planning (Wu and Dunn, 1995) is further translated into shelves' utilization at the retail locations.

This product placement process is extremely important and strategic for lean retailers which allocate families of products according to carefully planned store layouts based on economic indicators, product market share, inventory turns, and supplier development programs (Larson and Lusch, 1990; Goss, 1993; Nevill et al., 1998; Fernie et al., 2000; Dubelaar et al., 2001; Heizer and Render, 2004).

From an operational standpoint, retailing has been described as a carbon and energy intensive distributive activity (Hesse and Rodrigue, 2004; Brown et al., 2005; Busch, 2010), therefore particular processes such as product receiving, backroom storage, and product display are associated with VMI operations and directly interact with store layout considerations.

At the same time, the resulting dynamics between product assortment display and store layout are critical for retailers, since the amount of customer traffic and spending has been directly correlated with the time customers spend within the store (Goss, 1993; Babakus et al, 2004). Moreover, store size has been instrumental to determine its relationship with overall sales and store productivity (Hise et al., 1983; Good, 1984; Ingene and Lusch, 1999).

Although in many cases urban retail built environment have been gradually integrated into residential developments blurring the line between housing spaces and instrumental facilities designed for the efficient circulation of products and commodities (Goss, 1993), the size and magnitude of specific retail formats such as wholesale warehouses and big-box retailers have remained as independent facilities (Collis et al., 2000). The infrastructural performance from the retail built environment can be determined by the specific retail format taking place in the facility and the corresponding product assortment stored, serviced, and displayed within it.

For instance, membership-based wholesalers have achieved a partial reduction in packaging materials usage by allowing customers to purchase products in their bulk packaging presentations (Wu and Dunn, 1995). Organizations supplying these products usually specify that each individual product within a container or bundle is not intended for individual display and resale. Furthermore, the retailing space is subject to spatiotemporal processes where multiple agents such as staff members, suppliers, and costumers interact (Anderson et al., 2005; Quak and De Koster, 2007).

Given the warehouse-oriented type of floor layout from a wholesaler, product handling methods and consumer traffic are expected to differ from this kind of business compared to a big box retailer or category specialists. In the latter consumers can access deep product selections from a limited number of merchandise categories (Brown et al., 2005; Levy et al., 2005). Particularly, dedicated retail outlets for consumer electronics are intended to act as show rooms for customers instead of regular stockholding points. In consequence, customers expect to see and try the products while discussing about them with sales personnel (Appelqvist and Gubi, 2005).

Other category specialists carrying durable products such as apparel and clothes can further reduce its resulting carbon dioxide equivalents along the process. Its corresponding energy requirements due to product storage and display are expected to be less intensive than equivalent retail stores offering a mix of consumer electronics and consumable products. Consequently, product volume and variety mix considerations at the warehouse and distribution levels (MacDuffie et al., 1996; Salvador et al., 2002) can impact final product assortment on each type of retailing format.

As the VMI process achieves full implementation across different retail formats, backroom storage space requirements at the facility are reduced and can be allocated to highly coveted retail space. Other cumulative effects from the full integration of suppliers in order to maintain specific customer service levels are the different product display requirements, which in turn can affect the overall performance of the retailing facilities including energy requirements for regular operations, space allocation for incoming product, packaging materials usage, and carbon dioxide equivalents due to product transportation. Formally:

H4. The more supplier integration, the less carbon dioxide equivalents will result due to lean retailing operations.

These propositions described the relationships between lean-oriented best practices and specific operational elements that can contribute to the resulting greenhouse gas emissions from consumer goods procurement processes. The general proposition structure outlined at the beginning of the chapter is now populated with these insights.

In a similar fashion, the process under consideration and its corresponding outcomes are identified, but this time the implementation process represented by the central arrow is impacted by four process variables. Each one corresponding to a particular proposition directly supported by an underlying lean-oriented IMM (Figure 2). Particularly, the first and third propositions are aligned with the first part of the research hypothesis, while the rest of the propositions are focused on the second part.

The elements provided by these constructs can be organized into an experimental design that can support the examination of the distribution and retailing phases of consumer goods. The following chapter presents the methodology developed for this research. The first part of the chapter outlines the experimental design able to integrate the propositions developed to examine the research hypothesis. The second part of the chapter describes the development of a two-echelon supply chain discrete-event simulation model in order to conduct the research.

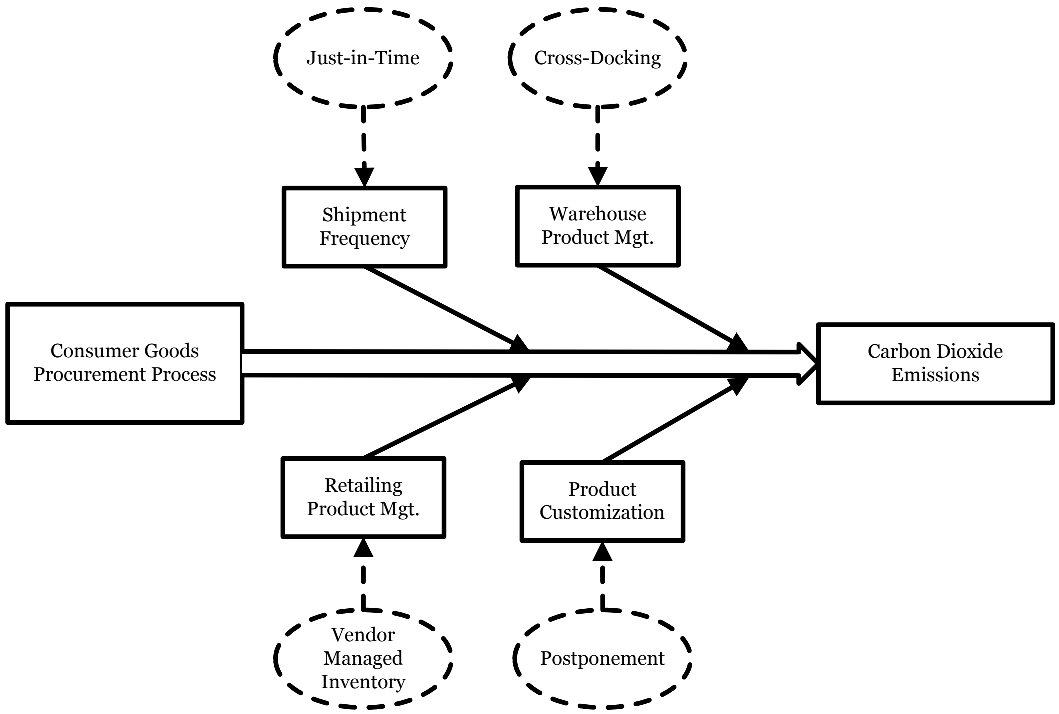


Figure 2: Integrated view of research propositions.

CHAPTER 4

METHODOLOGY

4.1 Introduction

Critical understanding of product procurement systems has been developed through the detailed modeling and characterization of process dynamics within supply chain operational domains. Levy (1995) conducted simulation studies of complex supply chains and determined that demand-related disruptions do not decline over time, whereas production-related disruptions do. Kainuma and Tawara (2006) developed computer simulations of two-stage supply chain models to measure return on assets, customer satisfaction, and life cycle assessment. Their results have shown shown that timely information sharing between supply chain members tend to decrease the average stock level in the system while reducing stock out occurrences at the retailing level.

Simulation methods have been used to study the interaction and effects of storage policies in traditional product warehouses and distribution centers (Rosenblatt and Roll, 1988; Van den Berg and Gademann, 2000; Caron et al., 2000; Petersen, 2000). Lee et al. (2002) characterized a supply chain by using a discrete-continuous simulation approach, where all the transportation of materials and products were defined as discrete events while operations such as manufacturing and retailing were considered continuous portions of the process. Sundarakani et al. (2010) used an analytical model to characterize the carbon footprint of a four-echelon supply chain by classifying its emission sources in stationary and non-stationary processes.

Transportation operations have been simulated to explore different truck utilization rates in order to identify better transportation resources allocation and process improvements (Wu and Dunn, 1995; Lumsden et al., 1999). Models addressing the concept of food-miles and overall supply chain freight requirements for consumable goods emphasized a product-based perspective, while assuming energy intensity due to temperature-controlled motor carriers and storage facilities as negligible (Webber and Matthews, 2008). The interest in operational improvements linked to economic performance has been defining research particularly focused on lean-oriented practices (Table 5).

Bookbinder and Locke (1986) developed a model to determine if JIT product distribution was a feasible alternative to traditional procurement methods. By comparing a three-echelon supply chain versus another one with two-levels they statistically determined that the model with fewer supply chain partners can achieve the same customer service level than the original three-level configuration.

Most of the simulation-based research from Just-in-time processes has been focused on determining optimal lot sizes for products, product flow along assembly lines, set-up times, lead times planning, and capacity planning within manufacturing environments (Fellers, 1984; Ebrahimpour and Fathi, 1985; Schroer et al., 1985; Lee and Seah, 1988; Goyal and Gupta, 1989; Sarker and Fitzimmons, 1989; Albino et al., 1992).

Fedrows (1989) created a postponement model that balanced the global efficiency achieved from a standardized product with the local responsiveness of product customization. His model assumed that each regional plant was able to contribute with very specific core processes in order to achieve a truly international competitive advantage in the market. Appelqvist and Gubi (2005) explored the possibility of reducing high-volume and low-variety electronic products inventory by implementing product postponement at the retail level. When setting aside any type of product demand seasonality, their simulation showed an average inventory reduction of 60% for the products under study.

Table 5. Simulation-based research overview

Research Scope	Sustainability Dimension	
	Economic	Environmental
Supply Chain	Rosenblatt & Roll, 1988; Levy 1995; Wu & Dunn, 1995; Lumsden et al., 1999; Van den Berg & Gademann, 2000; Caron et al., 2000; Petersen, 2000; Kainuma & Tawara, 2006; Webber & Matthews, 2008.	Sundarakani et al., 2010
Just in Time	Fellers, 1984; Ebrahimpour & Fathi, 1985; Schroer et al., 1985; Bookbinder & Locke, 1986; Lee & Seah, 1988; Goyal & Gupta, 1989; Sarker & Fitzimmons, 1989; Albino et al., 1992.	
Postponement	Fedrows, 1989; Appelqvist and Gubi, 2005.	
Cross-Docking	Rohrer, 1995.	
Vendor Managed Inventory	Disney et al., 2003.	

Rohrer (1995) designed a cross-docking model emphasizing optimal warehouse equipment configuration and supporting information technology platforms. The model considered the interaction between warehouse management systems, automation level of the facility, and space resource constraints. A generic two-level system dynamics model for Vendor Managed Inventory was developed assuming fixed lead-times between manufacturing and distribution operations. The model showed a reduction in the impact of vehicle reliability and general routing efficiency for distribution fleets (Disney et al., 2003).

From a functional standpoint, general transportation studies have provided isolated perspectives focused on operational performance and local process optimization. For instance, the quantification of motor carrier carbon dioxide emissions due to seasonal temperatures combined with specific engine operational conditions such as cold start, stabilizing run, and warm start have been reported (EPA, 2008).

Estrada-Flores and Eddy (2006) focused their research on the resulting temperature losses from refrigerated transportation units subject to multiple stops while delivering products along an optimal distribution network. In consequence, specific research based on an integrative process view able to integrate critical supply chain operations such as warehousing, transportation, and retailing emerges as a potential line of inquiry (Sinding, 2000; Fiksel, 2003; Korhonen and Seager, 2008; Fliedner and Majeske, 2010).

McKinnon and Woodburn (1994) asserted in their study of retail freight consolidation that the most promising direction for future research in integrated supply chains must consider the simulation of such critical operations. Specifically, discrete-event simulation provides a simplified environment able to mimic the behavior of real systems into which a number of situations and ideas can be tested (Disney et al., 2003; Kelton et al., 2010).

Essentially, this environment should only consider relevant elements from the process under study. These in turn can provide specific insights within the scope of the research hypothesis being addressed. Otherwise, attempting to include all decision horizons from the actual system can make the model intractable in the first place (De Koster et al., 2007) due to its increased level of complexity and potential inclusion of trivial elements (Coleman and Montgomery, 1993).

According to Maloni and Benton (1997), the use of simulation models provides a way to critically evaluate possibilities to improve supply chain performance since it is supported by a convenient laboratory environment for testing the effects of different factors. In addition, the prospective nature of simulation and its ability to test processes in a compressed time scale enables it to address questions for which process information might not be available given the current state of the system under study (Gupta et al., 2006).

The ability to generate a long-term vision of the processes under study supports the development of steady state scenarios including potential trends and dynamics among operational domains (Lee et al., 2002). This information can support the development of decomposition analysis for lean logistics and retailing processes. This type of analysis quantifies the contribution of changes in underlying process variables, its basic approach aims to quantify the process effects by changing one variable while holding all others constant (Fiksel, 2003; Hertwich, 2005).

Although the economic and environmental performance of contemporary supply chains has been studied independently, the sustainability assessment of such systems requires the convergence of theory and methodological approaches to improve their conceptualization and understanding. Particularly, the expanded notion of waste and non-value-added activities across downstream supply chain operations; can advance the critical understanding of their environmental performance in a world increasingly constrained by natural resources.

4.2 Experimental design for process modeling

According to Design of Experiments literature (Coleman & Montgomery, 1993; Kleijnen, 2005; Montgomery, 2005) and the operational elements identified in the research propositions, it is possible to define the following elements:

Problem statement

Quantify the carbon dioxide equivalents difference between a traditional inventory policy and lean-oriented inventory management methods such as Just-in-time, Postponement, Cross-docking, and Vendor Managed Inventory within a two-echelon supply-chain composed of distribution and retailing operations supporting the procurement of consumable and durable goods.

Response Variable

The main response variable of the experiment is annual carbon dioxide equivalents due to distribution and retailing processes (MT CO_2 e / year). This unit has been selected as each inventory management method is intended to run for a year in simulation time per experimental replication.

Experimental Factors & Levels

Considering the process descriptions from each inventory management method provided in chapter two, the experiment can be characterized as a 2^k factorial design (Coleman & Montgomery, 1993; Kleijnen, 2005; Montgomery, 2005). Particularly, this experimental design considers four factors with their corresponding high and low levels. The design factors under consideration are described as follows:

Factor # 1: Product shipment frequency between supply chain partners.

Product flow between warehouses and retail stores varies depending on the product replenishment policy implemented. The high level for this design factor is represented by Just-in-time and Cross-docking operations, while the rest of the IMMs encompass the low level of the factor. Organizations subject to high product shipment frequencies can deliver products to retail stores twice a week, while others can follow weekly, bi-weekly, or monthly schedules. This factor is measured in number of product shipments per month.

Factor # 2: Product customization capability at retailing stores.

The majority of traditional and lean-oriented IMMs handle final products between warehousing and retailing facilities, therefore displaying a low level of product customization capability. However, postponement practices are able to relocate the decoupling point of articles closer to consumers in order to increase their product customization capabilities. Hence, this IMM exemplifies the high level for this design factor. Provided that this type of operations requires additional space from retailing facilities to store final components and perform the actual product customization on-site, this factor is quantified in square footage devoted to product customization per retailing facility.

Factor # 3: Product storage time and management at warehousing facilities.

Given the nature of the different inventory management methods being addressed, it is possible to establish high and low factor levels based on the time products spend at warehousing facilities. The low level of this factor is primarily represented by Cross-docking and Just-in-Time operations that essentially manage products in a matter of hours between incoming and outgoing shipments according to product demand responsiveness. Conversely, the rest of the IMMs require longer storage horizons in compliance with their respective product procurement policies, therefore representing the high level of the factor. This factor is measured in days a product spends at warehousing facilities during the procurement process.

Factor # 4: Storage space devoted at retailing stores.

Traditional inventory management schemes such as Economic Order Quantity can foster increased space devoted to product storage at retailing stores, in some cases up to 30% of the whole facility space available. This scheme reflects an instance of the high level for this design factor. Conversely, the lean-oriented IMMs are focused in the gradual reduction of buffer inventories and associated space across supply chain partners; therefore their collective utilization represents the low level manifestation of this design factor, which is measured in storage square footage per retailing facility.

Although each design factor is initially associated with a different measurement unit, all aggregated process outcomes will be quantified in carbon dioxide equivalents. Considering that each IMM is conceptualized as a 2^4 factorial design, each one originally yielded up to 16 potential process factor configurations, some of them are deemed infeasible given their corresponding process definitions.

After examining the 80 potential process configurations, 8 of them reflect actual process operational conditions and slight variations that could provide additional insights to the research. Table 6 describes these eight configurations with their corresponding levels. Positive and negative signs stand for high and low levels respectively. A complete list of the initial process configurations per IMM can be found in Appendix A.

Three control variables are being considered throughout the experiment: 1) Energy mix supporting transportation and retailing operations; 2) Fleet efficiency due to cubic space utilization in forward distribution and backhauling operations; and 3) Supplier compliance toward retailer-enforced packaging regulations.

Table 7 provides the corresponding levels and operational domains for these control variables. The following section will describe the discrete-event simulation model to implement this research design.

Table 6. Experimental design factors and levels for selected process configurations

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
Economic Order Quantity (EOQ)	-	-	+	+
Just-in-time (JIT)	+	-	-	-
Postponement (P)	-	+	+	-
	-	+	+	+
Cross-Docking (CD)	+	-	-	-
	+	-	-	+
Vendor Managed Inventory (VMI)	-	-	+	-
	+	-	+	-

Table 7. Experimental levels for control variables.

Control Variables	Operational Domain	Levels	
		High (+)	Low (-)
Energy Mix	Retailing	Regular store configuration	Store with solar power technology
	Transportation	Motor carriers using diesel fuel	Motor carriers using ethanol blends
Fleet Efficiency	Transportation	Full-truck load shipments	Less-than-full truck load shipments
Supplier Compliance	Warehousing	Regular packaging materials	Environmentally friendly packaging materials

4.3 A discrete-event simulation model

The model comprises a two-echelon supply chain including fixed infrastructural elements in the form of warehousing and retailing facilities. Between these locations there is a component of mobile infrastructure represented by transportation of consumer goods and the corresponding backhauling operations. All the selected inventory management methods interact with the infrastructural elements within the system boundary described as a dashed line in Figure 3.

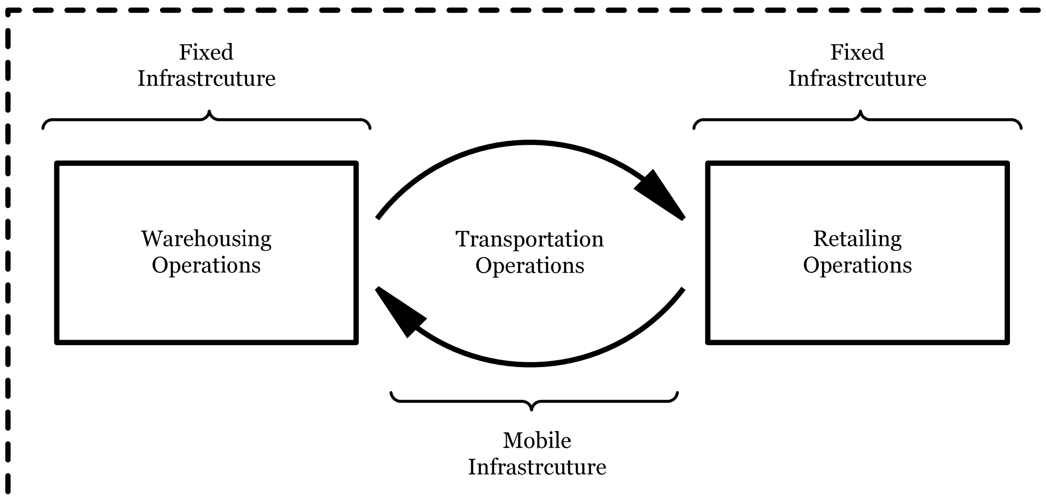


Figure 3: System boundary for lean logistics and retailing model.

The model addresses three operational domains encompassing warehousing, transportation, and retailing activities. Within each of them a series of discrete processes take place as outlined in Figure 4. Given the market demands for durable and consumable goods, retailing stores verify product availability. If confirmed, they proceed to fulfill consumer's orders on-site and update inventory levels accordingly. Otherwise, product orders are issued to the regional warehouse.

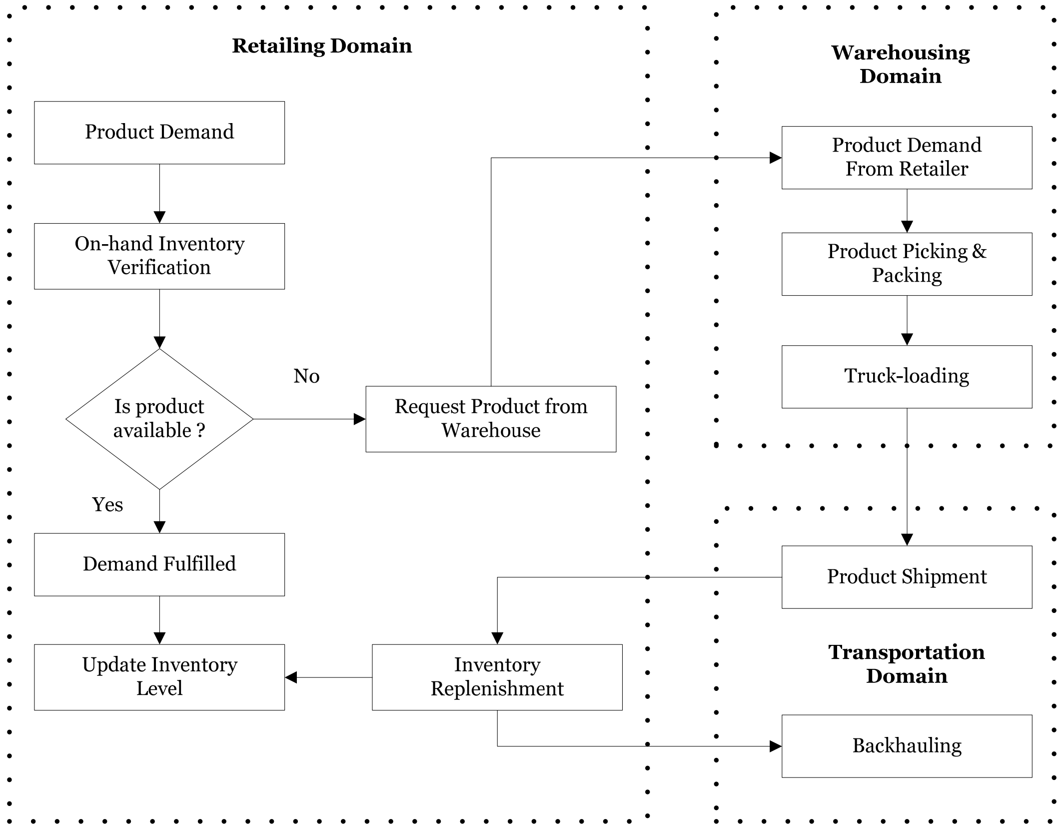


Figure 4: Operational domains and model processes.

Product warehouse acknowledges demand and proceeds to pick-up and collect the items from their storage locations. As transportation availability is confirmed, product cases are palletized and set ready for truck loading. Once motor carriers are loaded, they are dispatched to local retail stores. Backroom storage or direct replenishment on the shelves takes place upon product arrival. Then, motor carrier heads back to the distribution center.

The general structure and modeling of warehousing and retailing facilities is practically the same. Provided that no further product consolidation and shipment preparation takes place in the last set of nodes portraying the retailing facilities, the corresponding modules performing those functions are deactivated in the model.

Conversely, a warehousing node fully utilizes all the modules designed within it and allows for process re-tagging along the simulation runs. Therefore, this underlying design architecture critically supports the generalization potential of the model when addressing the simulation of extended and more complex supply networks, while keeping standard information input requirements across the development of additional nodes.

The model intends to describe process dynamics from local and regional supply chains as it considers operational domains closer to the market. Particularly, elements from facilities associated with leading organizations defined by the category specialist and big-box retailing formats (Messinger and Narasimhan, 1997; Fox et al., 2004) where identified prior modeling. These retailing formats were instrumental in the identification and definition of two functional units in the form of a personal computer and a gallon of milk (Choi et al., 2006; Singh et al., 2010).

These functional units flow across different operational domains as described in figure 5. Retailing operations consider five facilities including their corresponding consumer arrivals, storage, consumption, and replenishment of products. These retailing facilities are supported by a regional distribution center encompassing product picking and packing activities, truck-loading operations, and shipment coordination.

Product transportation and backhauling operations for consumable and durable goods under consideration encompass actual supply chain topologies of leading firms operating in the U.S. Southwest. For instance, the durable goods supply chain has its distribution center in Dinuba, California supporting the retail locations in Arizona, while the consumable goods supply chain describes a more local approach by having all its facilities in the State of Arizona (Tables 8 and 9). A geographical description of both supply chains is presented in Appendix B.

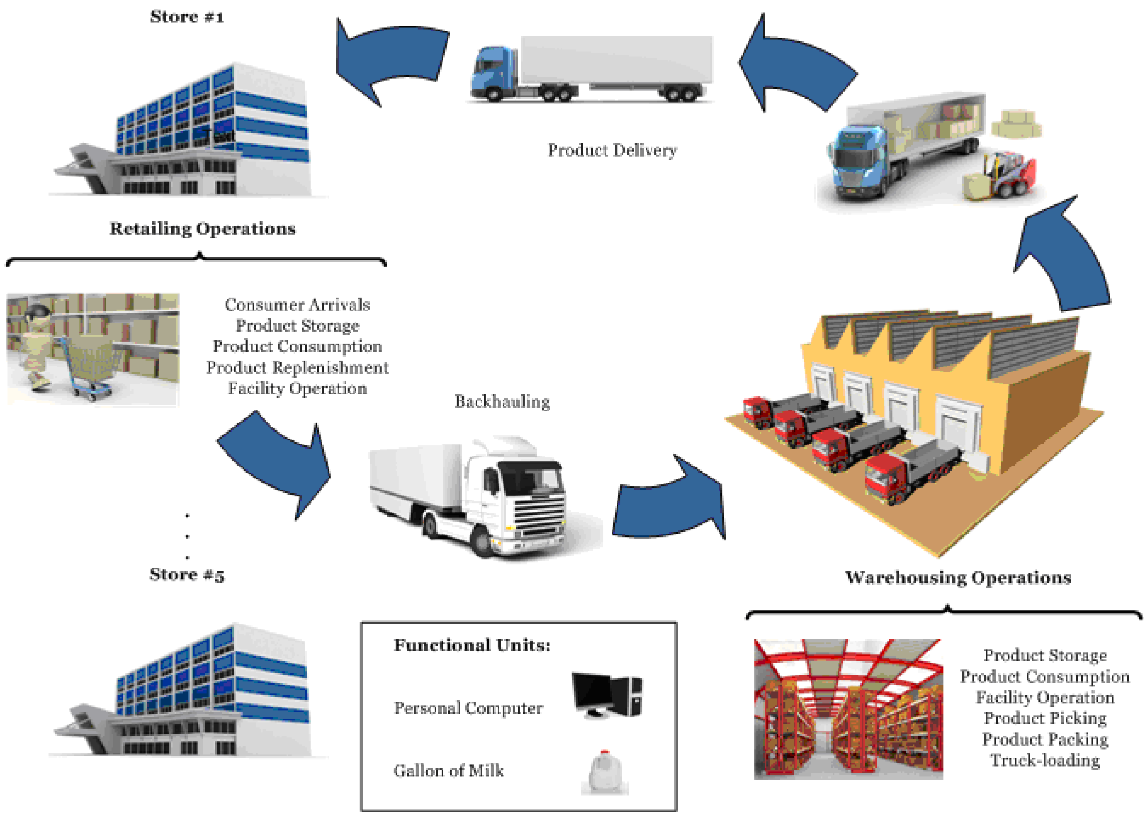


Figure 5: Lean logistics and retailing model.

The locations of several facilities supported the exploration of each supply chain and allowed field visits for data gathering. In addition, the rationale behind facilities modeling was extended to describe transportation activities. Although the spatiotemporal boundary of the system modeled describes the operational performance of a specific region, the underlying modules are flexible enough to incorporate different supply chain topologies.

Particularly, the U.S. Southwest presents an interesting case given the spread location of supply chain facilities subject to an environment defined by extreme temperatures. Among the organizations in the region, one global food and beverage leading company established a mixing center servicing not only the region, but also international demand coming from Northern Mexico.

Table 8. Durable goods supply chain locations.

	Distribution Center	
	Facility	**Address**
	Distribution Center	777 Monte Vista Drive, Dinuba, CA, 93618
	Retail Stores	
Store #	**Facility**	**Address**
S1	Tempe, AZ (Store 1002)	1900 E. Rio Salado Pkwy, Tempe, AZ, 85281
S2	Fiesta Mall, AZ (Store 260)	1455 W. Southern Ave, Ste 1082, Mesa, AZ, 85202
S3	Ahwatukee, AZ (Store 177)	5051 East Ray Road, Phoenix, AZ, 85044
S4	Chandler, AZ (Store 869)	3100 W. Frye Rd, Chandler, AZ, 85226
S5	Camelback, AZ (Store 253)	1949 East Camelback Road, Phoenix, AZ, 85016

Logistically, the mixing center is justified considering the resulting brand positioning and demand responsiveness in the market. However, the electricity requirements and corresponding greenhouse gas emissions are evident challenges for a facility exclusively handling refrigerated and frozen goods in a region where six months a year experiences temperatures ranging from 82° to 112° (Sara Lee, 2011).

Different examples can be found in the operations of progressive retailing organizations that are currently experimenting with new high-efficiency stores specifically designed for Western climates in the country. These facilities can incorporate photovoltaic arrays, evaporative cooling and radiant flooring technologies, light-emitting diodes for product display, and less resource intensive bathroom fixtures (Walmart, 2006).

Table 9. Consumable goods supply chain locations.

	Distribution Center	
	Facility	Address
	Distribution Center	23701 W. Southern Ave., Buckeye, AZ 85326
	Retail Stores	
Store #	Facility	Address
S1	Supercenter (Store 5768)	800 E. Southern Ave., Tempe, AZ 85282
S2	Supercenter (Store 2482)	857 N. Dobson Rd., Mesa, AZ 85201
S3	Supercenter (Store 2515)	3721 E. Thomas Rd., Phoenix, AZ 85018
S4	Supercenter (Store 1746)	1380 W. Elliot Rd., Tempe, AZ 85284
S5	Supercenter (Store 2112)	4915 N. Pima Rd., Scottsdale, AZ 85251

These processes insights resulted from the review of prior literature, industry reports, and personal consultation with industry experts. The latter was mainly supported by an open call for participation focused on supply chain managers, operations practitioners, and facilities personnel. A copy of this document is provided in Appendix C.

Process characterization was conducted through the use of the Arena Simulation software (version 11.0, Academic Edition). This platform is able to integrate system characteristics through the use of SIMAN simulation language (Murray & Sheppard, 1988; Beek & Rooda, 2000; Cimino et al., 2010; Kelton et al., 2010). The discrete-event simulation model encompasses three sub-models, one for each operational domain and their corresponding libraries. Figure 6 provides a desktop view from the model. Further descriptions of model components and structure within the simulation environment are available in Appendix D.

Model parameters definition was significantly shaped by direct process observation and interaction with company representatives. Overall, practitioners from retailing and warehousing operations showed a more structured understanding of their core processes compared to their transportation-oriented counterparts. The latter set of participants was mostly formed by third-party logistics organizations.

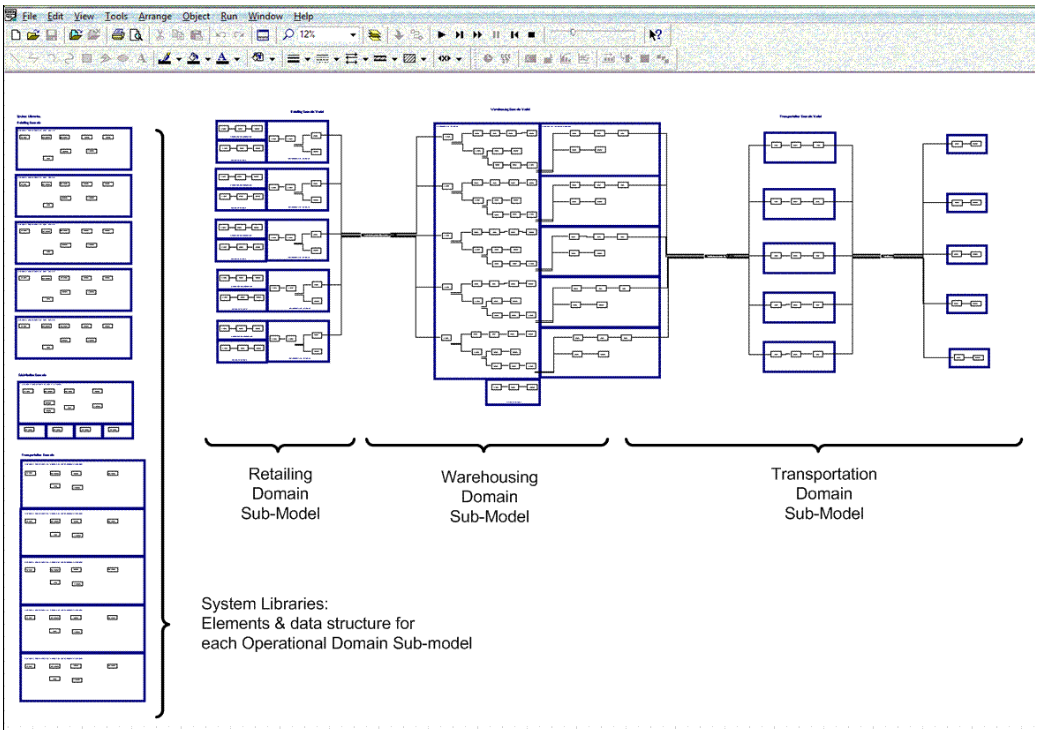


Figure 6: Simulation model overview.

As the interaction of product demand and inventory allocation across facilities was instrumental to drive supporting procurement processes. On-hand inventory levels were established for all facilities of the supply chain. Elements associated with product demand were customer arrivals for each store and corresponding demand on functional units.

Processes behind the daily operation of these facilities were defined on a time-based fashion as most of their corresponding process performance indicators are communicated in that manner. In addition, this time-scale across several unit processes was streamlined with the overarching temporal structure of the simulation. Each replicate consisted of a full year in simulation time.

Spatial proportions between retailing and warehousing facilities contributed to the product flow experienced in the supply chain. The flow of entities within the model allowed the connection between them and operational attributes such as emissions per product (Table 10). Transportation operations were embedded in the functional boundaries of the other two operational domains.

Table 10. Model parameters by operational domain.

Retailing Domian		
Name & Units	**Value**	**Source**
RS Inventory Level (product units)	1152	Actual count
CO2 Emissions per kWh (kg CO2 e)	0.6793	EPA, 2010
CO2 Emissions per product (kg CO2 e)	0.136	ICUSD, 2008
Daily electricity demand (kWh)	315	Walmart, 2009
RS Customer inter-arrival time (days)	EXPO(0.007)	Kelton et al., 2010
RS Customer demand (product units)	DISC(0.6,1, 0.9,2, 1.0,3)	Actual count
RS Operative time (days)	360	Kelton et al., 2010
RS Delivery lag (days)	TRIA(0.0368, 0.0514, 0.0660)	Google Maps, 2011
RS Product unloading lag (days)	UNIF(0.02, 0.03)	Sara Lee, 2011
RS Truck loading lag (days)	TRIA(0.0417, 0.0521, 0.0625)	Sara Lee, 2011
RS Backhauling lag (days)	TRIA(0.0368, 0.0514, 0.0660)	Google Maps, 2011
Note: RS stands for Retail Store.		
Warehousing Domain		
Name & Units	**Value**	**Source**
WH Inventory Level (product units)	5,760	Sara Lee, 2011
WH Emissions per kWh (kg CO2 e)	0.6793	EPA, 2010
CO2 Emissions per product (kg CO2 e)	0.317	ICUSD, 2008
Daily electricity demand (kWh)	6,491	Sara Lee, 2011
WH Product picking & packing time (days)	UNIF(0.02, 0.03)	Sara Lee, 2011
WH truck-loading time (days)	TRIA(0.0417, 0.0521, 0.0625)	Sara Lee, 2011
WH Operative Time (days)	360	Kelton et al., 2010
Note: WH stands for Warehouse.		
Transportation Domain		
Name & Units	**Value**	**Source**
TS Miles per Gallon	20.5	EPA, 2010
TS Emissions per Gallon (kg CO2 e)	10.15	EPA, 2010
TS Product Load Factor (product units)	857	Singh et al., 2010
TS Operative time (days)	360	Kelton et al., 2010
Note: TS stands for Transportation.		

On the one hand, warehousing operations included the time and resources associated with product picking & packing, truck-loading, and securing transport availability. On the other hand, retailing operations considered resources supporting truck receiving, product storage, and inventory replenishment on the store shelves.

Considering the supply chain topologies behind different retail formats associated with consumable and durable goods, it was possible to obtain time estimates due to traffic conditions for product delivery and backhauling operations (Table 11). Additional attributes for this operational domain are fuel yield, emissions, and storage capacity per truck. All variables and parameters in the simulation model are flexible enough to incorporate more facilities and increase the number of routes for the supply chain.

Table 11. Transportation time parameters by supply chain type.

From Distribution Center to		Value (days)	Source
Consumable Goods	Store # 1	TRIA(0.0368, 0.0514, 0.0660)	Google Maps, 2011
	Store # 2	TRIA(0.0382, 0.0503, 0.0625)	Google Maps, 2011
	Store # 3	TRIA(0.0323, 0.0424, 0.0521)	Google Maps, 2011
	Store # 4	TRIA(0.0372, 0.0517, 0.0660)	Google Maps, 2011
	Store # 5	TRIA(0.0389, 0.0507, 0.0625)	Google Maps, 2011
From Distribution Center to		**Value (days)**	**Source**
Durable Goods	Store # 1	TRIA(0.3993, 0.4375, 0.4757)	Google Maps, 2011
	Store # 2	TRIA(0.4031, 0.4431, 0.4826)	Google Maps, 2011
	Store # 3	TRIA(0.4014, 0.4438, 0.4861)	Google Maps, 2011
	Store # 4	TRIA(0.4059, 0.4479, 0.4896)	Google Maps, 2011
	Store # 5	TRIA(0.3958, 0.4323, 0.4688)	Google Maps, 2011

Given the experimental factor descriptions, each inventory management method and its corresponding process configurations are shown in Table 12. Shipments representing product delivery frequency can take place once or twice a week. Product storage time at warehousing facilities ranges from 3 to 7 days depending on the procurement method.

The spatial proportions built into the model allowed the incorporation of the storage space devoted at retailing facilities. In a similar fashion the resources and space devoted to conduct product customization were included. All experimental levels under consideration resulted from the combination of prior research, suggestions from supply chain practitioners, and process observations.

Table 12. Experimental levels for selected process configurations.

	F1: Product shipment frequency between supply chain partners. (Shipments/Month)	**F2:** Product customization capability at retailing stores. (Sq ft/ facility)	**F3:** Product storage time and management at warehousing facilities. (Days)	**F4:** Storage space devoted at retailing stores. (Sq ft/ facility)
Economic Order Quantity **(EOQ)**	4	0% of the facility	7	30% of the facility
Just-in-time **(JIT)**	8	0% of the facility	3	15% of the facility
Postponement **(P)**	4	5% of the facility	7	15% of the facility
	4	5% of the facility	7	30% of the facility
Cross-Docking **(CD)**	8	0% of the facility	3	15% of the facility
	8	0% of the facility	3	30% of the facility
Vendor Managed Inventory **(VMI)**	4	0% of the facility	7	15% of the facility
	8	0% of the facility	7	15% of the facility

Control variables addressed the three operational domains contained in the model. Energy mix at the facility level considered operational parameters from regular and high-efficiency stores able to incorporate white roofs and daylight harvesting systems into their operations (Walmart, 2010; Sara Lee, 2011). Regular transportation units relied on diesel, while others used different ethanol blends such as E85 (Granda et al., 2007; EPA, 2010). Fleet efficiency described motor carrier capacity for transporting full-truckloads of a given product. Less-than-full-truckload operations were considered as transportation units can allocate partial capacity and space to products under consideration (Table 13).

Table 13. Experimental levels associated with control variables.

Control Variables	Levels			
	High (+)	Sources	Low (-)	Sources
Energy Mix	1,575 kWh/day	Sara Lee, 2011	1,181 kWh/day	Walmart, 2009
	20.5 MPG on Diesel	EPA, 2010	14.35 MPG on E85	EPA, 2010
Fleet Efficiency	857 Gallons of Milk/Truck	Singh et al., 2010	Less than 857 Gallons of Milk/Truck	Singh et al., 2010
	100 Personal Computers/Truck	Choi et al., 2006	Less than 100 Personal Computers/Truck	Choi et al., 2006
Supplier Compliance	0.7 lb CO2 e / product	ICUSD, 2008	0.45 lb CO2 e / product	Walmart, 2008

Regular transportation units relied on diesel, while others used different ethanol blends such as E85 (Granda et a., 2007; EPA, 2010). Fleet efficiency described motor carrier capacity for transporting full-truckloads of a given product.

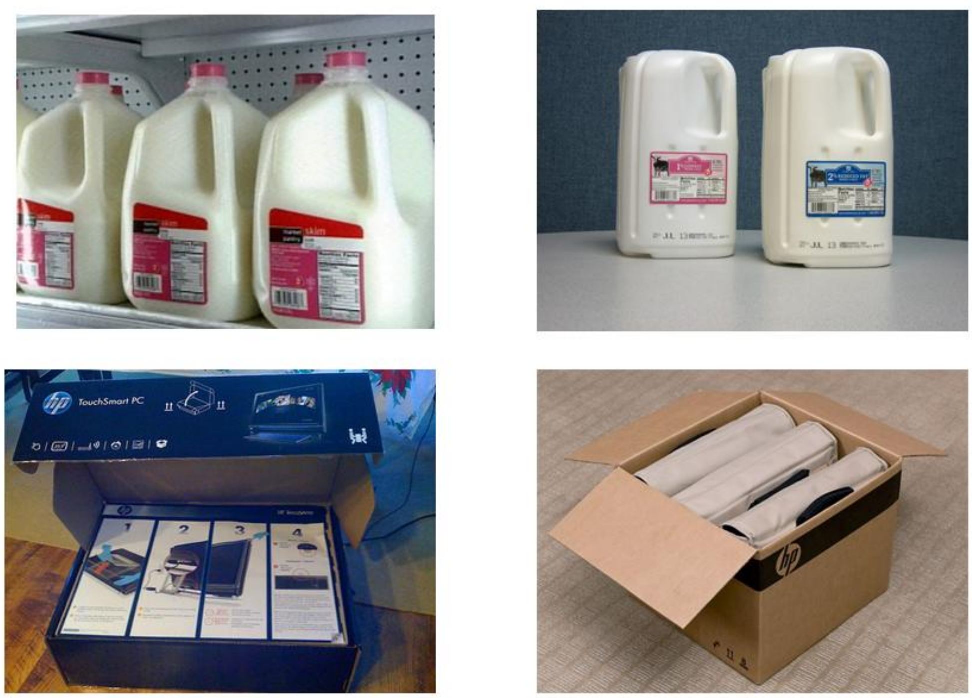


Figure 7: Traditional and improved product packaging.

Less-than-full-truckload operations were considered as transportation units can allocate partial capacity and space to products under consideration. Supplier compliance described the improvements in emissions per product resulting from the adoption of progressive design and packaging practices. Better product consolidation and cubic-space utilization at facilities and motor carriers result from these type of product configurations. Figure 7 shows traditional and enhanced product configurations. The following chapter presents the results from the discrete-event simulation model including model validation elements.

CHAPTER 5

MODEL RESULTS

5.1 Model validation

This process intends to substantiate that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model (Balci, 1997; Sargent, 2004). It is concerned with determining whether the conceptual description of the simulation model is an accurate representation of the system under study (Kleijnen, 1995; Giannanasi et al., 2001). In principle, this model implementation was validated through static and dynamic testing (Sargent, 2005; Finkbeiner, 2011).

The first approach was based on structured walk-through of processes in order to examine the design and architectural properties of the program. Each operational domain was analyzed on a process basis were disaggregation of components and activities took place at the Blocks and Elements panel-level. These represent the most elemental development units available within the simulation environment used. Therefore a set of Blocks and Elements panels can constitute a unit process (Kelton et al., 2010).

Dynamic testing required additional validation techniques such as parameter variability, traces, and internal validity. Parameter validity was supported by sensitivity analysis conducted across process configurations. By executing simulation replicates under different conditions, feasible outcomes at the process, operational domain, and supply chain levels were obtained.

As several entities are created, flow, and get disposed along the system, it was necessary to observe their behavior throughout the model in order to determine the accuracy and logic correctness of processes. For instance, customer arrivals taking place in a given retail store do not necessarily guarantee the purchase of a consumer good being studied.

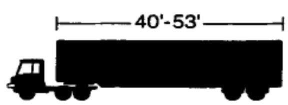
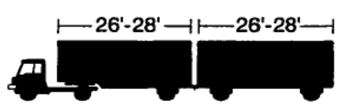
Similarly, product picking and packing activities at the central warehouse cannot take place unless one or several retail stores issue an inventory replenishment order after verifying their local product availability. In addition, internal validity of the model was confirmed by conducting several replications for each process configuration. As the number of replications gradually increased, results consistency was maintained at the process, operational domain, and supply chain levels.

Sensitivity analysis (Barton and Lee, 2002; Kelton et al., 2010) on motor carrier fuel economy was conducted. Prior research addressing inventory management of consumable goods has assumed truck weight capacity of approximately 43,500 pounds (Singh et al., 2010) with a traveling distance between distribution centers and retailing stores ranging from 250 to 425 miles (U.S. DOT, 2007). Conversely, truck weight capacity associated with durable goods transportation have been ranging from 5,500 to 35,500 pounds (Choi et al., 2006), with their corresponding traveling distances between supply chain facilities ranging from 143 to 700 miles (U.S. DOT, 2007).

Particularly, the discrete-event model incorporated the travel times and distances associated with the supply chain topologies of leading organizations located in the U.S. Southwest. Furthermore, the motor carrier modeled encompassed attributes of a cargo van or single-unit truck, therefore presenting a fuel economy comparable to a passenger vehicle (EPA, 2010). This light to medium heavy-duty vehicle is representative of the Class 2B motor carrier group responsible of 53% of total trucks operating in the country, the largest share among the eight classes of vehicles available (U.S. DOT, 2010b). Provided the attribute-based nature of the model, different types of trucks can be incorporated into the operations being modeled.

For instance, larger truck configurations can be either single-unit trucks weighting more than 10,000 pounds or a combination of vehicles consisting of tractors pulling one or more trailers. Tractor-trailers typically pull one trailer 40-53 feet long. A tractor pulling two trailers, neither of which is longer than 28.5 feet, is referred to as a western double or twin trailer. An additional configuration known as a longer combination vehicle (LCV) consists of more than two trailers with a combined length exceeding 57 feet (Braver et al., 1997).

Table 14. Sensitivity analysis of carrier fuel economy.

Motor Carrier	**Fuel Economy (MPG)**	**Source**	**Resulting Emissions (MT CO2e)**
Cargo van or Single-unit truck 	20.5	EPA, 2010.	771.417
	13.9	NCEP, 2004.	765.321
Tractor-trailer 	7.8	NCEP, 2004; U.S. DOT, 2010b.	764.945
Twin-trailer 	5.3	NCEP, 2004; U.S. DOT, 2010b.	770.663

According to the Goodyear Tire & Rubber Company field tests (2008), truck fuel economy can drop 5% for each 10,000 pounds increase in load. Considering fuel economy estimates from the National Commission on Energy Policy (2004) and the U.S. Department of Transportation (2010b), for single-unit trucks, tractor-trailers, and twin trailers, additional simulations were conducted finding minimum variations in model outcomes (Table 14).

Operational validity was greatly benefited by direct process observation, parameter sourcing from prior literature, and consultation with supply chain practitioners. Furthermore, the levels of carbon dioxide equivalents per product from the model are equivalent to those found in Open Input-Output models (TSC, 2011b). The level of granularity available for durable products in the Open I/O model allows it to converge to a value of 0.62kg CO2-eq; while a more aggregated level of processes associated with consumable goods result in 1.51kg CO2-eq versus 1.24kg CO2-eq indicated by the simulation model. Figure 8 provides a graphical description of the annual emissions calculated by the model along with current data from industry participants operating retail formats such as category specialist and super-center associated with consumable and durable goods.

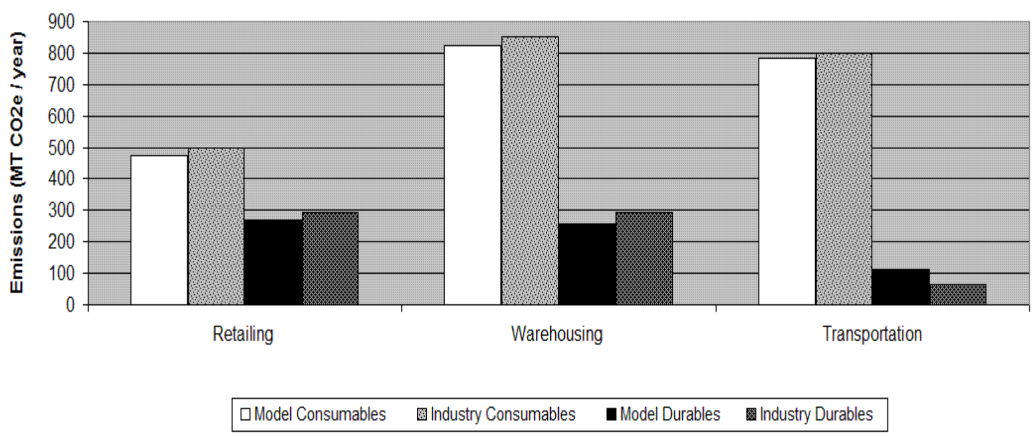


Figure 8: Supply chain emissions by operational domain.

Provided the quantitative nature of the experimental levels, it is possible to calculate response variable magnitudes associated with values along the range encompassed by the factor levels (Casella and Berger, 2002; Heizer and Render, 2004; Montgomery, 2005). In other words, annual supply chain emissions for a given process configuration can be described as a linear function of the time products spend at the warehouse level, frequency of product shipments, product storage capacity at retailing stores, and resources supporting product customization capabilities at the points of sale.

Testing for linearity allows the development of an adequate description of the system under study based on the lowest-order polynomial available. Otherwise, descriptions incorporating high-order polynomial terms do not necessarily improve the overall fit, but increase the complexity of the model and can often damage its usefulness in the generation of response variable estimates (Verwust, 1991; Montgomery, 2005).

Provided that coordinate pairs of data points from two continuous variables are displayed in a scatter plot, visual inspection of these bivariate plots becomes instrumental when addressing goodness-of-fit and the overall dispersion degree of the data around a normative model (Rodriguez et al., 1996; Nechar et al., 1998; Schumacker and Lomax, 2010).

Consequently, the presence of linearity supports the computation of point estimates, the derivation of interval estimates, and hypothesis testing (Poole and O'Farrell, 1970; Montgomery, 1991; Coleman & Montgomery, 1993; Casella and Berger, 2002; Kleijnen, 2005; Lichtenstein et al., 2007).

All experimental factors were statistically significant when conducting individual analysis of variance towards the main response variable, corresponding ANOVA tables can be found in Appendix E. Model outcomes due to the interaction of experimental factors are graphically described as follows.

Figure 9 describes the interaction between product warehouse storage time and shipment frequency among supply chain locations including their corresponding experimental levels. The plane describes the feasible outcomes from these two factors measured in metric tons of carbon dioxide equivalents per year (MTCO2e / year).

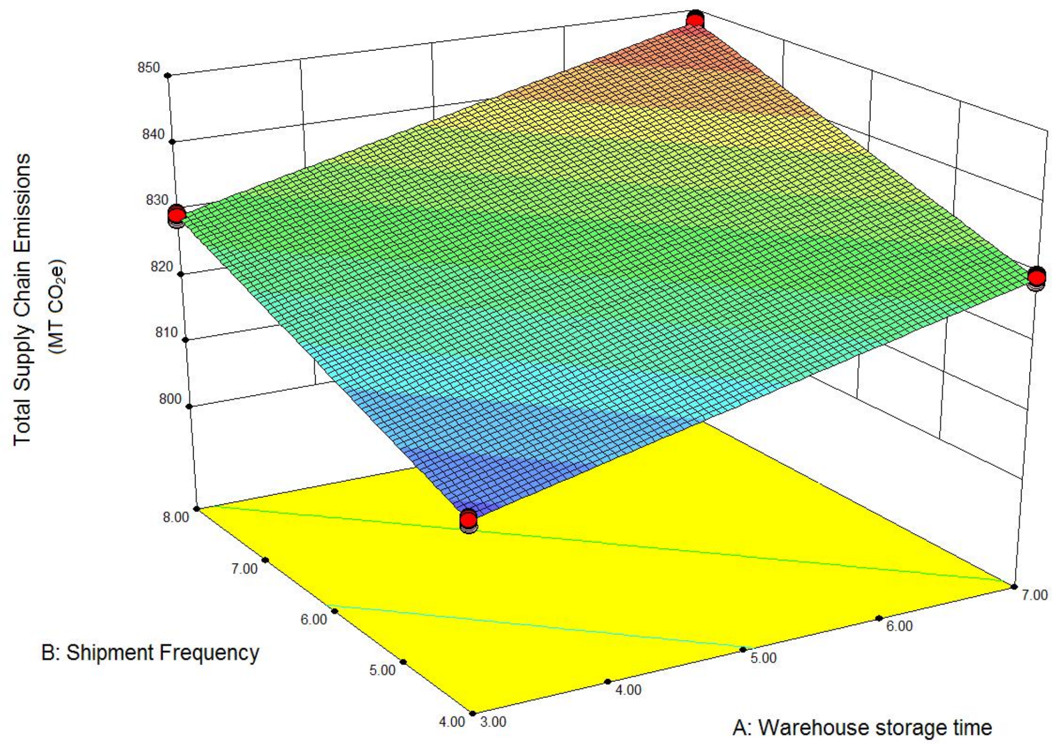


Figure 9: Two-factor model outcomes.

When a third experimental factor is incorporated, the corresponding outcomes can be expressed in a cubic array. Each experimental factor is represented by one of the three dimensions of the cube. Consequently, each vertex is associated with a high or low experimental level depending on the dimension or factor being studied (Figure 10). For instance, the letter C corresponds to the last experimental factor included.

The extreme points of that line segment represent its low and high levels tagged with a negative and a positive sign respectively. Building upon this graphical array, outcomes considering a fourth experimental factor can be expressed in a similar fashion. This time a full cube represents the outcomes from the low level, while another one encompasses the results from the high level. Both experimental levels are presented in Figure 11.

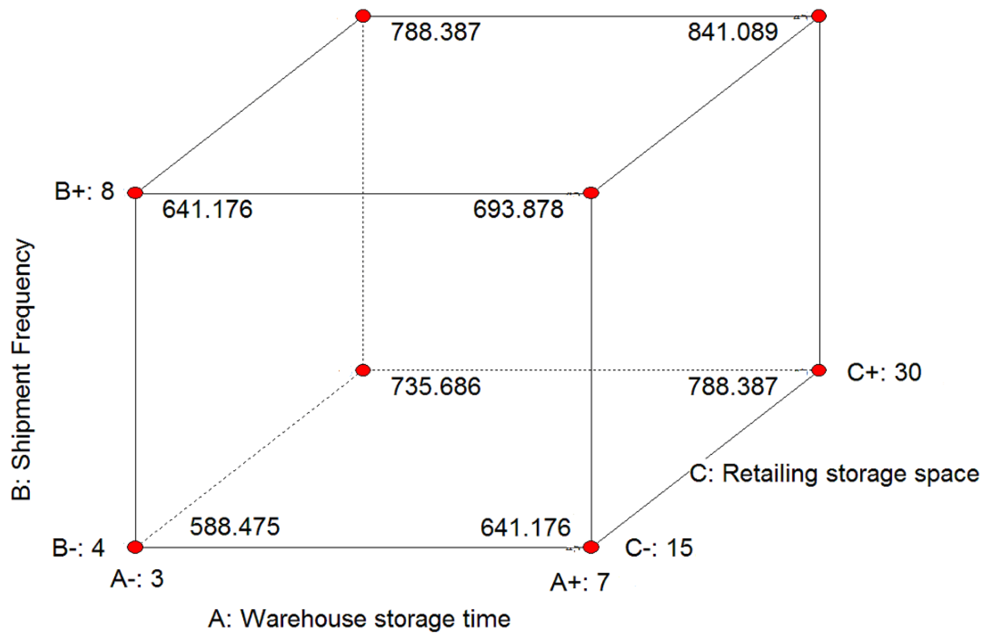
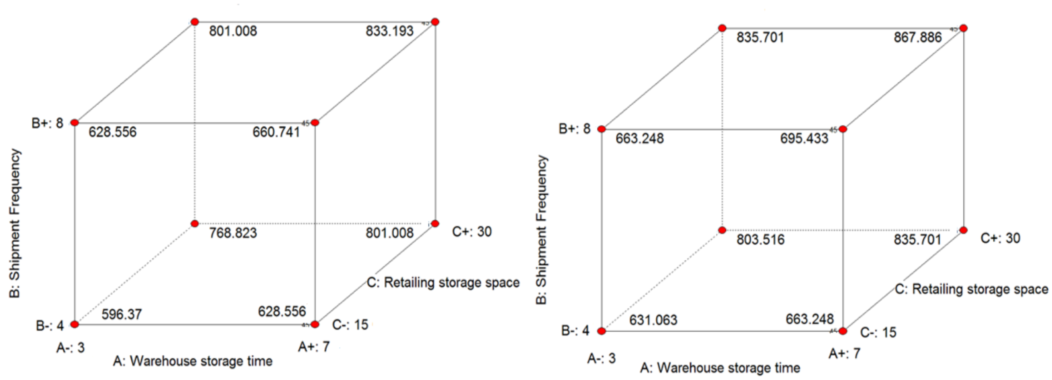


Figure 10: Three-factor model outcomes.



a) Low level b) High level

Figure 11: Four-factor model outcomes.

5.2 Regression modeling

In principle, a baseline model was established using just the selected control variables, and then sequentially added each of the other four variables into the model in order to test the four propositions. In addition, the simultaneous impact of each variable was tested in an aggregate model.

By examining the correlations in Table 15, it is possible to find support for all four propositions. Product shipment frequency between the central warehouse and retailing stores is significantly and positively correlated to the response variable. Conversely, product customization capabilities and storage space devoted at the retailing level are significantly and negatively correlated to the total supply chain emissions.

Resources supporting inventory management at the warehouse level are positively correlated with product shipment frequency, as more product picking, packaging, and truck-loading operations are required. Fleet efficiency is significantly and positively correlated with the energy mix supporting mobile and fixed infrastructure across the supply chain (0.3). Supplier certification programs highlighted the critical importance of adopting progressive product design and packaging practices that can positively impact fleet efficiency performance. Another significant aspect of these initiatives was the gradual incorporation of alternative sources of energy along the product replenishment process across supply chain levels.

Table 15. Correlations for model variables.

	1	2	3	4	5	6	7	8
(1) TotalSCE	1.00							
(2) ProdShip	**0.56**	1.00						
(3) ProdCust	**-0.25**	0.04	1.00					
(4) ProdWH	**0.08**	**0.22**	0.09	1.00				
(5) RetStorage	**-0.12**	0.07	0.08	-0.03	1.00			
(6) EnergyMix	0.00	0.00	-0.03	0.09	-0.03	1.00		
(7) Fleet	-0.01	0.00	0.01	0.04	-0.06	**0.30**	1.00	
(8) SupplierC	0.00	-0.06	-0.03	0.20	-0.03	**0.19**	**0.21**	1.00

Bolded entries were statistically significant at the p=0.05 level.

Table 16 provides the regression model estimates for the baseline case and the four propositions, for the main response variable under study. None of the control variables are significant in the baseline model. The next columns provide the estimate corresponding to each variable, and its standard deviation, along with a note associated with its statistical significance level.

H1 posits that product shipment frequency due to lean-oriented product procurement will be associated with higher carbon dioxide equivalents. The model supports this hypothesis (beta=0.2, p=0.089). H2 states that product customization capabilities will be associated with lower carbon dioxide equivalents; this is confirmed by the model (beta=-33.88; p=0.061). H3 establishes that warehousing practices due to lean-oriented product procurement will be associated with higher carbon dioxide equivalents; this is supported by the model (beta=0.16; p=0.035). Finally, H4 claims that product storage practices due to lean retailing will be associated with lower carbon dioxide equivalents; this is confirmed by the model (beta=-2.75, p=0.091). Examining the control variables, it is possible to see that after controlling for product shipment frequency, product customization capabilities at the retail level, and product warehousing practices; fleet efficiency and supplier compliance achieve statistical significance. In order to determine the joint effects of all the variables, an aggregate model was run incorporating each variable.

Here the effect due to product shipment frequency remains equally significant, while the effects associated with product customization capabilities at the retail level and product warehousing practices disappear. Product storage practices due to lean retailing become increasingly significant, while fleet.

Table 16. Model parameter estimates.

	Baseline	Total Supply Chain Emissions				
	estimate (S.D.)	H1	H2	H3	H4	Aggregate
ProdShip	x	0.20 (0.11)*	x	x	x	2.93 (1.51)*
ProdCust	x	x	-33.88 (17.43)*	x	x	-1.65 (4.53)
ProdWH	x	x	x	0.16 (0.07)**	x	0.04 (0.06)
RetStorage	x	x	x	x	-2.75 (1.59)*	-3.34 (1.20)***
EnergyMix	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)	0.01 (0.01)
Fleet	0.05 (0.05)	0.07 (0.03)*	0.07 (0.04)*	0.09 (0.04)**	0.08 (0.05)	0.05 (0.03)*
SupplierC	-1.64 (1.15)	-2.13(1.11)*	-2.26 (1.20)*	-3.21(1.28)**	-1.73 (1.24)	-2.20 (0.93)**

* Significant at the p=0.10 level.

** Significant at the p=0.05 level.

*** Significant at the p=0.01 level.

efficiency and supplier compliance remain significant. This finding suggests synergy between product shipment frequency and product management due to lean retailing practices. The following chapter discusses the results from the research. Encompassing how current findings confirm speculations from prior research, while addressing the synergy found between process variables associated with lean logistics and retailing operations and their corresponding environmental performance. In addition, model generalization potential into upstream supply chain operations and current retailing trends based on local product sourcing and the gradual servitization of the consumer goods industry procurement are covered at the end of the chapter.

CHAPTER 6

DISCUSSION

The characterization of a consumer goods supply chain into a two-echelon discrete-event simulation model allowed the examination of the research hypothesis. Product shipment frequency and supporting activities tend to be more carbon intensive when following a lean distribution approach, while resources allocated to inventory management at the retailing level contributed to a reduced amount of carbon dioxide emissions.

At the same time, the interaction between lean logistics and retailing processes described a significant effect on fleet utilization coupled with supplier compliance. Particularly, improved product design and packaging attributes support a better utilization of cubic space in motor carriers, short-term storage, and shelf space at retailing stores.

In principle, this research establishes a clear connection between independent investigations addressing lean logistics practices and lean retailing environments as separate activities and research fields. Rather than treating specific operational domains as organizational or functional silos, this study can be considered an integrative approach focused on several downstream supply chain processes.

The study confirms prior research speculations about potential outcomes from transportation operations subject to lean principles (Rodrigue et al., 2001; IBM, 2008; Rizet et al., 2010), while providing a simultaneous assessment of operations associated with the emerging field of lean retailing from an environmental standpoint. The scope and outcomes of this research provide a complementary approach to studies heavily concerned with the economic dimension and performance of lean logistics and retailing systems (Christopherson, 2007; Dong et al., 2007).

The traditional concept of inventory and its corresponding management implications are not portrayed as static magnitudes contained in material requirements planning, distribution resources planning, or product forecasts; but as a continuous flow of entities moving across operational domains able to capture the environmental implications of adopting lean best practices.

The attributional nature and system architecture of the discrete-event simulation model used in the study can allow the characterization of similar systems located in different regions and supported by completely different supply chain topologies, local processes, and parameters. Given the functional units considered in this study, it is feasible to describe the environmental performance of operations handling similar products including dairy, produce, or vaccines subject to time and temperature conditions.

Particularly, the challenges and environmental conditions provided by the U.S. Southwest were instrumental to acknowledge the type of innovations required by supply chains operating in this region. As an increased number of high-efficiency stores are designed and deployed over time, economies of scale in harnessing solar energy and coping with significantly less packaging materials are expected.

Current design trends in this type of facilities consider the implementation of cold water re-circulation systems built into the floor in order to provide temperature relief for persons inside the building while lowering the demand on electricity in air-conditioning and ventilation systems. Innovations of this nature will invariably call for a closer assessment of the total water footprint of these new facilities compared to traditional retailing configurations as they can pose additional stress on community water supplies.

Along the same lines, particular considerations towards additional ecosystem services can become relevant to further understand the environmental impact of this type of infrastructure. For instance, other geographies could be prone to harnessing eolic energy to support general operations or being able to capture more water due to a more intense precipitation pattern.

From a product assortment standpoint, supercenters and big-box retailers have gradually incorporated more consumer electronics into their offerings including products that were usually found only at category specialists. As retail organizations increased the allocation of shelf and storage space for these products, more competition among suppliers servicing the rest of the store took place.

At the same time, the general offering of fresh produce increased along with the value proposition of healthier food choices and support to local product sourcing strategies. A clear implementation of this value proposition came into being when leading retailers started the deployment of pilot grocery stores known as community neighborhood markets.

With almost 70% of total inventory requiring some degree of temperature control, they represent useful examples of an upcoming trend in retail formats based on facilities only using 10% of the space required from an average store. Daily deliveries of fresh produce, meats, and flowers support the business model of this format clearly incorporating several lean principles in the form of extremely reduced storage space and frequent product replenishment.

This emerging retail format can essentially serve as a launching pad for very niche specific products while garnering the benefits of local supply chains in different regions. Perhaps addressing the environmental dynamics from local supply chains and distributed retail formats such as the community neighborhood markets can be initially approached from a consequential LCA perspective.

Provided the local nature of product sourcing, the required system boundary expansion can encompass a discrete number of upstream supply chain operations in a feasible fashion including market mechanisms and size of change in demand. However, consequential LCAs tend to report lower environmental burdens compared to an attribution-based approach as any avoided burden is regularly subtracted from process totals (Thomassen et al., 2008). Another important element is the general direction of the system expansion.

Having a retailing operation as the focal point and conducting a system boundary expansion further down the supply chain can significantly increase the sources of variability associated with process and product emissions. For instance, McKinnon and Woodburn (1994) expanded the boundary of a retail-focused study in order to include product transportation incurred by consumers from their homes into the stores and back. Unfortunately, as shopping trips not necessarily involve the purchase of one article at a time, it is very difficult to de-aggregate consumer travel behavior information and allocate it to one particular product (Rizet et al., 2010).

The resulting loss in economies of scale associated with product distribution makes frameworks such as the PAS-2050 specification not applicable to this particular transportation segment. In addition, process assumption granularity increases significantly as it essentially involves assigning attributes to each potential consumer visiting the store including travel distance from home, goods purchased, and type of vehicle used. Conversely, the potential extensions for the discrete-event simulation model presented in this research find a better fit when focusing on upstream supply chain operations and the corresponding integration of multi-modal logistics systems.

Considering that significant inventory management takes place at regional, domestic, and international levels; the description and further parametrization of material handling schemes involving additional modes such as railroads, water, and air can be supported by aggregated demands from particular product families associated with the functional units currently addressed.

Given this expanded array of processes at each operational domain, additional variables associated with different transportation modes and supporting activities could supplement the process variables covered in the original model. By testing an extended version of the initial consumer goods supply chain, it is possible that variables that were initially found not significant in the aggregate model achieve statistical significance under the new configuration.

Process variables such as warehousing resources supporting inventory management and product customization capabilities at the retailing level can potentially offer different process insights from the integration of entire supply chain echelons. Having additional distribution centers forming an ample inventory pipeline beyond local sourcing points, can foster different demand penetration instances resulting in the location of product families' decoupling points at different supply chain stages other than the retail level. Particularly, a better understanding of postponement practices along consumer goods supply chains can contribute to the improved conceptualization of the current servitization of production systems. The underlying sustainability implications of this process are relevant since efficiency gains achieved by disciplines such as Industrial Ecology are frequently undone by the continued expansion of consumer expectations and demands (Dyllick & Hockerts, 2002; Jackson, 2005; Webber & Matthews, 2008).

As different production systems aim at developing a level of responsiveness able to accommodate increasingly participative and empowered customers in the creation of their own products, supply chains can become less efficient and more redundant in their design. An exploration in this direction could follow the observations from Korhonen and Seager (2008) who proposed that it may be beneficial to adopt practices that may be considered inefficient from an eco-efficiency perspective, but supportive of a systems-wide, long term view of sustainability.

Simultaneously, key process variables identified in this research could potentially be less significant as the research scope goes further up the supply chain. For instance, the influence of supplier certification programs focused on sustainability imperatives such as energy, climate, material efficiency, natural resources, and community engagement; is expected to have a significant impact in downstream processes as those programs were developed by leading retailers and implemented with their immediate supplier base.

As upstream operations are examined, the bulk of available environmental information is usually associated with sourcing of different materials and Toxic Release Inventories from manufacturing operations. Although, this information is often the result of organizational compliance with environmental standards and programs enforced in specific industries over time, products and processes from some proactive partners might be accredited by third party certification schemes facilitating their assessment.

Looking at intermediate procurement processes from manufacturers to regional markets brings an increased level of complexity due to fixed and mobile infrastructure encompassing roads, railways, airports, and intermodal freight terminals. Nonetheless, this configuration can bring more flexibility to explore the social implications of the system as its scope moves from local to regional, domestic or international levels. Therefore magnifying the diversity of challenges associated with this dimension of sustainability.

Similar to behavior-based industrial safety initiatives, waste audits at multiple facilities across the supply chain can start measuring waste streams including regular trash, recyclable content, and more complex solid waste. Keeping track of this and other critical resources can support the development of different process metrics such as the water footprint for a given unit process or an entire facility.

Further approaches to address the day to day performance of the supply chain in this area should require driving behavioral change among associates based on education and cultural awareness on resource conservation. As operational domains cross international borders and more organizations are involved in the total product sourcing process, transparent information about social compliance in the workplace is needed.

Socially responsible supply chains must have a clear understanding about the location of their business partners. In addition, the wide spread adoption of ethical standards must oversee human resources management elements such as wages, hours, health, safety, and human rights of employees. Another relevant contribution from supply chain partners is the potential impact they can have in their surrounding communities.

Specific opportunities consider the support of education and workforce development programs. Communities can greatly benefit from targeted investments in high school success programs, improving college access, job skill training, computer and financial literacy. Organizations and communities can mutually reinforce their connections by tapping local knowledge, leverage valuable resources, and building strong reputations.

The gradual assessment of upstream supply chain stages can supplement the original efforts developed by strategically positioned retailers around the globe. The increased quality in available information about the environmental performance of consumer goods supply chains can foster a more balanced distribution of organizational power and influence among traditional manufacturer and retailer operational dyads.

The generalization of current findings can also support the identification of generic supply chain improvement opportunities across priority product groups. Different functional units can be selected from these groups in order to address new product categories such as produce, poultry, red meat, textiles, and household furniture. Product grouping criteria can be based on total sales volume and market share, common manufacturing processes among products, supplier and retailers concentrations.

Consequently, sourcing practices such as product edit based on environmental performance of consumer goods can be fully internalized across different retail formats as more manufacturers and third party logistics organizations adopt a common set of standards and metrics to assess their operations. Eventually, these new metrics can be incorporated into Enterprise Resource Planning systems across the supply chain in order to build a transparent database useful for all stakeholders.

Retailing organizations paved the way for several innovative solutions to streamline the lean-based efforts from upstream supply chain operations, while keeping their prominent influence as ultimate points-of-sale. In addition, most of the efforts resulting from the on-line retailing movement have supplemented and strengthen these organizations by extending their reach and product offerings to more potential customers than ever. However, lean logistics and retailing operations are part of larger systems.

As demand-driven processes, they are subject to changes such as market composition and customer defection. Particularly, aging populations around the world could set another wave of market disintermediation across contemporary supply chains; potentially turning a percentage of retailing facilities into local distribution hubs able to provide direct deliveries of groceries and medicaments to neighboring customers unable to have the traditional retailing experience due to mobility or other health issue.

Latest generation of kitchen appliances are able to keep track of food consumption and availability at the household level in order to generate grocery lists for the users. These lists can be electronically shared with neighborhood markets and trigger the corresponding procurement process. Perhaps, in the long-rung distributed retailing facilities might still need to be flexible enough to integrate some elements from their logistics supporting operations in order to reach final customers.

The following chapter presents the overall conclusions from the research and identifies future work on lean logistics and retailing systems.

CHAPTER 7

CONCLUSIONS

Using theoretical insights from sustainability and supply chain literature a two-echelon supply chain discrete-event simulation model was developed to examine the environmental performance of lean logistics and retailing systems. Based on a detailed understanding of lean best practices, it was possible to identify distinctive process variables able to impact the resulting carbon dioxide equivalent emissions from consumer goods procurement processes.

Research propositions linking annual process greenhouse gas emissions to (1) shipment frequency between supply chain partners, (2) degree of proximity between products' decoupling point and final customers, (3) inventory turns at the warehousing level, and (4) degree of supplier integration, were tested. All four propositions were confirmed suggesting that lean distribution of durable and consumable goods can result in an increased amount of carbon dioxide emissions, while lean retailing operations can reduce process emissions.

From a broader perspective, this research advances the scientific understanding associated with the sustainability implications of the consumer goods industry. Particularly, this study provides a methodological approach able to quantify the environmental performance of contemporary supply chain practices. By modeling relevant elements and processes jointly identified in prior research and by current supply chain professionals, the study addresses the inherent complexity of product procurement systems performing within regions subject to fast paced urbanization and intensive resource demands from an increasing population.

The research not only integrates several downstream supply chain stages that have been addressed as independent operational domains, but establishes a clear line of scientific inquiry between the economic and social dimensions of critical processes currently shaping the design and performance of global organizations that have developed the strategic awareness about the importance of firm and product sustainability in the years to come.

Although the supply chain model comprised warehousing, transportation, and retailing operations from organizations located in the U.S. Southwest, the architecture of the model allows it to become a platform for the description of larger systems performing in complete different latitudes. Due to the model's attribution-based nature, the environmental performance of upstream supply chain operations including multi-modal transportation could potentially be addressed by a multi-echelon version of the model.

Adapting the proposed model in order to address upstream supply chain operations must acknowledge the following considerations: product and materials management implications associated with the transition from final products and sub-assemblies to bill-of-materials level components or raw materials depending on the selected system boundary; the sourcing of feasible operational parameters able to describe representative processes from multiple facilities such as rail freight stations, air cargo terminals, and sea-ports within the expanded supply network; and the identification of relevant attributes associated with products, components or materials and different carriers such as rail cargo wagons, airplanes, and barges.

Fundamental sources of information in order to support the description of this larger operational horizon include: the North American Industry

Classification System based on transportation modes (1995); the Commodity Flow Survey jointly developed by the U.S. Departments of Transportation and Commerce (2010c); the Waterborne Commerce Database from the U.S. Army Corps of Engineers (2009); and the Airborne Export Network Database jointly developed by the Bureau of Transportation Statistics and the Office of Airline Information (2011).

Provided that more than 90% of the imported and exported goods in the United States move by water and over one billion tons of domestic freight travels each year on marine highways (RILA, 2011), the level of process aggregation due to regional, domestic or international supply chain operations requires the use of meaningful performance indicators.

For instance, the transportation of bulk materials across locations is usually quantified in Ton-Miles (Gorman, 2008; Morey et al., 2010; U.S. DOT, 2010c). Relevant process attributes associated with multimodal shipments such as truck-rail shipments require the development of specific simulation modules known as intermodal transfer links. These modules are able to describe and account for resources and time allocated to transfer materials and goods from individual modal networks that converge on a given transfer point. Attributes associated with the expanded array of carriers to support this kind of operations are volume capacity, type of fuel used, loading and un-loading times.

The functional units selected for this study can draw parallels with larger product families currently using lean best practices along their procurement processes. Provided the demand-driven nature of the operations studied, it was possible to take the traditional concept of inventory and characterize it as a dynamic flow of entities delivering value at the retail level while acknowledging the environmental implications associated with their physical management and allocation of supporting resources along the inventory pipeline.

The supply chain design and managerial implications associated with the incorporation of the environmental dimension of lean principles into downstream processes, acknowledged the embedded operational trade-off between cumulative process efficiency and overall system resilience, both aspects grounded in supply chain and sustainability literature.

Particularly, finding synergy between product shipment frequency among supply chain partners and product management due to lean retailing practices; established a clear connection between distribution and retailing operations based on their integrated environmental performance. Addressing this sustainability dimension from lean systems represents a long overdue assessment for a set of practices widely introduced in contemporary supply chains over the last twenty-five years.

Given the critical importance of natural resources around the world, future studies can be focused on other fundamental impacts such as the water footprint of lean procurement of consumer goods. Perhaps, an increased number of investigations devoted to the environmental performance of upstream supply chain operations could become feasible as more organizations adopt a common set of environmental standards and process metrics across industries.

Currently, this research provides an in-depth look at logistics and retailing operations, both domains have been portrayed as non-dominant supply chain stages from a product-based standpoint in Life Cycle Assessment literature (Saouter & Van Hoof, 2001; Choi et al., 2006; Eberle et al., 2007; Cullen & Allwood, 2009). However, the strategic position of global retailers able to manage between 85% to 95% of their total inventories through lean-oriented practices and supporting infrastructure (Simchi-Levi et al., 2003, Sheu et al., 2006) requires the examination of global operations from a process-based standpoint.

By definition, the lean procurement methods addressed in the study consider supplier development programs an integral part towards continuous process improvement across the supply chain. In addition, these supplier assessment processes comprise the initial step in the development of sustainability indexes spearheaded by global retailers (Walmart, 2011). Consequently, the insights obtained about supplier integration can directly contribute to decision making processes associated with these strategic initiatives.

The next main step in sustainability indexes development requires the integration of a Lifecycle Analysis Database. A joint effort between supply chain partners including suppliers, manufacturers, third-party logistics organizations, and retailers; operations from some of these critical stakeholders have been modeled in the study.

The spatiotemporal boundary of the research is able to provide process insights compatible with current databases that generically describe logistics and retailing operations. As more regions are gradually incorporated including the topologies of the supply chains operating within them, a better understanding of their environmental and operational challenges can be achieved and eventually translated into timely and simple tools for consumers. This process synergy can foster the development of the scientific foundations supporting the emergence of sustainable indexes.

Considering the increasing amount of process attributes with direct implications in the health and safety of people performing activities across the supply chain, advanced characterizations of similar operational domains could potentially incorporate them. Emerging research able to address the social dimension of lean systems could supplement current literature limited to ergonomic factors and industrial safety compliance.

Although the development of recent frameworks such as the Guidelines for Social Life Cycle Assessment and the ISO 26000 standard on Social Responsibility can provide an initial platform to design further empirical research on lean procurement systems, the inherent complexity of the social dimension will not necessarily provide a streamlined set of effects such as the ones supporting the assessment of the economic and environmental dimensions. Specially, when coping with such a diverse array of elements ranging from process and product-level human toxicity to labor union regulations for a given industry or country.

In the long-term, it is important to acknowledge that the comprehensive study of lean systems from an economic standpoint combined with their on-going environmental examination, will supplement current seminal efforts in the social arena. Although the independent and focused study from each dimension is critical to obtain a deep understanding of the processes, the eventual integration of the three dimensions holds the prospect of delivering the most complete and effective sustainability understanding of the system under study.

Strategic planning and tactical decision making informed by this integrated assessment could better anticipate sustainability opportunities associated with the global procurement of consumer goods. In the meantime, supply chain strategic adaptation would be necessary to address the sustainability implications of current value propositions including retailing systems based on local product sourcing and the gradual servitization of industry.

REFERENCES

Abukhader, S.M. 2008. Eco-efficiency in the era of electronic commerce – should eco-effectiveness approach be adopted? *Journal of Cleaner Production* 16(1): 801-808.

Achabal, D.D., Mchintyre, S.H., Smith, S.A., and Kalyanam, K. 2000. A decision support system for vendor managed inventory. *Journal of Retailing* 76(4): 430-454.

Adair-Heeley, C.B. 1988. JIT purchasing: seven steps for successful implementation. *Production and Inventory Management Review* 8(12): 22-23.

Adams, C.A. 2004. The ethical, social and environmental reporting-performance portrayal gap. *Accounting, Auditing and Accountability Journal* 17(5): 731-757.

Adner, R. & Zemsky, P. 2006. A demand-based perspective on sustainable competitive advantage. *Strategic Management Journal* 27(3): 215-239.

Albino, V., Carella, G., and Okogbaa, O.G. 1992. Maintenance policies in just-in-time manufacturing lines. *International Journal of Production Research* 30(2): 369-382.

Alcott, B. 2005. Jevons' paradox. *Ecological Economics* 54(1): 9-21.

Alderson, W. 1950. Marketing efficiency and the principle of postponement. *Cost and Profit Outlook* 3(1): 15-18.

Allen, R. 1980. *How to save the world.* Barnes and Noble: Totowa, NJ.

Andel, T. 1996. Manage inventory, own information. *Transportation and Distribution* 37(5): 54-57.

Anderson, E., Day, G.S., and Rangan V.K. 1997. Strategic Channel Design. *Sloan Management Review* 38(4): 59-69.

Anderson, S., Allen, J., and Browne, M. 2005. Urban logistics – how can it meet policy makers' sustainability objectives? *Journal of Transport Geography* 13(1): 71-81.

Andries, B. and Gelders, L. 1995. Time-based manufacturing logistics. *Logistics Information Management* 8(1): 25-31.

Angell, L.C. and R.D. Klassen. 1999. Integrating environmental issues into the mainstream: An agenda for research in operations management. *Journal of Operations Management* 17(1): 575-598.

Angell, L.C. 2001. Comparing the environmental and quality initiatives of Baldrige Awards winners. *Production and Operations Management* 10(3): 306-326.

Ansari, A. and Modarress, B. 1986. Just-in-time purchasing: problems and solutions. *Journal of Purchasing and Materials Management* 22(2): 11-15.

Ansari, A. and Modarress, B. 1987. Potential benefits of JIT purchasing for US manufacturers. *Production and Inventory Management Journal* 28(2): 30-35.

Ansari, A. and Modarress, B. 1988. JIT purchasing as a quality and productivity centre. *International Journal of Production Research* 26(1): 19-26.

Antweiler, W. and Harrison K. 2003. Toxic release inventories and green consumerism: empirical evidence from Canada. *Canadian Journal of Economics* 36(2): 495-520.

Appelqvist, P. and Gubi, E. 2005. Postponed variety creation: case study in consumer electronics retail. *International Journal of Retail and Distribution Management* 33(10): 734-748.

Appelqvist, P., Lehtonen, J.M., and Kokkonen, J. 2004. Modelling for product and supply chain: literature survey and case study. *Journal of Manufacturing Technology Management* 15(7): 675-686.

Arnheiter, E.D., and Maleyeff, J. 2005. The integration of lean management and six sigma. *The TQM Magazine* 17(1): 5-18.

Arnold, T., and Chapman, S.N. 2004. *Introduction to Materials Management.* Upper Saddle River: Prentice Hall.

Arnold, U. and Bernard, K.N. 1989. Just-in-time: Some marketing issues raised by a popular concept in production and distribution. *Technovation*, 9(1): 401-430.

Arnold, U. 2000. New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept. *European Journal of Purchasing & Supply Chain Management* 6(1): 23-29.

Aykin, T. 1995. Networking policies for hub-and-spoke systems with applications to the air transportation systems. *Transportation Science* 29(3): 201-221.

Ayres, R.U., Ayres, L.W., and Martinas, K. 1998. Exergy, waste, accounting, and life-cycle analysis. *Energy* 23(5): 355-363.

Babakus, E., Bienstock, C.C., and Van Scotter, J.R. 2004. Linking perceived quality and customer satisfaction to store traffic and revenue growth. *Decision Sciences* 35(4): 713-737.

Bagchi, P.K., Raghunathan, T.S., and Bardi, E.J. 1987. The implications of Just-in-Time inventory policies on carrier selection. *Logistics and Transportation Review* 23(4): 373-384.

Balci, O. 1997. Verification, validation and accreditation of simulation models. *Proceedings of the Winter Simulation Conference*, 135-141.

Bartezzaghi, E. and Turco, F. 1989. Impact of JIT on production system performance: An analytical framework. *International Journal of Operations and Production Management* 9(8): 40-62.

Bartholdi, J.J. and Gue, K.R. 2000. Reducing labor costs in an LTL crossdocking terminal. *Operations Research* 48(6): 823-832.

Barton, P.I. and C.K. Lee. 2002. Modeling, simulation, sensitivity analysis, and optimization of hybrid systems. *ACM Transactions on Modeling and Computer Simulation*, 12(4): 256-289.

Bauman, H., and Cowell, S.J. 1999. An evaluative framework for conceptual and analytical approaches used in environmental management. *Greener Management International* 26(1): 109-123.

Beamon, B.M. 1999. Designing the green supply chain. *Logistics Information Management* 12(4): 332-324.

Becker, C.D. and Ostrom, E. 1995. Human ecology and resource sustainability: The importance of institutional diversity. *Annual Review of Ecology and Systematics* 26(1): 113-133.

Beek, D.A. and Rooda, J.E. 2000. Languages and application in hybrid modeling and simulation: Positioning of Chi. *Control Engineering Practice* 8(1): 81-91.

Benton, W.C. 1991. Safety stock and service levels in periodic review inventory systems. *Journal of the Operational Research Society* 42(12): 1087-1095.

Bernardini, O. and Galli, R. 1993. Dematerialization: Long-term trends in the intensity of use of materials and energy. *Futures* 9(1): 431-448.

Bhate, S. and Lawler, K. 1997. Environmentally friendly products: Factors that influence their adoption. *Technovation* 17(8): 457-465.

Billesbach, T.J. and Schniederjans, M.J. 1989. Applicability of just-in-time techniques in administration. *Production and Inventory Management Journal* 30(1): 40-45.

Billesbach, T.J. 1991. A study of the implementation of Just-in-Time in the United States. *Production and Inventory Management Journal* 32(1): 1-4.

Bishara, R.H. 2006. Cold chain management – an essential component of the global pharmaceutical supply chain. *American Pharmaceutical Review* 1(1): 1-4.

Bititci, U.S., Turner, T.J., and Ball, P.D. 1999. The viable business structure for managing agility. *International Journal of Agile Management Systems* 1(3): 190-199.

Bitran, G.R. and Chang, L. 1987. A mathematical programming approach to deterministic kanban system. *Management Science* 33(4): 427-441.

Blatherwick, A. 1998. Vendor-managed inventory: fashion fad or important supply chain strategy? *Supply Chain Management: An International Journal* 3(1): 10-11.

Bloom, P.N. and Perry, V.G. 2001. Retailer power and supplier welfare: the case of Wal-Mart. *Journal of Retailing* 77(1): 379-396.

Bookbinder, J.H. and Locke, T.D. 1986. Simulation analysis of just-in-time distribution. *International Journal of Physical Distribution and Materials Management* 32(1): 31-53.

Bowen, D.E. and Youngdahl, W.E. 1998. Lean service: in defense of a production-line approach. *International Journal of Service Industry Management* 9(3): 207-225.

Bowen, F.E., Cousins, P.D., Lamming, R.C., and Faruck A.C. 2001. The role of supply management capabilities in green supply. *Production and Operations Management* 10(2): 174-189.

Bowersox, D.J. and Closs, D.J. 1996. *Logistical Management: The Integrated Supply Chains Process.* New York: McGraw-Hill.

Bozer, Y.A., Quiroz, M.A., and Sharp, G.P. 1988. An evaluation of alternative control strategies and design issues for automated order accumulation and sortation systems. *Material Flow* 4(1): 265-282.

Braungart, M. and McDonough, W. 1998. The next industrial revolution. *The Atlantic Monthly* 282(4): 82-92.

Braver, E.R., P.L. Zador, D. Thum, E.L. Mitter, H.M. Baum, et al. 1997. Tractor-trailer crashes in Indiana: A case-control study of the role of truck configuration. *Accidents Analysis and Prevention*, 29(1): 79-96.

Brown, J.R., Dant, R.P., Ingene, C.A., and Kaufmann, P.J. 2005. Supply chain management and the evolution of the Big Middle. *Journal of Retailing* 81(2): 97-105.

Brown, L. 1980. Building a sustainable society. Norton: New York.

Brynzer, H. and Johansson, M.I. 1996. Storage location assignment: using the product structure to reduce order picking times. *International Journal of Production Economics* 46(1): 595-603.

Bucklin, L.P. 1965. Postponement, speculation and the structure of distribution channels. *Journal of Marketing Research* 2(1): 26-31.

Bureau of Transportation Statistics (BTS). 2011. *Air Cargo Summary Data*. Airborne Export Network Database. Accessed on November 16, 2011. http://www.transtats.bts.gov/freight.asp

Burnham, J.M. 1987. Some conclusions about JIT manufacturing. *Production and Inventory Management* 28(3): 7-11.

Burton, T.T. 1988. JIT/repetitive sourcing strategies: tying the knot with your suppliers. *Production and Inventory Management Journal* 29(4): 38-41.

Busch, T. 2010. Corporate carbon performance indicators revisited. *Journal of Industrial Ecology* 14(3): 374-377.

Buzzell, R.D. and Ortmeyer, G. 1995. Channel partnerships streamline distribution. *Sloan Management Review* 36(3): 85-96.

Cabeza, M. 1996. The concept of weak sustainability. *Ecological economics* 17(1): 147-156.

Cachon, G.P. and Fisher, M. 2000. Supply chain inventory management and the value of shared information. *Management Science* 46(8): 1032-1049.

Camuffo, A., Romano, P., and Vinelli, A. 2001. Back to the future: Benetton transforms its global network. *MIT Sloan Management Review* 9(1): 46-52.

Canel, C., Rosen, D., and Anderson, E.A. 2000. Just-in-time is not just for manufacturing: a service perspective. *Industrial Management and Data Systems*, 100(2), 51-60.

Carlson, J.G. 1989. JIT applications to warehousing operations. *Engineering Costs and Production Economics* 17(1): 315-322.

Caron, F., Marchet, G., Perego, A. 2000. Optimal layout in lower level picker-to-part systems. *International Journal of Production Research* 38(1): 101-117.

Carroll, A.B. 1999. *Corporate Social Responsibility: Evolution of a definitional construct. Business and Society* 38(3): 268-295.

Carson, R. 1962. Silent Spring. Buccaneer Books: New York.

Carter, J.R. and Fredenhall, L.D. 1990. The dollars and sense of electronic data interchange. *Production and Inventory Management Journal* 31(2): 22-25.

Casella, G. and Berger, R.L. 2002. *Statistical Inference.* Duxbury-Thomson Learning: Pacific Grove, CA.

Celley, A.F. and Clegg, W.H. 1986. Implementation of JIT in the United States. *Journal of Purchasing and Materials Management* 22(4): 9-15.

Cerin, P. and Dobers, P. 2001. What does the performance on the Dow Jones Sustainability Group Index tell us? *Eco-Management and Auditing* 8(3): 123-133.

Cernea, M.M. 1993. Culture and organization: The social sustainability of induced development. *Sustainable Development* 1(2): 18-29.

Cetinkaya, S. and Lee, C. 2000. Stock replenishment and shipment scheduling for vendor-managed inventory systems. *Management Science* 46(2): 217-232.

Chan, L.M., Muriel, A., Shen, Z.M., Simchi-Levi, d., and Teo, C. 2002. Zero-inventory-ordering policies for the single-warehouse multiretailer problem with piecewise linear cost structures. *Management Science* 48(11): 1446-1460.

Chapman, S. and Carter, P.L. 1990. Supplier/customer inventory relationships under just in time. *Decision Sciences* 21(1): 35-51.

Chase, R.B., Aquilano, N.J., and Jacobs, F.R. 1998. *Production and Operations Management.* New York: Irwin/McGraw Hill.

Chen, F. 1998. Echelon reorder points, installation reorder points, and the value of centralized demand information. *Management Science* 44(12): 221-234.

Chen. I.J. and Paulraj, A. 2004. Towards a theory of supply chain management: the constructs and measurements. *Journal of Operations Management* 22(2): 119-150.

Cheung, K.L. and Lee, H.L. 2002. The inventory benefit of shipment coordination and stock rebalancing in a supply chain. *Management Science* 48(2): 300-306.

Chew, E.P. and Tang L.C. 1999. Travel time analysis for general item location assignment in a rectangular warehouse. *European Journal of Operational Research* 112(1): 582-597.

Childerhouse, P., Aitken, J., and Towill, D.R. 2002. Analysis and design of focused demand chains. *Journal of Operations Management* 20(1): 675-689.

Choi, B., Shin, H., Lee, S., and Hur, T. 2006. Life Cycle Assessment of a Personal Computer and its effective recycling rate. *International Journal of Life Cycle Assessment* 11(2): 122-128.

Chong, H., White, R.E., and Prybutok, V. 2001. Relationship among organizational support, JIT implementation, and performance. *Industrial Management and Data Systems* 101(6): 273-280.

Christensen, L. 1996. JIT sensitive distribution – cutting waste and serving the customer. *Logistics Information Management* 9(2): 7-9.

Christopher, M. and Braithwaite, A. 1991. Managing the global pipeline. *The International Journal of Logistics Management* 2(2): 43-54.

Christopher, M. 1992. *Logistics and Supply Chain Management: Strategies for reducing costs and improving services.* London: Pitman Publishing.

Christopher, M. and Towill, D. 2001. An integrated model for the design of agile supply chains. *International Journal of Physical Distribution and Logistics Management* 31(1): 235-246.

Christopherson, S. 2007. Barriers to US style lean retailing: the case of Wal-Mart's failure in Germany. *Journal of Economic Geography* 7(1): 451-469.

Chu, P., Chung, K-J., and Lan, S-P. 1998. Economic order quantity of deteriorating items under permissible delay in payments. *Computers and Operations Research* 25(10): 817-824.

Cimino, A., Longo, F., and Mirabelli, G. 2010. A general simulation framework for supply chain modeling: State of the art and case study. *International Journal of Computer Sciences* 7(2): 1-9.

Clark, A.J. and Scarf, H. 1960. Optimal policies for a multi-echelon inventory problem. *Management Science* 6(4): 475-490.

Clarke, C.J. & Varma, S. 1999. Strategic risk management: the new edge. *Long Range Planning* 32(4): 414-424.

Claycomb, C., Germain, R., and Droge, C. 1999. Total system JIT outcomes: inventory, organization and financial effects. *International Journal of Physical Distribution and Logistics* 29(10): 612-630.

Colby, B.G. 2000. Cap-and-trade policy challenges: A tale of three markets. *Land Economics* 76(4): 638-658.

Collis, C., Berkeley, N., and Fletcher, D.R. 2000. Decline and policy responses in district shopping centers. *The Town Planning Review* 71(2): 149-168.

Coleman, D.E. and Montgomery, D.C. 1993. A systematic approach to planning for a designed industrial experiment. *Technometrics* 35(1): 1-12.

Comm, C.L., and Mathaisel, F. 2003. Less is more: a framework for a sustainable university. *International Journal of Sustainability in Higher Education* 4(4): 314-323.

Conroy, M. and Berke, P.R. 2004. What makes a good sustainable development plan? An analysis of factors that influence principles of sustainable development. *Environment and Planning* 36(1): 1381-1396.

Coombs, R. 1996. Core competencies and the strategic management of R&D. *R&D Management* 26(4): 345-355.

Cooper, J.C. 1993. Logistics strategy for global business. *International Journal of Physical Distribution and Logistics Management* 24(1): 12-23.

Cooper, J. 1994. *Logistics distribution planning*. London: Kogan Page.

Corbett, C.J. and Kirsch, D.A. 2001. International difussion of ISO 14000 certification. *Production and Operations Management* 10(3): 327-342.

Corbett, C.J. and Klassen, R.D. 2006. Extending the horizons: Environmental excellence as key to improving operations. *Manufacturing and Service Operations Management* 8(1): 5-22.

Costanza, R., L. Graumlich, W. Steffan, C. Crumley, J. Dearing, et al. 2007. Sustainability or collapse: What can we learn from integrating the history of humans and the rest of nature? Royal Swedish Academy of Science 36(7): 522-527.

Cox, A. 2001. Understanding buyer and supplier power: a framework for procurement and supply competence. *Journal of Supply Chain Management* 37(1): 8-15.

Crawford, K.M., Blackstone, J.H., and Cox, J.F. 1988. A study of JIT implementation and operating problems. *International Journal of Production Research* 26(9): 1561-1568.

Crawford, K.M. and Cox, J.F. 1990. Designing performance measurement system for Just-in-Time operations. *International Journal of Production Research* 28(11): 2025-2036.

Croom, S., Romano, P., and Giannakis, M. 2000. Supply chain management: an analytical framework for critical literature review. *European Journal of Purchasing and Supply Management* 6(1): 67-83.

Cullen, J.M. and Allwood, J.M. 2009. The role of washing machines in life cycle assessment studies. *Journal of Industrial Ecology* 13(1): 27-37.

Cusumano, M.A. 1994. The limits of Lean. *Sloan Management Review* 9(1): 27-32.

Dahlstrom, K. and Ekins, P. 2005. Eco-efficiency trends in the UK steel and aluminum industries. *Journal of Industrial Ecology* 9(4): 171-188.

Daly, H. and Cobb, J. 1989. *For the common good: Redirecting the economy towards community, the environment and a sustainable future.* Green Print: London.

Danese, P. 2006. The extended VMI for coordinating the whole supply network. *Journal of Manufacturing Technology Management* 17(7): 888-907.

Daniels, R.L., Rummel, J.L., and Schantz, R. 1998. A model for warehouse order picking. *European Journal of Operational Research* 105(1): 1-17.

Daniel, S.J. and Reitsperger, W.D. 1996. Linking JIT strategies and control systems: a comparison of the United States and Japan. *The International Executive* 38(1): 95-121.

Das, C. and Goyal, S.K. 1989. A vendors view of the JIT manufacturing system. *International Journal of Operations and Production Management* 9(8): 106-111.

Dasgupta, P., S. Levin, and J. Lubchenco. 2000. Economic pathways to ecological sustainability. *BioScience* 50(4): 339-345.

Davis, T. 1993. Effective supply chain management. *Sloan Management Review* 9(1): 35-46.

Davy, J.A., White, R.E., Merrit, N.J., and Gritzmacher, K. 1992. A derivation of the underlying constructs of Just-in-Time management systems. *Academy of Management Journal* 35(3): 653-670.

De Koning, H., Verver, J., Van del Heuvel, J., Bisgard, S., and Does, R. 2006. Lean six sigma in healthcare. *Journal for Healthcare Quality* 28(2): 4-11.

De Koster, R. 1994. Performance approximation of pick-to-belt order picking systems. *European Journal of Operational Research* 72(1): 558-573.

De Koster, R., De Brito, M.P., Van de Vendel. 2002. Return handling: An exploratory study with nine retailer warehouses. *International Journal of Retail and Distribution Management* 30(9): 407-421.

De Koster, R., Le-Duc, T., Roodbergen, K.J. 2007. Design and control of warehouse order picking: A literature review. *European Journal of Operational Research* 182(1): 481-501.

Dematic. 2008. *American Eagle Outfitters System*. System Overview Series: Grand Rapids, Michigan.

Desrochers, P. and Lam, K. 2007. Business as usual in the industrial age: relatively lean, green, and eco-efficient? *The Electronic Journal of Sustainable Development* 1(1): 35-46.

Disney, S.M. and Towill, D.R. 2002. A discrete transfer function model to determine the dynamic stability of a vendor managed inventory supply chain. *International Journal of Production Research* 40(1): 179-204.

Disney, S.M., Potter, A.T., and Gardner, B.M. 2003. The impact of vendor managed inventory on transport operations. *Transportation Research* 39(1): 363-380.

Disney, S.M. and Towill, D.R. 2003. Vendor-managed inventory and bullwhip reduction in a two-level supply chain. *International Journal of Operations and Production Management* 23(6): 625-651.

Donaldson, L. 2001. *The Contingency Theory of Organizations*. Thousand Oaks, CA: Sage.

Dong, Y., Carter, C.R., and Dresner, M.E. 2001. JIT purchasing and performance: an exploratory analysis of buyer and supplier perspectives. *Journal of Operations Management* 19(1): 471-483.

Dong, Y. and Xu, K. 2002. A supply chain model of vendor managed inventory. *Logistics and Transportation Review* 38(2): 75-95.

Dong, Y., Xu, K., and Dresner,M. 2007. Environmental determinants of VMI adoption: An exploratory analysis. *Transportation Research* 43(1): 355-369.

Dow, D., Samson, D., and Ford, S. 1999. Exploding the myth: do all quality management practices contribute to superior quality performance? *Production and Operations Management* 8(1): 1-27.

Drew, S.A., Kelley, P.C., & Kendrick, T. 2006. CLASS: Five elements of corporate governance to manage strategic risk. *Business Horizons* 49(1): 127-138.

Dreyer, L.C., A.L. Niemann, and M.Z. Hauschild. 2003. Comparison of three different LCIA methods: EDIP97, CML2001 and Eco-indicator 99- does it matter which one you choose? *International Journal of Life Cycle Analysis* 8(4): 191-200.

Du Pisani, J.A. 2006. Sustainable development – historical roots of the concept. *Environmental Sciences* 3(2): 83-96.

Dubelaar, C., Chow, G., and Larson, P.D. 2001. Relationships between inventory, sales and service in a retail chain store operation. *International Journal of Physical Distribution and Logistics* 31(2): 96-108.

Duclos, L.K., Siha, S.M., and Lummus, R.R. 1995. JIT in services: a review of current practices and future directions for research. *International Journal of Service Industry Managemen*t 6(5): 36-52.

Duke, R. 1998. A model of buyer-supplier interaction in the UK grocery retailing. *Journal of Retailing and Consumer Services* 5(2): 93-103.

Dunphy, D., Griffiths, A., and Benn, S. 2003. *Organizational change for corporate sustainability*. New York: Routledge.

Dyllick, T. and Hockerts, K. 2002. Beyond the business case for corporate sustainability. *Business Strategy and the Environment* 11(1): 130-141.

Eberle, U., Lange, A., Dewaele, J., and Schowanek, D. 2007. LCA study and environmental benefits for low temperature disinfection process in commercial laundry. *International Journal of Life-Cycle Assessment* 12(2): 127-138.

Ebrahimpour, M. and Fathi, B.M. 1985. Dynamic simulation of a kanban production inventory system. *International Journal of Operations and Production Management* 5(1): 5-14.

Ekins, P. 1996. How large a carbon tax is justified by the secondary benefits of CO2 abatement? *Resource and Energy Economics* 18(2): 161-187.

Ekins, P., Sandrine, S., Deutsch, L., Folke, C., and De Groot, R. 2003. A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological economics* 44(3): 165-185.

Ekins, P. 2005. Eco-Efficiency: Motives, drivers, and economic implications. *Journal of Industrial Ecology* 9(4): 12-14.

Elkington, J. 1997. *Cannibals With Forks: The Triple Bottom Line of 21st Century Business.* New Society Publishers: Stony Cree, Connecticut.

Ellram, L.M. 1991. Supply chain management: the industrial organization perspective. *International Journal of Physical Distribution and Logistics* 21(1): 13-22.

Environmental Protection Agency (EPA). 2011. U.S. Greenhouse Gas Inventory Report. Accessed on April 1, 2011. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Eppen, G.D. and Martin, R. K. 1988. Determining safety stock in the presence of stochastic lead time and demand. *Management Science* 34(11): 1380-1390.

Ernst, R. and Kamrad, B. 2000. Evaluation of supply chain structures through modularization and postponement. *European Journal of Operational Research* 124(1): 495-510.

Estrada-Flores, S. and Eddy, A. 2006. Thermal performance indicators for refrigerated road vehicles. *International Journal of Refrigeration* 29(1): 889-898.

Evans, B. and K. Theobald. 2003. LASALA: Evaluating Local Agenda 21 in Europe. *Journal of Environmental Planning and Management* 46(5): 781-794.

Evans, C.L. and Harrigan, J. 2005. Time and specialization: Lean retailing in general equilibrium. *The American Economic Review* 95(1): 291-313.

Fandel, G. and Reese, J. 1991. Just-in-time logistics of a supplier in the car manufacturing industry. *International Journal of Production Economics* 24(1): 55-64.

Faruk, A.C., Lamming, R.C., Cousins, P.D., and Bowen, F.E. 2002. Analyzing, mapping, and managing environmental impacts along supply chains. *Journal of Industrial Ecology* 5(2): 13-32.

Federgruen, A. and Zipkin, P. 1984. Computational issues in an infinite horizon multi-echelon inventory model. *Operations Research* 32(4): 818-836.

Fedrows, K. 1989. Mapping international factory networks. In Mapping International Manufacturing. Elsevier Science: Amsterdam.

Feitzinger, E. and Lee, H.L. 1997. Mass customization at Hewlett-Packard: the power of postponement. *Harvard Business Review* 75(1): 116-121.

Fellers, G. 1984. Use of GPSS/PC to establish manning level of proposed Just-in-time production facility. *Computers and Industrial Engineering* 11(1): 382-384.

Fernie, J., Pfab, F., and Marchant, C. 2000. Retail grocery logistics in the UK. *The International Journal of Logistics Management* 11(2): 83-90.

Fet, A.M. 2003. Eco-efficiency reporting exemplified by case studies. *Clean Technologies and Environmental Policy* 5(3): 232-239.

Fieten, R. 1989. Integrating key suppliers-essential part of JIT concept. *Engineering Costs and Production Economics* 15(1): 185-189.

Fiksel, J. 2003. Designing resilient, sustainable systems. *Environmental Science and Technology* 37(23): 5330-5339.

Fiksel, J. 2006. Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice and Policy* 2(2): 1-8.

Finkbeiner, M. 2011. *Towards life cycle sustainability management.* Springer: New York.

Finnveden, G., Nilsson, M., Johansson, J., Persson, A., Morberg, A., and Carlsson, T. 2003. Strategic environmental assessment methodologies – applications within the energy sector. *Environmental Impact Assessment Review* 23(1): 91-123.

Finnveden, G. and Moberg, A. 2005. Environmental systems analysis – an overview. *Journal of Cleaner Production* 13(12): 1165-1173.

Fisher, M.L. 1997. What is the right supply chain for your product? *Harvard Business Review* 75(1): 105-116.

Fliedner, G., and Majeske, K. 2010. Sustainability: The new lean frontier. *Production and Inventory Management Journal* 46(1): 6-13.

Flynn, B.B., Schroeder, R.G., and Sakakibara, S. 1995. The impact of quality management practices on performance and competitive advantage. *Decision Science* 26(5): 659-691.

Foran, B., Lenzen, M., Dey, C., and Bilek, M. 2005. Integrating sustainable chain management with triple bottom line accounting. *Ecological Economics* 52(2): 143-157.

Fox, E.J., A.L. Montgomery, and L.M. Lodish. 2004. Consumer shopping and spending across retail formats. *Journal of Business* 77(2): 25-60.

Frazier, G.L., Spekman, R.E., and O'Neal, C. 1988. Just-in-time exchange relationships in industrial markets. *Journal of Marketing* 52(1): 52-67.

Freeland, J.R. 1991. A survey of just in time purchasing practices in the United States. *Production and Inventory Management Journal* 32(2): 43-49.

Fulconis, F., Saglietto, L., and Pache, G. 2007. Strategy dynamics in the logistics industry: a transactional center perspective. *Management Decision* 45(1): 104-117.

Gates, J.B. 2004. The ethics commitment process: Sustainability through value based-ethics. *Business and Society Review* 109(4): 493-505.

Germain, R., Droge, C., and Daugherty, P.J. 1994. The effect of just-in-time selling on organizational structure: an empirical investigation. *Journal of Marketing Research* 31(4): 471-483.

Germain, R. and Droge, C. 1995. Just-in-time and context: predictors of electronic data interchange technology adoption. *International Journal of Physical Distribution and Logistics Management* 25(1): 18-33.

Getzner, M. (1999) Weak and strong sustainability indicators and regional environmental resources. *Environmental Management and Health* 10(3): 170-176.

Geyer-Allely, E. and Zacarias-Farah, A. 2003. Policies and instruments for promoting sustainable household consumption. *Journal of Cleaner Production* 11(1): 923-926.

Giannanasi, F., Lovett, P., and Godwin, A.N. 2001. Enhancing confidence in discrete event simulations. *Computers in Industry* 44(1): 141-157.

Giunipero, L.C. 1990. Organizational support for just-in-time implementation. *International Journal of Logistics Management* 1(2): 35-40.

Giunipero, L.C. 1990b. Motivating and monitoring supplier performance. *Purchasing and Materials Management* 26(3): 19-24.

Goetschalckx, M. and Jacobs-Blecha, C. 1989. The vehicle routing problem with backhauls. *European Journal of Operations Research* 42(1): 39-51.

Goetschalckx, M., Gu, J., and McGinnis, L. 2007. Research on warehouse operation: A comprehensive review. *European Journal of Operational Research* 177(1): 1-21.

Golden, J.S., ed 2010. An overview of ecolables and sustainability certifications in the global marketplace. Duke University Center for Sustainability and Commerce. Accessed on November 9, 2010. http://center.sustainability.duke.edu/sites/default/files/documents/ecolabelsreport.pdf

Golden, J.S., J. Carlson, K.E. Kaloush, and P. Phelan. 2007. A comparative study of the thermal and radiative impacts of photovoltaic canopies on pavement surface temperatures. *Solar Energy* 81: 872-883.

Gomes, R. and Mentzer, J.T. 1988. A systems approach to the investigation of just-in-time. *Journal of Business Logistics* 9(2): 71-88.

Good, W.S. 1984. Productivity in the retail grocery trade. *Journal of Retailing,* 60(3): 81-106.

Goodwin, B.K., Grennes, T.J., and Craig, L.A. 2002. Mechanical refrigeration and the integration of perishable commodity markets. *Explorations in Economic History* 39(1): 154-182.

Goodyear. 2008. *Factors affecting truck fuel economy.* Goodyear commercial tire systems from The Goodyear Tire & Rubber Company.

Gorman, M.F. 2008. Evaluating the public investment mix in US freight transportation infrastructure. *Transportation Research Part A*, 42(1): 1-14.

Goss, J. 1993. The magic of the mall: An analysis of form, function, and meaning in the contemporary retail built environment. *Annals of the Association of American Geographers* 83(1): 18-47.

Goswami, A., and Chaudhuri, K.S. 1992. An Economic Order Quantity model for items with two levels of storage for a linear trend in demand. *The Journal of the Operational Research Society* 43(2): 157-167.

Gowdy, J. and O'Hara, S. 1997. Weak sustainability and viable technologies. *Ecological Economics* 22(3): 239-247.

Goyal, S.K. 1985. Economic Order Quantity under conditions of permissible delay in payments. *Journal of the Operational Research Society* 36(4): 335-338.

Goyal, S.K. and Gupta, Y.P. 1989. Integrated inventory models: The buyer vendor coordination. *European Journal of Operations Research* 41(1): 261-269.

Goyal, S.K. and Deshmukh, S.G. 1992. A critique of the literature on Just-in-Time manufacturing. *International Journal of Operations and Production Management* 12(1): 18-29.

Graedel, T.E. and Allenby, B.R. 2003. *Industrial Ecology*. Upper Saddle River, New Jersey: Prentice Hall.

Granda, C.B., L. Zhu, and M.T. Holtzapple. 2007. Sustainable liquid biofuels and their environmental impacts. *Environmental Progress* 26(3): 233-250.

Grean , M. and Shaw, M.J. 2002. Chapter 8. Supply-chain partnership between P&G and Wal-Mart. In M.J. Shaw (ed.), *E-Business Management: Integration of Web Technologies with Business Models*. Norwell, MA: Kluwer Academic Publishers, 155-171.

Green, K., Morton, B., and New, S. 1996. Purchasing and environmental management: Interactions, policies and opportunities. *Business Strategy and the Environment* 5(1): 188-197.

Green, R.E., A. Balmford, P.R. Crane. G.M. Mace, et al. 2005. A Framework for improved monitoring of biodiversity: Responses to the World summit on sustainable development. *Conservation Biology* 19(1): 56-65.

Grewal, D., Gopalkrishnan, R.I., and Levy. M. 2002. Internet retailing: enablers, limiters and market consequences. *Journal of Business Research* 57(1): 703-713.

Grieco, P.L. 1989. Why supplier certification? And will it work? *Production and Inventory Management Review* 9(5): 38-42.

Gue, K.R. 1999. The effects of trailer scheduling on the layout of freight terminals. *Transportation Science* 33(4): 419-428.

Gunderson, L.H., Holling, C.S., and Light S.S. 1995. *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press: New York.

Gunningham, N. and J. Rees. 1997. *Industry self-regulation: An institutional perspective.* Law & Policy 19(4): 363-414.

Gupta, A.K. and Govindarajan, V. 2000. Knowledge flows within multinational corporations. *Strategic Management Journal* 21(4): 473-496.

Gupta, S., Verma, R., and Victorino, L. 2006. Empirical research published in Production and Operations Management (1992-2005): Trends and future research directions. *Production and Operations Management* 15(3): 432-448.

Gupta, Y.P. 1990. A feasibility study of JIT purchasing implementation in a manufacturing facility. *International Journal of Operations and Production Management* 10(1): 31-41.

Gupta, Y.P. and Heragu, S. 1991. Implications of implementing just in time Systems. *Technovation* 11(3): 143-162.

Hacking, T. and Guthrie, P. 2008. A framework for clarifying the meaning of triple bottom-line, integrated, and sustainability assessment. *Environmental Impact Assessment Review* 28(3): 73-89.

Hall, J. 2000. Environmental supply chain dynamics. *Journal of Cleaner Production* 8(1): 455-471.

Hall, R.W. 1983. *Zero inventories*, Homewood, IL: Dow-Jones-Irwin.

Hallowell, R. (1996). Southwest Airlines: a case study linking employee needs, satisfaction, and organizational capabilities to competitive advantage. *Human Resource Management,* 35(4), 513-525.

Handfield, R.B. 1993. A resource dependence perspective of Just-in-Time purchasing. *Journal of Operations Management* 11(1): 289-311.

Handfield, R.B. 1994. US global sourcing: patterns of development. *International Journal of Operations and Production Management* 14(6): 40-51.

Harber, D., Samson, D.A., Sohal, A.S., and Wirth, A. 1990. Just in time: the issue of implementation. *International Journal of Operations and Production Management* 10(1): 21-30.

Harrison, A. and Voss, C. 1990. Issues in setting up JIT supply. *International Journal of Operations and Production Management* 10(2): 84-93.

Hart, C.W.L. 1995. Mass customization: conceptual underpinnings, opportunities, nd limits. *International Journal of Service Industries Management* 6(2): 36-45.

Hart, S. 1995. A natural-resource view of the firm. *Academy of Management Review* 20(4): 986-1000.

Hart, S. and Ahuha, G. 1996. Does it pay to be green? An empirical examination of the relationship between emissions reduction and firm performance. *Business Strategy and the Environment* 5(1): 30-37.

Hart, S.L. 1997. Beyond greening: Strategies for a sustainable world. *Harvard Business Review* 75(1): 66-76.

Harvey, J. 1989. Just-in-time health and human services: a client approach. *Public Productivity and Management Review* 13(1): 77-88.

Haughton G. 1999. Environmental justice and the sustainable city. *Journal of Planning Education and Research* 18: 233-243.

Haughton, G. and C. Hunter. 1994. *Sustainable cities.* Kingsley: London.

Hausman, A. and Stock, J.R. 2003. Adoption and implementation of technological innovations within long-term relationships. *Journal of Business Research* 56(8): 681-687.

Hausman, W.H., Schwarz, L.B., and Graves, S.C. 1976. Optimal storage assignment in automatic warehousing systems. *Management Science* 22(6): 629-638.

Hawken, P., Lovins, A., and Lovins, L.H. 1999. *Natural Capitalism*. New York: Back Bay Books.

Hay, E.J. 1990. Implementing JIT purchasing. *Production and Inventory Management Review* 10(4): 38-40.

Hedberg, C. and Malmborg, F. 2003. The global reporting initiative and corporate sustainability reporting in Swedish companies. *Corporate Social Responsibility and Environmental Management* 10(3): 153-164.

Hediger, W. 1999. Reconciling weak and strong sustainability. *International Journal of Social Economics* 26(7): 1120-1144.

Heizer, J., and Render, B. 2004. *Operations Management.* Upper Saddle River: Prentice Hall.

Hellweg, S., Doka, G., Goran, and Hungerbuhler, F. 2005. Assessing the eco-efficiency of end-of-pipe technologies with the environmental cost efficiency indicator: A case study of solid waste management. *Journal of Industrial Ecology* 9(4): 189-203.

Hendricks, K.B. and Singhal, V.R. 1997. Does implementing an effective TQM program actually improve operating performance? Empirical evidence from firms that have won quality awards. *Management Science* 43(9): 1258-1274.

Hendrickson, C. and Horvath, A. 1998. Economic input-output models for environmental life-cycle assessment. *Policy Analysis* 32(7): 184-191.

Hedberg, C. & Malmborg, F. 2003. The global reporting initiative and corporate sustainability reporting in Swedish companies. *Corporate Social Responsibility and Environmental Management* 10(3): 153-164.

Heritier, A. & Eckert, S. 2008. New modes of governance in the shadow of hierarchy: Self-regulation by industry in Europe. *Journal of Public Policy* 28(1): 113-138.

Hernandez, A. 1989. *Just in Time Manufacturing.* Englewood Cliffs, NJ: Prentice-Hall.

Hertwich, E.G. 2005. Consumption and the rebound effect. *Journal of Industrial Ecology* 9(1): 85-98.

Heskett, J.L. 1964. Putting the cube-per-order index to work in warehouse layout. *Transport and Distribution Management* 4(1): 23-30.

Heskett, J.L. 1977. Logistics-essential to strategy. *Harvard Business Review* 55(1): 85-96.

Hesse, M. 2002. Shipping news: the implications of electronic commerce for logistics and freight transport. *Resources, Conservation and Recycling* 36(3): 211-240.

Hesse, M. and Rodrigue, J. 2004. The transport geography of logistics and freight distribution. *Journal of Transport Geography* 12(1): 171-184.

Higginson, J.K. and Bookbinder, J. 1990. Implications of just in time production on rail freight. *Transportation Journal* 29(3): 29-35.

Hill, T. 2000. *Manufacturing strategy, text and cases*. Boston: McGraw-Hill.

Hirschl, B., Konrad, W., and Scholl, G. 2003. New concepts in product use for sustainable consumption. *Journal of Cleaner Production* 11(1): 873-881.

Hise, R.T., Kelly, J.P., Gable, M., and McDonald, J.B. 1983. Factors affecting the performance of individual chain store units: an empirical analysis. *Journal of Retailing* 59(2): 22-39.

Hoekstra, S. and Romme, J. 1992. *Integrated Logistics Structures: Developing Customer Oriented Goods Flow*. London: McGraw-Hill.

Hoel, M. 1996. Should a carbon tax be differentiated across sectors? *Journal of Public Economics* 59(1): 17-32.

Holmberg, J. and Robert, K. 2000. Backcasting from non-overlapping sustainability principles – a framework for strategic planning. *International Journal of Sustainable Development and World Ecology* 7(1): 291-308.

Holmstrom, J. 1997. Product range management: a case study of supply chain operations in the European grocery industry. *Supply Chain Management* 2(3): 107-115.

Holmstrom, J. 1998. Business process innovation in the supply-chain a case study of implementing vendor managed inventory. *European Journal of Purchasing and Supply Management* 4(1): 127-131.

Hopwood, B., Mellor, M., and O'Brien, G. 2005. Sustainable development: Mapping different approaches. *Sustainable Development* 13(1): 38-52.

Hovi, J. and Holtsmark, B. 2006 Cap-and-trade or carbon taxes? The feasibility of enforcement and the effects of non-compliance. I*nternational Environmental Agreements: Politics, Law and Economics* 6(2): 137-155.

Howard, P.H. and Allen, P. 2006. Beyond organic: consumer interest in new labeling schemes in the Central Coast of California. *International Journal of Consumer Studies* 30(5): 439-451.

Huppes, G. and Ishikawa, M. 2005. A framework for quantified eco-efficiency analysis. *Journal of Industrial Ecology* 9(4): 25-41.

Hur, T., I. Kim, and R. Yamamoto. 2004. Measurement of green productivity and its improvements. *Journal of Cleaner Production* 21(7): 673-683.

Hussey, D.M., Kirsop, P.L., and Meissen, R.E. 2001. Global Reporting Initiative guidelines: An evaluation of sustainable development metrics for industry. *Environmental Quality Management* 11(1): 1-20.

Hustvedt, G. and J.C. Berbard. 2008. Consumer willingness to pay for sustainable apparel: The influence of labeling for fiber origin and production methods. *International Journal of Consumer Studies* 32(5): 491-498.

Hyland, P.W., Soosay, C., and Sloan, T.R. 2003. Continuous improvement and earning in the supply chain. *International Journal of Physical Distribution and Logistics Management* 33(4): 316-335.

Ilic, A., Staake, T., and Fleisch, E. 2009. Using sensor information to reduce the carbon footprint of perishable goods. *IEEE CS Pervasive Computing* 1(9): 1536-1268.

Ilinitch, A. and S. Schaltegger. 1995. Developing a green business portfolio. *Long Range Planning* 28(2): 29-37.

Im, J.H. and Lee, S.M. 1989. Implementation of Just-in-Time systems in US manufacturing firms. *International Journal of Operations and Production Management* 9(1): 5-14.

Ingene, C.A. and Lusch, R.F. 1999. Estimation of a department store production function. *International Journal of Physical Distribution and Logistics Management* 29(7): 453-463.

Inman, R.A. 1990. Quality certification of suppliers by JIT manufacturers. *Production and Inventory Management Journal* 31(2): 58-61.

Inman, R.A. and Mehra, S. 1991. JIT applications for service environment. *Production and Inventory Management Journal* 32(3): 16-21.

Inman, R.A. and Mehra, S. 1993. Financial justification of JIT implementation. *International Journal of Operations and Production Management* 13(4): 29-32.

Inman, P.R. (1999). Are you implementing a pull system by putting the cart before the horse? *Production and Inventory Management Journal* 40(2): 67-71.

International Business Machines Corporation. 2008. *Mastering Carbon Management*. Somers, NY.

International Organization for Standardization (ISO). 2006. *ISO 14040: Environmental management – Life cycle assessment – Principles and framework*. ISO: Switzerland.

Jacobs, F.R. and Weston, F.C, 2007. Enterprise resource planning (ERP) – A brief history. *Journal of Operations Management* 25(1): 357-363.

Jackson, M.C. 2000. *Systems Approaches to Management*. New York: Kluwer Academic Publishers.

Jackson, T. 2005. Live better by consuming less? *Journal of Industrial Ecology* 9(1): 19-36.

Jacques, P, Thomas R., Foster, D., McCann, J., and Tunno, M. 2003. Wal-Mart or World-Mart? A teaching case study. *Review of Radical Political Economics* 35(4): 513-533.

Jensen, R. 1982. Adoption and diffusion of an innovation of uncertain profitability. *Journal of Economic Theory* 27(2): 182-193.

Jonsson, H. and Silver, E.A. 1987. Stock allocation among central warehouse and identical regional warehouses in a particular push inventory control system. *International Journal of Production Research* 25(2): 191-205.

Joshi, S. 1999. Product environmental life-cycle assessment using input-output techniques. *Journal of Industrial Ecology* 2(3): 95-120.

Kainuma, Y., and Tawara, N. 2006. A multiple attribute utility theory approach to lean and green supply chain management. *International Journal of Production Economics* 101(1): 99-108.

Kaipia, R., Holmstrom, J., and Tanskanen, K. 2002. VMI: what are you losing if you let your customer place orders? *Production Planning and Control* 13(1): 17-25.

Kallio, J., Saarinen, T., Tinnila, M., and Vepsalainen. 2000. Measuring Delivery Process Performance. *International Journal of Logistics Management* 11(1): 75-87.

Kannan, V.R., and Tan, K.C. 2004. Just in time, total quality management, and supply chain management: understanding their linkages and impact on business performance. *The International Journal of Management Science* 33(1): 153-162.

Kant, R. and Grenoble, W.L. 1991. Modelling the effects of traffic congestion on JIT. *International Journal of Physical Distribution and Logistics Management* 21(2): 3-9.

Karagozoglu, N. and Lindell, M. 2000. Environmental management: Testing the win-win model. *Journal of Environmental Planning and Management* 43(6): 817-829.

Karlsson, C. and Norr, C. 1994. Total effectiveness in a just-in-time system. *International Journal of Operations and Production Management* 14(3): 46-65.

Karlsson, C. and Ahlstrom, P. 1996. Assessing changes towards lean production. *International Journal of Operations and Production Management* 16(2): 24-41.

Kates, R.W. and T.M. Parris. 2003. *Long-term trends and a sustainability transition.* PNAS 100(14): 8062-8067.

Kelton, W.D., Padowski, R.P., and Swets, N.B. 2010. *Simulation with Arena*. Boston: McGraw Hill.

King, A. and Lenox, M. 2000. Industry self-regulation without sanctions: The chemical industries Responsible Care Program. *Academy of Management Journal*, 43(4): 698-716.

King, A. and Lenox, M. 2001. Lean and green? An empirical examination of the relationship between lean production and environmental performance. *Production and Operations Management* 10(3): 244-256.

Kinnear, E. 1997. Is there any magic in cross-docking? *Supply Chain Management* 2(2): 49-52.

Kitazawa, S. and Sarkis, J. 2000. The relationship between ISO 14001 and continuous source reduction programs. *International Journal of Operations and Production Management* 20(2): 225-248.

Klassen, R.D. and Whybark, D.C. 1999. The impact of environmental technologies on manufacturing performance. *Academy of Management Journal* 42(6): 599-615.

Klassen, R.D. 2001. Plant-level environmental management orientation: The influence of management views and plant characteristics. Production and Operations Management 10(3): 257-275.

Klastorin, T.D., Moinzadeh, K., and Son, J. 2002. Coordinating orders in supply chains through price discounts. *IIE Transactions* 34(1): 679-689.

Kleijnen, J.P. 1995. Verification and validation of simulation models. *European Journal of Operational Research* 82(1): 145-162.

Kleijnen, J.P. 2005. An overview of the design and analysis of simulation experiments for sensitivity analysis. *European Journal of Operational Research* 164(2): 287-300.

Kleindorfer, P.R., Singhal, K., and Van Wassenhove, L.N. 2005. Sustainable Operations Management. *Production and Operations Management* 14(4): 482-492.

Knoepfel, I. 2001. Dow Jones Sustainability Group Index: A global benchmark for corporate sustainability. *Corporate Environmental Strategy* 8(1): 6-15.

Kobayashi, Y., Kbayashi, H., Hongu, A., and Sanehira, K. 2005. A practical method for quantifying eco-efficiency using eco-design support tools. *Journal of Industrial Ecology* 9(4): 131-144.

Kocabasoglu, C., Prahinski, C., and Klassen, R.D. 2007. Linking forward and reverse supply chain investments: The role of business uncertainty. *Journal of Operations Management* 25(1): 1141-1160.

Kochan, A. 1997. Ford –Valencia: just in time and just on site. *Assembly Automation* 17(1): 38-41.

Kogut, B. and Zander U. 2003. Knowledge of the firm and the evolutionary theory of the multinational corporation. *Journal of International Business Studies* 34(6): 516-529.

Kolk, A., D. Levy, and J. Pinske. 2008. Corporate responses in an emerging climate regime: The institutionalization and commensuration of carbon disclosure. *European Accounting Review* 17(4): 719-745.

Korhonen, J. and Seager, T.P. 2008. Beyond Eco-Efficiency: a resilience perspective. *Business Strategy and the Environment* 17(1): 411-419.

Kraemer, K.L., Dedrick, J., and Yasmashiro, S. 2000. Refining and extending the business model with information technology: Dell Computer Corporation. *The Information Society* 16(1): 5-21.

Krafcik, J.F. 1988. Triumph of the lean production system. *Sloan Management Review* 30(1): 41-52.

Krikke, H., Bloemhof-Ruwaard, J.M., and van Wassenhove, L.N. 2003. Current product and closed-loop supply chain design with an application to refrigerators. *International Journal of Production Research* 41(16): 3689-3719.

Kuby, M.J. and Gray, R.G. 1993. The hub network design problem with stopovers and feeders: The case of Federal Express. *Transportation Research* 27(1): 1-12.

Kulwiec, R.A. 1994. Retail distribution: Custom handling that goes with the flow. Modern Materials Handling 49(6): 30-33.

Kuosmanen, T. and Kortelainen, M. 2005. Measuring eco-efficiency of production with data envelopment analysis. *Journal of Industrial Ecology* 9(4): 59-72.

Lado, A.A., Boyd, N.G., Wright, P. 1992. A competency-based model of sustainable competitive advantage: Toward a conceptual integration. *Journal of Management* 18(1): 77-91.

Lamming, R. and Hampson, J. 1996. The environment as a supply chain management issue. *British Journal of Management* 7(1): 45-72.

Lamming, R.C., Caldwell, N.D., Harrison, D.A., and Phillips, W. 2001. Transparency in supply relationships: concept and practice. *Journal of Supply Chain Management* 37(4): 4-10.

Lampel, J. and Mintzberg, H. 1996. Customizing customization. *Sloan Management Review* 37(1): 21-30.

Lancioni, R.A., Smith M.F., and Oliva, T.A. 2000. The role of the internet in supply chain management. *Industrial Marketing Management* 29(1): 45-56.

Lang. J.C. 2005. Zero landfill, zero waste: The greening of industry in Singapore. I*nternational Journal of Environment and Sustainable Development* 4(3): 331-351.

Laroche, M., Bergeron, J., and Barbaro-Forleo, G. 2001. Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing* 18(6): 503-520.

Larson, P.D. and Lusch, R.F. 1990. Quick response retail technology: integration and performance measurement. *The International Review of Retail, Distribution and Consumer Research* 1(1): 17-35.

Laufer, W.S. 2003. Social accountability and corporate greenwashing. *Journal of Business Ethics* 43(3): 253-261.

Laws, D.R., Scholz, H., H. Shiroyama, L. Susskind, T., Suzuki, and O. Weber. 2004. Expert views on sustainability and technology implementation. *International Journal of Sustainable Development and World Ecology* 11(3): 247-261.

Lawson, A.M., Bersani, K.S., Fahim-Nader, M., and Guo, J. 2002. *Benchmark Input-Output Accounts of the United States, 1997.* U.S. Census Bureau: Washington: DC.

Leavy, B. 1994. Two strategic perspectives on the buyer-supplier relationships. *Production and Inventory Management Journal* 35(2): 47-51.

Lee, H.L. and Billington C. 1992. Managing supply chain inventory: Pitfalls and opportunities. *Sloan Management Review* 33(3): 65-73.

Lee, H.L. and Billington, C., and Carter, B. 1993. Hewlett-Packard gains control of inventory and services through design for localization. *Interfaces* 23(1): 1-11.

Lee, H.L. and Tang, C.S. 1998. Variability reduction through operations reversal. *Management Science* 44(2): 162-172.

Lee, H.L. and Whang, S. 2001. Winning the last mile of e-commerce. *MIT Sloan Management Review* 42(4): 54-52.

Lee, H.L. and Whang, S. 2002. *Supply Chain Management: Models, Applications, and Research Directions.* The Netherlands: Kluwer Academic Publishers.

Lee, L.C. and Seah, K.H.W. 1988. JIT and effects of varying process and set-up times. *International Journal of Operations and Production Management* 8(1): 19-24.

Lee, S.M. and Ebrahimpour, M. 1984. Just-in-time Production System: Some requirements for implementation. *International Journal of Operations and Production Management* 4(4): 3-15.

Lee, S.M. and Ansari, A. 1985. Comparative analysis of Japanese Just-in-time purchasing and traditional US purchasing systems. *International Journal of Operations and Production Management* 5(4): 5-14.

Lee, Y.H., Cho, M.K., Kim, S.J. and Kim, Y.B. 2002. Supply chain simulation with discrete-continuous combined modeling. Computers and Industrial Engineering 43(1): 375-392.

Levin, S.A. 1999. *Fragile Dominion: Complexity and the Commons*. Perseus Books: Reading, MA.

Levitt, T. 1976. The industrialization of service. *Harvard Business Review* 54(5): 63-71.

Levy, D.L. 1995. International sourcing and supply chain stability. *Journal of International Business Studies* 26(2): 343-360.

Levy, M. and Grewal, D. 2000. Supply chain management in a networked economy. *Journal of Retailing* 76(4): 415-430.

Levy, M., Grewal, D., Peterson, R.A., and Connolly, B. 2005. The concept of the Big Middle. *Journal of Retailing* 81(1): 83-88.

Lichtenstein, B.B., N.M. Carter, K.J. Dooley, and W.B. Gartner. 2007. Complexity dynamics of nascent entrepreneurship. *Journal of Business Venturing* 22(1): 236-261.

Lifset, R. 2001. Closing the loop and honing our tools. *Journal of Industrial Ecology* 5(4): 1-2.

Linton, J.D., Klassen, R., and Jayaraman, V. 2007. Sustainable supply chains: An introduction. *Journal of Operations Management* 25(1): 1075-1082.

Littig, B. and Griessler, E. 2005. Social sustainability: a catchword between political pragmatism and social theory. *International Journal of Sustainable Development* 8(1): 65-79.

Lopez, M.V., Garcia, A., and Rodriguez, L. 2007. Sustainable development and corporate performance: A study based on the Dow Jones Sustainability Index. *Journal of Business Ethics* 75(3): 285-300.

Lovell, M.C. 1992. Simulating the 100 per cent just in time economy. *International Journal of Production Economics* 26(3): 71-78.

Lovell, H., H. Bulkeley, and D. Liverman. 2009. Carbon offsetting: sustaining consumption? *Environment and Planning* 41(1): 2357-2379.

Lummus, R.R. and Duclos-Wilson, L. 1992. When JIT is not JIT. *Production and Inventory Management Journal* 33(2): 61-65.

Lummus, R.R. and Vokurka, R.J. 1999. Defining supply chain management: a historical perspective and practical guidelines. *Industrial Management and Data Systems* 99(1): 11-17.

Lumsden, K., Dallari, F., and Ruggeri, R. 1999. Improving the efficiency of the Hub and Spoke system for the SKF European distribution network. *International Journal of Physical Distribution and Logistics* 29(1): 50-64.

Lye, S.W., S.G. Lee, and M.K. Khoo. 2001. A design methodology for the strategic assessment of a product's eco-efficiency. *International Journal of Production Research* 39(11): 2453-2474.

Macbeth, D.K. 1987. Supplier management in support of JIT activity: A research agenda. *International Journal of Operations and Production Management* 7(4): 54-63.

MacDuffie, J.P. 1995. Human resource bundles and manufacturing performance. *Industrial Labor Relations Review* 48(2): 197-223.

MacDuffie, J.P., Sethuraman, K., and Fisher, M.L. 1996. Product variety and manufacturing performance: Evidence from the international automotive assembly plant study. *Management Science* 42(3): 350-369.

Maloni, M.J. and Benton, W.C. 1997. Supply chain partnerships: Opportunities for operations research. *European Journal of Operational Research* 101(1): 419-429.

Manoochehri, G.H. 1984. Suppliers and the Just-in-Time concept. *Journal of Purchasing and Materials Management* 20(1): 15-21.

Marien, E.J. 2000. The four supply chain enablers. *Supply Chain Management Review* 4(1): 60-68.

Marlow, P.B. and Paixao, C.A.C. 2003. Measuring lean ports performance. *International Journal of Transport Management* 1(1): 189-202.

Mason-Jones, R. and Towill, D.R. 1998. Shrinking the supply chain uncertainty circle. *IOM Control* 24(1): 17-22.

Mason-Jones, R. and Towill, D.R. 1999. Using the information decoupling point to improve supply chain performance. *International Journal of Logistics Management* 10(1): 13-26.

Mason-Jones, R., Naylor, B., and Towill, D.R. 2000. Lean, agile or leagile? Matching your supply chain to the marketplace. *International Journal of Production Research* 38(17): 4061-4070.

Matten, D. and Moon, J. 2004. Corporate social responsibility education in Europe. *Journal of Business Ethics* 54(1): 323-337.

May, A.D., Jopson, A.F., and Mathews, B. 2003. Research challenges in urban transport policy. *Transport Policy* 10(3): 157-164.

McDaniel, S. Ormsby, J., and Gresham, A. 1992. The effect of JIT on distributors. *Industrial Marketing Management* 21(1): 145-149.

McIntyre, K., Smith, H.A., Henham, A., and Pretlove, J. 1998. Logistics performance measurement and greening supply chains: Diverging mindsets. *The International Journal of Logistics Management* 9(1): 57-68.

McKinnon, A. and Woodburn, A. 1994. The consolidation of retail deliveries: its effect on CO2 emissions. *Transport Policy* 1(2): 125-136.

McKinnon, A. 2000. Sustainable distribution: opportunities to improve vehicle loading. *Industry and Environment* 23(4): 26-30.

McWilliams, A. and Siegel, D. 2001. Corporate social responsibility: A theory of the firm perspective. *The Academy of Management Review* 26(1): 117-127.

Meadows, D.L., et al. 1972. *The Limits to Growth.* Universe Books: New York.

Mehra, S. and Inman, R.A. 1992. Determining the critical elements of just-in-time management. *Decision Sciences* 23(1): 160-174.

Melnyk, S.A., Sroufe, R.P., and Calantone, R. 2003. Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of Operations Management* 21(3): 329-351.

Meppen, T. and Gill, R. 1998. Planning for sustainability as a learning concept. *Ecological Economics* 26(2): 121-137.

Messinger, P.R. and C. Narasimhan. 1997. A model of retail formats based on consumers economizing on shopping time. *Marketing Science* 16(1): 1-23.

Michaelis, L. 2003. The role of business in sustainable consumption. *Journal of Cleaner Production* 11: 915-921.

Michelsen, O., Fet, A.M., and Dahlsrud, A. 2006. Eco-efficiency in extended supply chains: A case study of furniture production. *Journal of Environmental Management* 79: 290-297.

Milgrom, P. and Roberts J. 1995. Complementarities and fit: Strategy, structure, and organizational change in manufacturing. *Journal of Accounting Economics* 19(2): 179-208.

Milian, R.E. 2010. *Green tactics from retailers and shopping centers*. International Council of Shopping Centers. New York: ICSC Publications.

Minton, A.P. and Rose, R.L. 1997. The effects of environmental concern on environmentally friendly consumer behavior: An exploratory study. *Journal of Business Research* 40(1): 37-48.

Mohanty, R.P. and Deshmukh, S.G. 2000. Reengineering of the supply chain management system: a case study. *Production Planning and Control* 11(1): 90-104.

Moller, A. and Schaltegger, S. 2005. The sustainability balance scorecard as a framework for eco-efficiency analysis. *Journal of Industrial Ecology* 9(4): 73-83.

Monden, Y. 1993. *Toyota Production System: An integrated approach to Just-in-Time.* London: Chapman and Hall.

Montalvo, C. 2003. Sustainable production and consumption systems – cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico. *Journal of Cleaner Production* 11(4): 411-426.

Montgomery, D.C. 1991. *Introduction to Statistical Quality Control*. John Wiley & Sons: New York.

Montgomery, D.C. 2005. *Design and Analysis of Experiments*. John Wiley and Sons, Inc: Hoboken, NJ.

Morash, E.A. and Clinton, S.R. 1997. The role of transportation capabilities in international supply chain management. *Transportation Journal* 36(3): 5-17.

Morey, R.V., N. Kaliyan, D.G. Tiffany, D.R. Schmidt. 2010. A corn Stover supply logistics system. *Applied Engineering in Agriculture*, 26(3): 455-461.

Morioka, T., Tsunemi, K., Yamamoto, Y., Yabar, H. and Yoshida, N. 2005. Eco-efficiency of advanced loop-closing Systems for vehicles and household appliances in Hyogo Eco-town. *Journal of Industrial Ecology* 9(4): 205-221.

Motwani, J., Geissdoerfer, K., Gleich, R., and Wald, A. 2009. State of development of Life-Cycle Cost analysis models in Strategic Cost Management. *Production and Inventory Management Journal* 45(1): 66-79.

Mukhopadhyay, T., Kekre, S., and Kalathur, S. 1995. Business value of information technology: A study of Electronic Data Interchange. *Management Information Systems Quarterly* 19(2): 137-156.

Murphy, P.R. and Poist, R.F. 2000. Green logistics strategies: An analysis of usage patterns. *Transportation Journal* 1: 5-15.

Murphy, P.R. and Poist, R.F. 2003. Green perspectives and practices: a comparative logistics study. *Supply Chain Management: An International Journal*, 8(2): 122-131.

Murray, B.C., Newell, R.G., and Pizer, W.A. 2009. Balancing cost and emissions certainty: An allowance reserve for cap-and-trade. *Review of Environmental Economics*, 3(1): 84-103.

Murray, K.J. and Sheppard, S.V. 1988. Knowledge-based simulation model specification. *Simulation* 50(3): 112-119.

Nahavandi, A. and Malekzadeh, A.R. 1988. Acculturation in Mergers and Acquisitions. *The Academy of Management Review* 13(1): 79-90.

National Commission on Energy Policy (NCEP) 2004. *Policy discussion on heavy duty truck fuel economy*. Engine Emissions Reduction Series. Washington, DC.

Naylor, J.B., Naim, M.M., and Berry, D. 1999. Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics* 62: 108-118.

Nechar, M., M.F. Molina, and J.M. Bosque-Sendra. 1998. Application of Doehlert optimization and factorial designs in developing and validating a solid-phase spectrophotometric determination of trace levels of cadmium. *Analytica Chimica Acta* 382(1): 117-130.

Nelson, P.A. and Jambekar, A.B. 1990. A dynamic view of vendor relations under JIT. *Production and Inventory Management Journal* 31(4): 65-70.

Nevill, S.J., Rudh, D.G., and Sadd, D.W. 1998. Real-world examples of inventory effectiveness. *Supply Chain Management Review* 2(3): 39-46.

Newman, R.G. 1989. Single sourcing: short term savings versus long term problems. *Journal of Purchasing and Materials Management* 25(2): 20-25.

Newton, T., and Harte, G. 1997. Green business: technicist kitsch? *Journal of Management Studies* 34(1): 75-98.

Nieuwlaar, E., Warringa, G., Brink, C., and Vermeulen, W. 2005. Supply curves for eco-efficient environmental improvements using different weighting methods. *Journal of Industrial Ecology* 9(4): 85-96.

Nitkin, D., and Brooks, L.J. 1998. Sustainability auditing and reporting: The Canadian experience. *Journal of Business Ethics* 17(13): 1499-1507.

Noori, H. and Chen, C. 2003. Applying scenario-driven strategy to integrate environmental management and product design. *Production and Operations Management* 12(3): 353-368.

Norman, W. and MacDonald C. 2004. Getting to the bottom of triple bottom line. *Business Ethics Quarterly* 14(2): 243-262.

North American Industry Classification System (NAICS). 1995. *Proposed new industry structure for air transportation, rail transportation, water transportation, truck transportation, transit and ground passenger transportation, pipeline transportation, scenic and sightseeing transportation, and support activities for transportation.* Washington, D.C.

Nunes, B. and D. Bennet. 2010. Green operations initiatives in the automotive industry: An environmental reports analysis and benchmarking study. *Benchmarking: An International Journal* 17(3): 396-420.

Ny, H., MacDonald, J.P, Broman, G., Yamamoto, R., and Robert, K. 2006. Sustainability constraints as system boundaries. *Journal of Industrial Ecology* 10(1): 61-77.

O'Brien, C. 1999. Sustainable production – a new paradigm for a new millennium. *International Journal of Production Economics* 60: 1-7.

O'Kelly, M.E. 1986. The location of interacting hub facilities. *Transportation Science* 20(2): 92-106.

O'Kelly, M.E. 1998. A geographer's analysis of hub-and-spoke networks. *Journal of Transportation Geography* 6(3): 171-186.

Olhager, J. 2003. Strategic positioning of the order penetration point. *International Journal of Production Economics* 85: 319-329.

Oliver, C. 1997. Sustainable competitive advantage: combining institutional and resource-based views. *Strategic Management Journal* 18(9): 697-713.

O'Neal, C.R. 1987. The buyer-seller linkage in a just-in-time environment. *Journal of Purchasing and Materials Management* 23(1): 34-40.

O'Rourke, D. 2005. Market movements: Nongovernmental organization strategies to influence global production and consumption. *Journal of Industrial Ecology* 9(1): 115-128.

Orr, D.W. 2002. Four Challenges of Sustainability. *Conservation Biology* 16(6): 1457-1460.

Pagh, J.D. and Cooper, M.C. 1998. Supply chain postponement and speculation strategies: How to choose the right strategy. *Journal of Business Logistics* 19(2): 13-33.

Patra, S.K., Lenka, T.P., and Ratha, P.C. 2010. An order level EOQ Model for deteriorating items in a single warehouse system with price depended demand in non-linear form. International *Journal of Computational and Applied Mathematics* 5(3): 277-288.

Pfeffer, J., Hatano, T., & Timo, S. 1995. Producing sustainable competitive advantage through the effective management of people. *Academy of Management Executive* 9(1): 55-72.

Pearce, D. 1991. The role of carbon taxes in adjusting to global warming. *The Economic Journal* 101(407): 938-948.

Pearce, J.A., Freeman, E.B., and Robinson, R.B. 1987. The tenuous link between formal strategic planning and financial performance. *The Academy of Management Review* 12(4): 658-675.

Perdue, B.C., Day, R.L., and Michaels, R.E. 1986. Negotiations styles of industrial buyers. *Industrial Marketing Management* 15: 171-176.

Perlin, S.A., Setzer, R.W., Creason, J., and Sexton, K. 1995. Distribution of industrial air emissions by income and race in the United States: An approach using the Toxic Release Inventory. *Environmental Science and Technology* 29(1): 69-80.

Petersen, C.G. 1997. An evaluation of order picking routing polices. *International Journal of Operations and Production Management* 17(11): 1098-1111.

Petersen, C.G. 1999. The impact of routing and storage policies on warehouse efficiency. *International Journal of Operations and Production Management* 19(10): 1053-1064.

Petersen, C.G. 2000. An evaluation of order picking policies for mail order companies. *Production and Operations Management* 9(4): 319-335.

Petersen, C.G. and Aase, G. 2004. A comparison of picking, storage, and routing policies in manual order picking. *International Journal of Production Economics* 92: 11-19.

Philipoom, P.R., Rees, L.P., Taylor, B.W. and Huang, P. 1990. A mathematical programming approach for determining workcentre lotsizes in a just-in-time system with kanbans. *International Journal of Production Research* 28: 1-15.

Pil, F.K., and Holweg, M. 2004. Linking product variety to order-fulfillment strategies.*Interfaces* 34(5): 394-403.

Poole, M.A. and P.N. O'Farrell. 1970. The assumptions of the linear regression model. *Transactions of the Institute of British Geographers* 52(1): 145-158.

Porter, M.E. and Van der Linde, C. 1995. Green and competitive: ending the stalemate. *Harvard Business Review* 73(5): 120-133.

Porter, M.E. and Van der Linde, C. 1995b. Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives* 9(4): 97-118.

Prater, E., Biehl, M., and Smith, M.A. 2001. International supply chain agility-tradeoffs between flexibility and uncertainty. *International Journal of Operations and Production Management* 21: 823-839.

Quak, H.J. and De Koster, M.B.M. 2007. Exploring retailers' sensitivity to local sustainability policies. *Journal of Operations Management* 25: 1103-1122.

Quariguasi, J, Walther, G., Bloemhof, J., Van Nunen, J.A.E.E., and Spengler, T. 2009. A methodology for assessing eco-efficiency in logistics networks. *European Journal of Operations Research* 193(3): 670-682.

Ragowsky, A. and Somers, T.M. 2002. Enterprise Resource Planning. *Journal of Management of Information Systems* 19(1): 11-15.

Ramasesh, R.V. 1990. Recasting the traditional inventory model to implement Just-in-Time Purchasing. *Production and Inventory Management Journal* 31(1): 71-75.

Ramdas, K. 2003. Managing product variety: a integrative review and research directions. Prod*uction and Operations Management* 12(1): 79-101.

Ramsay, K. and Wilson, I. 1990. Sourcing/contracting strategy selection. *Production and Inventory Management Journal* 35(2): 47-51.

Rao, K., Grenoble, W., and Young, R. 1991. Traffic congestion and JIT. *Journal of Business Logistics* 12(1): 105-121.

Rapert, M.I and Wren, B.M. 1998. Service quality as a competitive opportunity. *The Journal of Services Marketing* 12(3): 223-235.

Redman, C.L. 2005. Resilience Theory in Archeology. *American Anthropologist*. 107(1): 70-77.

Redman, C.L. and Kinzig, A. 2003. Resilience of past landscapes: Resilience theory, society, and the longue duree. *Conservation Ecology* 7(1): 1-19.

Research and Innovative Technology Administration (RITA). 2010. *Pocket Guide to Transportation 2010*. U.S. Department of Transportation. Washington, DC.

Research and Innovative Technology Administration (RITA). 2011. *Intelligent Transportation Systems for Maritime Applications.* U.S. Department of Transportation. Accessed on November 16, 2011. http://www.its.dot.gov/research/maritime_apps.htm

Ricker, F.R. and Kalakota, R. 1999. Order fulfillment: The hidden key to E-Commerce success. *Supply Chain Management Review* 1: 60-70.

Ring, P.S. and Van de Ven, A.H. 1992. Structuring cooperative relationships between organizations. *Strategic Management Journal* 13(7): 483-498.

Rizet, C., Cornelis, E., Browne, M., and Leonardi, J. 2010. GHG emissions of supply chains from different retail systems in Europe. *Procedia Social and Behavioral Sciences* 1(2): 6154-6164.

Robert, K., Schmidt-Bleek, B., Aloisi de Larderel, J., Basile, G, Hansen, J.L., Kuehr, R., Price, T.P., Suzuki, M., Hawken, P., and Wackernagel, M. 2002. Strategic sustainable development – selection, design and synergies of applied tools. *Journal of Cleaner Production* 10: 197-214.

Rodrigue, J. 1999. Globalization and the synchronization of transport terminals. *Journal of Transport Geography* 7: 255-261.

Rodrigue, J., Slack, B. and Comtois, C. 2001. Green logistics. *The Handbook of Logistics and Supply-Chain Managemen.* London: Elsevier.

Rodriguez, L.C., A.M. Garcia Campana, and J.M. Bosque Sendra. 1996. Statistical estimation of linear calibration range. *Analytical Letters* 29(7): 1231-1239.

Rohrer, M. 1995. Simulation and Cross Docking. Proceedings of the 1995 Winter Simulation Conference 1: 846-849.

Romero, B.P. 1991. The other side of JIT supply management. *Production and Inventory Management Journal* 32(4): 1-2.

Rondinelli, D.A. and Berry, M.A. 2000. Environmental citizenship in multinational corporations: Social responsibility and sustainable development. *European Management Journal* 18(1): 70-84.

Roodbergen, K.J. and De Koster, R. 2001. Routing methods for warehouses with multiple cross aisles. *International Journal of Production Research* 39(9): 1865-1883.

Ross, S.M. 2003. *Introduction to Probability Models*. Academic Press: London.

Rosenblatt, M.J. and Roll, Y. 1984. Warehouse design with storage policy considerations. *International Journal of Production Research* 22(5): 809-821.

Rosenblatt, M.J. and Roll, Y. 1988. Warehouse capacity in a stochastic environment. *International Journal of Production Research* 26(12): 1847-1851.

Rothenberg, S., Pil, F., and Maxwell. J. 2001. Lean, green and the quest for superior environmental performance. *Production and Operations Management* 10(3): 228-243.

Rothenberg, S. 2003. Knowledge content and worker participation in environmental management at NUMMI. *Journal of Management Studies* 40(7): 1783-1802.

Rubiano, O. and Crespo, A. 2003. The effectiveness of using e-collaboration tools in the supply chain: an assessment study with system dynamics. *Journal of Purchasing and Supply Management* 9: 151-163.

Rudenauer, I., Gensch, C., Griebhammer, R., and Bunke, D. 2005. Integrated environmental and economic assessment of products and processes. *Journal of Industrial Ecology* 9(4): 105-116.

Ruyter, K., Moorman, L., and Lemmink, J. 2001. Commitment and trust in Customer-Supplier relationships in high technology markets. *Industrial Marketing Management* 30: 271-286.

Sabath, R.E., Autry, C.W., and Daugherty, P.J. 2001. Automatic replenishment programs: the impact of organizational structure. *Journal of Business Logistics* 22(1): 91-105.

Sabath, R.E. 1995. Volatile demand calls for quick response: the integrated supply chain. *Losgistics Information Management* 8(2): 49-52.

Sadhwani, A.T., Sarhan, M.H., and Kiringoda, D. 1985. Just-in-time: an inventory system whose time has come. *Management Accounting* 67: 36-44.

St. Onge, A. 1996. New concepts in supply chain management. *Modern Materials Handling* 51(3): 33.

Sakakibara, S., Flynn, B.B., and Morris, W. 1997. The impact of Just-in-Time manufacturing and its infrastructure on manufacturing performance. *Management Science* 43(9): 1246-1257.

Saling, P., Kicherer, A., Dittrich-Kramer, B., Wittlinger, R., Zombik, W., Schmidt, I., Schroot, W., and Schmidt, S. 2002. Eco-efficiency analysis by BASF: The Method. *International Journal of Life Cycle Assessment* 7(4): 203-218.

Salvador, F., Forza, C., and Rungtusanatham, M. 2002. Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management* 20: 549-575.

Santilli, M., P. Moutinho, S. Schwartzman, D. Nepstad, L. Curran, at al. 2005. Tropical deforestation and the Kyoto protocol. *Climatic Change* 71: 267-276.

Saouter, E. and Van Hoof, G. 2001. A database for the life-cycle assessment of Procter and Gamble laundry detergents. *International Journal of Life Cycle Assessment* 6: 1-12.

Sara Lee 2010. *Sustainability report.* Sara Lee Corporation: Chicago.

Sargent, R.G. 2004. Validation and verification of simulation models. *Proceedings of the Winter Simulation Conference*, 17-28.

Sargent, R.G. 2005. Validation and verification of simulation models. *Proceedings of the Winter Simulation Conference* 130-143.

Sarker, B.R. and Fitzsimmons, J.A. 1989. The performance of push and pull systems: a simulations and comparative study. *International Journal of Production Research* 27(10): 1715-1731.

Savsar, M. 1997. Simulation analysis of maintenance policies in just-in-time production systems. *International Journal of Operations and Production Management* 17(3): 256-266.

Schmidheiny, S. 1992. *Changing course: A global business perspective on development and the environment.* Cambridge, MA: MIT Press.

Schmidt, W.P. and J. Sullivan. 2000. Weighting in life cycle assessment in a global context. *International Journal of Life Cycle Assessment* 7(1): 5-10.

Scholz, R.W. and Wiek, A. 2005. Operational eco-efficiency: Comparing firms' environmental investments in different domains of operation. *Journal of Industrial Ecology* 9(4): 155-170.

Schonberger, R.J. 1982. *Japanese Management Techniques*. New York: Free Press.

Schonberger, R.J., and Gilbert, J.P. 1983. Just-In-Tine Purchasing: A challenge for U.S. industry. *Management Review* 26(1): 54-68.

Schonberger, R.J. and Ansari, A. 1984. Just in time purchasing can improve quality. *Journal of Purchasing and Materials Management* 20(1): 2-7.

Schonberger, R.J. 1996. *World Class Manufacturing: The Next Decade*. New York: The Free Press.

Schot, J., Brand, E., and Fischer, K. 1997. The greening of industry for a sustainable future: Building an international research agenda. *Business Strategy and the Environment* 6: 153-162.

Schroer, B.J. Black, J.T. and Zhang, S.X. 1985. Just-in-time with kanban manufacturing system simulation on a microcomputer. *Simulation* 45(2): 52-70.

Schroeder, R.G.. Linderman, K., Liedtke, C., and Choo, A.S. 2008. Six Sigma: Definition and underlying theory. *Journal of Operations Management* 26: 536-544.

Schumacker, R.R. and R.G. Lomax. (2010). *A beginner's guide to Structural Equation Modeling*, Routledge: New York.

Selman, P. 2000. A sideways look at Local Agenda 21. *Journal of Environmental Policy & Planning* 2(1): 39-53.

Selto, F.H., Renner, C.J., and Young, S.M. (1995). Assessing the organizational fit of a just-in-time manufacturing system: testing selection, interaction and systems models of contingency theory. *Accounting, Organizations and Society* 20(7): 665-684.

Seppala, J., Melanen, M., Maenpaa, I., Koskela, S., Tenhunen, J., and Hiltunen, M. 2005. How can the eco-efficiency of a region be measured and monitored? *Journal of Industrial Ecology* 9(4): 117-130.

Seuring, S. and Muller, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* 16: 1699-1710.

Shah, R. and Ward, P. 2003. Lean manufacturing: context, practice bundles and performance. *Journal of Operations Management* 21(2): 129-149.

Shapiro, R.D. 1984. Get leverage from logistics. *Harvard Business Review* 62: 119-126.

Sharman, G. 1984. The rediscovery of logistics. *Harvard Business Review* 62(5): 71-79.

Sheu, C., Lee, L, and Niehoff, B. 2006. A voluntary logistics security program and international supply chain partnership. *Supply Chain Management: An International Journal* 11(4): 363-374.

Silver, E.A. 1990. Deliberately slowing down output in a family production context. *International Journal of Production Research* 28: 17-25.

Silvestro, R., Fitzgerald, L., Johnston, L., and Voss, C. 1993. Towards a classification of service processes. *International Journal of Service Industry Management* 3(3): 62-75.

Simchi-Levi, D., Kaminsky, P., and Simchi-Levi, E. 2003. *Designing and Managing the Supply Chain.* Boston: McGraw-Hill Irwin.

Simons, D., and Mason, R. 2003. Lean and green: Doing more with less. *ECR Journal* 3(1): 84-91.

Simpson, D.F., and Power, D.F. 2005. Use the supply relationship to develop lean and green suppliers. *Supply Chain Management: An International Journal* 10(1): 60-68.

Sinclair, D. and Zairi, M. 2000. Performance measurement: a critical analysis of the literature with respect to total quality management. *International Journal of Management Reviews* 2(2): 145-168.

Sinding, K. 2000. Environmental management beyond the boundaries of the firm: Definitions and constraints. *Business Strategy and the Environment* 9(2): 79-91.

Singh, J., Krasowski, A., and Singh, S.P. 2010. Life cycle inventory of HDPE bottle-based liquid milk packaging systems. *Packaging Technology and Science* 1(1): 1-12.

Slack, B. 1990. Intermodal transportation in North America and the development of inland load centers. *Professional Geographer* 42(1): 72-83.

Smaros, J. 2000. Viewpoint: reaching the customer through e-grocery VMI. *International Journal of Retail and Distribution Management* 28(2): 55-61.

Smaros, J., Lehtonen, J., Appleqvist, P. and Holmstrom, J. 2003. The impact of increasing demand visibility on production and inventory control efficiency. *International Journal of Physical Distribution and Logistics Management* 33(4): 336-352.

Snir, E.M. 2001. Liability as a catalyst for product stewardship. *Production and Operations Management* 10(2): 190-206.

Snyder, C.A., Cox, J.A., and Jesse, R.R. 1982. A dependent demand approach to service organizations planning and control. *The Academy of Management Review* 7(3): 455-466.

Sohal, A.S., Keller, A.Z., and Fouad, R.H. 1988. A review of literature relating to JIT. *International Journal of Operations and Production Management* 9(3): 15-25.

Song, J. 1998. On the order fill rate in a multi-item, base-stock inventory system. *Operations Research* 46(6): 831-845.

Song, J., Xu, S.H., and Liu, B. 1999. Order-fulfillment performance measures in an assemble-to-order system with stochastic leadtimes. *Operations Research* 47(1): 131-149.

Souza, G.C. 2009. Remanufacturing in closed-loop supply chains. *Production and Inventory Management Journal* 45(1): 56-65.

Spalding-Fecher, R. H. Winker, and S. Mwakasonda. 2005. Energy and world summit on sustainable development: what next? *Energy Policy* 33(1): 99-112.

Spangenberg, J.H. 2002. *Institutional sustainability indicators: An analysis of the institutions in Agenda 21 and a draft set of indicators for monitoring their effectivity*. Sustainable Development 10(1): 103-115.

Spangenberg, J.H. and Lorek, S. 2002. The changing contribution of unpaid work to the total standard of living in sustainable development scenarios. *International Journal of Sustainable Development* 5(1): 5-9.

Spencer, M.S. and Guide, V.D. 1995. An exploration of the components of JIT: Case study and survey results. *International Journal of Operations and Production Management* 15(5): 72-83.

Srivastava, S.K. 2007. Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews* 9(1): 53-80.

Sroufe, R. 2003. Effects of environmental management systems on environmental management practices and operations. *Production and Operations Management* 12(3): 416-431.

Sroufe, R. 2004. Effects of environmental management systems on environmental management practices and operations. *Production and Operations Management* 12(3): 416-431.

Stalk, G. 1988. Time – the next source of competitive advantage. *Harvard Business Review* 66(4): 41-51.

Stalk, G., Evans, P., and Schulman, L.E. 1992. Competing on capabilities: the new rules of corporate strategy. *Harvard Business Review* 70(2): 665-684.

Stenzel, J. and Stenzel, C. 2002. ERP system opportunities and limitations: an interview with Eli Goldrath. *Journal of Cost Management* 16: 5-12.

Stewart, R.B. and Wiener, J.B. 2003. *Reconstructing climate policy: Beyond Kyoto*. AEI Press: U.S.

Stratton, R., and Warburton, R.D.H. 2003. The strategic integration of agile and lean supply. *International Journal of Production Economics* 85(2): 183-198.

Subramanian, R., Talbot, B., and Gupta, S. 2010. An approach to integrating environmental considerations within managerial decision-making. *Journal of Industrial Ecology* 14(3): 378-398.

Sugimori, Y., Kusinoki, K., Cho, F., and Uchikawa, S. 1977. Toyota production system and Kanban system materialization of just-in-time and respect-for-human system. *International Journal of Production Research* 15(6): 553-564.

Suh, S., Lee, K.M., and Ha, S. 2005. Eco-efficiency for pollution prevention in small to medium-sized enterprises. *Journal of Industrial Ecology* 9(4): 223-240.

Sundarakani, B., de Souza, R., Goh, M., Wagner, S.M., and Manikandan, S. 2010. Modeling carbon footprints across the supply chains. *International Journal of Production Economics* 128: 43-50.

Sung, C.S. and Song S.H. 2003. Integrated service network design for a cross-docking supply chain network. *Journal of the Operational Research Society* 54: 1283-1295.

Svensson, G. 2007. Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example. *Supply Chain Management: An International Journal* 12(4): 262-266.

Tan, C., 2001. A framework of supply chain management literature. European *Journal of Purchasing and Supply Management* 7: 39-48.

Taylor, M. and Hallsworth, A. 2000. Power relations and market transformation in the transport sector: the example of the courier services industry. *Journal of Transport Geography* 8: 237-247.

Terry, J.C. and Yandle B. 1997. EPA's toxic release inventory: Stimulus and response. Managerial and Decision Economics 18(1): 433-411.

The Sustainability Consortium (TSC). 2011. About the Consortium: Who we are. Accessed on October 23, 2011. http://www.sustainabilityconsortium.org/who-we-are/

The Sustainability Consortium (TSC). 2011b. Open IO Beta 1.5. Accessed on October 20, 2011. http://www.sustainabilityconsortium.org/open-io/

Tobin, G.A. 1999. Sustainability and community resilience: the holy grail of hazards planning? *Global Environmental Change* 1(1): 13-25.

Trip, J.J. and Bontekoning, Y. 2002. Integration of small freight flows in the intermodal transport system. *Journal of Transport Geography* 10: 221-229.

Turner, B.L., Kasperson, R.E., Matsol, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J., et al. 2003. A framework for vulnerability analysis in sustainable science. *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8074-8079.

Twede, D., Clarke, R.H., Tait, J.A. 2000. Packaging postponement: a global packaging strategy. *Packaging Technology and Science* 13(3): 105-115.

Tyan, J. and Wee, H. 2003. Vendor managed inventory: a survey of the Taiwanese grocery industry. *Journal of Purchasing and Supply Management* 9: 11-18.

Tyteca, D. 1998. On sustainability indicators at the firm-level: Pollution and resource efficiency as a necessary condition toward sustainability. *Journal of Industrial Ecology* 2(4): 61-77.

Ulanowicz, R.E., Goerner, S.J., Lietaer, B., and Gomez, R. 2009. *Quantifying sustainability: Resilience, efficiency and the return of information theory. Ecological complexity* 6: 27-36.

United Nations. 2011. *The Millennium Development Goals Report.* UN: New York.

United Nations Division for Sustainable Development Department of Policy Co-Ordination and Sustainable Development (UNDPCSD). 1995. *Work Program on Indicators of Sustainable Development*. UN:New York.

United Nations Environment Program (UNEP). 1994. *Company Environmental Reporting: a Measure of the Progress of Business and Industry Towards Sustainable Development*, Technical Report 24. UNEP Industry and Environmental Office: Paris.

United Nations Environment Program (UNEP). 1998. Cleaner Production. *Industry and environment review* 21(4): 1-5.

U.S. Army Corps of Engineers. 2009. *Waterborne Commerce Database*. Navigation Data Center – Waterborne Commerce Statistics Center. Accessed on November 16, 2011. http://www.ndc.iwr.usace.army.mil//index.htm

U.S. Census 2010. Population Clock. U.S. Census Bureau. Accessed on March 9, 2011. http://www.census.gov/

U.S. Census 2011. Population Clock. U.S. Census Bureau. Accessed on November 1, 2011. http://www.census.gov/

U.S. Department of Agriculture. 2010. Milk Production. Accessed on January 11, 2011. http://usda.mannlib.cornell.edu/usda/current/MilkProd/MilkProd-11-18- 2010.pdf

U.S. Department of Transportation. 2007. Commodity Flow Survey. Bureau of Transportation Statistics. Accessed on November 20, 2010. http://www.bts.gov/publications/commodity_flow_survey/

U.S. Department of Transportation. 2010. *DOT Strategic Sustainability Performance Plan*. U.S. DOT: Washington, D.C.

U.S. Department of Transportation. 2010b. *Factors and considerations for establishing a fuel efficiency regulatory program for commercial medium and heavy-duty vehicles*. National Highway Traffic Safety Administration: Washington, D.C.

U.S. Department of Transportation. 2010c. *Commodity Flow Survey*. Economics and Statistics Administration: Washington, D.C.

U.S. Energy Information Administration. 2010. Commercial Buildings: Energy use by type of building. Accessed on February 7, 2011 http://www.eia.doe.gov/energyexplained/index.cfm?page=us_energy_commercial

U.S. Environmental Protection Agency. 2008. Kansas City PM Characterization Study. Accessed on November 9, 2010. http://www.epa.gov/otaq/emission-factors-research/index.htm

U.S. Environmental Protection Agency. 2010. Inventory of U.S. Greenhouse Gas Emissions and Sinks. Accessed on September 15, 2011. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

U.S. Green Building Council. (2009). LEED for Retail. Accessed on February 2, 2010. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1734

Van den Berg, J.P., Sharp, G.P., Gademann, A.J.R.N., and Pochet, Y. 1998. Forward-reserve allocation in a warehouse with unit-load replenishments. *European Journal of Operational Research* 111: 98-113.

Van den Berg, J.P. and Gademann, A.J.R.N. 2000. Simulation study of an automated storage/retrieval system. *International Journal of Production Research* 38: 1339-1356.

Van Hoek, R.I. 1997. Postponed manufacturing: a case study in the food supply chain. *Supply Chain Management* 2: 63-75.

Van Hoek, R.I., Peelen, E. and Commandeur, H.R. 1999. Achieving mass customization through postponement: a study of international changes. *Journal of Market Focused Management* 3: 353-368.

Van Hoek, R.I. and Van Dierdonck, R. 2000. Postponed manufacturing supplementary to transportation services? *Transportation Research* 36(3): 205-217.

Van Hoek, R.I. 2000a. The thesis of leagility revisited. *International Journal of Agile Management Systems* 2: 196-201.

Van Hoek, R.I. 2001. The discovery of postponement: a literature review and directions for research. *Journal of Operations Management* 19(2): 161-184.

Van Hoek, R, 2001. E-supply chains – virtually non-existing. *Supply Chain Management: An International Journal* 6(1): 21-28.

Verfaillie, H.A. and Bidwell, R. 2000. *Measuring Eco-Efficiency – A guide to Reporting Company Performance.* World Business Council for Sustainable Development.

Vergin, R.C. and Barr, K. 1999. Building competitiveness in grocery through continuous replenishment planning: insights from the field. *Industrial Marketing Management* 28: 145-153.

Verwust, T. 1991. Logarithmic transformations in biomass estimation procedures: Violation of the linearity assumption in the regression analysis. *Biomass and Bioenergy* 1(3): 175-180.

Von Wright, G.H. 1997. *Progress: Fact and Fiction*. The Idea of Progress Series: Berlin.

Walmart 2006. Walmart opens next generation Western Climate Specific High Efficiency Pilot Store. Accessed on January 31, 2010. http://walmartstores.com/Sustainability/

Walmart 2008. Walmart is taking the lead on sustainable packaging. Accessed on April 21, 2010. http://walmartstores.com/Sustainability/

Walmart 2009. Walmart powers facilities with solar energy. Accessed on May 5, 2010. http://walmartstores.com/Sustainability/

Walmart 2009b. Walmart looks into renewable fuels. Accessed on June 13, 2010. http://walmartstores.com/Sustainability/

Walmart 2009c. Walmart is building better stores. Accessed on July 20, 2010. http://walmartstores.com/Sustainability/

Walmart 2011. *2011 Global Responsibility Report*. Wal-Mart Stores, Inc: Bentonville, AR.

Waller, M.A., Johnson, M.E., and Davis, T. 1999. Vendor-managed inventory in the retail supply chain. *Journal of Business Logistics* 20(1): 183-203.

Waller, M.A., Cassady, C.R., and Ozment, J. 2006. Impact of cross-docking on inventory in a decentralized retail supply chain. *Transportation Research* 42: 359-382.

Walley, N. and Whitehead, B. 1994. It is not easy being green. *Harvard Business Review* 72(3): 46-52.

Walsh, J.P. 1988. Top management turnover following mergers and acquisitions. *Strategic Management Journal* 9(2): 173-183.

Walters, D. 1999. Marketing and operations management: an integrated approach to new ways of delivering value. *Management Decision* 37(3): 248-258.

Wasco, W.C., Stonehocker, R.E., and Feldman, L.H. 1991. Success with JIT and MRPII in a service organization. *Production and Inventory Management Journal* 32(4): 15-20.

Waters-Fuller, N. 1995. Just-in-time purchasing and supply: a review of the literature. *International Journal of Operations and Production Management* 15(9): 220-236.

Webber, C.L. and Matthews, H.S. 2008. Food-miles and the relative climate impacts of food choices in the United States. *Environmental Science and Technology* 42(10): 3508-3513.

Webster, S. and Mitra, S. 2007. Competitive strategy in remanufacturing and the impact of take-back laws. *Journal of Operations Management* 25: 1123-1140.

Weidema, B.P., Thrane, M., Christensen, P., Schimdt, J., and Lokke, S. 2008. Carbon Footprint: A catalyst for life cycle assessment? *Journal of Industrial Ecology* 12(1): 3-6.

Welford, R., Young, W., and Ytterhus, B. 1998. Towards sustainable production and consumption: A literature review and conceptual framework for the service sector. *Eco-Management and Auditing* 5(1): 38-56.

Wernick, I., Herman, R., Govind, S., and Ausubel, J.H. 1996. *Daedalus* 125(3): 171-198.

Westbrook, R. 1988. Time to forget JIT? Observations on a visit to Japan. *International Journal of Operations and Production Management* 8(4): 5-21.

Wheeler, D. and Elkington, J. 2001. The end of the corporate environmental report? *Business Strategy and the Environment* 10(1): 1-14.

Wikner, J., Towill, D.R., and Naim, M. 1991. Smoothing supply chain dynamics. *International Journal of Production Economics* 22(3): 231-248.

Wilding, R. 1998. The supply chain complexity triangle: uncertainty generation in the supply chain. *International Journal of Physical Distribution and Logistics Management* 28: 519-616.

Wilkinson, B. and Oliver, N. 1989. Power, control and the kanban. *Journal of Management Studies* 26(1): 48-58.

Willis, T. and Huston, C. 1990. Vendor requirements and evaluation in a JIT environment. *International Journal of Operations and Production Management* 10(4): 41-50.

Wilson, N. 1996. Supply chain management: a case study of a dedicated supply chain for bananas in the UK grocery market. *Supply Chain Management: An International Journal* 1(2): 28-35.

Winker, J., Towill, D.R., and Naim, M. 1991. Smoothing supply chain dynamics. *International Journal of Production Economics* 22(3): 231-248.

Witt, C.E. 1992. Cross-docking: A proven plan for profit. *Material Handling Engineering* 47(11): 93-96.

Woensel, T.V., Creten, R., and Vandaele, N. 2001. Managing the environmental externalities of traffic logistics: The issue of emissions. *Production and Operations Management* 10(2): 207-223.

Womack, J., Jones, D. and Roos, D. 1990. The machine that changed the world. New York: Rawson/Macmillan Publishing.

Womack, J., and Jones, D. 1996. *Lean thinking.* New York: Simon and Schuster.

Won, J. and Olafsson, S. 2005. Joint order batching and order picking in warehouse operations. *International Journal of Production Research* 43(7): 1427-1442.

World Business Council for Sustainable Development and the United Nations Environment Program. 1998. *Cleaner Production and Ecoefficiency: Complementary approaches to Sustainable Development*. France: UNEP.

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press: Oxford.

World Resources Institute (WRI). 1997. *Resource flows, the material basis of industrial economies.* Climate, Energy and Transport series: Washington, DC.

Wu, H. and Steve, C.D. 1995. Environmentally responsible logistics system. *International Journal of Physical Distribution and Logistics Management* 25(2): 20-38.

Yang B. and Burns, N. 2003. Implications of postponement for the supply chain. *International Journal of Production Research* 41(9): 2075-2090.

Yang, B., Yang, Y., and Wijngaard, J. 2005. Impact of postponement on transport: an environmental perspective. *The International Journal of Logistics Management* 16(2): 192-204.

Young, W. and Tilley, F. 2006. Can business move beyond efficiency? The shift toward effectiveness and equity in the corporate sustainability debate. *Business Strategy and the Environment* 15: 402-415.

Youngdahl, W.E. 1996. An investigation of service-based manufacturing performance relationships. *International Journal of Operations and Production Management* 16(8): 31-45.

Ytterhus, B.E., Arnestad, P., and Lothe, S. 1999. Environmental initiatives in the retailing sector: An analysis of supply chain pressures and partnerships. *Eco-Management and Auditing* 6: 181-188.

Zhu, J. 1996. Data envelopment analysis with preference structure. *Journal of Operational Research Society* 47(1): 136-150.

Zinn, W. and Bowersox, D.J. 1988. Planning physical distribution with the principle of postponement. *Journal of Business Logistics* 9(2): 117-136.

APPENDIX A

EXPERIMENTAL DESIGN FACTORS AND LEVELS PER INVENTORY MANAGEMENT METHOD

Table A.1
Economic Order Quantity (EOQ).

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
1	-	-	-	-
2	-	-	+	-
3	+	-	-	-
4	+	-	+	-
5	-	-	-	+
6	-	-	+	+
7	+	-	-	+
8	+	-	+	+
9	-	+	-	-
10	-	+	+	-
11	+	+	-	-
12	+	+	+	-
13	-	+	-	+
14	-	+	+	+
15	+	+	-	+
16	+	+	+	+

Process configuration selected for simulation is shaded.

Table A.2
Just-in-Time (JIT).

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
1	-	-	-	-
2	-	-	+	-
3	+	-	-	-
4	+	-	+	-
5	-	-	-	+
6	-	-	+	+
7	+	-	-	+
8	+	-	+	+
9	-	+	-	-
10	-	+	+	-
11	+	+	-	-
12	+	+	+	-
13	-	+	-	+
14	-	+	+	+
15	+	+	-	+
16	+	+	+	+

Process configuration selected for simulation is shaded.

Table A.3
Postponement.

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
1	-	-	-	-
2	-	-	+	-
3	+	-	-	-
4	+	-	+	-
5	-	-	-	+
6	-	-	+	+
7	+	-	-	+
8	+	-	+	+
9	-	+	-	-
10	-	+	+	-
11	+	+	-	-
12	+	+	+	-
13	-	+	-	+
14	-	+	+	+
15	+	+	-	+
16	+	+	+	+

Process configurations selected for simulation are shaded.

Table A.4
Cross-docking.

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
1	-	-	-	-
2	-	-	+	-
3	+	-	-	-
4	+	-	+	-
5	-	-	-	+
6	-	-	+	+
7	+	-	-	+
8	+	-	+	+
9	-	+	-	-
10	-	+	+	-
11	+	+	-	-
12	+	+	+	-
13	-	+	-	+
14	-	+	+	+
15	+	+	-	+
16	+	+	+	+

Process configurations selected for simulation are shaded.

Table A.5
Vendor Managed Inventory (VMI).

	Design Factors			
	F1: Product shipment frequency between supply chain partners.	**F2:** Product customization capability at retailing stores.	**F3:** Product storage time and management at warehousing facilities.	**F4:** Storage space devoted at retailing stores.
1	-	-	-	-
2	-	-	+	-
3	+	-	-	-
4	+	-	+	-
5	-	-	-	+
6	-	-	+	+
7	+	-	-	+
8	+	-	+	+
9	-	+	-	-
10	-	+	+	-
11	+	+	-	-
12	+	+	+	-
13	-	+	-	+
14	-	+	+	+
15	+	+	-	+
16	+	+	+	+

Process configurations selected for simulation are shaded.

APPENDIX B

GEOGRAPHICAL DESCRIPTIONS OF SUPPLY CHAINS

Figure B.1: Regional description of durable goods supply chain
Industry reference: Best Buy
Nomenclature: A - Distribution Center
B, C, D, E, & F - Retail Stores

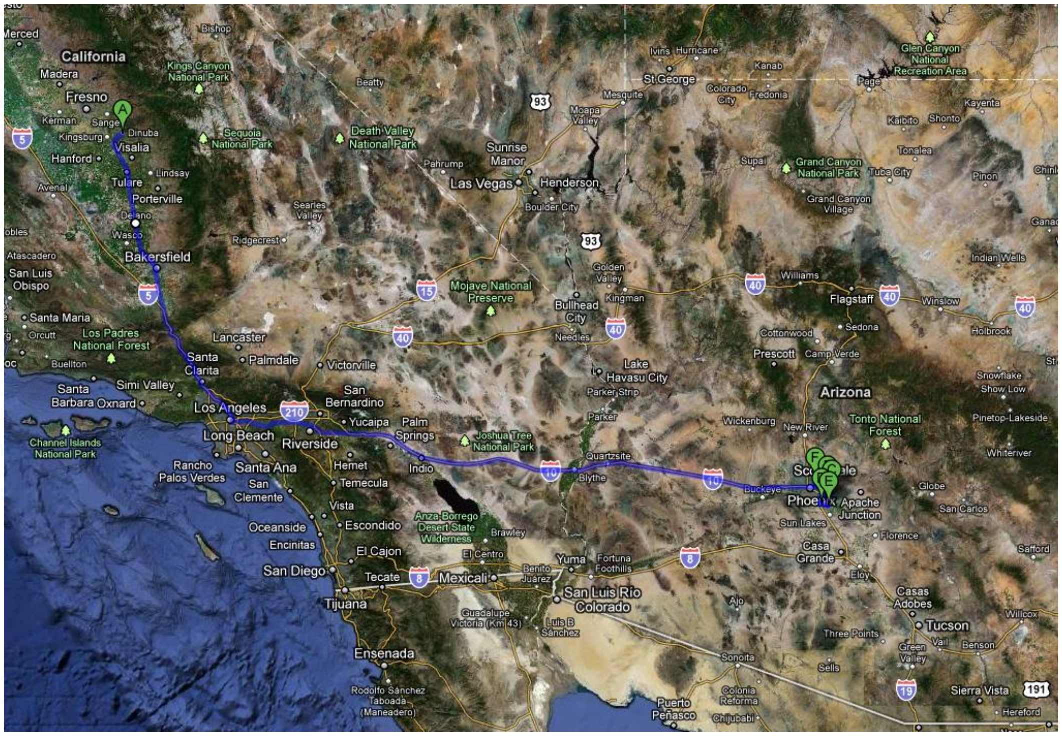


Figure B.2: Routing detail description for durable goods supply chain
Industry reference: Best Buy
Nomenclature: A - Distribution Center
B, C, D, E, & F - Retail Stores

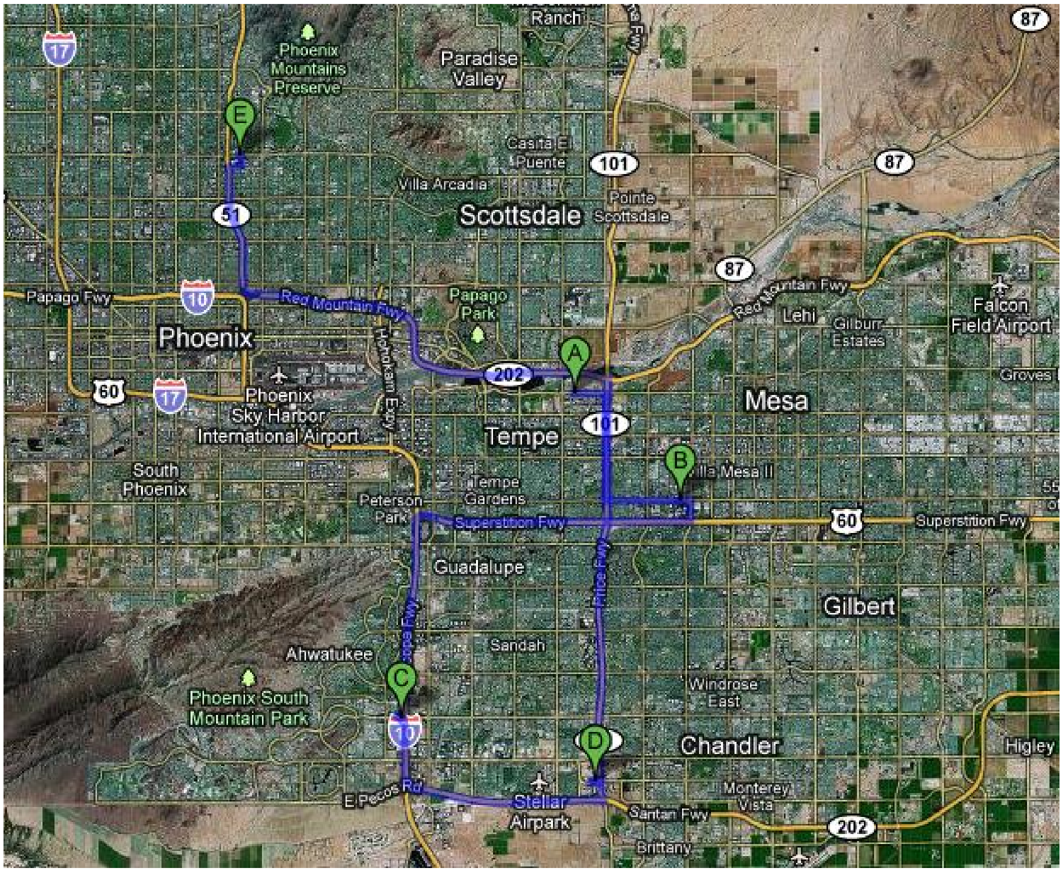


Figure B.3: Local routing detail description for durable goods supply chain
Industry reference: Best Buy
Nomenclature: A, B, C, D, & E - Retail Stores

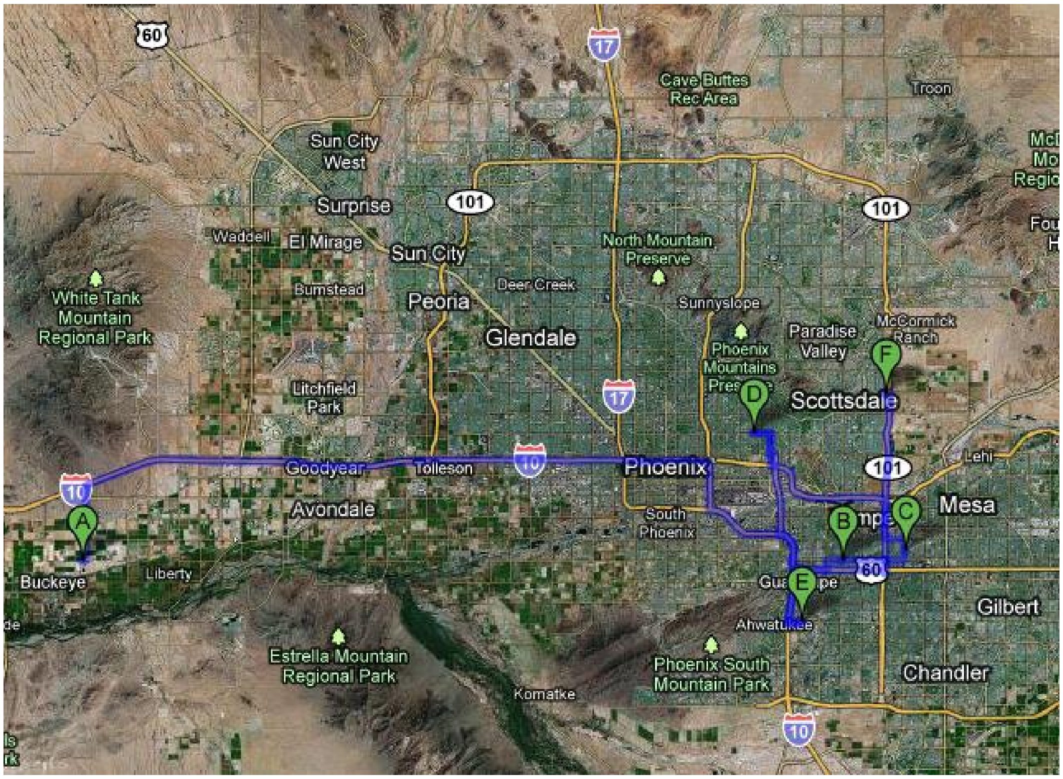


Figure B.4: Regional description of consumable goods supply chain
Industry reference: Walmart
Nomenclature: A - Distribution Center
B, C, D, E, & F - Retail Stores

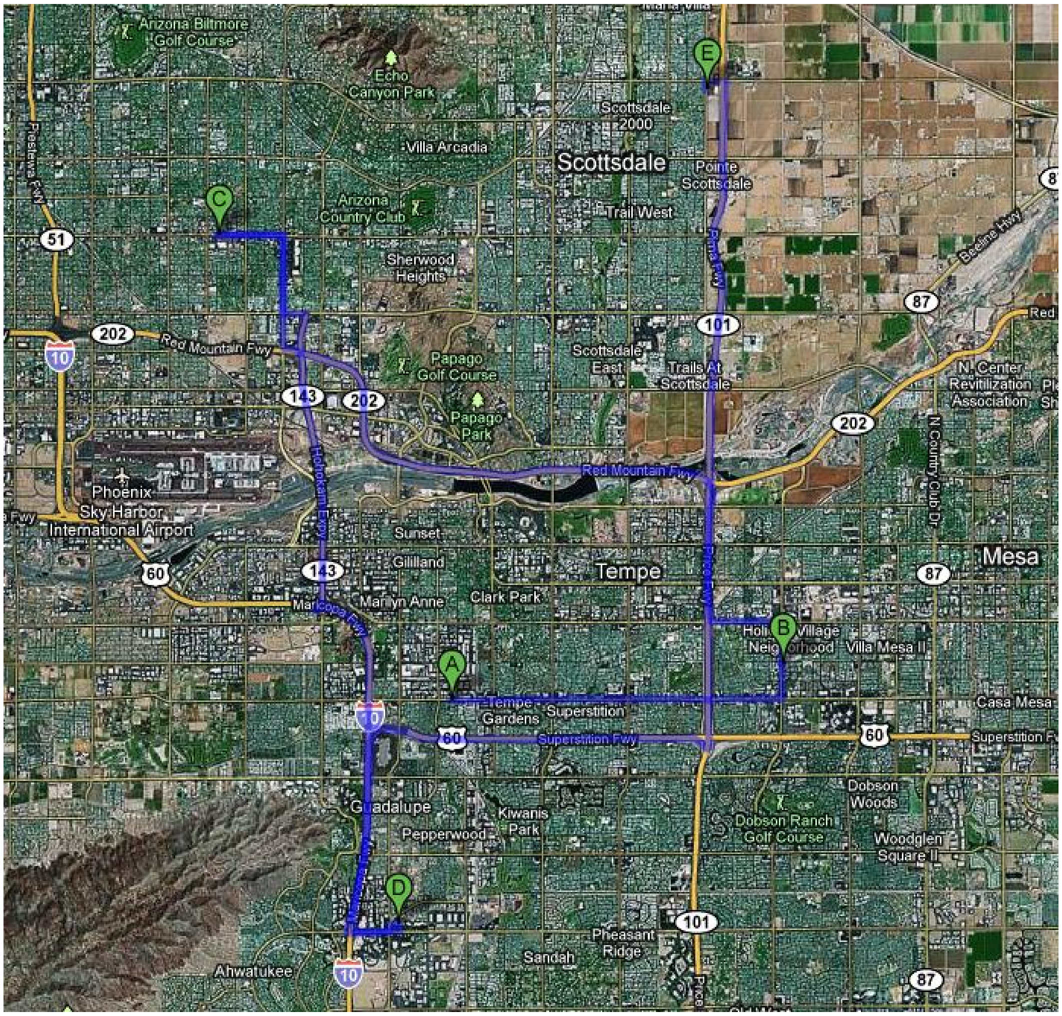


Figure B.5: Local routing detail description for consumable goods supply chain
Industry reference: Walmart
Nomenclature: A, B, C, D, & E - Retail Stores

APPENDIX C

INDUSTRY CALL FOR PARTICIPATION

Modeling energy and carbon dioxide impacts from Lean Logistics & Retailing practices

Opportunity

As part of the Systems Science research initiative, the Sustainability Consortium is conducting research on the energy and carbon dioxide impacts due to lean logistics and retailing practices associated with Consumer Packaged Goods.

While there is a significant amount of research on the operational implications of applying lean philosophy and principles into manufacturing settings, there is no study focused on the environmental performance of lean logistics and the emerging field of lean retailing.

As several organizations adopted lean-oriented inventory management methods such as Just-in-time, Postponement, Cross-docking, and Vendor Managed Inventory over the past two decades they experienced improved process efficiencies and superior economic performance. However, these practices have not been examined from an environmental performance standpoint.

Similarly, current key performance indicators along supply chains focus on short-term objectives while environmental performance metrics require extended operational horizons in order to uncover the cumulative effects of tactical plans executed as part of business strategies from consumer goods organizations. In consequence, our research question is:

Do current best practices in lean logistics and retailing lead to increased environmental performance or do they trade off better cost and delivery performance for higher energy and carbon dioxide impacts?

Company Participation

Given the demand responsiveness, improved cost, and delivery performance behind lean logistics and retailing practices, this research aims to characterize them in a series of simulation models able to capture operational assumptions that could potentially influence their corresponding environmental performance.

A clear challenge for this type of research is the lack of information and data available from state-of-the-art operations to ground and validate these models. Consequently, we reach out to leading organizations that have adopted any of these lean-oriented practices to request their support in informing our parameter development process by sharing general process information from warehousing, transportation, and retailing operations.

Participation in the research consists of a series of semi-structured interviews with selected supply chain and operations managers and personnel. Interviews would be conducted via telephone for convenience. Each interview would last approximately 30-60 minutes. It would also be helpful to examine company policy and guidelines, published initiatives and strategy, and training materials related to lean logistics and retailing practices performed by the organization.

Value

The assessment of energy and carbon dioxide impacts from current lean logistics and retailing practices represents a strategic piece of information in order to examine and develop key performance indicators able to capture the environmental performance of core processes from Consumer Packaged Goods organizations.

The implicit ability to test potential scenarios for Just-in-time, Postponement, Cross-docking, and Vendor Managed Inventory practices provides a critical opportunity to identify and assess environmental improvement areas along the supply chain while maintaining strategic awareness of their corresponding economic implications.

By considering warehousing, transportation, and retailing operations in this simulation-based research, it is possible to obtain greater insights about the interactions between lean processes and its supporting built and mobile infrastructure. In addition, a study of this nature can provide a deeper understanding of the environmental implications due to top customer service levels driving core organizational processes.

A systems view of the collective environmental performance of lean practices across warehousing, transportation, and retailing stages of the supply chain can better inform decision-making processes toward corporate and product sustainability.

Contact Information

If interested in participating, or to learn more details of the project, please direct inquiries to the persons below:

Marco Ugarte, PhD Student and Research Lead

Gustavo.Ugarte@asu.edu

Dr. Kevin Dooley, Research Advisor and Consortium Co-Director

Kevin.Dooley@asu.edu

Dr. Jay Golden, Research Advisor and Systems Science Working Group Coordinator Jay.Golden@duke.edu

APPENDIX D

A DISCRETE-EVENT SIMULATION MODEL FOR LEAN LOGISTICS AND RETAILING

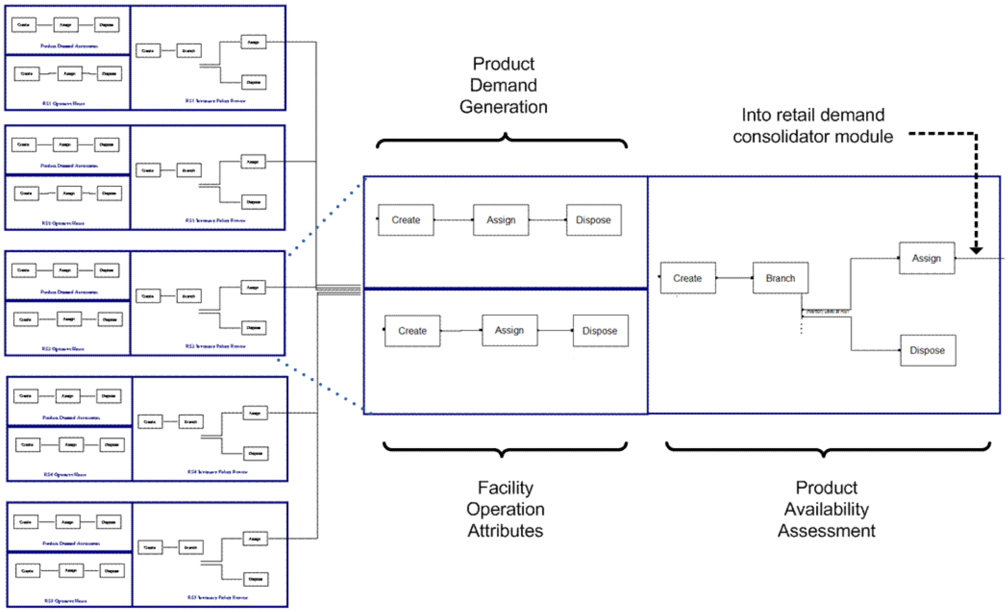


Figure D.1: Retailing domain sub-model.

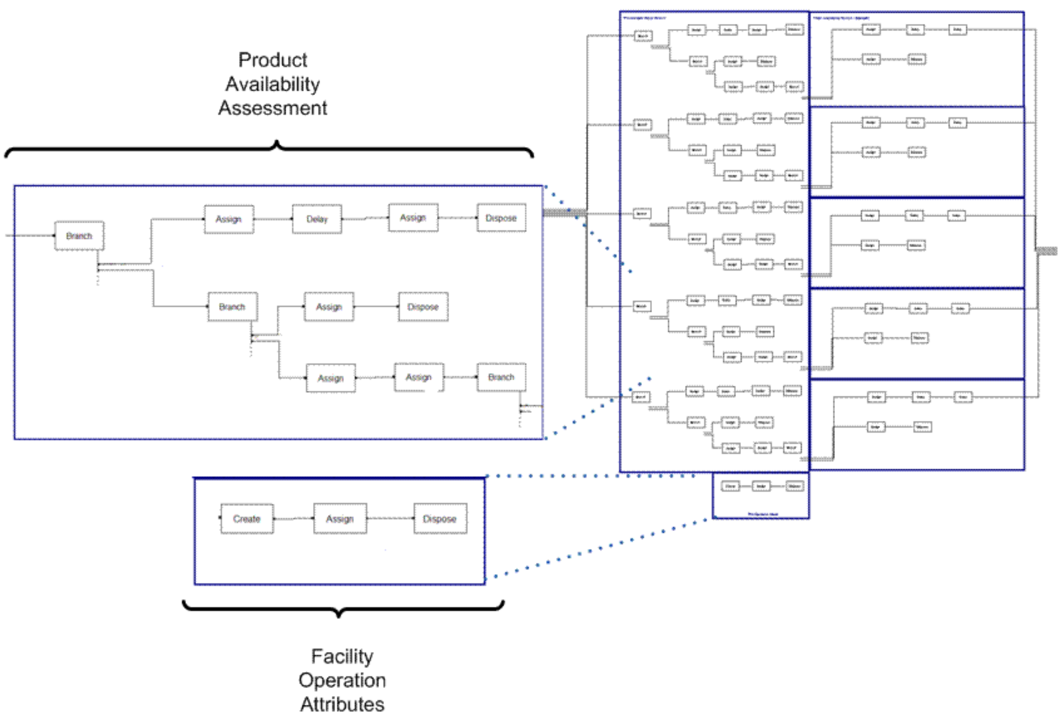


Figure D.2a: Warehousing domain sub-model.

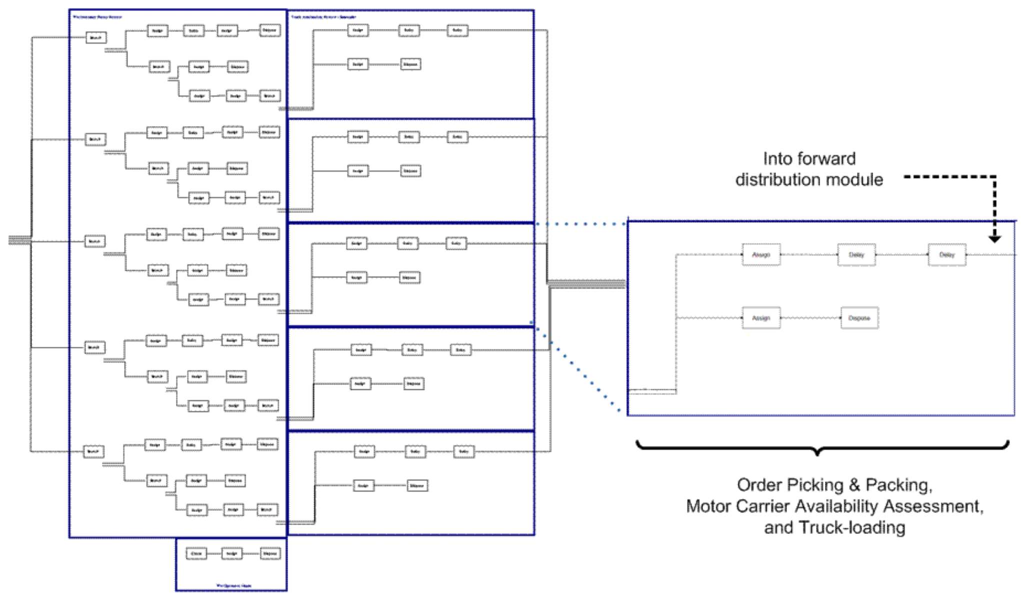


Figure D.2b: Warehousing domain sub-model.

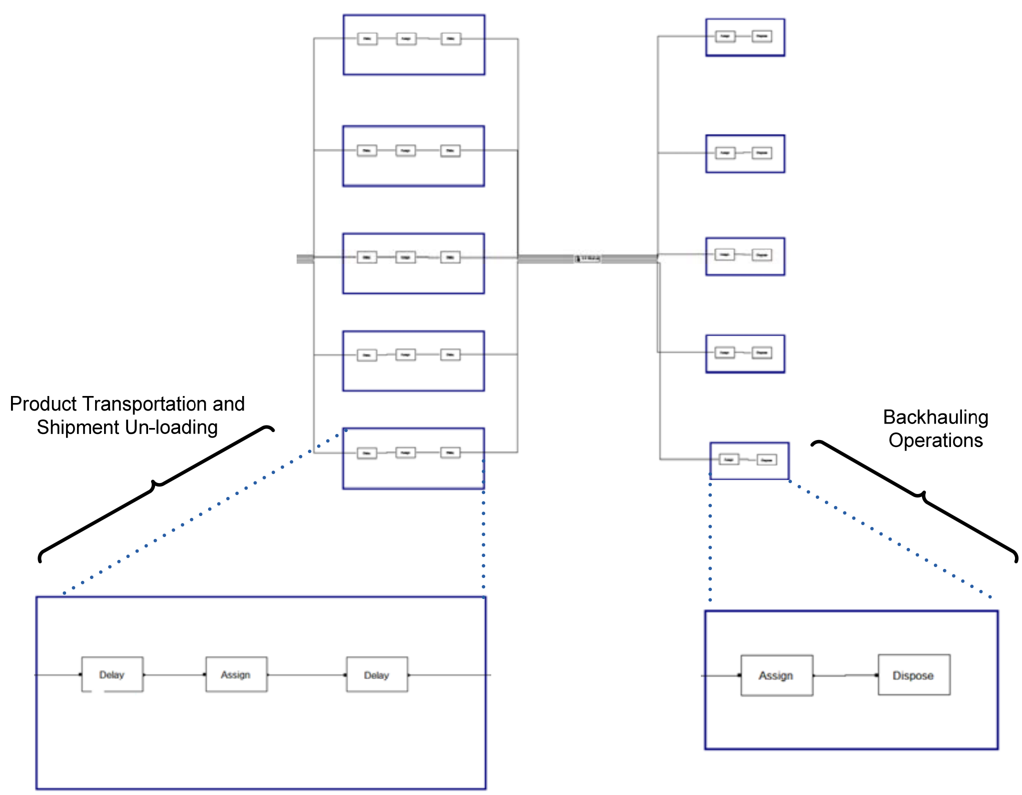


Figure D.3: Transportation domain sub-model.

BIOGRAPHICAL SKETCH

Marco Ugarte was born in Mexico City on March 18, 1981. He received his elementary education from the English College Elizabeth Brock, where he also completed middle-school studies. In 1996, he entered to Tec de Monterrey through a High School scholarship. Upon receiving a B.S. in Industrial and Systems Engineering and a M.E. in Quality and Productivity Systems from the same institution in 2003 and 2005 respectively, he joined the Industrial and Systems Engineering Department as Assistant Professor. Since 2001, Marco has been an active member for APICS, The Association for Operations Management. Holding leadership positions at the regional and national levels in Mexico and the United States respectively, he has been designated Certified in Production and Inventory Management (CPIM) and Certified Supply Chain Professional (CSCP). In 2008, Marco entered the School of Sustainability at Arizona State University to pursue his doctoral studies as a Conacyt Fellow. He was a Research Associate for the EPA National Center of Excellence and The Sustainability Consortium throughout his academic program.