

Kersten, Wolfgang (Ed.); Blecker, Thorsten (Ed.); Ringle, Christian M. (Ed.)

## Proceedings

# Sustainability in Logistics and Supply Chain Management: New Designs and Strategies

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**Wolfgang Kersten, Thorsten Blecker and  
Christian M. Ringle (Eds.)**

# **Sustainability in Logistics and Supply Chain Management**



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*(Editors)*

**Sustainability in Logistics  
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New Designs and Strategies

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# Preface

The HICL-Conference celebrates its 10th anniversary, indicating major interest in the research fields of supply chain management and logistics. Thanks to the large number of outstanding research contributions to this year's conference, the proceedings comprise of three volumes. They are dedicated to make recommendations for new approaches and solutions that enable companies to cope with current and future challenges in supply chains and logistics.

The second volume of the 2015 conference provides valuable insights into the highly relevant topic of sustainability in logistics and supply chains. Contributions concern achievement of sustainability and application of sustainability concepts in various supply chains.

We would like to thank the international authors for making this volume possible. Their research papers contribute to logistics and supply chain management research. This book would not exist without good organization and preparation. We would like to thank Niels Hackius and Irene Sudy for their efforts to prepare, structure, and finalize this book. We would also like to thank Pascal Freigang, Beverly Grafe, Julian Schäfer, and Henning Schöpfer for their contributions to the print layout.

Hamburg, August 2015

Prof. Dr. Dr. h. c. Wolfgang Kersten  
Prof. Dr. Thorsten Blecker  
Prof. Dr. Christian M. Ringle





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I.  
Sustainability  
Achievement  
in Supply Chains



# Closed-Loop Supply Chains for Cradle to Cradle Products

*Katharina Kalogerakis, Viktoria Drabe, Mugundan Paramasivam and Cornelius Herstatt*

As attention around environmental sustainability themes is increasing, a multiple attribute environmental sustainability philosophy called Cradle to Cradle (C2C) has recently been developed and presented. The C2C concept provides a new vision of environmental sustainability to companies, to do “more good” to the environment rather than “less bad”. An important and central aspect is to eliminate the concept of waste by closing technical as well as biological cycles.

The aim of this paper is to analyze which factors from closed-loop supply chain management can facilitate the realization of the technical cycle of C2C certified products. Based on six case studies of different companies, we investigate which factors of existing closed-loop supply chain concepts are critical for the C2C technical cycle. Altogether this research links the theory of closed-loop supply chains to the concept of C2C and provides new insights concerning successful implementation of the technical cycle.

**Keywords:** Cradle to Cradle, Product Recovery, Closed-loop Supply Chain, Sustainability

## 1 Introduction

Sustainability and environmental themes are receiving much attention in all kinds of communities and forums around the world (Bjørn and Hauschild, 2013). In order to deal with increasing waste and pollutions as well as scarcity of natural resources the concept of a circular economy gains popularity (Ellen MacArthur Foundation, 2012, 2013, 2014). Based on the general theory of circular economy, the US-American architect William McDonough and the German chemist Michael Braungart introduced a multiple attribute environmental sustainability philosophy called "Cradle to Cradle" (C2C) through their book "Cradle to Cradle - Remaking the way we make things" (2002).

C2C is a relatively new sustainability approach that is opposite to the familiar and traditionally followed cradle to grave paradigm in which resources are extracted, used and disposed of (Bolus et al., 2013, McDonough and Braungart, 2002). Cradle to cradle reflects an idea in which the materials are treated as resources and flow perpetually in a cyclical metabolism without losing their quality (Braungart et al., 2007). In order to realize this circular industrial system, it is necessary that the material flows are redirected and do not end at waste disposal sites (Braungart et al., 2007). This redirection of material flows can be enabled by closed-loop supply chains and reverse logistics.

The aim of this paper is to analyze which factors from closed-loop supply chain management can facilitate the realization of the technical cycle of C2C certified products. Supply chains of six existing C2C products from different companies are investigated. Based on a framework for product recovery, factors of existing closed-loop supply chain concepts are analyzed

concerning their impact on the C2C technical cycle. Altogether, the theory of closed-loop supply chains is integrated into the concept of C2C in order to provide new insights concerning successful implementation. Furthermore, our analysis of C2C supply chains also enriches closed-loop supply chain theory.

In the next section, theories and concepts relevant to this research are presented. This includes the C2C process, closed-loop supply chains and reverse logistics as well as a framework for product recovery in closed-loop supply chains. Section three describes the qualitative research approach chosen. Afterwards, findings of the case studies are presented. The paper concludes with a discussion of results and an outlook on future research.

## **2 Theoretical Foundations**

This section outlines the theoretical background needed to answer the research question. First, the Cradle to Cradle process is explained. Second, the concepts of closed-loop supply chain and reverse logistics are defined. Third, the theoretical foundations are closed with a description of a traditional closed-loop supply chain framework.

### **2.1 Cradle to Cradle Process**

Published in 2002, the book "Cradle to Cradle - Remaking the way we make things" by McDonough and Braungart has introduced a new paradigm of producing and consuming to both academics and practitioners. Today, the concept is widely discussed in different industries and institutes world-

wide (Bjørn and Hauschild, 2013). Furthermore, many companies have implemented C2C standards and achieved a certification for their efforts. Currently, there are more than 150 companies worldwide holding a C2C certificate for over 370 products (Cradle to Cradle Products Innovation Institute, 2015).

The C2C paradigm formulates a new perspective for the development of products and services and is understood as the conceptual counterpart to the cradle-to-grave concept, which in turn frames the take-make-waste economy (Bjørn and Hauschild, 2013, Bolus et al., 2013). "Cradle-to-cradle design enables the creation of wholly beneficial industrial systems driven by the synergistic pursuit of positive economic, environmental and social goals." (Braungart et al. 2007, p. 1343). In line with the shift to a circular economy system, Braungart and McDonough suggest to focus on eco-effectiveness instead of eco-efficiency, which is the more common concept representing the target of reduced emissions and decrease of negative externalities (Huesemann, 2004). Ultimately, through eco-effectiveness C2C aims for a "transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth" (Braungart et al. 2007, p. 1338). This shift from efficiency to effectiveness leads to a redefinition of waste (Bjørn and Hauschild, 2013, McDonough and Braungart, 2013). Hence, it can be said that companies following the C2C process adopt a holistic approach towards environment and society in order to do 'more good' rather than 'less bad'.

The three key pillars of the C2C paradigm are: (1) Waste equals food, (2) Use current solar income and (3) Celebrate diversity (McDonough et al., 2003).



These principles are complemented by the idea of two cycles (called metabolisms) which integrate either biological or technical nutrients in a cyclical flow (see figure 1). The focus of this research effort is on the technical metabolism which addresses products that are not compostable or natural but can be ideally disassembled after their use phase. The materials that are circulating within this cycle are regarded as technical nutrients and are intended to remain in the cyclical system endlessly without any loss of quality (Braungart et al., 2007, El-Haggar, 2007). Some of the most prominent examples of products processed in such technical cycles are office chairs designed and produced by Herman Miller or Steelcase (Braungart and McDonough, 2011, Rossi et al., 2006).

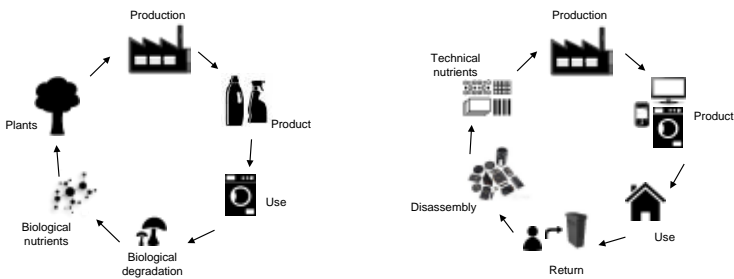


Figure 1 The biological and technical cycle (adapted from EPEA, 2010)

## 2.2 Closed-Loop Supply Chain and Reverse Logistics

At the beginning of this millennium attention on closed-loop supply chain research was increasing (Savaskan et al., 2004). The growing interest in this topic is also illustrated by the literature review of Govindan et al. (2015) which is based on 382 papers published between 2007 and 2013.

A business definition of closed-loop supply chain management is provided by Guide and van Wassenhove (2009, p.10): "Today we define closed-loop supply chain management as the design, control, and operation of a system to maximize value creation over the entire life-cycle of a product with dynamic recovery of value from different times and volumes of return over time." A closed-loop supply chain can be divided into forward supply chain activities and additional reverse supply chain activities (Govindan et al., 2015, Guide et al., 2003).

Closed-loop supply chain management deals in general with three types of returns (Guide and Van Wassenhove, 2009): (1.) Commercial returns are sent from consumers to the reseller within a limited period after purchase. (2.) End-of-use returns are usually due to technical upgrades entering the market. (3.) End-of-life returns occur when the product can no longer be used or is obsolete. In order to deal with these different types of product returns several activities need to be managed. Reverse logistics covers the acquisition of the product from the consumer, disposition activities as sorting, testing and grading, remanufacturing/ repair as well as remarketing of the recovered product (Guide and Van Wassenhove, 2002, 2009). Similarly, Fleischmann et al. (2000) describe collection, inspection/ separation, re-

processing, disposal and re-distribution as essential steps in a product recovery network. Transportation and storage is needed to link these steps to a reverse supply chain.

Closed-loop supply chains and reverse logistics are an important part of the C2C approach. Since it works on the principle of "Waste equals Food", returned products serve as input either to the technical or the biological metabolism. In consequence, reverse logistics play a pivotal role in moving the end-of-life or end-of-use products (waste) from their point of consumption to points of refurbishment and redistribution as an input material (food) in the technical recovery cycle. It can be expected that the concepts and solutions discussed as closed-loop supply chains and reverse logistics help to understand and manage the technical C2C metabolism. In order to adapt closed-loop supply chain characteristics to a company-specific environment, a framework is suggested in the following section.

### **2.3 Framework for Product Recovery in Closed-Loop Supply Chains**

In their work "A Framework for Reverse Logistics" de Brito and Dekker (2004) elaborate a detailed content analysis of reverse logistics issues. They use a definition of reverse logistics originating from the European Working Group on Reverse Logistics (REVLOG): "The process of planning implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal." (De Brito and Dekker 2004, p.5) Although they focus on the value adding streams of reverse logistics, they emphasize the fact that reverse logistics can contribute to

sustainable development, but should not be seen as an equivalent to green logistics (de Brito and Dekker, 2004). Hence, their framework seems to be the ideal basis for merging C2C and reverse logistics concepts as is the aim of this paper. Furthermore, its holistic perspective addressing the questions "why, what, how, who" constitutes a fertile basis for qualitative case studies. They themselves also used their framework for case study analysis in a subsequent publication (de Brito et al., 2005). Based on the general questions raised in their framework, the following attributes are relevant for our research and investigated in detail:

1. Why are products returned?
  - Drivers
  - Reasons for returns
2. What is returned?
  - Product Characteristics
3. How does reverse logistics work in practice?
  - Collection strategies
  - Recovery methods
4. Who is acting in reverse logistics?
  - Actors

### 2.3.1 Drivers

Normally it can be said that companies involve in product recovery because of direct and indirect economic gains, legislative reasons or to improve their corporate citizenship (de Brito and Dekker, 2004).

Direct economic gains occur, for example, if companies take advantage of usable parts of returned products in the process of production. Thereby,

they decrease incurred costs for new raw material supplies. Indirect economic gains can result from an improved image of the company. As consumers are increasingly aware of environmental concerns, they appreciate companies that act environment friendly. Hence, companies are able to decrease costs and improve the image of the company (Akdoğan and Coşkun, 2012, Carter and Ellram, 1998, de Brito and Dekker, 2004).

In some cases companies are involved in product recovery due to legislation which mandates them to recover its products or take them back after use (de Brito and Dekker, 2004). Prominent examples are the End-of-life Vehicles Directive (ELV) or Waste Electrical and Electronic Equipment Directive (WEEE) launched by the European Commission. Corporate citizenship programs are used by companies to express that they care for the society including environmental issues, diversity, safety and human rights (Carter and Jennings, 2002). These programs in turn are expected to increase indirect economic gains of the company by an improved reputation.

### 2.3.2 Reasons for Return

De Brito and Dekker (2004) distinguish between returns that occur due to the distribution network (e.g. recall or commercial returns), manufacturing returns (e.g. faulty products and left overs) and customer returns due to services, guarantees or end-of-life of the products. For our analysis of C2C closed-loop supply chains, it is sufficient to apply the rather broad classification of 'end-of-use' and 'end-of-life' returns.

Returned products which are no longer used by the original owner, but for which a new customer can be found, are categorized as end-of-use returns.

These products might need some repair or remanufacturing, but can be re-introduced to the market. When a product is returned, because it has no remaining use and no new customer can be found, in contrast to the above definition, it has reached the end of its life. Value assessment of end-of-life products is only based on their materials (Guide and Van Wassenhove, 2009, Krikke et al., 2013).

### 2.3.3 Product Characteristics

Due to the focus on what happens with products after their use phase or their end-of-life, characteristics of the product are of special relevance, i.e. the product's material composition, its recovery potential and the use patterns of consumers during the product life. The product's composition covers aspects that are relevant for the transport of the product and its disassembly, such as product size and the number of components as well as the manner how the components and materials are compound (de Brito and Dekker, 2004).

The factors determining the recovery potential of a product, its deterioration characteristics, are as well a critical attribute. There are three kinds of potential deterioration, intrinsic, economic and homogenous. The first one addresses whether the product ages during the use phase. The economic perspective regards the monetary value and how fast it decreases. The homogeneity covers the question whether the components of the product are subject to equal aging or value decrease processes (de Brito and Dekker, 2004).

How and where the product is used also substantially influences the possibilities of reverse logistics. The use patterns may vary with regards to the

location, duration and intensiveness. Furthermore, the user might be an individual customer or a large corporate business (de Brito and Dekker, 2004).

All these factors have to be considered when developing a product recovery system. In particular, for the recovery of Cradle to Cradle products, the material composition, for example, is important and should ideally be addressed during the product development phase as in this stage toxic materials could be replaced by non-hazardous materials and the components could be composed in a way that facilitates easy disassembly (Braungart et al., 2007, Rossi et al., 2006).

#### **2.3.4 Collection Strategies**

Collection strategy refers to the process in which the used products are collected from the consumers and brought to a place for further processing. Collection encompasses auxiliary activities like transporting and storing for further processing. Aras et al. (2010) distinguish two main collection strategies: Drop-off strategy and pick-up strategy. In a drop-off strategy the customer is more actively involved in returning the product to some kind of collection point for used products. Otherwise, a pick-up strategy involves additional actors (producer/ retailer/ third party) in the collection process. Furthermore, three different basic collection models can be characterized based on the actors involved. (1) In the model-M the manufacturer directly collects from the consumer without the involvement of other parties. (2) In the model-R the retailer is active at the interface between manufacturer and consumer. The retailer collects the used products from the consumer and afterwards sells them to the manufacturer. (3) In the model-3P, finally,

another third-party is in charge of the collection process (Kumar and Putnam, 2008, Savaskan et al., 2004).

### 2.3.5 Recovery Methods

Recovery is the last step after collection and inspection/ selection/ sorting processes of the returned products are completed (de Brito and Dekker, 2004, Fleischmann et al., 2000). Different recovery methods can be distinguished. Direct recovery can occur if the quality of the returned product is good enough for reuse, resale or redistribution without further processing. Otherwise, several options of recovery processes are available including repair, reconditioning, remanufacturing and recycling. Finally, if a returned product cannot be reprocessed due to economic or technical reasons, it needs to be disposed (incineration or land-fill) (de Brito and Dekker, 2004, Fleischmann et al., 2000, King et al., 2006).

A good characterization of these four recovery methods is provided by King et al. (2006). From the different options of recovery, the narrowest loop is a simple repair in which specified faults of the product are corrected. Reconditioning requires more work than repair. Major components of the product are rebuilt, but altogether the quality of the reconditioned product is expected to be less than the quality of a newly manufactured product. In contrast, remanufactured products are supposed to reach the quality of the originally manufactured product with the same warranties. For example, in the 1990s Xerox established remanufacturing facilities for their photocopiers in several countries (King et al., 2006).



Recycling is the process in which the product is recovered at material level. Out of the recovered material new products and components are manufactured. Products to be recycled are dismantled and sorted and processed to recover raw materials (Thierry et al., 1995). Although this is the most widespread recovery method, more energy is needed for recycling compared to the other three recovery methods (King et al., 2006). The choice of an adequate recovery method depends on the quality of the returned product, but also on general product characteristics. An overview of different practices of recovery methods for diverse industries is given in Flapper et al. (2005) or Ferguson and Souza (2010).

Since C2C works on the principle "Waste equals Food", recovery methods are essential to transform the supposed wastes into raw materials for other processes. In this context a distinction between upcycling and downcycling is made. If the recycled material is recovered back into material of at least the same level of quality, then this process is called upcycling. Otherwise, if the product is recycled in such a way that the material recovered is of inferior quality and consequently production of the same high quality product is not possible, this process is called downcycling. In short, upcycling enables materials to retain their status as resources and downcycling just delays dumping of the material at landfills or incineration. In order to create cyclical Cradle to Cradle metabolisms it is necessary to upcycle the products rather than to downcycle (Braungart et al., 2007, McDonough and Braungart, 2002).

### 2.3.6 Actors

Diverse actors can be involved in reverse logistics of closed-loop supply chains. Depending on the specific processes chosen for collection, recovery and redistribution different actors appear (de Brito and Dekker 2004). For example, looking back at the collection strategies, manufacturers, retailers and/or third parties can be involved. Furthermore, also the customer is an important actor in reverse logistics. He either needs to return the used product or to initiate other collection processes when the useful life of the product ends for him.

Finally, also governmental institutions can play an important role in reverse supply chain management. As described above, legislation can drive companies to initiate reverse supply chains and can also influence the choice of product recovery strategies.

## 3 Research Approach

Based on the theoretical foundations built in the previous chapter, our research aims to identify factors influencing the reverse supply chain of C2C products. Since this is an explorative form of research, a qualitative research method is chosen. Qualitative research can be done in several ways which include ethnography, grounded theory, narrative analysis, case study analysis etc. (Guest et al., 2013). According to Yin (2003), case study analysis is an appropriate method, if the investigator cannot exert control over the phenomenon and if the focus of the research question is contemporary. Hence, we chose this approach to study C2C closed-loop supply chains.

The method of sampling involved in this research is purposeful sampling. According to Patton (1990, p.169) "the logic and power of purposeful sampling lies in selecting information-rich cases for study in depth". Information-rich cases are the ones from which the researcher can learn a lot regarding the central research question. Altogether six cases were selected based on two criteria as follows:

1. The company should have C2C certified products in its portfolio
2. The company should be involved in the take back and recovery of the same.

Data collection was preliminarily done from resources and documentations available online, for example company websites, annual reports, sustainability reports etc. Furthermore, four telephone interviews were conducted to receive more detailed information.

The following table gives an overview of the six cases studied.

Table 1 Overview of the six case studies

Company, Country	Product	Closed-Loop Supply Chain
Van Gansewinkel Groep, Netherlands	Office paper	Confidential documents are collected and shredded upon the request of the customer. Out of this recycled material new office paper is produced by Steinbeis.

---

Company, Country	Product	Closed-Loop Supply Chain
Shaw Industries, USA	Carpet	Old carpets are collected and sent for recycling. The recycled material has the same quality as virgin material. Fibers can be reused as fibers and backings can be reused as backings.
Desso, Netherlands	Carpet	Desso collects used carpets and recycles them to a quality equivalent to that of virgin material using a proprietary technology called Re-finity. Fibers are recycled into fibers and backings into backings
Herman Miller, USA	Office furniture	The responsibility of reverse logistics rests with Herman Miller. Old chairs are collected by Herman Miller without any charge to the customer. If possible, chairs are refurbished and reused. Otherwise, the product is disassembled to the elementary level and then transferred to recyclers to recycle them.

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Company, Country	Product	Closed-Loop Supply Chain
Ahrend, Netherlands	Office furniture	After use the furniture is collected by Ahrend. Then it is decided if it can be refurbished. If the collected furniture cannot be refurbished it is recycled by Van Gansewinkel.
Royal Auping, Netherlands	Mat- tresses	When delivering new mattresses, Auping offers its customers to collect their old mattresses. The used mattresses are further recycled by Retour Matras.

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## 4 Findings

### 4.1 Drivers

Anticipated economic benefits were the major motivating factor, both directly and indirectly, to start C2C innovations in products and processes. In all cases studied, responsible managers were convinced of the positive impact C2C implementation will have for the company as well as for the society as a whole.

Direct economic gains include cost savings from using recycled instead of new materials and cost savings from waste reduction. Indirect economic

gains are, however, also very important. For example, the new environmental attributes of the Mirra chair produced by Herman Miller enhanced its market reception (Rossi et al., 2006). Similarly, Desso's EBIT and percentage of sales increased significantly after implementation of the C2C concept (Crainer, 2012). Hence, indirect economic benefits can result from improved products with a positive impact on consumer's health as well as the environment.

Furthermore, all companies described in the case studies have a time-bound corporate social responsibility (CSR) goal concerning take back programs and closing the production loop. These elements of CSR also improve the image of the company and can lead to economic gains. Since CSR goals are top management decisions, the change towards closing the production loop has to come from within the top management.

Legislation and economic benefits interact. If economic benefits of product recycling are higher than traditional disposal strategies, as it is for example the case with paper recycling, then the need for regulations is usually lower.

Hence, not all analyzed C2C cases are situated in an industry influenced by legislation concerning take-back or disposal of end-of-life products. Only the carpet manufacturers (Shaw Industries and Desso) as well as the mattress manufacturer (Auping) act in domains where legislative disposal restrictions exist. However, their C2C efforts surpass legal requirements. Shaw Industries and Desso are actively involved in the upcycling of carpet returns and Auping plans a future upcycling project of mattress returns. Altogether, legislation can positively influence closed-loop supply chains, if end-of-life products harm the environment irreversibly and their disposal

by traditional means (landfills or incineration) is economically more beneficial than recovery processes.

One concrete example on the empowering role of government are the Netherlands. There, Cradle to Cradle is a widely known topic, which is also evident by the numerous examples of C2C products coming from the Netherlands. The Dutch government introduced the National Environmental Policy Plan (NEPP) already in 1989. This plan calls for shared responsibility due to new ambitions and lack of confidence in traditional approaches (Bressers and de Bruijn, 2005). Furthermore, the Dutch government is working with various stakeholders from knowledge institutes, business sectors and social organizations to implement a Policy Document on raw materials which would present a holistic Dutch strategy for raw materials. One of the agenda points of the policy is the closing of cycles by promoting reuse and recycling (Van Gansewinkel, 2011).

## 4.2 Reasons for Returns

End-of-use returns appear in the two case studies dealing with office furniture supply chains (Hermann Miller and Ahrend). In these cases the C2C products can be disassembled into sub-assemblies. Fleischmann et al. (2000) classify this kind of supply chain as an assembly product remanufacturing network in which the products can be disassembled into individual components. Therefore, it can be concluded that for companies dealing with products which can be disassembled into components repair, reconditioning and remanufacturing are valuable options. In the other cases, only recycling can be used to close the production loop. In these cases end-of-use returns can be compared to end-of-life returns. Hence, the carpet,

mattress and paper manufacturers only focus on recycling the product either themselves or with the help of partners in their reverse supply chain.

### 4.3 Product Characteristics

The influence of product characteristics on product recovery put forward in the theories of supply chain management is relevant for C2C reverse supply chains, too. Based on our case study analysis the ease of disassembly as well as homogeneity and recyclability of materials seem to be important factors that need to be addressed in the design phase of the product. The cases of carpet supply chains show that ease of disassembly, homogeneity and recyclability of materials are important characteristics to recover old carpets. In the paper supply chain homogeneity of the collected old paper also impacts the quality of the newly recycled paper. Therefore it can be concluded that in order to use product returns as raw material in the same supply chain, recyclability of used materials is a very important aspect. Furthermore, homogeneity of materials and ease of disassembly positively influence product recovery within the same supply chain. The example of Herman Miller points out how important the ease of disassembly can be for the product recovery process. In the course of C2C implementation, they assessed the potential to disassemble the returned product according to different aspects. One aspect was the possibility to disassemble the product using simple tools, such as screwdrivers, in less than 30 seconds (Rossi et al., 2006).



#### 4.4 Collection Strategies

The pickup collection strategy is used in all cases discussed. Based on our findings, it seems to be the most suitable collection strategy for Cradle to Cradle closed-loop supply chains. The collection of used C2C products from the consumers is influenced by three factors: (1.) financial incentives, (2.) level of information and awareness and (3.) level of convenience. Financial incentives are given only indirectly by collecting the product from the consumer without any cost and thereby reducing disposal costs for the consumer. None of the companies pays the consumer for the returned products. Information about the take back program and recovery methods are communicated to the consumer. Only if the consumer is aware about recovery processes and positive effects for him and the environment, he is able to participate. Besides, the take back programs are made as convenient to the consumer as possible by reducing efforts of customers due to collection of the used products. For example, customers of Desso just need to stack the old carpet tiles in a pile which is perceived as a minimal effort from the interviewee. In the case of Van Gansewinkel office paper, the discarders of old paper just need to drop their used paper in an exclusive container specifically provided by Van Gansewinkel for the collection of confidential information. And in the case of Auping, in order to enhance the convenience of the customers, old mattresses are collected when new ones are delivered.

## 4.5 Recovery Methods

The cases discussed clearly show that products are recovered following traditional reverse logistics steps including collection, inspection, sorting and recovery. As long as materials can be recycled, disposal activities are not found in any of the cases.

Looking at the choice of recovery methods introduced in section 2.3.5, only two of the analyzed cases are involved in recovery methods other than recycling. The manufacturers of office chairs Hermann Miller and Ahrend also repair and recondition the returned chairs if possible. For example, often upholstery of the chair is sufficient in order to resell it. In contrast to the other C2C products analyzed, the office chairs are the only products that can be disassembled. Hence, this exemplifies how product characteristics influence the recovery process.

As already explained, C2C theory distinguishes between upcycling and downcycling of materials. Only upcycling enables endless technical cycles of material reuse. In downcycling processes, although materials are recovered they are not of the same quality as new materials and their final disposal is only delayed. Looking at the cases, it becomes obvious that companies still struggle to realize true upcycling processes. However, Shaw Industries, Desso and Van Gansewinkel use recycled materials actually within the same production cycle. Desso and Shaw Industries have developed their own proprietary technology for separating the fiber from the carpet backing in order to upcycle these materials for their own production process. The paper manufacturer Steinbeis, partnering with Van Gansewinkel in the office paper case, developed an environmental friendly de-inking process to upcycle the collected waste paper (Océ, 2011). Hence, upcycling

often only becomes feasible with the advent of new technologies. As not every component of a returned product can be recycled, sorting and separating process are crucial and influence technologies needed for product recovery.

Auping on the contrary designs its C2C mattresses to ensure recyclability, but so far does not use recycled materials for their new mattresses. Similarly, Hermann Miller and Ahrend give away the sorted materials of their disassembled chairs to external recycling companies, if the chairs cannot be refurbished. Hence, these materials do not stay within the same supply-chain cycle, but recyclability in general is aimed for.

## 4.6 Actors

Three scenarios can be found in the analyzed cases of C2C closed-loop supply chains:

1. Manufacturers involved in recovery themselves
2. Manufacturers partnering with recyclers in the recovery process
3. Only third-party recyclers involved in recovery

Only Shaw Industries, the world's largest post-consumer carpet recycler, closes the material loop itself without the need of external recycling companies. The office furniture manufacturers Hermann Miller and Ahrend as well as the carpet manufacturer Desso involve external recycling companies into their reverse supply chains. For instance, Aquafil manufactures yarn for Desso from the semi-processed collected used carpets. In the cases of office furniture (Ahrend and Hermann Miller), the manufacturer itself is involved in the refurbishment process when the product is returned due to

end-of-use reasons. But after internal testing and sorting of returned products, parts that cannot be refurbished are passed on to external recycling companies. And the Van Gansewinkel group, a large recycling company from the Netherlands, chose Steinbeis as a manufacturing partner to produce C2C paper. Hence, in four out of six cases collaborations between manufacturers and recyclers enabled closed-loop supply chains. Auping on the contrary is neither involved in collecting, sorting nor recycling of returned mattresses.

It is also important to note that all analyzed case companies cooperate with EPEA (Environmental Protection Encouragement Agency) or MBDC (McDonough Braungart Design Chemistry), the US-American equivalent to EPEA in Europe. These firms support the companies that are striving for C2C implementation and certification with necessary know how on materials and processes. In all cases, these partners were necessary to design the products and develop their supply chains. Moreover, the collaboration with suppliers is facilitated by these partners as EPEA and MBDC can sign non-disclosure agreements with the companies' suppliers and thus get access to data on materials and compositions which the suppliers would usually not like to reveal to the manufacturers due to confidentiality concerns.

One other important actor is the customer of the product who, in all cases, is needed to make the closed-loop supply chain work. In all case studies it was observed that the customer needs incentives, either in the form of financial benefits or high convenience, in order to participate in the return process of the purchased products. These benefits can also result from an additional service offered, as for example the paper shredding in the Van Gansewinkel case. Moreover, the customer influences recycling operations.

If for example in the case of Auping, the customer does not return a dry mattress, the material loses its value and cannot be recycled properly. Furthermore, the customer can facilitate the recovery process through his decision to either buy or lease the product. A leasing option is for example offered by Desso. Therefore, informing the customer about the return process and his role in it is critical for companies which want to establish a C2C closed-loop supply chain.

#### **4.7 Summary of Findings**

Based on the above discussions factors influencing the closed-loop supply chain of C2C products processed in technical cycles are identified. An illustration of the coherences is provided in figure 2. It complements the original technical C2C metabolism (see figure 1) presented in section 2.1 with strategic factors relevant at different points of the cycle.

As depicted, economic gains, legislation, and corporate social responsibility influence the actors' involvement in the technical cycle of C2C products. Product characteristics are crucial to enable closed-loop supply chains. Especially material composition and recovery potential of the whole product are issues that need to be addressed in the early phases of the product development and hence influence the production.

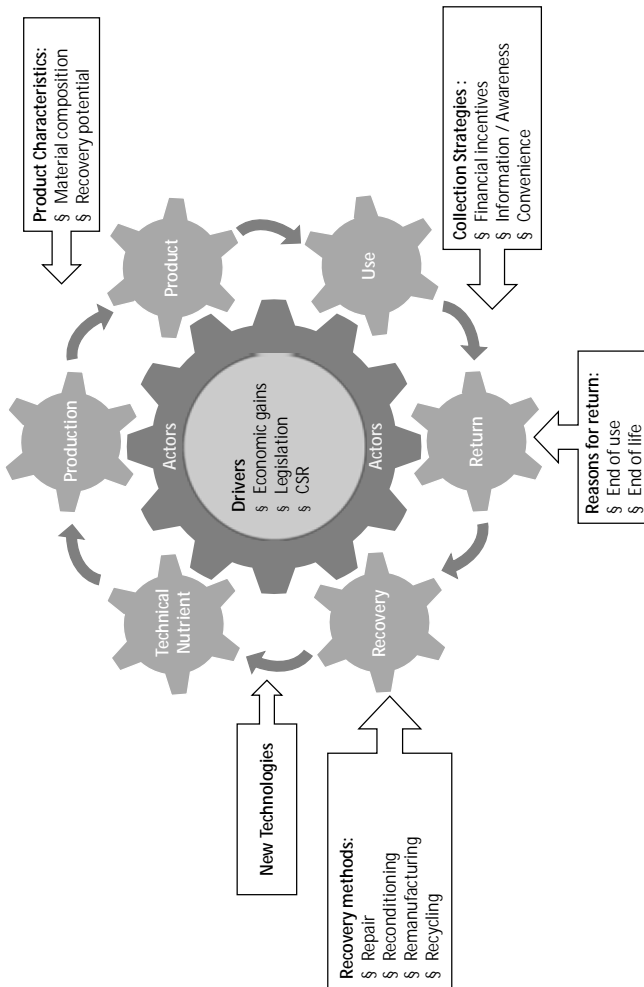


Figure 2 Factors influencing the supply chain of C2C products in the technical cycle (own illustration)

In order to retrieve the used product from the consumer, product collection strategies need to be available. So far, indirect financial incentives and convenience factors for consumers are provided in order to assure the return of used products. Furthermore, the consumer needs to be aware of collection and recovery processes. Insufficient information at this point will result in loss of materials. Products are either returned due to end-of-life or end-of-use reasons. For products that can be disassembled and are returned after the end of their use phase the most valuable recovery methods are repair, reconditioning and remanufacturing. In all other cases, product recovery is implemented as a recycling process in which the product is converted into technical nutrients. Here, in order to reach upcycling instead of downcycling new technologies play a significant role in closing the loop. The objective is to obtain technical nutrients that can eventually be re-used in the production of new products in the same or different supply chain without a significant loss of quality.

## 5 Conclusion

Theories of closed-loop supply chain management and reverse logistics can be used to expand the C2C product recovery concept. In the presented work, critical factors of closed-loop supply chains have been identified for C2C products on the basis of a product recovery framework. Based on six case studies, the identified factors can guide managers in implementing a technical cycle system for C2C in their companies. Those companies that are already pursuing closed-loop supply chain methods seem to be very well equipped for the implementation of C2C standards. Elements of

closed-loop supply chains such as product characteristics or collections strategies can valuably enrich the perspective on a technical cycle for C2C products and hence make it easier to realize. Furthermore, the C2C cases offer an additional perspective for closed-loop supply chain theory by providing evidence from companies that are engaged in sustainability. Although direct as well as indirect economic gains are a major driver for C2C implementation, usually fundamental change processes are needed. Hence, support from the top management is decisive for success.

As the main findings of this research are based on the limited number of six cases, results need to be assessed carefully in order to draw conclusions for different settings. Especially as product characteristics seem to play a critical role influencing the design of closed-loop supply chains, further research is needed to verify these first findings presented. Hence, C2C products from different industries should be analyzed to generalize or differentiate our results. Furthermore, as we only provided an overview of critical factors, further research could provide important insights on certain details of C2C closed-loop supply chains, for example on collection strategies or recovery methods.



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# Building Sustainability into the Value Co-creation in Supply Chains

*Claudine Soosay*

This study investigates the sustainability initiatives implemented by various firms in a food supply chain in relation to the value creation activities. As there is increasing interest on how organizations, particularly focal firms, instill or drive sustainable efforts among partner firms in the supply chain, we aim to derive a deeper understanding of how both sustainability strategies and value propositions are inter-related. A qualitative, exploratory case study is employed to address various operations and initiatives evident among firms in a single supply chain in Australia to gain deeper insights into their activities and management approach; and also to understand the context and motivations for sustainability implementation. Our findings depict that sustainability provides both tangible and intangible benefits alongside with enhanced operations. While the rewards are deemed as marginal upstream, it is the downstream players that reap most of these benefits and enhanced reputation. It is well known that focal firms drive sustainable practices in their supply chains for strategic reasons and to enhance value. However the collaborative co-creation of value along the chain requires a focus on achieving both firm and stakeholder value propositions as well as optimal outcomes for all.

**Keywords:** Sustainable Supply Chains, Value Co-creation, Case Study, Resources and Capabilities

## 1 Introduction

The importance of sustainability in today's new global business environment is recognized as a core capability and means to competitiveness. Many organizations have realized that sustainability requires an integrated approach involving various firms in the supply chain. New business models have been developed, which require that firms should seek to optimize value rather than attempt to maximize the value delivered to any one set of interests. These business models factor in the dynamics of supply chains warranting for strategic relationships in enabling sustainability at the inter-organizational level. This involves firstly, long-term relationships that reduce opportunistic behaviors and that reinforce mutual trust; secondly, significant specific investments by organizations that indicate commitment to collaboration and a willingness to cooperate; and thirdly, clear and unambiguous distinctiveness of partner competencies and a balanced integration of them (Baglieri and Zamboni, 2005).

It is established that sustainability can be more effectively implemented with focal firms championing and driving the efforts of their supply chain members both upstream and downstream. This is because they are held accountable for both the social and environmental impacts evident in the chain and are compelled to make decisions and actions governing their supply chain partners (Ciliberti et al, 2008). Therefore, the visible actions and behaviors of focal firms depict what the firm values in the eyes of consumers and stakeholders. Their proactiveness and other awareness building mechanisms (such as in the form of policies, mission statements, internal awareness, communication, training programs, ethical and environmental reporting), could serve as a means to instill supply chain partners

to embrace similar sustainable actions or best practices in sustainability (Gallear et al, 2012). Additionally, there are stakeholders (including consumers) who pressure firms to ensure and report environmentally and socially responsible behaviors along the supply chain. This can be addressed through various measures, such as documenting partner firm requirements, monitoring their performance and compliance; and further engaging in activities building sustainability awareness among firms in the supply chain (Jamison and Murdoch, 2004). Underpinned by the service dominant logic (SDL) to conceptualize value co-creation among firms and the stakeholder theory, this study investigates the sustainability initiatives implemented in a food supply chain based in Australia. It is motivated by a central research question, 'How do firms instill sustainability in their supply chains; and how do these relate with the co-creation activities that enhance value for businesses in the long-term?'

We seek a deeper understanding of the outcomes faced in embedding sustainability practices in supply chain partners. There is growing interest on how organizations, particularly focal firms, facilitate or drive such initiatives among partners. We investigate this in the context of knowledge and capabilities transferred between the business to business (B2B) interactions in the supply chain. Key processes have been identified as contributing to firm-level capabilities; the capacity to identify opportunities and the ability to facilitate changes in operations or processes that results in a sustainable supply chain.

## 2 Literature Review

Supply chains comprise a network of independent yet interconnected organizations with several interrelated activities. These activities commence from upstream with the production and supply of raw materials sent to other organizations for manufacture, processing and transformation into finished products. They then flow through various organizations downstream, including wholesalers, distributors, warehousing and logistics providers before reaching retailers to be sold to end consumers (Thomas and Griffin, 1996). The processes are often complex and require integrated efforts. The success of a business therefore depends on how effectively these partners organize and interact with each other in the supply chain to create value. To be competitive in today's business environment, firms need to be able to eliminate redundant activities across the supply chain to improve costs, timeliness, flexibility, responsiveness and also sustainability (Cooper and Ellram, 1993; Crook et al, 2008; Deshpande, 2012).

### 2.1 Service Dominant Logic for Value Co-creation

The service dominant paradigm (Lusch and Vargo, 2006) highlights how the co-creation of value can be embedded during various interactions taking place during the lifecycle of the product and involving a network of actors in B2B relations (Lacoste, 2015). This is described as the process when actors get together for the co-production of value (Normann and Ramirez, 1993). Similarly, we advocate that this can be applied in a supply chain setting where value in products and services involves the participation of various supply chain partners, with focal firms ensuring that the upstream and



downstream activities can yield intended value propositions of the product. Although value in principle is perceived in monetary terms, there are other forms of value that occur from the relationships and coordinated efforts between firms in the supply chain. Biggemann et al (2014) espouse that relational synergies occur when a long-term relationship between two organizations delivers more collective value than the value that the organizations acting independently could deliver. Value created in interaction may result from sharing resources, knowledge and technology, and also include sustainability practices among firms. Although business relationships are considered important in value creation, greater understanding is needed about the processes by which value is created along the supply chain (Anderson, 1995) and how sustainability could be embedded within. From a business model perspective, Nenonen and Storbacka (2010) prescribe a framework depicting the managerial opportunities for focal firms to influence value co-creation in a network or supply chain. These lie in the design principles, resources and capabilities which are present in markets, product or service offering, operations and management. It can be applied to a supply chain context whereby "the effectiveness of a business model in value co-creation is defined by the internal configurational fit between all business model elements and the external configurational fit between suppliers' and customers' business models" (p.43). While Payne et al (2007) had earlier proposed a model delineating the value co-creation process, it did not explain the types of resources from each actor or the interface types enabling this co-creation of value.

## 2.2 The Need for Sustainability

A growing area of concern is the issue related to sustainability, where firms face constant pressure by various stakeholders to pursue not only economic gains, but also to address social and environmental considerations at both organizational and supply chain levels (Hofmann et al, 2014). It is important to note that the actions and behavior of partners are important as their environmental and social impacts affect the brand and reputation of the focal company ultimately (Braziotis et al, 2013). There have been a number of reputable firms, whose image had been tarnished due to instances of their supply chain members' practices violating social or environmental issues. For example, Apple Inc. was criticized for their Chinese suppliers' environmental air and water reservoir pollution with hazardous waste and breach in workplace health and safety. Similarly, the publicized case of Nestlé sparked public concern when one of its palm oil suppliers upstream in the chain was contributing towards the destruction of rainforests (Skapinker, 2010). The consequent loss of equity and reputation are often difficult to reverse. The responses and reactions of these firms have been to establish corporate social responsibility programs (CSR) within their communities in order to restore their corporate brand and reputation. These violations generally tend to occur in upstream practices and players, but it is also possible for violations to occur downstream in the chain; such as through greenhouse gas emissions in the distribution of final products. Therefore, the importance of what stakeholders and consumers associate with sustainability is paramount not only to businesses, but also to the supply chain.

## 2.3 Drivers for Sustainable Supply Chains

Studies on firms' rationale to implement sustainability in supply chains suggest two major motives: strategic reasons and economic gains. Strategic reasons entail maintaining brand image, enabling new market entry, setting industry standards, creating complementary relationships with supply chain partners, reducing risks of public criticism and to enhance value. Economic gains allow the firms to generate long-term revenues, maximize investment returns, and reduce costs of detrimental consequences or damage recovery of criticisms for unsustainable practices or products. Managers in firms are motivated to adopt sustainable supply chains based on various reasons including the desire for a particular corporate image with customers and other stakeholders (Ageron et al, 2012), or because it is part of the overall corporate mission (Foerstl et al, 2010; Walker and Jones, 2012).

### 2.3.1 Stakeholder Pressure

The literature shows that stakeholder pressure on sustainability in supply chain management may result in sustainability awareness, adoption of sustainability goals, and/or implementation of sustainability practices (Meixell and Luoma, 2015). Stakeholders are any individuals or group of people that affect or are affected by an organization (Freeman, 1984). These include shareholders, senior management, employees, customers and suppliers as 'internal' to the supply chain; or government, non-governmental organizations (NGO), community groups, media, competitors and trade associations as 'external' to the supply chain. Within the premises of

the stakeholder theory, Freeman (1984) assesses the existence of a relationship between firms and different groups. Stakeholder theory underpins all parties influencing or being influenced by the firm. There are three main elements to the theory; namely the organization, the actors, and the nature of their relationship (Lozano, 2005). When observing the first and second elements of the stakeholder theory (i.e. the organization and the actors who relate with it), it can be viewed from a stakeholder perspective how the company acts within the society itself, as well as who affects and is affected by the organization. When considering the corporation and the relationship it has on the society, from a stakeholder theory perspective, there is a shift from firm-centered thinking to systems-centered thinking. The third element explains the nature of the relationships which exist between the organization and its stakeholders, i.e. involving interdependency and co-responsibility.

Meixell and Louma (2015) highlight that undoubtedly stakeholders who pressure firms toward sustainability aim for the implementation of specific sustainability practices, but not all firms will result in this implementation. Nevertheless, such pressure can create awareness in firms about their (stakeholders') interest in sustainability, and subsequent adoption of objectives to achieve these. These authors also depict that external stakeholders such as customers, government, shareholders, NGOs, and society in general have the ability to influence public opinion regarding the organization's environmental practices (Sarkis et al, 2010). As a consequence, firms and their supply chains are subjected to stakeholder impositions to implement sustainable practices.

### 2.3.2 Regulation

Regulation refers to the rules imposed by government on companies; but at current there are no universal laws governing sustainability as a whole. Different nations and States have got their own jurisdictions and governing criteria. Examples include New Zealand's 1991 Resource Management Act, which codified much of its land use and natural resource regime around the paradigm of sustainable development, and Australia's federal legislation, the Environment Protection and Biodiversity Conservation Act 1999, which incorporated the concept of ecologically sustainable development and associated principles as foundations for decision-making. The area of environmental and sustainability law is widely recognized since the 1992 United Nations conference on the Earth Summit, with the adoption of Agenda 21 and the Rio Declaration of Environment and Development, which called on each nation to establish its own national laws for environment and development. The aim is to minimize or eliminate natural resource exploitation and pollution (Benidickson, 2011). Unfortunately, despite the efforts to streamline or standardize environmental regulation, "the financial commitments needed to build the capacity for providing a legal foundation for sustainable development were stripped from the text of Agenda 21. Even when the nations met in Monterrey, Mexico, to pledge the funding for implementing Agenda 21, the commitments turned out to be mostly symbolic" (p.10). Although efforts from the Business Council for Sustainable Development and the 'Rio Conventions' have received widespread recognition, there remain governmental and business interests who oppose environmental law reforms on the surmise that they could impede economic development. As a result, there is no international legally binding

agreement on environmental regulation. Nonetheless, the United Nations Environment Program (UNEP), through its Montevideo programs, serves as a catalyst for various multilateral environmental agreements and has supported the national and international emphasis on environmental laws. It is also evident in many countries with dedicated administrative systems and environmental protection agencies that enforce laws to control pollution and conserve flora and fauna.

Many corporations have promulgated social responsibility not only towards the environment, but also for health and safety compliance. According to Wahl and Bull (2014), private regulation in global supply chains have emerged in the form of codes and standards developed and administered by companies, industry associations and NGOs. These authors posit that such regulations are adopted on a voluntary basis to maintain reputation or ethical standards, particularly in the area of social responsibility. As a result, sustainability is an emerging area of concern for businesses today and it is evident that many focal firms are strategically embedding environmental and social initiatives in their supply chains to indicate their commitment to not only stakeholders, but also customers.

### **3 Methods**

This study is based on a qualitative, exploratory research design due to the limited empirical findings pertaining to how sustainability is implemented in supply chains from a value co-creation perspective. A case study is employed to address various operations and initiatives evident among firms

in a single supply chain to gain deeper insights into their activities and management approach; and also to understand the context and motivations for sustainability implementation (Yin, 2009; Eisenhardt, 1989). The case was selected based on purposive sampling, where published sustainability reports of Australian firms were easily accessible. Initially six firms were chosen on the basis that majority of their supply chain partners were also located in Australia. Subsequently, we considered the firms' accessibility and strategically chose those firms which allowed for a personal face-to-face contact. Also, due to any sensitive data that might arise, building a trusting relationship through personal contact is crucial for the quality of the data. After several weeks of regular contacts and conversations with managers, an organization based in Queensland agreed to participate in this study and provided consent for the researchers to interview its supply chain members. The data collection was conducted through personal face-to-face and online (via skype) semi-structured interviews with eleven managers in total. Whenever possible, one or two other employees of the firms were interviewed to obtain a broader perspective pertaining to their operations and sustainability initiatives. Additionally, secondary or published data were collected through annual reports, sustainability reports, other documents and press releases. This multiple source approach allowed the researchers to triangulate the data which increases the validity and reliability of the results. Interviews were digitally audio-recorded and fully transcribed for analysis. Thematic networks were used for analyzing qualitative and secondary data using Nvivo QSR software (Attride-Stirling, 2001). The process entailed coding the data to identify themes, constructing and ana-

lyzing thematic networks before interpreting the patterns of findings. Interviewees were prompted to describe their initiatives to instill and implement sustainability in the supply chain and to define the value creation activities wherever possible.

## **4 Findings**

### **4.1 Overview of the Supply Chain and the Firms**

Due to the need for commercial confidentiality, the firms in the supply chain studied are referred to as an input supplier, a wheat farmer, a milling firm, a bakery (focal firm) and its franchise retailer. Figure 1 illustrates the supply chain investigated. The Focal Firm is a family owned and operated business, based in Queensland with over 100 employees. The company was established over 60 years ago specializing in baked food products. They own and manage the operational aspects of the business which include baking and retail franchising. The company has over 50 retail stores and is still looking to grow the business. Each franchise outlet receives freshly baked products daily from their central production sites. They are committed to the highest standards in quality, service, brand and design in order to maintain their competitive position in the marketplace. They have won a few awards for their success and sustainability performance. This is characterized by their commitment to reducing carbon footprints and water usage, not only at the firm level, but also at the supply chain level. The Retailer Firm operates as a franchise purchased in 2007 under the Focal Firm's branding. It is located in the city of Brisbane serving over 500 customers a day, primarily office workers and the general public.



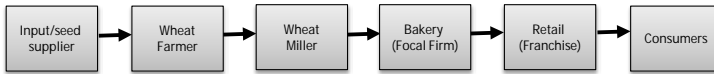


Figure 1 The players in the supply chain

The owners have lamented that the franchising model is under significant pressure currently, largely due to a saturated market in the food sector, the competition from nearby fast food outlets and also because of consumers' evolving tastes and demands. Profit margins are relatively low, considering food price-sensitivity and a constantly high employee turnover rate. Baked food variety is usually quite limited and determined by the Focal Firm as they adopt a commissary system to deliver ready-to-serve products, or products that only need to be reheated before serving. Nevertheless, the franchise outlet has been economically sustainable over the years, based on volume of products sold.

The Wheat Miller is acknowledged as one of Australia's largest processors and distributors of flour and pre-mixed baking products. The business has over thirty years' experience and reputation in flour milling and food ingredient production for bakeries. Majority of their employees possess extensive training and knowledge in wheat variety, storage and milling. They operate their milling factories in various locations throughout Australia, including several additional facilities that produce specialty pre-mixes, wheat for noodles, frozen bakery products and food ingredients. They are notably selective of farmers who can produce high quality grains in order to reap the finest flours milled. They possess the capability to deliver their products throughout the country by adopting centralized distribution systems within each State and also through the use of third-party logistics providers.

The Wheat Farmer has been growing wheat as a major crop for the past twenty-eight years in the South Eastern agricultural region in Queensland after taking over the business from his father. He operates a 900-hectare paddock specializing in Australian Prime Hard (APH) wheat, which is suitable to produce not only high-protein Chinese and Japanese noodles, but also high protein and high volume breads. Hard wheat is also known to be blended with lower protein wheat to produce flours suitable for various baked products. Overall wheat harvest is dependent upon rainfall. The year 2014 experienced an unexpected dry spell in Queensland with scarce rainfall, which resulted in lower soil moisture levels than normal and delayed the planting of wheat crops in April. Despite the dry season, majority of crops survived on stored soil moisture enabling a reasonable harvest. The Wheat Farmer stores seeds from the previous season to grow in the following year, but occasionally purchases seed from a certified supplier or seed breeder when introducing a new variety or extra seed. This is because wheat yield and quality perform differently depending on soil conditions and rainfall regime. 70 percent of all wheat harvested is sold to the wheat miller to be produced into flour, while the remaining is exported overseas. The Input Supplier is a family owned business located in the wheat belt region in Queensland. The business has been operating for 35 years with over twenty employees and specializes in the wholesale of quality assured seed varieties to growers, as well as farm inputs and machinery (such as poly tanks, irrigation equipment, sprayers, augers, fencing and silos). Apart from the commercial retail of their own certified seed lines, they also act as an agent for other seed companies. The company offers advice on farming and quality assurance systems for farmers in seed production, processing,

treatment and storage; enabling full traceability of processes from the farm through transportation and to the wheat miller.

## 4.2 Embedding Sustainability Practices with Value Co-creation

### 4.2.1 Focal Firm

During the interviews with the Focal Firm (bakery), the owner reiterated the importance of being a responsible business. He said:

“For us, sustainability is about acknowledging the impact our business has on our stakeholders, whether it be employees, customers or the communities that we operate in ... It is about being a responsible business, considering the people and environment ... We try to have a proactive approach to sustainability as it determines how we will perform in the long-term and how it impacts on our brand. This means working closely with our franchise stores, suppliers and wheat producers; and treating employees well”.

It is evident that the Focal Firm has established collaborative relationships with their upstream suppliers to take a sustainable approach to the business and to ensure the supply of quality products in the long run. They had engaged in conversations with two wheat growers in the past, primarily about the types and varieties of wheat grown, the farming practices that affect the quality of wheat; and to learn more about crop management and yield. As explained by the operations manager, this helps to ensure consistency, softness, freshness and quality of bread ultimately.

The value proposition in the Focal Firm is about baking 'consistent quality bread' to enhance sales and customer satisfaction, to maintain cost efficiencies in their operations and to invest in their employees. Value is created through the conversion of wheat flour into quality finished baked products. As the operations manager mentioned "We regularly research consumer tastes and demand for bread and other baked products;...and we try to work closely with our suppliers to achieve such products". The business currently uses locally produced ingredients as much as possible. Apart from wheat flour, other ingredients include eggs, milk, butter, flavorings and non-wheat grains such seeds, nuts or dried fruit – all sourced locally. They also purchase in bulk to minimize packaging. For example flour and other dried ingredients are transferred directly into their bin containers from the delivery truck using a pencil auger, therefore eliminating the need for packaging. They are committed to reducing their carbon footprints. A number of initiatives have been implemented in their production facilities, which aim to reduce energy and water consumption. Finished products are packaged using materials which not only maintain freshness of baked products, but also reduce the environmental impact and ecological footprint. The owner added, "We label the products with clear nutrition information to allow consumers to make informed choices of what they are consuming". From a corporate responsibility perspective, the business provides various development opportunities for employees and also works with their retail franchise outlets to improve product and service delivery.

#### 4.2.2 Wheat Miller

Four managers were interviewed at the Wheat Miller. The general manager explained the processes involved at their milling factories from a value creation perspective. Wheat grains received from farmers are firstly sorted and graded into various categories and quality ratings. The grains are then washed and tempered before grinding. Thereafter wheat flour are sifted, purified and fortified with additional ingredients such as thiamine and folic acid. All operations are guided by HACCP standards ensuring food safety and quality control. They have invested in state of the art technology and machinery to facilitate efficiency and quality in their operations. The production manager stated that these have helped bring down costs over the years and reduced human errors because most of their machinery are operated electronically.

In terms of sustainability, the factory manager reiterated their commitment to producing food products in a responsible manner, reducing their environmental impact and improving the communities in the agricultural regions where they are located. They also work with government departments, non-governmental organizations (NGOs) and communities to engender sustainable economic development and promote responsible practices. As the general manager highlighted, 90 percent of their employees are hired from the local region, thereby providing secure, healthy work environments and economic development to the area.

They also continuously seek new ways to assist farmers produce a more effective harvest in a sustainable way and to embrace efficient farming methods. As the marketing manager commented:

“We encourage our suppliers (farmers) to adopt more sustainable practices through reduced use of fertilizers and pesticides...while diseases may impact on yield and quality of wheat, we advise farmers that many of the diseases can be controlled simply through cultural practices and good farm hygiene....for example crop rotation is one method.”

### 4.2.3 Wheat Farmer

We interviewed the owner of the business and two managers on site. They realize that conventional farming practices using chemical pesticides, herbicides and fertilizers are unsustainable. Over the years, the business has invested in more effective eco-friendly methods such as more practical water use, energy-efficient farming machinery and organic fertilizers. All these help to conserve resources and reduce greenhouse gas emissions. They have also sought advice not only from the input suppliers, but also from industry associations such as the Grain Growers Limited, the Australian Grain Growers Co-Operative, Queensland Farmers Federation, the Grain Producers Australia and the National Association of Wheat Growers. The owner of the business expressed concerns about the low profit margins not meeting the high cost of capital, where in some years losses are incurred: “Climate change today can have a huge impact on crop yields at our farms. One would expect good rainfall in Queensland, but 2014 has seen a dry spell.... We were lucky to get adequate rains during the August-September months which helped produce a reasonable crop...but it is hard to predict how sustainable the business will be in the long-term.... The cost of being sustainable is high, not forgetting the costs of labor and fuel constantly rising...It is worrying about how long before I can recoup these costs.”

Leaf and stem diseases are common in wheat crops, particularly in wetter climates such as in Queensland. Many farmers have faced huge losses as a result and need to rely on new varieties that can withstand diseases or use other alternative methods such as spraying with fungicide. From a value creation perspective, wheat farming ensures consistent supply and quality of wheat produced which in turn results in baked bread sold to end consumers. The farmer is aware of how critical this is, with the regular conversations and relationships with downstream partners in the supply chain. As a result, he has adopted a different business model to effectively manage farm activities more sustainably. Nevertheless it was felt that sustainable practices are more costly.

Table 1 below depicts a summary of the sustainability initiatives undertaken by the firms in the supply chain and the value creation activities.

Table 1 Summary of sustainable practices and value creation activities

	Sustainability initiatives	Value creation activities
Farmer	CO <sub>2</sub> reduction through efficient use of machinery	Better use of harvesting tools and techniques for greater efficiencies
	Optimizing resource use (energy, water and land)	More effective irrigation and farm techniques
	GHG emissions management	Use of organic farm manures and fertilizers
	Optimizing land use	More effective storage of wheat and seeds  Adopting direct soil nutrient management practices that have environmental benefits



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	Sustainability initiatives	Value creation activities
Wheat Miller	HACCP standards for food safety	Sorting and grading wheat for quality control
	Good Manufacturing practices and traceability systems enabling effective use of energy and machinery.	Cleaning and tempering of wheat grains to ensure high quality flour
	More reliable equipment and electronic controls to reduce labor costs.	Grinding, sifting and purification
	Food safety, health and wellbeing	Enrichment (e.g. added folic acid, thiamine, iron and vitamins)
	Increased sanitation and reduced use of pesticides	Packaging, Storage
	Provide employment for local communities and contribution to economic development	Recruitment, training and development of employees in the local area

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	Sustainability initiatives	Value creation activities
Bakery	Reducing food miles/GHG emissions	Source locally produced ingredients
	Minimize cost and packaging	Purchase in bulk
	Energy and water use	Delivery to retail stores using optimized routing systems, scheduling, real-time tracking
Retail Store	Food safety, health and wellbeing	Labelling products with clear nutrition information
	Reduce GHG emissions	Switch to green energy
	Minimize waste, environmental friendly practices	Do away with plastic bags, use degradable plastic bags, recycled paper

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## 5 Discussion and Conclusion

The case study illustrates various initiatives undertaken by firms to become more sustainable in relation to value enhancement. Based on the service dominant logic, value is collaboratively created and various resources need to be combined to achieve this value (Vargo and Lusch, 2010). This co-creation of value along the chain requires a focus on achieving both firm and stakeholder value propositions. Hence, we identify how both sustainability strategies and value propositions are inter-related. The idea of value creation according to Smith and Colgate (2007) can be conceptualized using four categories: functional/instrumental, experiential/hedonic, symbolic/expressive and cost/sacrifice – where sustainability lies somewhere between the experiential/hedonic, symbolic/expressive modes (Biggemann et al, 2014). Based on the interviews with managers in various firms, our findings depict that sustainability provides intangible benefits through enhanced reputation (Fairfield et al, 2011; Caniëls et al, 2013), reduced costs and also improved sales (Lo 2014) furthestmost downstream in the chain. While the rewards are deemed as marginal upstream (especially with the low profit margins by wheat farmers), it is the downstream players that reap most of these benefits and enhanced reputation. As we postulate earlier, focal firms drive sustainable practices in their supply chains for strategic reasons such as maintaining brand image, enabling new market entry and setting industry standards and to enhance value.

As businesses seek to achieve sustainable outcomes, stakeholders would need to know the rationale of resource combinations and allocations, and discern how this creates value. We advocate that an important concern is to realize the consumer value that would ultimately guide the resources

and goals of a supply chain. This often gets overlooked when organizations become too focused on operational efficiencies and profitability. Therefore, it is the role of the focal firm to realize this value and take additional steps to embed this into the value proposition and work collaboratively with suppliers and customers at multiple levels to achieve optimal results for all members in the supply chain.

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# Social Media Effect on Sustainable Products Purchase

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Nowadays social media have become a key platform where consumers interact with each other. Further, people are growing to be more aware of sustainability-related issues in general and sustainable products/brands-related matters in particular. This study investigates the effects of social media on consumer purchase behavior, with an exclusive focus on sustainability. In order to understand the needs and motivations of consumer engagement with sustainable products and/or brands, we surveyed a number of social media users residing in Germany. The collected data were analyzed using partial least squares structural equation modeling (PLS-SEM). Our findings helped shed the light on the effects social media have on consumers' choices regarding sustainable products/brands purchasing; they also helped identify the main drivers behind these effects.

**Keywords:** Sustainability, Social Media Dependency, Consumer Behavior, PLS-SEM

# 1 Introduction

## 1.1 Sustainable Supply Chain Management

Nowadays it has become less unusual for supply chain management (SCM) researchers and practitioners to incorporate sustainability in their work. In fact, as a result of a demanding globalization, companies are now expected to play a role that goes beyond the limit of the traditional "profit seeking". Today, companies are also assumed to be sensitive to environmental and social issues; and while dealing with economic issues is the heart of business, managing pressing issues such as unsafe and poor working conditions or environment-harmful production are also considered important (Brandenburg et al., 2014; Linton et al., 2007; Seuring, 2013; Walker and Jones, 2012; Wolf, 2011). Furthermore, the pressure from customers, regulatory bodies, non-governmental organizations, and internal pressures from employees coerce companies to incorporate sustainability issues into their SCM (Carter and Easton, 2011; Gold et al., 2010; Krause et al., 2009).

Sustainability in SCM is defined as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainability, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements" (Seuring and Müller, 2008, p1700).

The goals of a sustainable SCM is to render maximum value to all stakeholders and fulfill customer requirements by achieving sustainable flows of products, services, information and capital as well as cooperation among supply chain participants (Seuring, 2013; Wolf, 2011; Pagell and Wu, 2009).

Due to the rising transparency offered by new form of media e.g. internet, social media, etc., and the increasing awareness customers are getting to understand well the products/brands and want to know more about the conditions under which products were manufactured and ask questions regarding sustainability of the products/brands (Carter and Rogers, 2008).

## 1.2 Social Media

Today, more than a third of world's entire population is using internet, out of which 53% are less than 34 years of age (comScore, 2015). Half of the internet users are active on social media (ITU, 2015). Out of 55.6 million internet users in Germany, 45 million are engaged in online purchasing activities (Statistisches Bundesamt, 2015). This demonstrates the remarkable and significant rise of internet and social media use during the past few years. Internet is increasingly shaping consumers' habits and influencing their daily purchase behaviors by offering an indispensable platform where companies connect with customers to communicate their sustainability change initiatives (Hennig-Thurau and Walsh, 2003; Men and Tsai, 2012; Reilly and Weirup, 2010). On one hand, internet offers various ways to obtain products/brands-related information from individuals, groups and organizations. Examples of such sources include blogs, forums, wikis, content-sharing platforms, social networking, etc. (Hennig-Thurau and Walsh, 2003; Reilly and Weirup, 2010). On other hand, companies that utilize social media have better access and bigger reach to a larger pool of customers and consequently an increased opportunity to reach more customers and increased likelihood of making a purchase (Dei Worldwide, 2008).

Social Media is defined as “a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of user generated content” (Kaplan and Haenlein, 2010, p61). Users of these applications create, initiate, share, and exchange information in a virtual community (Blackshaw and Nazzaro, 2006). And later this information is used by consumers with the intent of educating each other about products, brands, services and/or issues (Ngai et al., 2015; Xiang and Gretzel, 2010).

Because of its interactive nature, social media provide access to other consumer’s opinions, comments and personal experiences relating to products, brands and/or services (Xiang and Gretzel, 2010). This leads us to consumers perceived word-of-mouth (WOM) messages which are more reliable, credible, and trustworthy compared to traditional communication channels such as promotions, company initiated communications, etc., (Brown et al., 2007). Due to the free exchange of content, WOM on social media has the potential to go viral; in addition to that a single WOM message can reach and influence many receivers (Brown et al., 2007). At the same time, social media can have a significant impact on the spread of both positive and negative WOM. If a negative WOM is spread online and users start building on each other’s comments, it may affect the potential user’s intention to purchase of the involved product/brand as a consequence (Grégoire et al., 2015; Markos-Kujbus and Gati, 2013).

Despite the increasing relevance of social media there is a lack of research literature that investigates the importance of its effect and impact on consumers purchase behavior, regarding sustainable products/brands and

services. This study explores the exploitation of consumer knowledge regarding sustainability, gained from social media while making purchase decision about a particular product/brand. Hence the research questions of this paper are as follows:

Q1: Do social media have any effect on consumer's choices, beliefs and behavior when it comes to sustainable products/brands?

Q2: How significant is their impact?

Q3: What are the drivers of these effects?

This paper employs Media System Dependency theory (MSD) as its main theoretical framework to investigate the drivers of consumers' dependency on social media for information about sustainability and how it affects their purchase behaviour. The paper is structured as follows. In section 2, we review relevant literature in order to develop our research hypotheses. The data collection procedure and the sample along with the definitions and measurement of the constructs are described in section 3. Afterwards, the partial least squares structural equation modeling (PLS-SEM) results of both the measurement and structural model are reported in section 4. Finally, the study findings are summed and discussed in section 5.

## **2 Literature Review and Hypothesis Development**

### **2.1 Media System Dependency Theory**

In order to have a good understanding of the impact of social media on consumers' beliefs and behavior regarding sustainable products/brands, this research paper refers to the literature from the perspective of media effects

theories. Particularly, we believe that MSD offers a good theoretical framework to tackle the issue of social media effects on consumers' purchase decisions with respect to sustainability (Ball-Rokeach and DeFleur, 1976). MSD is built around the distinguishing and pivotal conceptualization of media dependency relations. Ball-Rokeach and DeFleur (1976) define dependency as "a relationship in which the satisfaction of needs or the attainment of goals by one party is contingent upon the resources of another party" (Ball-Rokeach and DeFleur, 1976, p6). Accordingly, although media can control relevant important resources, influences engendered by media won't be powerful unless a dependency on these resources exists. Therefore, "whatever the particulars of the relationship, it is the relationship that carries the burden of explanation" (DeFleur and Ball-Rokeach, 1989, p303). Individual media dependency (IMD) or the micro level of MSD, occurs when the accomplishment of personal goals is contingent upon the acquisition of information resources that are controlled by media (Ball-Rokeach, 1985). In fact, MSD posits that individuals are driven by the fundamental motives of survival and growth that can be converted into specific understanding, orientation and play goals that require the employment of media information resources and hence dependencies. Further, these dependency relations consist of personal and social levels, resulting in six different media dependency dimensions: self-understanding, social understanding, action orientation, interaction orientation, solitary play and social play. Understanding dependencies stem from the individual motivation to acquire the necessary knowledge that allows for a meaningful comprehension of one's self and the social environ. Moreover, orientation dependencies occur when individuals refer to media information resources for decision-making

guidance to achieve a convenient behavior on both the personal and social level. Finally, contingency upon media in order to achieve entertainment and tension release goals either alone or while interacting with others, can bring about play dependencies (Ball-Rokeach, 1985).

Since MSD posits that media effects on individuals can manifest themselves as cognitive, affective and behavioral changes, this paper attempts to investigate how dependency on social media for sustainability information can alter users purchase behavior and beliefs (DeFleur and Ball-Rokeach, 1989; Ball-Rokeach and DeFleur, 1976).

## 2.2 Hypothesis Development

We define dependency on social media for sustainability information, as individuals' contingency upon social media information resources in order to attain their objectives of making the right decisions when it comes to purchasing sustainable products/brands.

Further, individuals are less likely to engage in purchasing when they perceive themselves as lacking the sufficient knowledge to make the right purchase decisions. In fact, consumer confusion is associated with several negative effects such as altering users' brand choice, postponing and eventually abandoning the purchase to avoid cognitive strain (Mitchell and Papavassiliou, 1999).

In the context of green products, previous research has shown that confusion about the attributes that make products/brands environmental-friendly damage consumers' trust. On the other hand, trust in a product's environmental performance leads to purchase intention (Chen and Chang,

2012a; 2012b). Furthermore, the research shows that perceived lack of expertise was a major obstacle that held back consumers from purchasing green products, particularly, when the informational messages available to consumers were scarce, numerical and undetailed. Contrarily, detailed verbal informational cues that educate users about the attributes of green products were proven to significantly enhance purchase behavior (Gleim et al., 2013).

In the offline context, such product information is either scarce or hard to provide without causing information overload and hence leading to consumer confusion (Mitchell and Papavassiliou, 1999), and would rather be embedded in social media, where users can easily find various and rich information that they can discuss and digest at their own pace. In fact, information richness of user-generated content is shown to have a better effect on purchase behavior than it is the case for marketer-generated content.

Furthermore, Hennig-Thurau and Walsh, (2003) reveal that retrieving information from online consumer-opinion platforms where users can communicate and compare their products, experiences, has a strong impact on purchase behavior. Here, dependent users are by definition the ones who satisfied such goals through social media information resources. Hence we posit that these users are more educated and aware about sustainability-related issues and products and therefore act more responsibly towards the society and the environment. Incidentally, previous media dependency research provides empirical support to the positive effect of media dependency on purchase intentions (Bigné-Alcañiz et al., 2008; Ruiz Mafé and Sanz Blas, 2006; Patwardhan and Yang, 2003).



Therefore, we hypothesize that dependency on social media for sustainability information will have a positive effect on the intention to purchase sustainable products/brands.

H1: Dependency on social media for information about sustainability has a positive effect on the intention to purchase sustainable products/brands.

Willingness to seek information about sustainability revolves around the purposeful effort to change one's state of knowledge about sustainability issues. Hence, it is intuitive to assume that users who seek to enrich their knowledge about the subject are driven by understanding and orientation motivations that manifest as goals. Based on the previous arguments, social media are a favorable candidate when it comes to providing detailed and rich information resources about sustainability and therefore consumers with such objectives are likely to become dependent on social media. Furthermore, previous research support this assumption; for instance, a study by Bickart and Schindler (2001) shows that consumers who acquired information from online discussions displayed greater interest in the product topic than those who got their information from marketer-generated sources. Other studies have shown that motivation is a relevant driver of internet dependency (Sun et al., 2008) and that perceived usefulness leads to dependency on internet for online shopping information (Bigné-Alcañiz et al., 2008). This implies that motivated users who perceive online resources as useful will likely become dependent. More specifically, Hennig-Thurau et al. (2004) reveal that making better purchase decisions and saving decision-making time were the most relevant motives behind the use of online consumer-opinion platforms, which means that consumers could

fulfill their goals of obtaining guidance for convenient purchase decisions effectively. Therefore, we posit that:

H2: Willingness to seek information about sustainability has a positive effect on the dependency on social media for sustainability information.

We refer to Chen and Chang (2012b) to introduce two new constructs: sustainability trust on social media and sustainability risk on social media. On one hand, sustainability trust on social media is defined as the willingness to depend on a product/brand that has received positive statements regarding its sustainability features by former, actual, or potential consumers via social media, based on the belief or expectation resulting from its credibility, benevolence, and ability about its sustainability performance. On the other hand, sustainability risk on social media is about the expectation of negative consequences affecting sustainability as a result of purchasing products/brands that have been exposed to negative statements by former, actual, or potential consumers on social media, concerning their sustainability features.

The occurrence of dependency on social media for decision-making about sustainable products/brands means that the information provided by the medium was perceived to a great extent as necessary, unique, credible and useful for consumers' orientation goals attainment. Hence, it would be reasonable to assume that dependent users are likely to adopt the information, and ultimately the beliefs supplied to them by other former, actual, or potential sustainable products/brands' consumers on social media, regarding sustainability attributes. In fact, previous studies have shown that perceived information usefulness (Cheung and Thadani, 2012; Lee et al.,

2008) along with information credibility lead to the adoption of both positive and negative WOM online.

Therefore, we posit that dependent users are more likely to adopt other consumers' statements on social media and hence would be more prone to expect negatively commented products/brands to be risky and harmful towards the environment and society. Similarly dependency would lead to a higher perceived trust in the sustainable features of positively commented on products/brands. Further, previous MSD literature has proved that dependency can lead to higher perceived food-related risk (Tucker et al., 2006) and also to stronger fan page loyalty (Ruiz-Mafe et al., 2014). Based on the previous arguments, we hypothesize that:

H3: Dependency on social media for sustainability information has a positive effect on sustainability trust on social media.

H4: Dependency on social media for sustainability information has a positive effect on sustainability risk on social media.

Former research has shown that perceived risk can have a strong negative impact on purchase intentions (Kim et al., 2008; Littler and Melanthiou, 2006; Park et al., 2005; Mitchell, 1999; Wood and Scheer, 1996). Similarly, in the context of green products, perceived risk of negative environmental consequences was proved to damage purchase intention (Chen and Chang, 2012b). Furthermore, consumers who perceive negatively commented on products/brands on social media as harmful to the environment and society are assumed to be more educated about such products and their negative impact on sustainability. Such users adopt other consumers' negative WOM about products/brands' sustainability attributes and accordingly expect negative outcomes from such purchases. Hence they are more likely

to avoid buying such products and their associated brands because they are aware of their negative consequences, and therefore they are more likely to engage in a sustainability-friendly purchase behavior.

H5: Sustainability risk on social media has a positive impact on the intention to purchase sustainable products/brands.

Finally, several studies have revealed that perceived trust is a key driver of purchase intention (See-To and Ho, 2014; Lin and Lu, 2010; Hsin Chang and Wen Chen, 2008; Kim et al., 2008). More specifically, trust in the environmental performance of products was shown to increase green products purchase intention (Chen and Chang, 2012b). Further, social media users who adopt positive WOM are likely to perceive themselves as acquiring sufficient information about trustworthy products with sustainability attributes. Such consumers perceive recommended products/brands as credible about their claims regarding sustainability and expect beneficial outcomes on the environmental and social level from attributes. In other words, they regard buying these products as a way to support sustainability. Therefore, we posit that these users would favor sustainable products/brands when it comes to making purchase decisions.

H6: Sustainability trust on social media has a positive impact on the intention to purchase sustainable products/brands.

### **3 Methodology and Measurements**

#### **3.1 Data Collection and the Sample**

In order to obtain data for this study we conducted an online survey targeting educated social media users aged between 18 and 55 years old, currently residing in Germany. The survey was accessible for approximately one month starting from June 22nd, 2015. The participants were offered complete anonymity.

Ninety-one German residents answered the survey. Nine participants reported not being social media users and thus were disqualified. The remaining 82 responses were clear of any issues. To ensure that all questions be answered, participants were required to answer all questions prior to submission. After an initial screening of the data, no cases were removed from the sample.

The initial view of the data showed gender distribution to be far from balanced with only 26.8% of the respondents being female and 73.2% being male. The mean age of the respondents was 28, with age ranging from 20 to 54. The majority of the respondents were highly educated with 57.32% of them having bachelor's degrees and 21.95% postgraduate degrees.

#### **3.2 Constructs Measurements**

All questionnaire items were measured on a seven-point Likert scale ranging from "strongly disagree" to "strongly agree", with the exception of the constructs sustainability trust and sustainability risk, where items meas-

urement points varied between “very unlikely” and “very likely”. Definitions and measurements of the constructs employed in this study are explained in the following sections.

### **3.2.1 Sustainability Information Seeking (WSS)**

To measure sustainability information seeking, this study employs the following items adapted from (Borah, 2014): (1) regarding sustainability issues, I seek more information supporting my opinion; (2) regarding sustainability issues, I seek more information supporting the other opinions; (3) regarding sustainability issues, I seek more information that offers a balanced view; (4) regarding sustainability issues, I seek more opinions supporting my point of view; (5) regarding sustainability issues, I seek more opinions supporting the other points of view.

### **3.2.2 Dependency on Social Media for Sustainability Information (DSM)**

Measurement for dependency was adapted from the action orientation scale developed by Grant (1996). Respondents were provided by seven items to indicate the extent to which social media information helped them to: (1) decide whether to buy sustainable products/brands or not; (2) decide which products/brands are sustainable and which are not; (3) decide whether to buy a certain sustainable product/brand or not; (4) know what sustainable products/brands make good impressions on others; (5) decide what sustainable products/brands to buy; (6) decide between different sustainable products/brands alternatives; (7) choose the right sustainable product/brand.

### **3.2.3 Sustainability Risk on Social Media (SR)**

Five items were adapted from Chen and Change (2012b) to measure the perceived risk when respondents read negative statements from other users on social media, regarding products/brands sustainability features: (1) the product/brand will not meet desired sustainability criteria; (2) the product/brand will not work properly with respect to sustainability requirements; (3) I would face negative consequences if I use this product/brand (because of social or environmental harm); (4) using the product/brand will negatively affect sustainability aspects (e.g. environment, work conditions, etc.); (5) using the product/brand would damage my reputation or image as a person who cares about sustainability.

### **3.2.4 Sustainability Trust on Social Media (ST)**

Respondents were provided with five items adapted from Chen and Change (2012b), to measure their perceived trust in products/brands once they read positive statements from other users on social media, regarding sustainability features: (1) the product/brand's sustainability reputation is generally reliable; (2) the product/brand will work properly with respect to sustainability requirements; (3) the product/brand's claims regarding sustainability are generally trustworthy; (4) the product/brand's concerns about sustainability meet my expectations; (5) the product/brand keeps promises and commitments regarding sustainability.

### 3.2.5 Intention to Purchase (IP)

This research refers to Chen and Change (2012b) to measure intention to purchase. Six measurement items were included: (1) I intend to purchase sustainable products/brands because of their sustainability concerns; (2) I expect to purchase sustainable products/brands in the near future; (3) I avoid buying products/brands which are potentially un-sustainable; (4) overall, I am glad to purchase sustainable products/brands because they are sustainable; (5) when I have to choose between two similar products/brands, I choose the one that is more sustainable; (6) I will not consider the sustainability related issues when making a purchase.

## 3.3 Data Analysis

We performed the data analysis using the PLS-SEM approach. Researchers concur that PLS presents a very attractive and solid approach to analyzing data especially when dealing with small sample sizes such as the present case. The PLS approach regroups two steps; during the first, we examined the measurement (outer) model to ascertain its reliability and validity. Then, in the second step, we assessed the structural (inner) model with regards to the significance of its paths and  $R^2$  values. Our software of choice for the purpose of this analysis was SmartPLS 3.0 Professional.

### 3.3.1 Measurement Model Assessment

The first criterion we examined was the indicator reliability, according to (Chin, 1998) and Hulland (1999) indicator reliability is confirmed if each indicator has a loading value of 0.70 or higher. Our results showed that, for



the larger part, the items' loadings were highly satisfactory; the only exceptions were: three IP indicators that presented values lower than the required threshold and therefore were excluded. Satisfyingly, the Average Variance Extracted (AVE) for IP increased vigorously ensuing the deletion of the three indicators. However, following the recommendation of Hair et al. (2014) four indicators were kept although boasting outer loadings below the 0.70 threshold. These items are: WSS4, SR3; SR5 and IP3, particularly since the loss of content that would result from their deletion surpasses any benefits that may result from keeping them (increase in AVE and/or composite reliability).

Turning to the internal consistency reliability, we used composite reliability (CR) to measure it as advised by Hair et al. (2014); Generally, a CR of 0.70 or higher is regarded as acceptable for research (Bagozzi and Yi, 1988; Chin, 2010; Henseler et al., 2009; Vinzi et al., 2010). Favorably, the product of the analysis estimated all CR values for the present model at 0.70 or higher (see Table 1).

Table 1 Assessment results of the measurement model

Construct	Item	Load- ing	Indica- tor reli- ability	Compo- site reliabil- ity	AVE	t-Value
	DSM1	0.85	0.73			18.58
	DSM2	0.89	0.8			37.05
	DSM3	0.94	0.88			67.49
DSM	DSM4	0.71	0.5	0.96	0.77	9.13
	DSM5	0.93	0.87			59.85
	DSM6	0.9	0.81			37.34
	DSM7	0.88	0.77			19.8
	IP1	0.87	0.76			22.68
IP	IP2	0.81	0.65	0.84	0.63	7.97
	IP3	0.7	0.48			8.13

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Construct	Item	Load- ing	Indica- tor reli- ability	Compo- site reliabil- ity	AVE	t-Value
	SR1	0.87	0.75			8.83
	SR2	0.84	0.7			6.83
SR	SR3	0.64	0.41	0.88	0.6	3.64
	SR4	0.84	0.7			7.62
	SR5	0.64	0.41			3.94
	ST1	0.89	0.8			36.27
	ST2	0.85	0.73			19.56
ST	ST3	0.83	0.69	0.93	0.72	13.95
	ST4	0.79	0.62			10.76
	ST5	0.87	0.76			33.22

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Construct	Item	Load- ing	Indica- tor reli- ability	Compo- site reliabil- ity	AVE	t-Value
	WSS1	0.78	0.61			11.51
	WSS2	0.82	0.68			18.63
WSS	WSS3	0.75	0.57	0.88	0.61	13.86
	WSS4	0.67	0.45			6.43
	WSS5	0.85	0.73			22.46

Consequently, as a result to the first two assessments, the models' reliability has been established. Next, we use AVE to assess the convergent validity. Typically, an AVE that is higher than 0.50 is required. Here, all AVE values were observed to be superior to 0.50 with SR having the lowest AVE (estimated at 0.59).

Finally, we used the Fornell-Larcker criterion (See Table 2) and the Heterotrait-Monotrait Ratio of Correlations (HTMT) criterion (See Table 3) to assess the discriminant validity. Our findings, visible in Table 3, clearly show all HTMT values to be lower than 0.90. As a result, the condition for discriminant validity is satisfied.

Table 2 Discriminant validity assessment- Fornell-Larcker criterion

	DSM	IP	SR	ST	WSS
DSM	0.88				
IP	0.50	0.80			
SR	0.27	0.25	0.77		
ST	0.53	0.36	0.47	0.85	
WSS	0.58	0.44	0.16	0.18	0.78

Table 3 Discriminant validity assessment- HTMT criterion

	DSM	IP	SR	ST	WSS
DSM					
IP	0.60				
SR	0.28	0.30			
ST	0.56	0.43	0.52		
WSS	0.62	0.55	0.20	0.18	

### 3.3.2 Structural Model Assessment

First, we calculated the Variance Inflation Factor (VIF) values to uncover any possible collinearity issues. Our findings (See Table 3) show all VIF estimates to be smaller than 5; therefore this model satisfies the recommendation of Hair et al. (2014) in regards to collinearity.

Next, we calculated t-values to examine the significance of path coefficients. Hair et al. (2014) suggest the number of bootstraps to be set to 5000. For two-tailed tests, the significance thresholds for the t-values are 2.58, 1.96 and 1.75 for 99%, 95% and 90% confidence level respectively (Hair et al. 2014).

Our results (See Figure 1) show that  $WSS > DSM$ ,  $DSM > ST$ ,  $ST > IP$  and  $DSM > IP$  are significant at 99% confidence level (t-value  $>2.58$ ); they also show  $DSM > SR$  to be significant at 95% confidence level (t-value  $>1.96$ ). Furthermore, the path coefficients for these relationships were estimated at 0.20

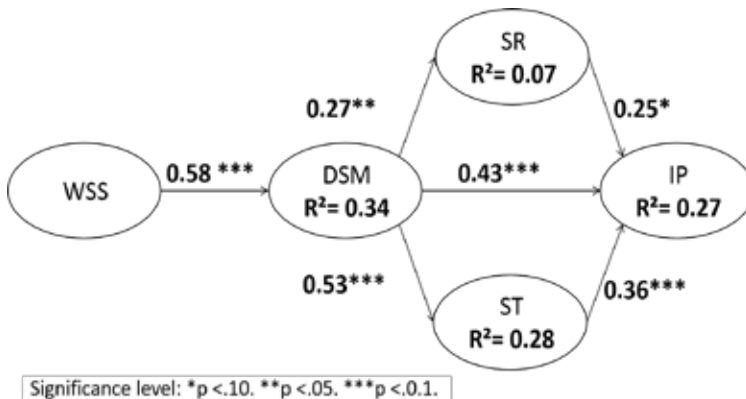


Figure 1 Path coefficients and significance level of the relationships

Table 4 Assessment results of the structural model

Endogenous variable	Exogenous variable	Path coefficient	VIF	t-value	f <sup>2</sup>
DSM (R <sup>2</sup> =0.34)	WSS	0.58	1	8.10	0.51
ST (R <sup>2</sup> =0.28)	DSM	0.53	1	5.75	0.39
SR (R <sup>2</sup> =0.07)	DSM	0.27	1	2.47	0.08
IP (R <sup>2</sup> =0.27)	DSM	0.50	1.39	5.75	0.18

or higher which satisfies the minimum threshold suggested by (Chin 1998) for path coefficients. The only relationship that did not satisfy the minimum requirements for significance was SR > IP with a t-value estimated at 1.91. As a result Hypothesis 5 (SR > IP) was rejected.

We then calculated the R<sup>2</sup> values for each exogenous variable in our model. The results (displayed in Table 3) show that three out of the four endogenous variables are well explained by their relationships. The highest R<sup>2</sup> was estimated at 0.34 for DSM, followed by ST (0.28), IP (0.27) and finally SR (0.07). It is important to know that, typically, a R<sup>2</sup> of 0.20 is regarded as high in the field of consumer behavior (see Hair et al. 2011; Hair et al. 2014).

To summarize, the findings of the present research show that all hypothesized relationships outside of H5 are supported. Therefore we accept H1,

H2, H3, H4 and H6. Furthermore, the results of the effect sizes ( $f^2$  values) show that the strongest effect size recorded was for Sustainability information seeking on Dependency on social media for sustainability information (0.51), followed by the effect of this latter on Sustainability trust (0.39) and to a smaller degree on Sustainability risk (0.08). For Intention to purchase the only construct that had a relatively significant effect was Dependency on social media for Sustainability information estimated at 0.18; the remaining effect sizes were too small ( $< 0.02$ ) and were therefore deemed insignificant.



## 4 Conclusion

The major aim of this study was to identify the effects -if existent- of social media on consumer's purchase behavior when it comes to sustainable products/brands; for that purpose, we conducted an online survey and used structural equation modeling to analyze the data. The results of the analysis helped lay out the main drivers influencing consumers' intention to purchase a product/brand; they also served to measure the size of their impact. Our findings showed that consumers' willingness to seek sustainability information pushes them to regard social media as an important source for this specific type of information; this resulting dependency in turn affects their' views -both positive (trust) and negative (risk)- of the product/brand's position associated with sustainability. Furthermore, consumers' intention to purchase a certain product/brand was found to be subject to their dependency on social media for sustainability information. Interestingly, results show that while perceived trust in positively commented products/brands on social media has a significant influence on purchase intention although small, the corresponding influence of perceived risk was noted to be insignificant.

To conclude, we can say that it is now clear that social media do in fact influence consumers' behavior and choices in regards to sustainable products/brands; and as much as it is proof of a new era consumer empowerment, it is proof of the dependency of many on social media for this type of information.

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# New Strategies to Improve Sustainability through Supplier Assessment

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Sustainability is today consolidated as a mandatory business rule. Multinational companies whose operations affect economies, societies and environment worldwide, are key triggers to transform supply chains towards sustainable development. In this context, this paper aims to understand how some German companies have been using supplier assessment as a new strategy to improve their sustainability. The content analysis method was used to collect and analyse materials published in corporate responsibility reports, annual reports and corporate websites. The selected companies, Beiersdorf, Heidelberg Cement, MAN, RWE and ThyssenKrupp, are important players in different industries. The findings offer valuable examples of initiatives such as development of specific requirements for assessing suppliers, adoption of international standards, use of specific strategies to stimulate communication with suppliers, among others. However, it was also clear the lack of investments in areas that might offer interesting results for increasing network sustainability. Imprecise goals, problems with data visibility and managerial failures in projects with supply chain partners hinder continuous improvements towards a collaborative approach. The process of assessing suppliers in attempt to monitor and encourage sustainability practices is still limited. Moreover this paper highlights the need of innovative and concrete actions to align business, environment and society within supply chain partners.

**Keywords:** Sustainability, Supply Chain, Practices, Supplier Assessment

## 1 Introduction

According to a survey lead by McKinsey in 2010, more than 50 percent of executives evaluated “sustainability – the management of environmental, social, and governance issues – as very or extremely important in a wide range of areas, including new-product development, reputation building, and overall corporate strategy”. However, the survey shows that only a few companies are taking a proactive approach in order to implement sustainability in their activities. Only around 30 percent of executives consider sustainability as a priority and search actively for opportunities to invest in sustainability (Mckinsey, 2010).

Another study stated that Germany has more industry-leading sustainable companies than the United States, Britain and Japan combined. German companies appear as leaders in the field of sustainability (Dow Jones, 2013, p.9-10).

The present research combines these observations. And in particular how German companies try to integrate the concept of sustainability along their supply chain. Nowadays, multinationals spread their activities all over the world and have a potential influence in many different countries and are responsible for the well-being of many people, be it their employees or the communities shaped by their activities. This paper aims to identify how supplier assessment is becoming an important topic when analyzing sustainability integration into worldwide businesses.

## 2 Sustainable Supply Chain

Sustainability is currently the new buzzword, not only in our everyday life but also in the business world. It can be explained by many factors: a new way to consume energy, a better understanding of climate changes and an increasing transparency of environmental and social actions of organizations (Carter and Easton, 2011, p.46). The concept of the triple bottom line, coined by John Elkington in 1994 and key to sustainability, means that business success is no longer defined only by monetary gain but also by the impact that the activities of an organization have on society as a whole (Elkington, 1998).

For large firms, an indication that their level of commitment with sustainability is increasing is the numbers of reports published including actions towards sustainable development (Wu, Dunn and Forman, 2012, p.192). In addition, companies realize how social and environmental responsibility can boost their performance (Porter M.E. and C. van der Linde, 1995, p.120; Zadek, 2004, p.126). This includes contributing to communities, improving workplace conditions, eliminating waste and using resources more efficiently. However, it is still difficult to guarantee that companies are actually implementing what they publish and not just publishing good actions to impress their stakeholders (Kolk, 2003, p.289). It is clear though that environmental, social and economic responsibilities are not opposing forces (Tate, Ellram and Kirchoff, 2010, p.21-22).

With the rising awareness of consumer, incorporating sustainability into the corporate strategy is a way to match stakeholder's expectations, from investors to communities, while taking into account social and environment impacts (Prokesch, 2010, p.1). Moreover, the increasing phenomena

of outsourcing and of international purchasing make relationships and co-operation with suppliers directly related to supply chain sustainability and overall business performance (Genovese, Lenny Koh, Bruno and Esposito, 2013, p.2868). A sustainable supply chain (SSC) performs well on traditional measures of profit and loss as well as on an expanded conceptualization of performance including social and natural dimensions (Pagell, 2009, p.44-55). Through their management, firms act reasonably towards communities, while also gaining considerable financial and other intangible benefits (Dey, LaGuardia and Srinivasan, 2011, p.1250). The overall performance of the supply chain (SC) is improved by creating competitive advantages to all members (Wu, Dunn and Forman, 2012, p.184). Nevertheless, many studies show that, due to high complexity, a total integration of all participants along the supply chain might be an inappropriate approach in practices (Keating, Quazi, Kriz and Coltman, 2008; Douglas M. Lambert Martha C. Cooper Janus D. Pagh, 1998; Choon Tan, Krause and Hanfield, 1998). Instead, firms rely on key SC members to promote integration (Choon Tan, Lyman and Wisner, 2002, p.615).

Supplier assessment (SA) refers to the process of gathering and processing information in order to evaluate and approve the performance of suppliers or potential supplier and to mitigate associated risks (Klassen and Vachon, 2003, p.340). The goal is to ensure the suppliers' performance, with the purpose of reducing cost, risk, and leading to continuous improvement in sustainability aspects. Facing the challenge to implement sustainability along the SC, companies have been developing strategies to extend their processes of corporate governance to their SC partners (Kytte, Hamilton and Ruggie, 2005, p.11). Working directly with suppliers is the only solution to

play a critical and direct role to achieve performance improvement for the buyers (Krause, Scannell and Calantone, 2000, p.37).

First, communicating the company's requirements to the supplier is necessary. Many companies build codes of conducts (CoC) to assess environmental or social impact of suppliers' activities across their global SC. A CoC is "a set of written principles, guidelines or standards, which are intended to improve the company's social and environmental performance" (Pedersen and Andersen, 2006, p.229). CoC works as a set of criteria for evaluating and selecting suppliers, and determines the minimum level of requirements in order to create a more sustainable supply chain. In 2008, over 92% of the world's largest 250 companies published a CoC (KPMG, 2008, p.5), a strategy to reduce the risks of negative publicity. A good example of thoughtful company is IKEA that in the end of the 90s realized how the environmental or social conditions of its suppliers could damage their image (Pedersen and Andersen, 2006, p.232). The IKEA CoC was then developed and defines what the company requires from its suppliers in terms of working conditions, child labour, environment and forestry management and what suppliers can expect from the company.

As CoC is just a published document, it is particularly weak in terms of efficient monitoring, and most of the companies develop a complementary system to guarantee that the established requirements are being implemented (Kolk, Tulder and Welters, 1999, p.174). Among the vast possible methods to measure suppliers' sustainability, some might be highlighted: assessment guides, questionnaires, audits and on-site inspections. These methods raise the issue of how critical is the flow of information through supply chain. A SSC requires good communication between the company

and their suppliers. The buyers have to communicate their standards and the assessment process allow these firms to know more about the suppliers' performance (Dey, LaGuardia and Srinivasan, 2011, p.1247).

After defining standards, communicating them to suppliers and building methods to assess their compliance, the companies decide when, how often and the operative manner in which to implement the assessment process, and consequently including incentives and sanctions from the obtained results (Peters, 2010, p.28). In the most extreme case, a negative evaluation may conclude the termination of the business relationship (Delmas and Montiel, 2009, p.179). Assessing suppliers is not a simple process, especially when firms have to deal with contractors and sub-contractors. The well-known case from Mattel exemplifies the challenges in assessing suppliers. The company had to recall more than 14 million toys after identifying that some of them were not in accordance with a specific safety regulation (lead painting for instance) due to contractors and sub-contractors failures (Roloff and Abländer, 2010, p.525; Enderwick, 2008, p.221).

### 3 Methodology

Content Analysis was used to collect initiatives currently implemented by five selected companies from five different industries. This technique can be used for systematically collecting and analysing with a large number of words into fewer content categories (Weber, 1990, p.37).

The study and evaluation of the published materials of companies allow to draw relevant information about sustainable activities and strate-

gies (Tate, Ellram and Kirchoff, 2010, p.32). The analysis of sustainable initiatives was made through the study of Corporate Responsibility Reports (CCR) which most of the time detail actions and information about environmental and social strategies decided by the company. They contain targets, goals, policies, programs and projects that contribute that make a supply chain more sustainable, through a cut of the company's carbon footprint and/or the increase of social responsibility (Lai, Wu and Wong, 2013). Additionally, corporate websites, annual reports (AR) and other documents were also used in order to collect more information. As the researched companies are well-known, well established within the German market and all follow the GRI standards, it was assumed that they really implement what they officially publish. They might implement more than it is published but they would improbably publish fake information. This method has this limitation and further research could be the use of additional external sources to confirm all the collected information.

The sample selection process followed two particular criteria, based on international and well recognized rankings. From an economic and financial point of view, all the five researched companies are part of the DAX group, the stock market index consisting of the 30 major German companies trading on the Frankfurt Stock Exchange. Using this ranking, it was possible to target German traded companies. For them, company's practices are expected to be transparent, updated, detailed and reliable. Secondly, all selected companies should be ranked in the Newsweek Magazine.

The MAN Group is one of Europe's leading companies in mechanical engineering employing a workforce of 53,500 worldwide. Today MAN can be defined through three activities: automotive industry, production of diesel

Table 1 Sample of five German companies

Company Name	Industry
MAN	Vehicles & Components
HeidelbergCement	Construction
ThyssenKrupp	Materials
Beiersdorf	Household & Personal Products
RWE	Utilities

and turbomachinery. Thus, MAN supplies trucks, buses, diesel engines, turbomachinery and special gear units.

HeidelbergCement is one of the world's largest cement producer, employing some 53 000 people in more than 40 countries. In 2010, 78 million tons of cement were produced. In the same year, it was the world's third largest cement producer, the market leader in aggregates and fourth in ready-mix concrete.

ThyssenKrupp is a corporation based in Duisburg and Essen. There are currently around 160,000 employees in nearly 80 countries. It's one of the largest steel producers in the world, and also manufactures elevators, automotive components and industrial services.



Beiersdorf AG is a company based in Hamburg that manufactures personal care products. Its brands include Labello and Nivea. Today more than 16000 people are working for Beiersdorf in 125 countries.

RWE is an electric utility company based in Essen. Through its different affiliates, the energy company supplies electricity to more than 16 million customers and gas to more than 8 million customers, mainly in Europe. RWE employs more than 66 000 people.

Table 2 presents the documents used to collect data about each of these companies.

Table 2 Documents used to collect data

Company	Document used
MAN	Supplier Code of Conduct (MAN, 2015), CCR 2013 (MAN, 2013), "Sustainability in supplier Relationships" developed by Volkswagen Group (Volkswagen, 2014), Corporate website (MAN, n.d.), VW website
Heidelberg-Cement	Supplier Code of Conduct (Heidelbergcement, 2011b), CCR 2011-2012 (Heidelbergcement, 2011a), Purchasing Guideline (Heidelbergcement, 2006), corporate website (Heidelbergcement, n.d.)
ThyssenKrupp	Supplier Code of Conduct (Thyssenkrupp, 2014b), AR 2013-2014 (Thyssenkrupp, 2014a), corporate website (Thyssenkrupp, n.d.)

Company	Document used
Beiersdorf	Supplier Code of Conduct (Beiersdorf, n.d.), Sustainability Review 2013 (Beiersdorf, 2013b), GRI Report 2014 (Beiersdorf, 2014b), Disclosure regarding Beiersdorfs Environmental and Health and Safety Data Reporting (Beiersdorf, 2013a), AN 2014 (Beiersdorf, 2014a), Raw Materials Policy (Beiersdorf, n.d.), corporate website (Beiersdorf, n.d.)
RWE	Code of Conduct (RWE, 2005), CCR 2014 (RWE, 2014), Flyer Supplier Management (RWE, n.d.), corporate website (RWE, n.d.)

## 4 Findings

### 4.1 Extend Sustainability along the Supply Chain

All of the five selected companies stated that sustainability is part of their corporate spirit and understand supplier's assessment/relationships as a strategy to extend the idea of sustainability along the supply chain. MAN considers "itself responsible for promoting sustainability along the entire value supply chain and thereby ensuring stable and efficient flows of goods and supplies". HeidelbergCement explains that they are aware of being judged "according to [their] success in terms of ensuring compliance with

sustainability standards throughout our supplier chain". Beiersdorf understands that in order to offer respectful and high-quality products, they need to "guarantee that [their] suppliers also assume social, ecological and economic responsibility" (Beiersdorf, n.d., p. responsible sourcing); in other words, that the entire supply chain is aligned in the same cause. The company considers that we are all responsible for the common present and future and that it's possible to contribute to a better world by respecting some principles. RWE "is aware of the role it plays in society and of its responsibility towards its customers and business partners as well as its shareholders and employees". Because of this responsibility, RWE commits itself to respect and implement sustainability principles along its SC and with its suppliers. At last, ThyssenKrupp "considers sustainability to be an essential component of [their] business processes". That is why their suppliers are "an integrated part of [their] sustainability strategy".

Thus, all companies insist on the fact that fair and long-term relationships with suppliers are essential to push them to implement sustainability into their activities. Building strong links with suppliers allow these companies to go deeper in the process of greening the supply chain. HeidelbergCement focus on the importance of the different dimensions, be it technical, commercial or environmental in order to build efficient collaboration with suppliers. MAN aims to engage in long-term relationships with their suppliers. At RWE, all processes of selection and assessment of suppliers aim to build close and long-term cooperation with the best ones. That applies for the purchase of goods, services and plant components. For ThyssenKrupp, "supplier relationships are also geared to the long term and designed to guarantee stability of supply".

## 4.2 Sustainability Requirements

The first step of implementing sustainability along the supply chain is to make the requirement available to the suppliers. This communication is made through different kind of documents such as CoC or purchasing guidelines. For being worldwide, it is expected that all researched companies have procurement guidelines and established procedures about purchasing. However only documents from MAN, RWE and HeidelbergCement were available for public consultation.

RWE developed a precise and detailed procurement guideline where supplier relationship and assessment are presented. The criteria to control suppliers are described. Except the conventional criteria such as commercial aspects, RWE cares about industrial safety and environmental protection. Furthermore, for the procurement of biomass, RWE uses the Green Gold Label established by Essent in 2002. It is a track and trace system and a certification programme for assurance of sustainable biomass sourcing. A label is an easy and clear requirement that companies can use. HeidelbergCement has developed purchasing guidelines for the procurement of goods and service to guide supplier relationship. The document presents health, environmental and safety aspects as important in the assessment of suppliers. Moreover, environment and ethics are presented as two dimensions that procurement teams take into account. All procurement processes of MAN refer to the Volkswagen Group which developed a document with all the requirements regarding sustainability in its relationships with business partners.

Another key document to communicate principles and goals the company wants to respect and wants their partner to respect is the Code of Conduct

(all companies condemn child labour, corruption and discrimination - based on gender, races or sexual orientation-, and demand employment rights, environment protection and occupational safety). All researched companies have developed codes dedicated to suppliers and business partners, except RWE which uses the same CoC for employees and suppliers. Although some considerable differences were identified. First is the preciseness of the document. Except RWE, all companies refer to international standards, such as the International Labor Organization (ILO), ISO or OHSAS 18001 for ThyssenKrupp. Beiersdorf has a precise CoC by quoting the relevant standards for each requirement. RWE built its CoC through the UN Global Compact principles in the areas of human rights, labor, environment and anti-corruption. The document outlines goals and principles which guide its business activities, though does not mention international standards or labels.

Another distinction is about the design of CoC. While RWE, MAN and ThyssenKrupp seem to invest a lot on building a flourished document, HeidelbergCement and Beiersdorf's documents look like working documents. A last variation can be noticed in the scope considered in the CoC. All companies, except for RWE include sub-contractors in their CoC. Suppliers are required to claim the same demands from them. It shows a wish to extend sustainability as far as possible along the supply chain.

### **4.3 Supplier Monitoring and Assessment**

Assessment can be conducted by different ways. One is through Risk Management which consists of identification, assessment and prioritization of risk in order to prevent problems. It is said to be the first step of sustainable

assessment. As worldwide companies, all five implement definitely risk management procedures, but some of them highlight it in their corporate web-sites and reports as a way to be more sustainable. RWE introduced the Counterparty Risk Assessment, made at least every year and potentially up to 4 times per year if necessary. This procedure is based on many criteria since suspicions relating to non-sustainable actions were raised (money laundering, financial crimes, terrorist organizations and financing, corruption and breaches of ethical standards, human rights and environmental destruction). RWE says that business relations will be suspended if suspicions arising from the counterpart Risk Assessment are confirmed. Additionally, a software identifies any emerging corruption risks at an early depending on the country and sector profile. ThyssenKrupp uses a global risk management tool for “building an integrated risk map” in order to “ensure that earnings and cash risks are recorded locally by operational risk managers and reported through a series of approval and aggregation processes via the business area management boards to corporate level”. Many risks are taken into consideration such as those associated with information security, compliance, sales and environmental. HeidelbergCement developed a Group-wide risk management system, coordinated by the Group Insurance&Corporate Risk Department. All risks that could threaten the Group, including social and ecological risks, all over the plants and regions, are recorded systematically. MAN and Beiersdorf don't inform about Risk Management in their Sustainability reports and pages related to sustainability.

All five researched companies described in public documents their supplier assessment process. Beiersdorf has established auditing procedures to insure that the principles of the CoC are respected via Standardized Self-assessment Questionnaires (SAQ) provided by SEDEX, recognition of third party audits and corrective action plans. SEDEX is a non-profit organization dedicated on “driving improvements in ethical and responsible business practices in global supply chains” by helping companies to assess suppliers via easy tools and to drive green improvements along the supply chain. SEDEX uses online databases that encourage members to store, share and report on information in four key areas which are Labour Standards, Health & Safety, Environment and Business Ethics. In order to ensure relevant environmental and safety data, a follow-up process to enhance data quality and coverage is also carried out. Additionally, SEDEX has developed SMETA, an audit procedure which consists in a compilation of good practices in ethical audit technique. SMETA is designed to reduce duplication of effort in ethical trade auditing by developing several tools to assess suppliers, such as a common best practice guidance on conducting ethical trade audits, a common set of instructions on the items to be checked by auditors or a common audit report format. Additionally, Beiersdorf is a member of AIM Progress which is a forum of leading Fast Moving Consumer Goods (FMCG) manufacturers, assembled to enable and promote responsible sourcing practices and sustainable supply chains, while reducing the duplication of supplier assessments. To reduce audit duplication, costs and fatigue companies - through the Mutual Recognition mechanism - recognize supplier audits completed on behalf of another company. Any violation of the CoC

may “provide Beiersdorf with a reason to terminate the business relationship, including any subordinate delivery agreements” (Beiersdorf, n.d.). HeidelbergCement enforces audits, however, details on if they are implemented and how, are not made public. In the CoC, the possibility of assessment is mentioned but without any conditions or information about the application but “a termination of the contractual relationship will ultimately result” if necessary (HeidelbergCement, 2011b). Furthermore HeidelbergCement is part of the Cement Sustainability Initiative (CSI) which is a global effort by 25 major cement producers with operations in more than 100 countries who believe there is a strong business case for the pursuit of sustainable development. The CSI Guidelines for Emissions Monitoring and Reporting in the Cement Industry have been developed and identify the specific pollutants and emission sources which all CSI member companies have agreed to monitor.

ThyssenKrupp declares that they regularly conduct a supplier compliance review. Suppliers are supposed to complete self-assessment questionnaire once a year. If needed, ThyssenKrupp reserves the right to appoint a qualified third party to perform sustainability audit at suppliers’ sites. This procedure is explained in details in the company CoC. An interesting information is that “the supplier shall bear all costs and expense for this audit if the annual turnover of the supplier with ThyssenKrupp exceeds 100,000 €. The audit cost should usually not exceed a limit of 5,000 Euros.” If a supplier is suspected of violating any of the principles presented in the CoC, the company reserves the right on the one hand to request from the supplier that all relevant information be disclosed and on the other to stop any business with the supplier. In the event that a supplier evidently fails to follow



requirements or refuses to set up measures in order to improve its sustainability, ThyssenKrupp will immediately end all contracts with the supplier. One of the four pillars of sustainability developed by the Volkswagen Group and integrated by MAN is supplier monitoring and development. MAN deals with sustainability requirement towards their suppliers, from the cognizance of the sustainability requirements to the implementation of sustainability in supplier relations. According to this process, MAN integrates sustainability into the quality process audit and leads sustainability questionnaires. No information about these questionnaires, their content, their use or if they are fulfilled by suppliers or MAN teams are available. The integration of sustainability training on suppliers into the process is an interesting topic. An e-platform gathers all information, each supplier is called to fulfil an online questionnaire about sustainability, and has access to e-learning options. In the CoC, MAN specifies that any business relationship can be terminated if the basic principles are not implemented.

RWE verifies each suppliers's compliance with the CoC via self-questionnaires and audits of supplier's sites. Suppliers are required to answer these self-evaluation questionnaires in order to prove that they fulfil the requirements. Future targets and goals are fixed with suppliers. Simultaneously, RWE built an e-platform where suppliers can find all documents and information about the requirements. Through this platform, suppliers have access to the requirements, questionnaires and also to all the Business Terms and Conditions. RWE says it does not have any business dealings with suppliers which are known to infringe the principles of its CoC. They seem to deal only with suppliers which follow the sustainable requirements. Furthermore, RWE is part of Better Coal which gathers many actors of the coal

mining sector in order to improve working and environmental conditions in mining sites. As of now, only one on-site audit has been led by a third-part firm, but in the future the idea of this project is to implement more audits and assessment.

## 5 Discussions and Conclusion

As shown in this research, sustainability seems to be a new buzzword in academia and in the business world. As companies face pressure from customers and governments, they are investing on sustainable actions and realizing that following the triple bottom line concept can be profitable. All researched firms seem to be actively involved in sustainable development through the strategy of supplier assessment. They realized that working directly and deeply with suppliers may reduce risks overall and support the achievement of performance improvement for buyers (Krause, Scannell and Calantone, 2000). While in most companies worldwide corporate sustainability is still restricted to internal activities, the researched and mentioned companies have been implementing a broader strategy considering also their suppliers. They seem to integrate sustainability in purchasing decisions as suggested in the literature (Gimenez and Sierra, 2012, p.191).

The use of standards and internationally well-known references are practices that make requirements clear and precise. They should be an extension of the companies values and of the CoC a document that formalizes and communicate the importance of their stakeholders' commitments. Among the sample, social requirements are precise thanks to ILO stand-

ards, while environmental aspects seems to be vague and subjective. Except for the ISO 14001 standards mentioned by Beiersdorf, ThyssenKrupp, MAN and HeidelbergCement, for instance, no goals towards their suppliers were found in terms of reducing emissions, waste recycling rate, reduction of water and energy consumption, optimization of processes. The process of tracking and tracing data across the supply chain is a known challenge that may justify this shortage (Dey, LaGuardia and Srinivasan, 2011). However, one may be aware that information management is one of the core and critical processes when assessing suppliers.

Besides the lack of goals and key performance indicators towards their business partners, some other opportunities for improvements in companies' CoC were identified. Firms usually use the CoC to protect themselves from bad buzz, which can be triggered by a single unsustainable operation (Dey, LaGuardia and Srinivasan, 2011, p.1237). All companies stated that their CoC is a reference document when assessing suppliers, but it was not clear how the audit process is implemented and how they verify suppliers' compliance with the established standards.

This deficiency of preciseness regarding companies' assessment process raises a question: are they powerful enough to impose sustainable standards to their suppliers? The question is even more critical in raw material procurement. Is it economically and strategically possible to reject a fuel supplier for RWE, for instance, when they don't comply with environmental or human standards, considering the current energy market situation? Most requirements developed in CoC, Corporate Responsibility Report and purchasing guidelines are built for goods and services and not for raw materials. HeidelbergCement and RWE specify that their documents are not

applicable for fuel and cement. It shows an exceptional situation for this kind of purchase. A second relevant observation points to the suppliers' origins. It is easier to require sustainable criteria for suppliers based in Europe where standards are high and well controlled. A different reality exists when supplying from companies in developing countries.

Therefore, supplier assessment seems to depend on the supplied materials (products or services), on suppliers' origins and on the closeness with its customers. The closer to the customers, the more developed are the actions related to supplier assessment. Beiersdorf, which produces household & personal products, seems to get more pressure from its customers and thus implement more actions towards its suppliers.

Collaboration between companies may also be a solution to make supplier assessment more feasible. Better Coal initiative, partially launched by RWE allows the establishment of standards and evaluation of results on third-part audits. The AIM Progress Initiative, for instance, intends to share and learn from each member about responsible sourcing practices and create synergies through mutual recognition of audits. As audits and assessment can be complicated and costly to implement, the motto "an audit for one is an audit for all" could foster assessments and reduce the cost in terms of money, time and qualification for firms. Cement Sustainability Initiative gathers companies accounting around 30% of the world's cement production what could enable the integration of sustainability into the Cement Industry. For companies with difficulties on setting up clear goals and requirements for their suppliers, collaborative approaches such as the Better

Coal Initiative allow integration of participants, standardization of requirements, cost reduction and the impact of companies' business on the environment and people's lives

The present paper aimed to understand how some German companies have been using supplier assessment as a new strategy to improve their sustainability. It was shown that the researched companies, recognized as benchmarks of sustainability, have been investing in this issue and are facing diverse challenges regarding data management, transparency, standards and goals setting as well as collaboration with their supply chain business partners.

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# Market Barrier Integrated Approach for Manufacturing Footprint Decision Support

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The sales potentials for automotive companies in Europe are decreasing, and emerging markets, such as the BRIC-states or the ASEAN countries, are now in the focus of European automobile manufacturer's attention. However, the governments of these high potential market states try to cap the import-rate of European cars and decrease the international competition for the local automotive industry by creating trade barriers. Car manufacturers and suppliers struggle with the planning of following a local manufacturing strategy and the related set up of regional supply chain networks. The decision finding process shows different deficits. Especially the high dynamic of the business environment and the related uncertainties are not in the scope of current planning processes. Approaches are missing which allow decision owners to evaluate the impact of changing trade barriers on the supply chain network. Derived from state-of-the-art analysis, tariff and non-tariff trade barriers will be classified in the context of opening up new automotive markets. Next to a classification, an existing simulation-based planning approach for robust manufacturing footprint decisions is extended by the consideration of the classified trade barriers.

**Keywords:** Trade Barriers, Manufacturing Footprint Decision, Supply Chain Management, Automotive Industry

## 1 Introduction

The global development in vehicle sales reveals two major trends. On the one hand, the main automotive markets West Europe, North America and Japan stagnate on a high level for years now (OICA 2014; VDA 2013). On the other hand, there are emerging markets, which show a growing demand for passenger cars and still have a considerable growth potential (Schade et al. 2012; Dudenhöfer et al. 2012). This saturation of the main markets and its derived competitive pressure between the original equipment manufacturers (OEMs) as well as the structural change in the emerging markets necessitate the opening up of new markets for the car manufacturers (Dehnen 2012; Garcia Sanz 2012). Especially the BRIC-states and the ASEAN member-countries are now in the focus of European automobile manufacturer's attention. The first group of states in particular, led by the now world's largest automobile market, China, shows remarkable high sales potential, which is the result of a strong economic upswing as well as a low car density compared to the main markets (ACEA 2013; Dudenhöfer et al. 2012). Ebel and Hofer, for example, predict that in 2020 only 35 percent of the global car sales will be witnessed in the core markets (Ebel and Hofer 2014). In comparison, in 2013 we saw a 44 % market share of the core markets (OICA 2014).

However, the entry of the European car manufacturers and suppliers into the new economically relevant markets is significantly constrained through protectionist actions in the form of trade barriers (Love and Lattimore 2009). These actions are motivated in different ways. By creating trade barriers, the governments of the high potential market states mostly try to cap

the import-rate of European cars and decrease the international competition for the local automotive industry as well as increase the know-how transfer (Neumair et al. 2012). Due to the trade barriers, the car manufacturers and suppliers need to build up local manufacturing sites in order to be able to offer their products to a competitive price.

Within the footprint planning workflow several planning teams and decision makers are involved in the decision finding process. Most approaches for manufacturing footprint planning do not correlate with the workflow management and the organizational structure of the company, which leads into different “planning isles”, where planners work isolated. These “planning isles” will cause different deficits according to find the right manufacturing footprint. First of all, not all relevant cost components are taken into account over the whole supply chain. For example, costs for supplier development in order to be able to generate the required local content quotas are missing in the established processes. Other cost components missing are market barrier-induced costs, or capital commitment costs. Furthermore trade barriers are only considered in the form of tariffs in the processes although they can have a wide range of forms and can also be very dynamic in their nature caused by changes by the local governments in short time frames. These changes can have significant impacts on the developed supply chain networks. Therefore it is necessary to know the relevant trade barriers in the emerging markets and integrate them in manufacturing footprint decision support systems. Consequently, a model has to be developed, which ensures a holistic view on the complex task of the manufacturing footprint decision.

The paper is organized in five major sections. Section two briefly describes the requirements for a support system and presents the existing planning support approaches. Section three uses a literature and database review to identify and categorize main trade barriers concerning the automotive industry. The 4th section presents the developed planning approach, which integrates the trade barrier view. The final section summarizes the findings of this paper and discusses the need for further research in this field.

## 2 Manufacturing Footprint Decision Support

OEM manufacturing sites are part of a complex supply chain network with several suppliers and logistic providers. Given the problem and the coherence of supply chain networks and footprint decisions, the following requirements can be deduced.

The manufacturing plants are exposed to different dynamic impact factors such as changing inflation and exchange rates or the change of custom rates along intercontinental E2E (end-to-end) supply chain network. Therefore the occurrence of uncertainties along the supply chain and the dynamic adaption of solutions have to be considered in the support system. Next, for long-term strategic decision support problems such as the manufacturing footprint planning a total cost evaluation is required (Kinkel 2009). Especially in the context of developing emerging markets the cost effects of trade barriers increases significantly and should be integrated in footprint decisions. Another requirement to be mentioned is that a planning approach should take qualitative and quantitative factors along the supply chains into account. This is due to the fact that footprint decisions

are determined by manifold impact factors. Additionally, because of the long planning horizon and the related planning uncertainties, the planning approach should support an aggregation of factual connection of supply chains based on the availability of relevant data. At the same time, the approach should support a detailed evaluation of different footprint scenarios. Next to the major requirements mentioned above, there are several more requirements, which have to be met by the planning support systems. They are listed in Sprenger et al. 2014. Following, some of the most prominent planning approaches for the described task are presented.

The planning approach by Chopra and Meindl describes a framework for decision support in supply chain design (Chopra and Meindl 2001). According to supply chain strategy, structural problems, including facility selection, will be solved when using optimization. They have designed a highly practical planning approach for strategic network problems, but realistic uncertainties, the impact of trade barriers as well as typical qualitative (location) factors disappear with highly abstracted KPI-analysis or are not even considered.

The manufacturing footprint planning approach from Kinkel responds to these uncertainties with a scenario-based procedure (Kinkel 2009). There planning uncertainties with optimistic, realistic and pessimistic scenario set ups are encountered (Sprenger et al. 2014). The approach provides different modules such as facility controlling, scenario management and the optimization of the existing footprint (Kinkel 2009). However the number of impact factors is limited and trade barrier aspects stay unstudied within the total cost evaluation.

In contrast Goetschalckx and Fleischmann present a planning approach which reflects quantitative and qualitative factors and provides different holistic methods (Goetschalckx and Fleischmann 2005). The planning approach consists of four planning steps which are developed in an iterative procedure. This approach is designed to solve any SCD-planning problems, which leads to a high abstraction level of this approach. High abstracted information can cause wrong footprint decisions with enormous financial losses, which can't be revised (Günter and Tempelmeier 2012).

A planning approach which enables decision makers to evaluate different supply chain design scenarios in a much more detailed level is provided by Seidel (Seidel 2009). Similar to approach by Chopra and Meindl, the supply chain strategy and targets are defined in the first place to derive relevant scenarios afterwards. Based on the established scenarios, a basic material flow optimization will be implemented. Using the network-simulation, an evaluation according to logistic-related KPI's of different supply chain designs can be conducted. This is an iterative planning procedure and the results can be used for both the decision and implementation. Trade barriers are not in the scope of this approach.

Kuhn et al. have developed a general procedure for strategic logistics planning based on Seidel's planning approach (Kuhn et al. 2010). The central method is the simulation of both basic and detailed planning. Next, qualitative methods are provided for the identification and generation of scenarios. In comparison to Seidel's model, the implementation phase is much more detailed and allows basically an integration of quantitative trade barriers. Qualitative impact factors are only covered rudimentarily in the approach.



The results of the literature review show that there are different planning steps necessary for a stable footprint decision support. Most of the analyzed planning approaches show a similar problem solving procedure based on the supply chain strategy. Some of them integrate qualitative as well as quantitative methods. Based on the review, the existing planning approaches can be characterized as ambivalent. On one hand “classic” footprint approaches (Kinkel 2009) focus especially on location specific impact factors (like labor costs, incentives and facility investment). On the other hand supply chain design (Seidel 2009) approaches consider in the first place logistic-related factors (transport costs, inventory level etc.). However, the understanding and consideration of trade barriers within the analyzed approaches is very limited. That means the evaluation scope and the understanding of total cost should be extended by the qualitative and quantitative impact of trade obstacles.

### **3 State of the Art Review of Trade Barriers Concerning the Automotive Industry**

Trade barriers, also referred as market barriers, remain loosely defined in research and practice. This is due to the fact that trade barriers differ from different industrial sectors and over time there appear new kind of measures while other ones are abolished. This is why literature only states common trade barriers, hardly focusing on specific industrial sectors. In order to generate a common understanding of trade barriers concerning the automotive industry in particular, relevant trade barriers in the international trade are compiled and the findings are validated and extended

through studies and database analysis of the current situation in selected emerging markets regarding the automotive sector. These markets are the ones with a high potential for the automotive industry, namely the BRIC states China, India, Brazil, Russia, and the three largest auto markets of the ASEAN countries Thailand, Indonesia and Malaysia.

### **3.1 Characterization of Trade Barriers**

There are two general principles of trade policy, namely free trade and protectionism. While the former implies a broader waiver of governmental intervention in foreign trade, the latter describes the opposite, the governmental restriction of imports or the support of the export economy (Büter 2013). Protectionism is implemented in the form of trade barriers. These can be national laws, regulations and other measures inducted by governments targeting foreign products and services to affect them adversely against local products (MacLean 2006). However, natural trade barriers such as language barriers, cultural unfamiliarity or transport risks are not included in the definition of protectionism (Haas and Neumair 2006) and are therefore not in the focus of this research paper.

International trade organizations, such as the World Trade Organization (WTO), aim a total waiver of trade barriers in the international trade. Even though the OECD estimates that a further reduction of trade barriers will have a significant positive effect on the global welfare for developing and developed countries alike (Love and Lattimore 2009), there are still different motivations for the governments to implement trade barriers, partially against WTO Regulations. The protection of the local economy is clearly one of the main intentions. Specific industrial sectors are advantaged and

supported against foreign products and services. The argumentation for protectionism is obvious. A developing local industry means a higher deployment and as a result a stronger national economy (Dunn and Mutti 2004). Therefore local investments are focused and a know-how transfer is encouraged through the benefited settlement of new technologies. However, this argumentation is highly discussed in literature (Dunn and Mutti 2004; Love and Lattimore 2009). Another motivation for trade barriers to be mentioned is the increase of the export volume, which will lead to a more equal balance of trade. Furthermore trade barriers are used as an additional source of revenue from governments, as a measure for retaliation for foreign import restrictions, as payments against dumping prices as well as a preferential treatment of certain trading partners (Eibner 2007).

The motivations differ from different sectors and countries. Focusing on the automotive industry, one of the most important motives is the local establishment of automotive know-how in order to develop a local industry and protect it from international competition (Humphrey and Memedovic 2003). Furthermore the establishment of production and sales of more ecologically efficient cars is focused in some emerging markets (ICCT 2013).

### **3.2 Classification of Trade Barriers Concerning the Automotive Industry**

Trade barriers are commonly categorized into tariff and non-tariff trade barriers. The first group consists of duties for imported or exported products as well as duty-like levies (Reuvid & Sherlock 2011; Köhne 2015). Tariffs can be distinguished on the basis of their effect. In the automotive sector, the use of import tariffs is wide-spread in emerging markets. Taking a look

on the BRIC states as well as the three biggest car markets in the ASEAN region, namely Thailand, Malaysia and Indonesia, as shown in table 1, it can be seen that all of these high potential market countries use import tariff measures to protect their developing automotive industry as well as intend to force OEMs to increase production in their countries by lowering the duty rates for knocked down vehicle kits (GTAI 2014a; GTAI 2014b; GTAI 2015a). Export duties on the other hand are not relevant for the automotive sector. It applies to more regulated sectors like the defense industry. Other levies are less common but are still a used measure. In India and Malaysia, for example, the governments demand a levy on light vehicles marking it as a countervailing duty and excise duty respectively, which is to be paid besides the actual import duty (GTAI 2014c; GTAI 2014b). Nonetheless, the advantage of tariffs as trade barriers is that unlike non-tariff trade barriers (NTBs), tariffs are very clear in their definition and are subjected to reporting.

However, the balance between tariff and non-tariff trade barriers is changing through the liberalization of the world trade, which leads to reduction of tariff trade barriers. Therefore governments tend to use more NTBs as they are not clearly defined and less transparent (OECD 2005; Jansen et al. 2014). NTBs can be defined as "any government policy, other than a tariff, which reduces imports but does not similarly restrict domestic production of import substitutes" (Dunn and Mutti 2004). Some kind of measures, like import quotas, can uniquely be identified as trade barriers, while the analysis of administrative measures, due to the fact that they are hard to reveal and their effects on the international trade cannot be readily measured, are difficult to define and analyze (OECD 2005). However, the review has shown

that NTBs take many different forms and are also heterogeneous across different countries. A very wide-spread form of non-tariff trade barriers are quantitative restrictions, such as import quotas, local content schemes or voluntary export restraints (Vousden 1990). Especially local content restrictions and its extension referred as local value added restrictions are very common in the emerging markets. This kind of measure is very powerful to force the European car manufactures to invest in local production as well as to boost a know-how transfer. In Brazil the local content restrictions are put into practice through the INOVAR-AUTO regulations, which describe a new kind of credit point generation system through local investments. Duty and tax reductions can be attained, if the OEM can evince that a sufficient amount of credits has been generated by local sourcing and production. Other measures to generate credits are for example local investments in research and development and the production of more energy efficient vehicles (PWC 2014; ICCT 2013). Thailand is another example, where a local value added of 40% is demanded. Besides the local sourcing and assembly of the cars, there are several processes defined, which have to be conducted locally to attain import duty reductions (GTAI 2015b).

Table 1 Automotive Trade Barriers in selected Emerging Markets  
(Sources: Germany Trade & Invest, Country Automotive Studies 2014 and 2015; Central Board of Excise and Customs, India; International Trade Administration, U.S.; PricewaterhouseCoopers Autofacts Brazil 2012; World Economic Forum Enabling Trade Programme 2014; European Commission Market Access Database; EABC Business Position paper 2012; World Bank Policy Research Working Paper 5060 2009; OECD Trade Policy Study 2005; VDA Annual Report 2013; OEM Expert Interviews)

Trade Barriers	China	India	Brazil	Russia	Thailand	Indonesia	Malaysia
Import Duty	up to 25%	up to 125%	up to 55%	up to 15%	up to 80%	up to 125%	up to 30%
Import Levy		8 – 24%					up to 105%
Import Quota			INOVAR				
Local Content	50-60%		INOVAR				
Local Value Added		Main Car Parts	INOVAR	60%	40%		
Subsidiary Restrictions	Joint Venture Restrictions					After Sales Restrictions	

Trade Barriers	China	India	Brazil	Russia	Thailand	Indonesia	Malaysia
Other Invests	CCC		INOVAR				
Certification			Restrictions for some parts apply				
Licensing			LCVM				Open / Franchise APs
Duty Processing				Apply	Apply		
Approval Processing					Apply		
Nonspecific Terms of Trade				Apply			



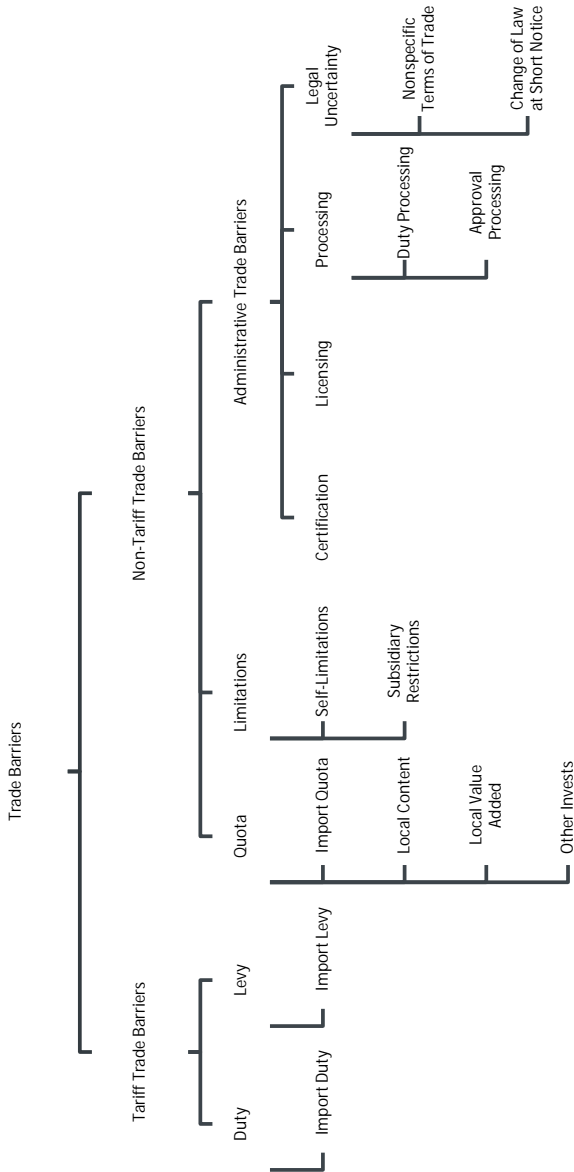


Figure 1: Classification of Trade Barriers concerning the Automotive Industry

Even though India has not specified local content quotas, the government has described several major car parts to be assembled in India in order to get further duty reductions besides a tariff reduction for a part by part supply of the plants. Import quotas for light vehicles are less common in the considered emerging markets or are only implemented in a less restrictive form. For example, the tax reduction in Brazil only applies on the first 4.800 imported cars a year (PWC 2012). Self-limitations also referred as voluntary export restraints, which are imposed by the exporting country do not apply for light vehicles from the European Union. However, another restriction, which is hardly seen in literature, is restriction on subsidiaries. A local production in China can only be conducted by companies, which are in a Chinese majority ownership with a share of minimum 60 % (Liu and Dicken 2006). Indonesia has a similar limitation, which applies to companies performing in the after-sales business (GTAI 2014a). The already mentioned administrative measures can be separated into the four groups: certification, licensing, processing and legal uncertainty. While the first two groups, which are commonly referred as technical barriers to trade (TBT), are very specific and are stated in official documents, the other two groups are hard to reveal. Certifications as well as licensing requirements apply in the considered emerging markets, which mean that the OEMs have to face higher compliance costs (Bao 2014). Although delays in the duty and approval processing as well as unclear terms of trade cannot be stated as official trade barriers, they are cited as one of the most incisive protectionism measures by U.S., European and Asian automotive companies (WEF 2014; OECD 2005). The review of literature as well as the analysis of trade barriers in selected emerging markets results in a classification of trade barriers,

which are highly relevant for the automotive industry. The findings are summarized in figure 1.

#### **4 A Model for a Trade Barrier Integrated Manufacturing Footprint Decision Support**

For the described footprint decision support task, a trade barrier integrated approach has been developed, as shown in figure 2. The developed model is an extension of the existing model described by Sprenger et al. (Sprenger et al. 2014). The aim of this model is to support a cost minimal footprint decision for the opening up of defined target markets while considering the x-tier Supply Chain delivery costs. Therefore, the focus of the original model has been adopted to include an OEM view into the decision finding process and not only limit the focus to a supplier view. One of the most important tasks to reach this goal is the integration of market barrier dynamics into the decision support. As seen in chapter 2, the existing approaches are not adequately considering the market barrier aspects. The proposed approach separates the specific steps of the model as well as the identified market barriers, which are relevant for the auto-motive industry, into qualitative and quantitative factors. The advantage of this procedure is that barriers, which cannot be quantified monetarily, are still taken into consideration to ensure a holistic view. Another advantage is that the decision finding process is designed to scope as much relevant information as possible, which is available in an early phase, before entering the detailed evaluation phase. This process supports a fast and more focused evaluation of a footprint decision support. Before the decision finding support process

can be performed, footprint targets like logistic performance or maximum total costs for a location has to be defined.

The qualitative part of the model consists of three steps. First of all, possible manufacturing footprint locations are identified and checked against specific knock-out criteria in the country, state and community (CSC) analysis. Examples for this kind of criteria are sufficient regional sales volume for OEMs, minimum number of qualified suppliers, which are able to pro-

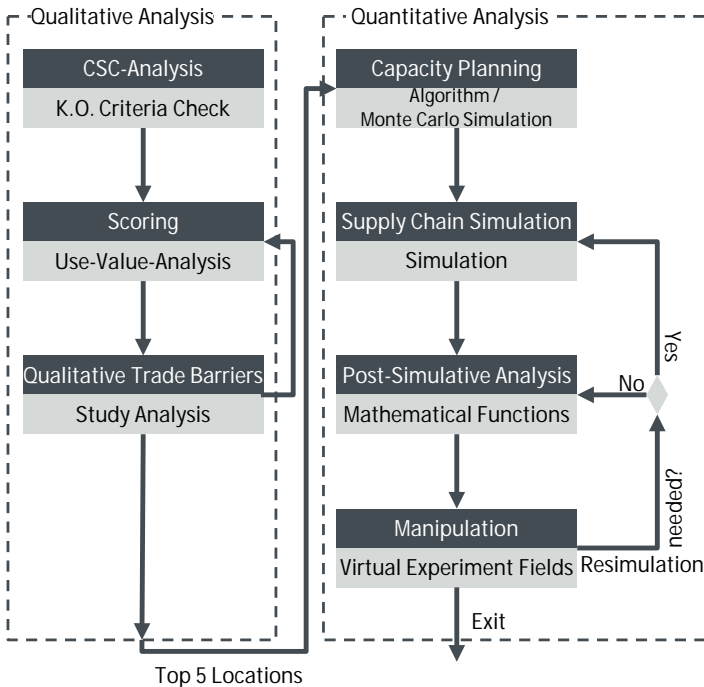


Figure 2 Trade barrier integrated manufacturing footprint decision support approach

duce a sufficient amount of parts or infrastructural criteria such as the distance to an international harbor. Any possible country or region, which fails to fulfill the requirements, will be deleted from the list. The consideration of all the factors together, which can vary within the supply chain, results in a list of regions that may be potential manufacturing locations.

Because in the CSC-analysis only fundamentally relevant criteria are inspected, this step does not have to be performed on every footprint decision finding process. The result of this analysis only has to be validated, if major criteria changes are done or the location environments have changed radically.

Next, a use-value analysis is conducted considering soft location factors, such as political instability or corruption level. Because the quantification of the impact of soft location factors is quite difficult, the weighting and the scoring should be done by experts of the specific region within the company. After this step, a short list of regions for a potential manufacturing plant ordered by company related priorities are identified. The short list should not contain more than three to five countries in order to efficiently perform the next step of the model.

The third step of the presented model is the analysis of qualitative trade barriers, which is the first major addition to the existing model. These are in particular import quotas as well as processing and legal uncertainty listed under administrative trade barriers. Sources like the World Trade Organization (WTO) or the World Bank have to be contacted in order to get the information. These organizations conduct studies on the legal situation regarding trade and therefore gather information about the experiences of companies, which already completed their market entry process. Because

the evaluation of trade barriers is a very time intensive task, the number of countries, which are analyzed, has to be kept very small as mentioned above. It is mandatory to clearly understand the trade barriers. Therefore it can be necessary to get into discussion with the local governments in case of any unclear terms of trade. If the obstacles caused by trade barriers, like too many changes in the terms of trade, which means a high degree of uncertainty in the planning process, are too high, this country will be deleted from the short list. Nevertheless, if there are too many possible locations to be deleted from the list after this analysis step, a reassessment of locations have to be done again in step two following the iterative logic of the model.

As a result of the qualitative analysis part of the presented model a list of the top five possible locations is defined. These five locations are now taken into an in-depth four step quantitative analysis. The first step of the quantitative part is the capacity planning step. In here all location relevant cost factors, such as production costs, personal costs, facility costs and/or incentives are calculated using a linear programming method. Therefore an overview of future projects is needed as an input. It is obvious that due to market dynamics, there is an uncertainty in the probability of occurrence of planned projects. In order to account for uncertainty, a Monte Carlo simulation is used and linked with the project specific confidence level. As a result, the potential locations are listed with a cost evaluation depending on the project constellation of the upcoming years.

The results of the first four steps will be used to lower the number of potential locations and to transform and create relevant data for the further planning step of simulation. First, different supply chain configurations are

modelled and evaluated using the method of simulation by integrating the locations into the existing supply network. Depending on the different project constellations, different sourcing strategies, transportation variants and distribution strategies will be modeled. The results of the supply chain simulation are needed to calculate the relevant cost factors, as described in the following step.

Here a quantitative post-simulation analysis is conducted. This is another major addition to the original model. In this step all relevant cost factors within the supply chain induced by a location are calculated. Therefore a mathematical function is proposed to support the location decision. Here, the quantitative trade barriers are integrated in the analysis. The mathematical function consists of the location cost factors considered in step four, the trade barrier-induced cost factors, material transfer costs and supply chain logistic costs. The authors propose an integration of the x-tier supplier delivery costs as this will have an effect on the material price.

Table 2 Notation of the cost function

Indices	Parameters	Variables
b = Country Boarder (1,...,B)	AIC <sub>b</sub> = Additional Investment Costs	$\alpha_{pv}$ = Transferrate
c = Tariff Category (1,...,C)	ASC <sub>e</sub> = Additional Sourcing Costs	
e = Local Supplier (1,...,E)	CCC <sub>ts</sub> = Capital Comittment Costs	
l = Location (1,...,L)	LABC <sub>l</sub> = Labor Costs	
p = Part (1,...,P)	LEV <sub>bc</sub> = Levy Costs	
s = Supplier (1,...,S)	LIC <sub>l</sub> = Location Investment Costs	
t = Tier-level (1,...,T)	LICLC <sub>l</sub> = Location Intralogistic Costs	
v = Material Transfer (1,...,V)	LS <sub>l</sub> = Location Subsidies	
	MHC <sub>ts</sub> = Material Handling Costs	
	MLC <sub>l</sub> = Manufacturing Loca- tion Costs	



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Indices	Parameters	Variables
	MPC <sub>ts</sub> = Material packaging Costs	
	MTC <sub>ts</sub> = Material Transporta- tion Costs	
	MWC <sub>ts</sub> = Material Warehous- ing Costs	
	PMC <sub>p</sub> = Part Material Costs	
	SCLC <sub>i</sub> = Supply Chain Logistic Costs	
	SDC <sub>e</sub> = Supplier Development Costs	
	TAR <sub>bc</sub> = Tariff Costs	
	TBIC <sub>i</sub> = Trade Barrier induced Costs	

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Cost function:

$$\sum_{l=1}^L (MLC_l + SCLC_l + TBIC_l + TMTC_l) \quad (1)$$

The parameters will be detailed in the following:

$$MLC_l = LABC_l + LIC_l + LILC_l - LS_l \quad (1.1)$$

$$SCLC_l = \sum_{t=1}^T \sum_{s=1}^S (MTC_{ts} + MWC_{ts} + MHC_{ts} + MPC_{ts} + CCC_{ts}) \quad (1.2)$$

$$TBIC_l = \sum_{b=1}^B \sum_{c=1}^C (TAR_{bc} + LEV_{bc}) + \sum_{e=1}^E (ASC_e + SCD_e) + AIC_b \quad (1.3)$$

$$TMTC_l = \sum_{p=1}^P \sum_{v=1}^V PMC_{pv} (1 + \alpha_{pv}) \quad (1.4)$$

Using the presented cost function, the manufacturing footprint costs per location can be calculated. These cost factors are further detailed to a granulation level (formulae 1.1 – 1.4), which allows an in-depth understanding of the cost factors. In the next step, parameters of the simulation model are systematically manipulated and systems behavior is investigated. Manipulated parameters are, for example, volumes, exchange rates and efficiency factors of a plant. Based on an empirical analysis of the model's behavior, an evaluation of robustness is possible. For a reliable realization of different simulation experiments, Virtual Experiment Fields (VEF) and experiment plans are defined. VEF are an effective approach to increase the speed

of decision support based on simulation (Deiseroth et al. 2013). After the data manipulation, it has to be checked if a re-simulation of the model is needed. If not, a post-simulative analysis is done, accordance with the iterative logic of the model. The model exits, when a robust cost minimal location is found, which is within the cost and performance range defined in the beginning in all simulated scenarios.

## 5 Conclusion

This paper presents an approach for a cost minimal manufacturing footprint decision support, which integrates the aspects of trade barriers in the consideration. We analyzed the state-of-the art manufacturing footprint decision support models. The findings have been summarized and critically evaluated in terms of meeting the named requirements. The consideration of trade barriers especially was not sufficient in the analyzed models. Therefore, we conducted an in-depth analysis of automotive relevant trade barriers in selected emerging markets in order to understand the effects of trade barriers on the manufacturing footprint decision process. Using the results, an existing model focusing on automotive supplier footprint decision process is adopted to include the OEM view and to integrate the analysis of trade barriers. The model describes a process, which is designed to include all relevant data available in the specific process phase. The process is separated into a qualitative and a quantitative part, which allows a holistic view on the described task.

The findings presented in this paper do contribute to both research as well as practice. With regard to research, the findings contribute to further developments of process models and frameworks with a holistic view in the context of automotive manufacturing footprint decision finding process research. With regard to practice, the existing planning processes can be focused using the proposed process steps, which can lead to shorter planning durations. For example, it was shown that only a limited number of trade barriers are relevant for the automotive industry. With this knowledge the planning processes can strongly be focused. As a result, the car manufacturers are able to better react to the dynamic environment in the emerging markets. However, the findings of this paper are part of ongoing research of the authors in the field of robust manufacturing footprint decisions and optimization of market entry planning processes in the automotive industry.

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# Reverse Channel Design: Profitability vs. Environmental Benefits

*Lan Wang, Gangshu Cai, Andy Tsay and Asoo Vakharia*

Environmental issues are a growing priority in supply chain management, which has heightened the interest in remanufacturing. A key attribute of a remanufacturing strategy is the division of labor in the reverse channel, especially whether the remanufacturing should be performed in-house or outsourced to a third party. We investigate this decision for a retailer who accepts returns of a remanufacturable product. Our formulation considers the relative cost-effectiveness of the two approaches, uncertainty in the input quality of the collected/returned used products, consumer willingness-to-pay for remanufactured product, and the extent to which the remanufactured product cannibalizes demand for new product. Our analysis predicts the retailer's propensity to remanufacture, which provides a metric of the environmental impact of each strategy.

**Keywords:** Reverse Channel Design, Remanufacturing, Outsourcing,  
Environmental Impact

## 1 Introduction

Sustainability initiatives are at the forefront of many firms' agendas today. Consumers and government mandates are both calling for environment-friendly business practices. Remanufacturing is one approach to sustainability, with benefits that include the diversion of discarded products from landfills, reduced virgin raw material usage, and energy consumption lower than in original manufacturing (U.S. EPA 1997). It is perceived as an environment-friendly end-of-use management option for many product categories (Örsemir, et al 2014). For example, remanufacturing in the auto industry saves over 80% of the energy and raw material required to manufacture a new part, and keeps used parts ("cores") out of landfills. Gutowski, et al (2011) find that remanufacturing consumes less energy than does manufacturing of new products, and evidence suggests that remanufacturing can be superior to recycling in material consumption and overall environmental impact (Fullerton and Wu, 1989). Remanufactured products can be made to perform as well as new products.

GameStop, the consumer electronics retailer that specializes in video-game consoles, motivates our study. The company's retail stores serve as collection centers for used game consoles. Collected consoles are sent to a facility dedicated to testing and refurbishing. Those consoles that undergo refurbishing are sent back to the retail stores to be sold for less than the retail price of new consoles. These less expensive consoles help the company reach consumers who could not or would not buy the product new, and also stimulate the sales of a complementary product carried by GameStop, i.e., game software. Success in this part of the business model

has motivated the company to increase collections (by offering store credits or cash for used consoles), and build its own remanufacturing facility in Grapevine, Texas.

Superiority of an in-house approach to remanufacturing in-house is not a foregone conclusion. A significant number of third-party firms offer remanufacturing/refurbishing expertise, making viable the outsourcing of these activities. As a general business practice, outsourcing is attractive due to its avoidance of direct ownership of workforce, assets, and infrastructure, which increases financial and operational flexibility. Outsourcing may also provide access to specialized and focused expertise. Disadvantages include a possible reduction in product quality, communication and coordination difficulties, and the possibility of the third-party emerging as a competitor by leveraging its inside access to proprietary product and process knowledge (Tsay 2014).

This paper evaluates whether a retailer such as GameStop should remanufacture in-house or outsource this reverse channel activity, an important question which has received little attention in the literature. As we are interested in more than the retailer profitability that results from each alternative, we also consider the environmental consequences.

Our analysis has several noteworthy features. First, the problem we address is grounded in reality. Choosing to remanufacture in-house or outsource the process is not only relevant for GameStop (as can be seen in our motivating example) but it is becoming increasingly relevant for other firms who currently perform these activities in-house (see, for example, Martin, et al, 2010). Second, the choice of reverse channel explicitly incorporates the volume of collected products available for remanufacturing. Third, we

consider uncertainty in the quality of collected products, which makes the cost of each strategy a function of this quality level. Fourth, we endogenize the specification of a base-line quality level for qualifying for remanufacture. This allows prediction of the percentage of collected products that will be remanufactured, providing a measure of environmental impact. Finally, our model of consumer behavior incorporates the possibility that remanufactured product may cannibalize the sales of the new product.

The remainder of this paper is organized as follows. The next section reviews the relevant literature. Section 3 formulates a model of each approach to remanufacturing. Section 4 presents our structural analysis and managerial insights. Section 5 analyzes the impact of the remanufacturing strategies on the environment and proposes an approach that can align profit and environmental objectives. Finally, Section 6 discusses implications of this research and concludes the paper.

## 2 Relevant Literature

Guide and Van Wassenhove (2009), Tang and Zhou (2012), and Souza (2013) provide broad reviews of extant literature on reverse supply chains. This section comments specifically on the four distinguishing features that position our research in this literature: (1) consumer choice, (2) uncertainty in product returns, (3) in-house versus outsourced remanufacturing, and (4) the environmental impact of remanufacturing.

In the area of consumer choice, the vertical differentiation framework has been used to examine whether an OEM should offer remanufactured ver-

sions of its products. Our paper also uses a vertical differentiation framework to depict cannibalization. Consumers in our model value the remanufactured product less than they do the new product, but the valuation is based on perception rather than any real difference in quality.

Uncertainty in the quality and quantity of returns is a major concern in product recovery. Guide and Van Wassenhove (2009) observe that the decision to introduce a remanufactured product depends more on market (demand) or supply (quantity and quality) constraints than on technical operating constraints. We align with this research by treating the quantity of product returns as exogenous (in a deterministic way). Following these observations we allow incoming product return quality to be stochastic and consider remanufacturing costs to be a function of the quality level of the used products. In addition, we endogenize the retailer determination of the base-line quality level, which is the threshold that used products must exceed to qualify for remanufacture.

The general in-house versus outsource decision is the subject of a vast amount of study in multiple disciplines, for which Tsay (2014) can serve as an overview. Regarding the decision for remanufacturing in particular, the available research is sparse since the options have been limited. That is, remanufacturing activities have until recently been carried out primarily by small, independent, and privately-owned outside service providers (Guide, 2000). As the volume of remanufacturing has grown, more firms have begun performing these activities in-house or evaluating the ramifications of doing so. Our research informs this possibility directly. Our model of the outsourcing approach assumes the third-party charges the retailer a per-unit

fee for performing the remanufacturing, and controls the decision of how much of the collected used goods to actually remanufacture.

The literature on the environmental impact of remanufacturing is growing (see, for example, Corbett and Kleindorfer, 2001a; and Corbett and Kleindorfer, 2001b). We are able to assess the environmental impact of each strategy choice as measured by the volume of the collected/used products remanufactured since we endogenize the base-line quality level decision for each strategy choice. This allows characterization of key trade-offs. For instance, a low base-line quality level leads to a less environmental harm (as more collected/used products are remanufactured) but also higher costs. Enabling simultaneous consideration of financial and environmental goals aligns with work such as Tang and Zhou (2012), who formulated a "PPP ecosystem" to illuminate the triple-bottom-line objective (profit, people, and planet).

In sum, we draw upon and extend prior research in remanufacturing to examine how a firm evaluates the strategic choice between an in-house remanufacturing channel and an outsourced one. Our analysis integrates a combination of salient factors that has not previously been studied: uncertainty in the quality of product returns; costs and efficiencies specific to each strategy choice; endogenization of the base-line quality level decision which drives the volume of collected/used products that are remanufactured; and cannibalization effects when remanufactured and new products are both available to consumers. The next section describes our analytical framework.



### 3 Analytical Framework

#### 3.1 Preliminaries

Our stylized reverse supply chain setting for a single product is as follows. A single retailer serves a market by offering a new product (identified by subscript  $n$ ) as well as a remanufactured version of the same product (identified by subscript  $r$ ). The new product is procured by the retailer from a supplier at wholesale price  $w_n$  and offered to customers at retail price  $p_n$  which is pre-specified by the supplier (of course,  $p_n > w_n$  and both these prices are assumed to be exogenous). A key decision for the retailer is to determine the remanufactured product price  $p_r$ , with a requirement that  $p_r < p_n$ . All events transpire within a single period.

The product has a specified performance capability when functioning properly, which we call "functional quality." We assume that remanufacturing restores used goods to exactly the functional quality level of the new product, in accord with GameStop's actual practice. To simplify analysis without loss of generality, we normalize this quality level to 1 (i.e.,  $q_n = q_r = 1$ ). A consumer derives one of the following two net utility levels from purchasing a new or remanufactured product, respectively:

$$u_n = \gamma q_n - p_n = \gamma - p_n \quad (1)$$

$$u_r = \alpha \gamma q_r - p_r = \alpha \gamma - p_r \quad (2)$$

$\gamma$  in these utility functions is the consumer's willingness-to-pay and uniformly in the interval  $(0,1)$ . In equation (2),  $\alpha \in (0,1)$  is a constant reflecting consumer perception that the remanufactured product is inferior to the new product quality-wise, which is reminiscent of the term "perceived

quality." Any subsequent use of the term "quality" will refer to functional quality, and perceived quality will always be explicitly labeled as such. A consumer's choice between new and remanufactured products is driven by comparing the net utility levels in equations (1) and (2). This leads to: (a) Case 1: If  $\frac{p_r}{\alpha} < p_n$ . In this case, the consumers with willingness-to-pay  $\gamma \in [\frac{p_r}{\alpha}, \frac{p_n - p_r}{1 - \alpha}]$  prefer to buy a remanufactured product. Those with  $\gamma \in [\frac{p_n - p_r}{1 - \alpha}, 1]$  will buy a new product; or (b) Case 2: If  $\frac{p_r}{\alpha} \geq p_n$ . In this case, all consumers with  $\gamma \in [p_n, 1]$  will buy new products while the remainder will buy nothing.

We deemphasize Case 2 for the remainder of the paper since in that setting only the new product would be offered. Then the reverse channel would not exist, obviating the need for any decision between in-house remanufacturing and outsourcing. Focusing on Case 1 with market size normalized to 1 leads to the following demand functions for the two product types:

$$D_n = 1 - \frac{p_n - p_r}{1 - \alpha} \quad (3)$$

$$D_r = \frac{\alpha p_n - p_r}{\alpha(1 - \alpha)} \quad (4)$$

Total market coverage is then  $1 - \frac{p_r}{\alpha}$ . These demand variables (as well as the various decision variables and performance outcomes) will later be further subscripted with  $i$  to indicate dependence on the design of the reverse channel, i.e., whether the retailer remanufactures in-house (identified by a subscript of  $i=1$ ) or outsources the activity to a third-party (a subscript of  $i=2$ ). We refer to the former strategy as "In-house" and the latter as "Outsourcing."

The supply of product available to meet the above demand is denoted by  $S$ .  $S$  is the amount of collected product available for remanufacturing, which is exogenous to the model and normalized to take a maximum value of 1 ( $0 < S \leq 1$ ).  $S$  is the ratio of total collected items to total cumulative sales, with collection activities carried out by the retailer (e.g., GameStop retail stores accepting used game consoles) or a third-party.

The functional quality of a collected item is  $\theta$ , which is uniformly distributed on the range  $(0,1)$  with probability density  $f(\theta)$ . The fraction of returned products available for remanufacturing for each strategy choice is  $\int_0^{\tilde{\theta}_i} f(\theta) d\theta = 1 - \tilde{\theta}_i$ , where  $\tilde{\theta}_i$  represents the base-line quality level such that all collected items with at least this functional quality will be remanufactured. This endogenously-determined threshold also indicates the proportion of collected products destined for disposal, hence serves as our measure of environmental impact. The "best" environmental outcome is  $\tilde{\theta}_i = 0$ , i.e., remanufacturing of 100% of collected items.  $\tilde{\theta}_i = 1$  (no remanufacturing) is the "worst" outcome.

The two strategies differ in cost. The per-unit cost associated with remanufacturing is a function of effort expended to restore to the quality level of the new product. Given  $q_n = q_r = 1$ , the per-unit cost of remanufacturing under strategy choice  $i$  is defined as  $C_i = c_i(1 - \theta)$ , where  $\theta$  is the quality of each collected item ( $0 \leq \theta \leq 1$ ).

The parameter  $c_i$  allows the two strategies to differ in their efficiency of remanufacturing. This leads to these expressions of the total expected remanufacturing cost for each strategy:

In-house:

$$\int_{\tilde{\theta}_1}^1 c_1(\theta) S f(\theta) d\theta = \int_{\tilde{\theta}_1}^1 c_1(1 - \theta) S f(\theta) d\theta = \frac{c_1 S (1 - \tilde{\theta}_1)^2}{2} \quad (5)$$

and; Outsourcing:

$$\int_{\tilde{\theta}_2}^1 c_2(\theta) S f(\theta) d\theta = \int_{\tilde{\theta}_2}^1 c_2(1 - \theta) S f(\theta) d\theta = \frac{c_2 S (1 - \tilde{\theta}_2)^2}{2} \quad (6)$$

The next two sub-sections describe our approach for analyzing each strategy.

### 3.2 In-house Remanufacturing

For this strategy choice the retailer's two decision variables are the price of the remanufactured product ( $p_r$ ) and the base-line quality level ( $\tilde{\theta}_1$ ) such that all collected items whose incoming quality exceeds  $\tilde{\theta}_1$  will be remanufactured. Since the total quantity of collected items is exogenous, the cost of acquiring these goods will be unaffected by the retailer's reverse channel decisions, so we assign this fixed cost a value of zero for the sake of simplicity. Our analysis does not consider the sales of complementary products (such as game software for GameStop) since many retailers of remanufactured goods do not have this kind of product portfolio.

The retailer's total profit is revenue generated from selling new and remanufactured products less the costs of procuring new product and remanufacturing collected items.

This results in the following constrained profit-maximization problem, with the constraint specifying that sales volume of the remanufactured product cannot exceed the total collections:

$$\text{Max}_{0 \leq p_{r1} \leq \alpha p_n, 0 \leq \tilde{\theta}_1 \leq 1} \pi_1 = (p_n - w_n)D_{n1} + p_{r1}D_{r1} - \frac{c_1 S(1 - \tilde{\theta}_1)^2}{2} \quad (7)$$

s.to:  $c_1$

$$D_{r1} \leq S \int_0^{\tilde{\theta}_1} f(\theta) d\theta = S(1 - \tilde{\theta}_1) \quad (8)$$

The constraint in equation (8) always binds at optimality and Table 1 reports the resulting optimum.

Table 1 shows that the solution is driven by  $c_1$ , the remanufacturing efficiency parameter. The following properties hold:

(a) When  $c_1 \in (0, x - y]$ , the retailer charges a price for the remanufactured product that does not depend on  $c_1$ , and remanufactures all collected products. The total market served by both products will be greater than when only the new product is offered, although retailer profit declines (linearly) with  $c_1$ , in this range. The underlying intuition is that when remanufacturing can be done very efficiently, all collected products will be remanufactured  $\tilde{\theta}_1^* = 0$  and put on the market. Given this fixed demand, the retailer's chosen selling price for the remanufactured product and therefore revenue are both invariant to the remanufacturing cost in the given range. Any increase in the cost of remanufacturing reduces the retailer's profit (linearly).

(b) When  $c_1 \in (x - y, 1)$ , remanufacturing cost increases, the retailer will raise the selling price of remanufactured product and remanufacture less.

The net effect is to decrease demand for the remanufactured product while increasing demand for the new product. As with the efficient case, the retailer cannot avoid a decline in profit when  $c_1$  increases, but here the relationship is non-linear.

Table 1 Optimal solution for In-house remanufacturing  
where  $x = \alpha w_n$  and  $y = 2\alpha(1 - \alpha)S$ .

	Range for $c_1$	
	$c_1 \in (0, x - y]$	$c_1 \in (x - y, 1]$
$p_{r1}^*$	$\alpha[p_n - S(1 - \alpha)]$	$\alpha p_n - \frac{\alpha^2(1 - \alpha)S w_n}{2\alpha(1 - \alpha)S + c_1}$
$\tilde{\theta}_1^*$	0	$1 - \frac{\alpha w_n}{2\alpha(1 - \alpha)S + c_1}$
$D_{n1}^*$	$1 - p_n - \alpha S$	$1 - p_n - \frac{\alpha^2 S w_n}{2\alpha(1 - \alpha)S + c_1}$
$D_{r1}^*$	S	$\frac{\alpha S w_n}{2\alpha(1 - \alpha)S + c_1}$
$\pi_1^*$	$(p_n - w_n)(1 - p_n) + \frac{S}{2}[2\alpha w_n - c_1 - 2\alpha(1 - \alpha)S]$	$(p_n - w_n)(1 - p_n) + \frac{\alpha^2 S w_n^2}{4\alpha(1 - \alpha)S + 2c_1}$

### 3.3 Outsourcing of Remanufacturing

In this strategy a third-party remanufactures the returned items and then the retailer sells these alongside brand-new products (i.e., the reverse supply chain now contains a second decision-maker). We assume that number of collected/used items available for remanufacturing (i.e.,  $S$ ) is the same as for the In-house strategy. As explained in the previous sub-section, the cost of acquiring these items would show up in the retailer's profit function as a fixed cost, so we set this value to zero. The used goods are provided as input materials to the third-party, who remanufactures for a per-unit fee. We refer to this fee as a wholesale price, although it could also be interpreted as a fee for providing the remanufacturing services. This is consistent with standard practices in outsourced manufacturing in general, where an OEM client might directly procure and ship some portion of the raw materials to its contract manufacturer, meaning that the final invoice should net out the cost of these materials.

We analyze this outsourcing approach as a two-player decision problem with the third-party as Stackelberg leader and the retailer as follower. The third-party's decision variables are the per-unit wholesale price for the remanufactured product  $w_{r,2}$  and base-line quality level  $\tilde{\theta}_2$ , while the retailer chooses the remanufactured product's selling price  $p_{r,2}$ . The third-party sets  $w_{r,2}$  to maintain incentive-compatibility for the retailer. All information is common knowledge.

We first characterize the demand for the remanufactured product ( $D_{r2}$ ) as a function of the  $w_{r2}$  faced by the retailer. The retailer's profit-maximization problem is:

$$\text{Max}_{w_{r2} \leq p_{r2}} \pi_2 = (p_n - w_n)D_{n2} + (p_{r2} - w_{r2})D_{r2} \quad (9)$$

where  $D_{n2}$  and  $D_{r2}$  are as defined earlier in equations (3) and (4). Equation (7) is strictly concave in  $p_{r2}$  for a given  $w_{r2}$ . The retailer's best-response selling price for the remanufactured product is:

$$p_{r2}(w_{r2}) = \alpha p_n - \frac{(\alpha w_n - w_{r2})}{2} \quad (10)$$

Substituting equation (10) into equation (4) indicates that at a given  $w_{r2}$  the demand for the remanufactured product is:

$$D_{r2}(w_{r2}) = \frac{(\alpha w_n - w_{r2})}{2\alpha(1 - \alpha)} \quad (11)$$

We assume that  $\alpha w_n - w_{r2} \geq 0$  so that demand for remanufactured product is non-negative. The third-party's profit-maximization problem is then:

$$\text{Max}_{w_{r2} \leq \alpha w_n, 0 \leq \tilde{\theta}_2 \leq 1} \pi_{20} = w_{r2}D_{r2} - \frac{c_2 S(1 - \tilde{\theta}_2)^2}{2} \quad (12)$$

s.to:

$$D_{r2} \leq S \int_0^{\tilde{\theta}_2} f(\theta) d\theta = S(1 - \tilde{\theta}_2) \quad (13)$$

Table 2 shows the resulting Stackelberg equilibrium. Table 2 shows how the equilibrium for the outsourcing option is shaped by  $c_2$ , the third-party's remanufacturing efficiency parameter. The following properties hold:



When  $c_2 \in (0, x - 2y]$ , the third-party charges a wholesale price for the remanufactured product that does not depend on the cost of remanufacturing, and remanufactures all collected products. The retailer in turn holds fixed the remanufactured product's selling price. Within the stated range of third-party remanufacturing cost, the third-party profit decreases (linearly) with  $c_2$  while the retailer profit is constant. With demand being constant, the retailer's selling price for the remanufactured product is invariant to the remanufacturing cost in the given range. The constant demand for both products and constant product prices makes the third-party profit decline (linearly) as remanufacturing costs increase.

When  $c_2 \in (x - 2y, 1)$ , remanufacturing costs increase, the third-party remanufactures a smaller quantity and increases the wholesale price. In turn the retailer also increases the remanufactured product's selling price (to cover increases in the wholesale price), which decreases demand for this category. Once again, adding the remanufactured product to the portfolio increases total market coverage. Profits for both the third-party and the retailer decline (non-linearly) as the remanufacturing cost increases.

Table 2 Equilibrium for Outsourcing of remanufacturing  
Where  $x = \alpha w_n$  and  $y = 2\alpha(1 - \alpha)S$ .

	Range for $c_2$	
	$c_2 \in (0, x - 2y]$	$c_2 \in (x - 2y, 1]$
$w_{r2}^*$	$\alpha[w_n - 2S(1 - \alpha)]$	$\alpha w_n - \frac{2S\alpha^2(1 - \alpha)w_n}{4\alpha(1 - \alpha)S + c_2}$
$p_{r2}^*$	$\alpha[p_n - S(1 - \alpha)]$	$\alpha p_n - \frac{S\alpha^2(1 - \alpha)w_n}{4\alpha(1 - \alpha)S + c_2}$
$\tilde{\theta}_2^*$	0	$1 - \frac{\alpha w_n}{4\alpha(1 - \alpha)S + c_2}$
$D_{n2}^*$	$1 - p_n - \alpha S$	$1 - p_n - \frac{S\alpha^2 w_n}{4\alpha(1 - \alpha)S + c_2}$
$D_{r2}^*$	$S$	$\frac{S\alpha w_n}{4\alpha(1 - \alpha)S + c_2}$
$\pi_2^*$	$(p_n - w_n)(1 - p_n) + \alpha(1 - \alpha)S^2$	$\frac{(p_n - w_n)(1 - p_n)}{S^2(1 - \alpha)\alpha^3 w_n^2} + \frac{S^2(1 - \alpha)\alpha^3 w_n^2}{[4\alpha(1 - \alpha)S + c_2]^2}$
$\pi_{2o}^*$	$\frac{S}{2}[2\alpha w_n - c_2 - 4\alpha(1 - \alpha)S]$	$\frac{S\alpha^2 w_n^2}{8\alpha(1 - \alpha)S + 2c_2}$

The next section provides structural insights regarding how the retailer should choose between the In-house and Outsourcing strategies.

## 4 Design of the Reverse Channel for Remanufacturing

This section guides the retailer's decision of whether to remanufacture in-house or outsource to a third-party. Assessment of the two options is with respect to two distinct metrics: retailer profitability and environmental impact. The latter is proxied by the fraction of the collected second-hand product that actually proceeds to remanufacture. The analysis focuses on the remanufacturing efficiency of each strategy choice. What follows will make use of the following ordering of the boundaries of the distinct cases appearing in Tables 1 and 2, which are straightforward consequences of our parameter assumptions:  $0 < x - 2y < x - y < 1$ .

### 4.1 Profitability

The following Proposition identifies when each approach to remanufacturing will provide the retailer with superior profits. Figure 1 then presents the findings visually.

Proposition 1: Define  $\hat{c} = \frac{x^2 - y^2}{y}$  and  $g(c_1) = y(\sqrt{1 + \frac{c_1}{y}} - 2)$  where

$$x = \alpha w_n \text{ and } y = 2\alpha S(1 - \alpha).$$

If  $c_1 \in (0, \hat{c}]$ , then regardless of the value of  $c_2$ , In-house is more profitable for the retailer;

If  $c_1 \in (\hat{c}, 1)$ , then: (a) If  $c_2 \in (g(c_1), 1)$ , In-house is more profitable for the retailer; and (b) If  $c_2 \in (0, g(c_1))$ , Outsourcing is more profitable for the retailer.

The retailer's decision of whether to outsource remanufacturing incorporates a cost effect and a revenue effect. The cost effect stems from the relative magnitudes of  $c_1$  and  $c_2$  while the revenue effect is tied to increases in sales of the new and/or remanufactured products. When remanufacturing can be conducted cheaply in-house, the cost effect discourages outsourcing even if the third-party can also perform the task at low cost ( $c_2$  is very small). When both parties can remanufacture at low cost, the profit margins are high and so is revenue since all collected items tend to be remanufactured. This makes the retailer reluctant to share the profit with the third-party, as outsourcing would necessitate. When the In-house remanufacturing cost is large, the retailer's decision is driven by the cost differential between the two strategies. As long as  $c_2$  is sufficiently small, the wholesale price will be low and the resulting sales of remanufactured product will make Outsourcing attractive. But as  $c_2$  increases and closes the gap between the two strategies' retail prices for the remanufactured product, in which case the retailer will opt to remanufacture In-house. These findings are on display in Figure 1. The following observation characterizes how the cost parameters impact the price of the remanufactured product and the demand for both products.

Observation 1

1. If  $c_1 \in (0, x - y]$  and  $c_2 \in (0, x - 2y]$ , In-house and Outsourcing strategies are identical in the price of the remanufactured product and the demand for both products.
2. If  $c_1 \in (x - y, 1)$  and  $c_2 \in (x - 2y, 1)$ , the more profitable remanufacturing strategy will be the one for which the remanufactured product has the lower price and the larger demand.

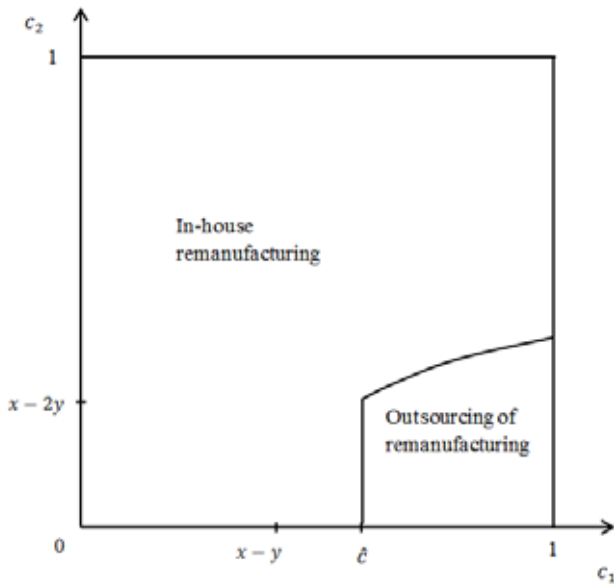


Figure 1 Regions where each strategy is preferred from a profit perspective

We next discuss the strategy choice from an environmental perspective.

## 4.2 Environmental Impact

Our measure of the environmental impact is  $\tilde{\theta}_i$  which represents the fraction of collected items that will not undergo remanufacturing. Lower values are better for the environment. The following Proposition identifies the strategy that is better in this respect, then Figure 2 illustrates the findings.

**Proposition 2** : The more environmentally friendly strategy can be identified as follows, with  $x = \alpha w_n$  and  $y = 2\alpha(1 - \alpha)S$ :

If  $c_1 \in (0, x - y]$  and  $c_2 \in (0, x - 2y]$ , both strategies identically achieve the lowest possible environmental impact;

If  $c_1 \in (x - y, 1)$  and  $c_2 \in (0, x - 2y)$ , Outsourcing is superior;

If  $c_1 \in (0, x - y]$  and  $c_2 \in (x - 2y, 1)$ , In-house is superior;

If  $c_1 \in (x - y, 1)$  and  $c_2 \in (x - 2y, 1)$ , then: (a) if  $c_1 - c_2 < y$ , In-house is superior; (b) if  $c_1 - c_2 = y$ , both strategies have the same environmental impact; and (c) if  $c_1 - c_2 > y$ , Outsourcing is superior.

This Proposition and the corresponding Figure 2 show that when both strategies can remanufacture at low cost, all units will be remanufactured. When In-house is relatively higher in cost than Outsourcing, the third-party chooses a lower base-line quality level than the retailer would. This makes Outsourcing the better choice for the environment. When the remanufacturing costs of both strategies are high, the size of the gap between the two costs defines when each strategy will dominate. In-house tends to be the better choice in more of the cases.

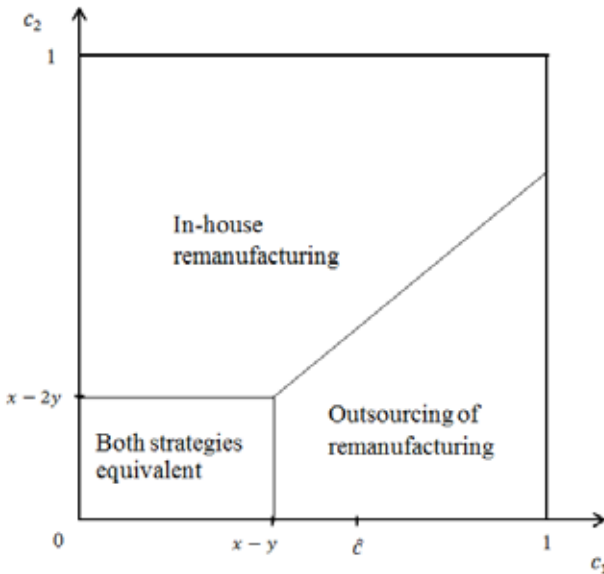


Figure 2 Regions where each strategy is preferred from an environmental perspective

### 4.3 Joint Consideration of Profit and Environmental Impact

Here we evaluate the extent of incongruence between the retailer's pursuit of profit and concern for the environment. This entails combining the analytical conclusions of Propositions 1 and 2. Figure 3, which overlays Figures 1 and 2, graphically illustrates when the profit and environmental objectives can be achieved with the same remanufacturing strategy, and when the objectives conflict. In this Figure, the labels I, O, P, and E refer to In-

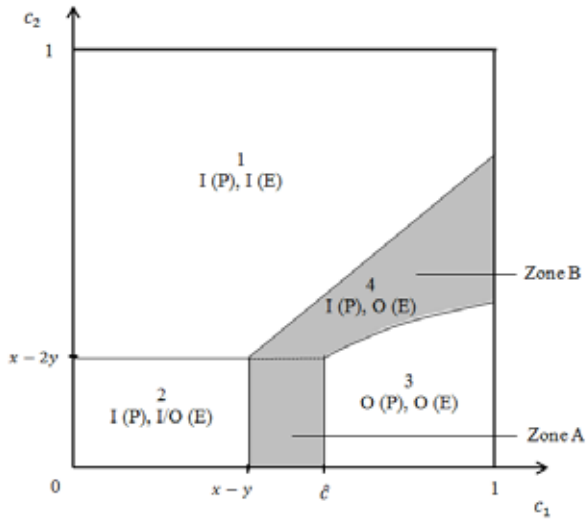


Figure 3 Profit vs environmental impact: region of "conflict"

house, Outsourcing, profitability, and environmental-friendliness, respectively. Then  $I(P)$  indicates that In-house remanufacturing is more profitable,  $O(E)$  indicates that Outsourcing strategy is more environmentally-friendly,  $O/I(E)$  indicates that the environmental impact is the same for both strategies, and so on.

Figure 3 displays four regions. In two of them the retailer can maximize profit and minimize environmental impact simultaneously, by remanufacturing In-house in region 1 and by Outsourcing the remanufacturing in region 3.



Both options have equal environmental impact in region 2, while In-house provides superior profit. Region 4 exhibits "conflict," in that In-house gives greater profit while Outsourcing is better for the environment.

Three of the regions require no special intervention since the profit and environmental objectives can be satisfied simultaneously. "Conflict" occurs in region 4. Based on the conditions in Proposition 3, this region is divided as follows into two parts that reflect the efficiencies at which each party can remanufacture (see Figure 3):

Zone A (efficient remanufacturing):  $c_1 \in [x - y, \hat{c}]$  and  $c_2 \in (0, x - 2y)$ ;

and Zone B (inefficient remanufacturing):

$$c_1 \in [x - y, 1] \text{ and } c_2 \in \max \left\{ x - 2y, y \left( \sqrt{1 + \frac{c_1}{y}} - 2 \right), c_1 - y \right\}$$

The next section investigates ways to align the objectives in these two zones.

## 5 Alignment of Profit and Environmental Goals

This section outlines an approach to aligning the profit and environmental objectives within each of the two zones in the region of "conflict."

In the "conflict" region the retailer maximizes profit by remanufacturing In-house, but Outsourcing would be better for the environment. This section explores whether changing the contract with the third-party to one that shares the third-party's profit can lead the retailer to prefer Outsourcing. This would resolve the conflict if, relative to the In-house decision absent profit-sharing, the equilibrium solution would (a) give the retailer at least as much profit, and (b) assure at least as much remanufacturing.

As a basis for the proposed mechanism, we assume that the retailer offers the third-party the opportunity to remanufacture some of the  $S$  used items provided the latter would agree to share a percentage  $\rho$  of its profits. Hence, our contract design is viable when the third-party agrees to these terms. Contingent on this, the third-party acts as Stackelberg leader in setting the wholesale price. The third-party's decision problem is:

$$\text{Max}_{w_r^p \geq 0, 0 \leq \tilde{\theta}_2^p \leq 1} \pi_{20}^p = (1 - \rho) \left[ w_r^p D_r^p - \frac{c_2 S (1 - \tilde{\theta}_2^p)^2}{2} \right] \quad (14)$$

s.to:

$$D_r^p \leq S \int_0^{\tilde{\theta}_2^p} f(\theta) d\theta = S(1 - \tilde{\theta}_2^p) \quad (15)$$

As in the earlier analysis of Outsourcing, the constraint will bind at optimality. The third-party's wholesale price for the remanufactured good (denoted as  $w_r^p$ ) must take into account the retailer's best-response decisions that drive the value of  $D_r$ .

The retailer's profit-maximization problem is:

$$\begin{aligned} \text{Max}_{w_r^p \leq p_r^p} \pi_2^p &= (p_n - w_n) D_n + (p_r^p - w_r^p) D_r \\ &+ \rho \left[ w_r^p D_r - \frac{c_2 S (1 - \tilde{\theta}_2^p)^2}{2} \right] \end{aligned} \quad (16)$$

where  $D_n = 1 - \frac{p_n - p_r^p}{1 - \alpha}$  and  $D_r = 1 - \frac{\alpha p_n - p_r^p}{\alpha(1 - \alpha)}$ . It is straightforward to show that  $\pi_2^p$  is concave in  $p_r^p$ . This leads to:

$$p_r^p(w_r^p) = \alpha p_n - \frac{S\alpha(1-\alpha)[\alpha w_n - (1-\varrho)w_r^p]}{2S\alpha(1-\alpha) + \varrho c_2} \quad (17)$$

and consequently,

$$D_r(w_r^p) = \frac{S[\alpha w_n - (1-\varrho)w_r^p]}{2S\alpha(1-\alpha) + \varrho c_2} \quad (18)$$

The incentive-compatible profit-maximization problem for the third-party is then:

$$\begin{aligned} \text{Max}_{w_r^p \geq 0, 0 \leq \tilde{\theta}_2^p \leq 1} \pi_{20}^p = (1-\rho) \left\{ w_r^p \left[ \frac{S[\alpha w_n - (1-\rho)w_r^p]}{2S\alpha(1-\alpha) + \rho c_2} \right] \right. \\ \left. - \frac{c_2 S(1-\tilde{\theta}_2^p)^2}{2} \right\} \quad (19) \end{aligned}$$

s.t.:

$$\frac{S[\alpha w_n - (1-\rho)w_r^p]}{2S\alpha(1-\alpha) + \rho c_2} \leq S(1-\tilde{\theta}_2^p) \quad (20)$$

The results of the equilibrium solution for this problem are displayed in Figure 4. It can be seen that the profit-sharing mechanism can resolve the conflict in only part of the conflict region.

Conflict persists in the areas of Figure 4 we label Zones C and D. In both zones, when  $c_2$  is sufficiently lower than  $c_1$ , profit-sharing creates the prospect that the retailer can enhance its profit relative to the the corresponding spot of Zone A of Figure 3. At the same time, the third-party has incentive to raise the wholesale price ( $w_r^p$ ) to offset the profit-sharing, whereby

the retailer ends up with less profit than under the original in-house strategy. The underlying reason is that the third-party always has an incentive to push up the transfer price after the retailer has decided to outsource the remanufacturing.

The agreement to share its profit induces the third-party to lower the baseline quality threshold for remanufacturing, making the Outsourcing strategy with profit-sharing more environmentally friendly than the original Outsourcing strategy choice. The wholesale price also goes up, raising the possibility that the third-party is not necessarily worse off for entering into the profit-sharing scheme.

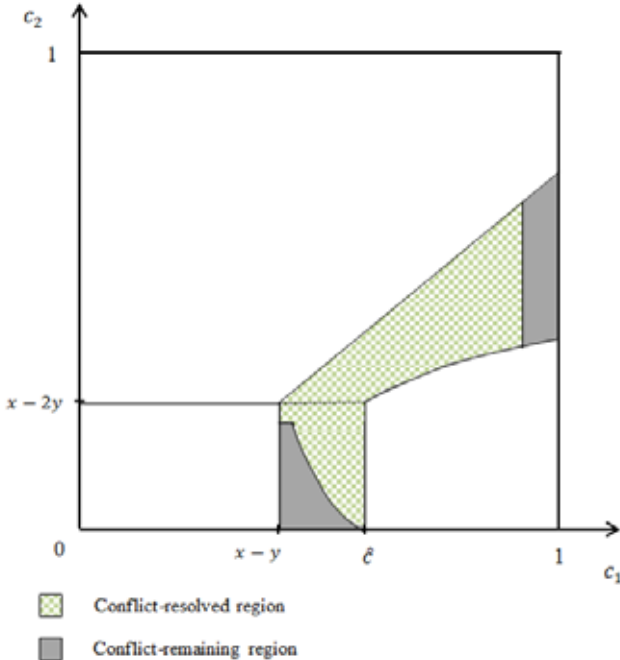


Figure 4 Area where profit-sharing mechanism can resolve conflict

## 6 Implications and Conclusions

Our research is motivated by the case of GameStop, who initially outsourced the remanufacturing of game consoles then subsequently built this capability internally. We have provided parametric guidelines for making the strategic choice between the In-house and Outsourcing options. We have introduced a metric of the environmental impact of each approach to remanufacturing.

The major contributions and managerial insights stemming from this research are as follows. First, we have analytically determined the optimal/equilibrium selling price of remanufactured product, base-line quality level for remanufacturing, retailer profit, and market shares for new and remanufactured products under each strategy choice. We have identified cases in which the retailer should not remanufacture all of the collected products.

Second, we have found cases where In-house remanufacturing is preferred, even though Outsourcing provides access to more efficient remanufacturing capability. This is because the third-party expects compensation.

Third, we have determined when profit and environmental objectives are at odds. Practitioners should find this particularly useful when faced with public pressure to prioritize environmental protection. To resolve this conflict, we propose a profit-sharing agreement between the third-party remanufacturer and the retailer. For this we show that the Outsourcing can be made to dominate In-house remanufacturing in both retailer profitability and environmental impact. Unfortunately, this approach does not work in all cases of conflict between the two goals.

Future research can examine mechanisms by which the retailer acquires used products and how this moderates the choice of the remanufacturing strategy. For instance, the terms of GameStop's trade-in program impact both the quantity and quality of returned game consoles, which our model has identified as key determinants of the relative desirability of the In-house and Outsourcing approaches. A second issue of interest would be the moderating role of product lifecycle on the choice of the remanufacturing strategy. It is reasonable to hypothesize that Outsourcing might be preferred during the start-up and decline phases, while In-house would outperform in the growth and maturity phases.

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## II. Application Areas of Sustainability



# Sustainable Distribution in the Consumer Goods Supply Chain

*Juliana Kucht Campos and Dustin Schoeder*

Sustainability in logistics and efforts to increase economic gains while managing the impact on the environment and on society have been discussed in all spheres of companies' decision-making processes. Especially in the consumer goods industry, customers' pressures are becoming more intense, not only related to product stewardship but also to supply chain responsibility. This paper intends to discuss how companies have been preparing themselves or reacting to these new demands. Using the content analysis method, practices published in public reports and implemented by top ranked sustainable companies were collected and analyzed. The practices were structured according to a newly developed framework for sustainable supply chains and are focused on distribution activities. These activities account for a large percentage of companies' carbon footprint and therefore offer ample opportunity for improvements in sustainability. The results show that the bulk of companies' investments related to sustainability is in Equipment and Vehicles technologies, especially battery electric vehicles. To understand more about this new trend, a survey was conducted with 33 companies from different industries in order to detect business users' profiles as well as their technical characteristics. The paper's results include insights about the challenges and opportunities in the consumer goods industry towards a sustainable supply chain network.

**Keywords:** Sustainability, Supply Chain, Consumer Goods, Electric Vehicles

## 1 Sustainable Distribution Practices

The impact of the distribution of goods on the environment and on society is a topic well discussed and with growing research interest. The distribution of goods affects local air quality, generates noise and vibration, causes accidents and significantly contributes to global warming. Transport's share in global greenhouse gas emissions in 2000 had reached 14% (Stern, 2007, p.171) and continues to grow. Due to the growth of e-commerce, globalization and customers' demands, the amount of freight transport is growing substantially. Actions related to distribution activities offer strategic opportunities to decrease companies' carbon footprint, overall costs and negative impact on people's lives. According to a framework developed by Juliana Campos from the logistics department of the Technische Universität Berlin (still not published), practices related to distribution can be clustered in four groups: structure and network, modes of transport, distribution processes and equipment and vehicles (E&V). The focus of the present paper is on E&V related practices, the most cited practice within the selected companies. In other words, the paper explores how members of consumer goods supply chains use E&V improvements towards a more sustainable distribution.

According to the United States Department of Energy, two-thirds of future fuel efficiency gains will come from improvements in engine and exhaust systems (McKinnon, Browne and Whiteing, 2010, p.142). More efficient vehicles such as those complying with EURO emission standard are becoming more commonly used, especially in commercial transport. Metro Group declared that 95% of their trucks are EURO 5. Increasing efficiency also includes the use of less dense material in the chassis (Liimatainen, Stenholm,

Tapio and McKinnon, 2012, p.836). The use of aluminum instead of steel, for example, can cut up to 3000kgs of the tare/empty weight of the truck. This is a good solution when the problem is weight rather than space. Benefits include fuel savings and, consequently, reductions in the amount of emissions (McKinnon, Browne and Whiteing, 2010, 142). Efforts to increase vehicle capacity include the use of "mega trucks" that offers efficiency gains on the main haul (Gross et al., 2013, p.45). Among the various social impacts, infrastructure damage, additional congestion and an increased risk of accidents are highlighted on the literature (Grant, Trautrim and Wong, 2013, p.69). Regenerative braking, aerodynamics accessories and "next generation tires", which can raise fuel efficiency by 3.5-8%, offer additional improvements (Schönberger, Galvez-Martos and Styles, 2013, p.279). As for logistics service providers (LSPs), electric mobile powertrains in particular have a large potential to cut GHG emissions in transportation. Despite the current moderate level of development of this technology, various companies have already implemented electric vehicles, electric trucks and container stackers as part of their sustainability initiatives. By implementing this technology, they reduce their carbon footprint and at the same time meet customer's demand for more sustainable and eco-friendly logistics services. Furthermore, using electric vehicles is viewed as an approach to diversification, particularly in urban distribution (Smart e-User project, 2015a). Tightening regulations with regard to emissions or access permissions of city centers further spur the utilization of electric vehicles in order to serve customers in these urban areas. A major challenge with regard to electric vehicle adoption though is, that for most logistics companies their own user profile of a vehicle applied in urban distribution is still unknown.

## 2 Methodologies

In attempt to research how companies are using E&V improvements towards a more sustainable distribution, two methodologies were applied. First, to collect data about companies current practices related to E&V, content analysis was used. This included initiatives, practices, actions, programs or strategies recently implemented by two from the consumer goods industry, one from the retail sector (table 1) and six companies from the transportation and logistics industry (table 2). This method typically allows researchers to systematically evaluate and synthesize texts with a large number of words into smaller categories (Weber, 1990, p.37). The use of Corporate Sustainability Reports as source of information is a common practice in the research community (Bowers, 2010, p.253; Tate, Ellram and Kirchoff, 2010, p.21-22) and was one of the most relevant sources for this paper. Corporate Sustainability Reports constitute a freely available source of information that includes detailed information about environmental, social and economic strategies planned or implemented by the company. It also includes other important data related to targets, goals, mission statement, policies, programs and projects. Additionally, websites, case studies and other reports published by these companies were analyzed. All companies selected for this research were listed on the Newsweek Green Ranking 2012 or 2014 with the rationale that they represent some of the benchmarks in their industries.

Table 1 Researched Companies – Consumer Goods manufacturers and Retailer

Company	Industry Domain
Adidas (Adidas Group, 2014)	Consumer Goods
Beiersdorf (Beiersdorf, 2013)	Consumer Goods
Metro Group (Metro Group, 2013)	Retail

Table 2 Researched Companies - Logistics Service Providers

Company	Industry Domain
Deutsche Post DHL (DHL) (Deutsche Post DHL, 2013)	Transport and Logistics
FedEx (FedEx, 2013)	Transport and Logistics
Norfolk Southern (NS) (Norfolk Southern, 2013)	Transport and Logistics
Union Pacific (UP) (Union Pacific, 2014)	Transport and Logistics
United Parcel Service (UPS) (UPS, 2013)	Transport and Logistics
CSX (CSX, 2013)	Transport and Logistics

Table 3 Traffic volume by industry sector in urban distribution in Berlin

Industry Sector	Share of traffic volume caused by commercial transportation	Share of traffic volume caused by business passenger transportation
Health/Social Sector	-	6%
Construction Industry	26%	28%
Retail	16%	13%
Other Professional/Scientific Services	-	15%
Transportation and Warehousing	21%	.
Other Commercial Services	7%	7%
Manufact. Industry	7%	7%
Sum of all recorded km per year in 1'000	160'527	486'609



The second methodology used to study the use of battery electric vehicles consisted of an online survey with various companies in Berlin. According to the KID 2010 study, 70% of the overall volume of traffic in urban commercial transport in the city of Berlin is centralized in some industry sectors (DLR, 2012). The details are in Table 3.

Furthermore, in order to evaluate existing user profiles in urban distribution, over 120 companies in the Berlin area were contacted. 33 companies participated in the study, equaling a return rate of 27,5%. By means of a questionnaire containing 56 questions, participants were asked to specify their fleet structure, ownership of vehicles, touring development behavior, touring patterns, including e.g. average route, longest route, average number and length of stops etc., shift patterns, and user expectation towards electric vehicles.

Table 4 Researched Companies – Consumer Goods manufacturers and Retailer

Industry Sector	Number of Participating Companies
Health and Social Sector	5
Construction Industry	3
Retail	1
Manufacturing Industry	1

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Industry Sector	Number of Participating Companies
Other Professional and Scientific Services	4
Other Commercial Services	6
Other Commercial Services	6
Sum	33

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### 3 Findings – Practices Implemented by Companies

Among all the possible implemented practices in attempt to improve supply chain sustainability, some interesting examples were found within the selected companies' experience. In a first sight, it was clear the difference between manufacturers, retailers and LSPs. When implementing new technologies in E&V, most of the initiatives and investments come from the transport and logistics industry. Metro, representing the retail industry, seems to use some electric vehicles still as a pilot test. And lastly, manufacturers seem not to be involved at all in this topic (at least they haven't published about it). Since most of the distribution activities involving E&V from Adidas and Beiersdorf are outsourced, this result is not a surprise. It was expected, though, their involvement with collaborative initiatives with

LSPs, as well as the publication of this holistic approach regarding supply chain sustainability.

In a detailed research about companies efforts related to E&V, good examples are highlighted. The most common practice found within the researched companies is the use of alternative fuels. DHL (Deutsche Post DHL, 2013, p.65) and UPS (UPS, 2013, p.12-14) intensified investments in natural gas vehicles. UP (Union Pacific, 2014, p. 39) is evaluating not only liquefied natural gas (LNG) but also bio-diesel, propane and hydrogen. They pride themselves in being the only major railroad company worldwide with extensive gas turbine experience, having made its first investments in gas turbine-electric locomotives in 1952. NS (Norfolk Southern, 2012) highlights the use of 100 percent renewable diesel fuel at a rail terminal in Mississippi.

This research showed that the most widely used alternative energy source are battery electric vehicles (BEV). Use of a battery-operated switcher locomotive has been tested by NS since 2009 (Norfolk Southern, 2014). The company, along with other logistics service providers such as DHL (Deutsche Post DHL, 2013, p.65-66), UPS (UPS, 2013, p.14) are investing in this kind of vehicle.

Retailers seem to follow the same path as Metro Group invests in vehicles and charging stations (Metro Group, 2013, p.81). By doing so, they aim to reduce the carbon footprint and meet the demand of a growing number of clients. Interviews from DHL stated that BEV are ideal for frequent stops and starts - precisely like they occur in urban distribution. Investments in BEV are steadily increasing. Currently, FedEx employs more than 118 BEV

and additionally Zero Emission Electric Tricycles, used for package deliveries and collections in Paris (FedEx, 2015). FedEx (FedEx, 2013, p.9-19) and UPS (UPS, 2013, p.14) also invest in hybrid-electric vehicles. As part of the DHL project “CO<sub>2</sub> free delivery in Bonn”, the company plans to use 141 BEV in Bonn (DHL, 2015). In other cities in Germany, the company is testing and evaluating the exact user profile for BEV within urban mail, parcel and courier distribution.

Other companies, such as Meyer & Meyer, are currently applying battery electric trucks (7.5 to 12 tons) in their deliveries, despite the fact that these types of vehicles are not available in the market yet. Because of this lack of availability of electric trucks in the market, companies are investing in collaborative initiatives. Meyer & Meyer, for instance, has constructed a prototype vehicle - in association with Fraunhofer – in order to assess the usability of these trucks in the day-to-day business (Nanu project, 2015). The motivation for all these logistics companies to use BEV – apart from the increasing demand of their clients – are the opportunities for cost reduction and risk diversification (Smart e-User project, 2015b; a). According to DHL, the cost reduction potential is one major driver. This is because BEV have significantly lower operational costs than conventional vehicles with an internal combustion engine (ICE). A second important driver for the utilization of BEV is risk reduction. In light of tightening CO<sub>2</sub> and emission regulations in urban areas, logistics companies – and Courier Express Parcels (CEP) companies in particular – are using BEV in order to keep their business model working, even if major European cities start restricting access to city centers for ICE-vehicles either entirely or during certain time. How-

ever, one major challenge of all companies applying BEV in urban distribution is to figure out how to integrate vehicles with this new technology into existing logistics structures and processes.

Besides classic logistics companies and CEP-companies, other logistics related organizations, such as port and airport operators, have also begun using electric vehicles. For instance, the port of Long Beach, the Westhafen city port in Berlin, Stuttgart Airport and the port of Hamburg are using electric-powered reach stackers and container tractors at their sites (KV-E-Chain project, 2015; Port of Long Beach, 2015; Fairport STR, 2015). Their primary reason is to reduce pollution at port sites. In these cases, the new technology of electric mobility is exclusively applied to reduce emissions and the local CO<sub>2</sub> footprint. Similar reasons apply for the use of electric powered aircraft tugs, for instance at Stuttgart airport.

As previously identified, the use of BEV is increasing and it is the most cited initiative, implemented especially by LSPs and retailers, in order to decrease costs and emissions in logistics-related activities. Nevertheless, the current user profile of these vehicles is still largely unknown and is being researched worldwide. In an attempt to obtain a better image of these profiles, the mentioned survey was conducted to identify some technical characteristics from each of them. This information allows companies to better understand differences between industry sectors and user profiles, as well as opportunities and challenges when planning or implementing this technological trend. Results are presented in the next section.

Another finding from the content analysis pertains to consumer goods manufacturers. A review of Adidas and Beiersdorf reports and public documents did not reveal any concrete initiatives related to E&V. Both Adidas

and Beiersdorf state as their policy and targety to minimize emissions derived from transport but both seem not to integrate outsourced LSPs solutions, such as BEV use, in their own sustainability reports.

Adidas is listed as a supporter in an initiative, launched in 2011 that aims to support the mass-market deployment of clean vehicles in the northeast and mid-Atlantic states of United States. However, until now, no further information was published involving Adidas employment of these kind of vehicles (Transportation & Climate Initiative, 2015).

Beiersdorf introduced in 2013 a Green Car Policy in some countries but this applies only for employees transport (Beiersdorf, 2015). In late 2012, Beiersdorf SpA, joined eMilan project and installed an electric vehicle recharge point at its Milan offices (eMobility News - Bosch Italy, 2012). Details are not evident about how this rechaging point is used, although it is not expected to be used for recharging their trucks. Regarding freight transport, the company seems to focus on practices to optimize container loading, truck capacity utilization, transport routes and other logistics processes. In Spain, for instance, collaboration with other manufacturers allow shipments combining to the same 'ship-to' address. According to the company's website, since June 2012 truck usage has dropped by 27% and CO<sub>2</sub> emissions have been reduced by 32% (Beiersdorf, 2015). Other initiatives implemented with LSPs include investments in tools to measure their Europe-wide CO<sub>2</sub> emissions from transport and warehouses. This initiative is aligned with their membership in 'Green Freight Europe', an independent voluntary program in Europe for improving environmental performance of road freight transport (Green Freight Europe, 2015). This initiative provides a platform

for reporting CO<sub>2</sub> emissions and standards for the monitoring process. Collaborative initiatives from Beiersdorf seem to aim more at logistics processes optimization and information sharing/controlling than investments in E&V from their business partners. Other initiatives implemented by LSPs involve reducing the rolling and wind resistance of vehicles. DHL, NS and UP are among them. DHL, for instance, established a partnership with Fujitsu to discuss alternatives to reduce the environmental impacts of their client's logistics operations is the use of more efficient tires by transport partners (Deutsche Post DHL, 2014). NS equipped 100 percent of all railcar wheels with low-torque roller bearings. Estimations are fuel savings of 1 to 2 percent over the older bearings they replace (Norfolk Southern, 2013, p. 24). UP is testing train cars with premium low friction bearing seals that reduce torque, contributing to energy savings (Union Pacific, 2014, p.40).

An innovation being tested by FedEx involves developing and installing aerodynamic-shaped plastic, fiberglass and metal fairings to reduce wind resistance and air turbulence. Consequences were increase on fuel efficiency by 5 % (FedEx, 2013). DHL in England fitted more than 1,000 trailers with aerodynamic "teardrops" (Deutsche Post DHL, 2013, p.65) while Union Pacific is exploring modifications such as the Arrowedge® for freight cars and double-stack intermodal trains. Replacing less efficient aircrafts with more efficient ones also allow for estimated fuel savings of more than 37 million gallons per year (avoiding 353,792 metric tons of CO<sub>2</sub> emissions) (Union Pacific, 2014, p.40).

## 4 Findings – Users’ profile for BEV in Urban Distribution

To evaluate the identified user profiles for electric vehicles in urban distribution, it is necessary to create a target profile. Comparison with the target profile allows detecting the suitability of the identified user profiles for electric vehicle usage. Currently, the electric driving technology has special restrictions compared with ICE. Based on a survey and expert interviews conducted in the “Smart e-User” research project the following criteria were identified for the target profile:

- Range: The average and maximum tour length should not exceed 100 km, so that the current battery capacity of electric vehicles - in changing climatic conditions - is sufficient.
- Charging time: Charging the battery needs additional time compared to refueling the tank of vehicles with an internal combustion engine. Thus, for multi-shift operation it is necessary to consider the standing time at the delivery point, respectively at the customers and between operations. In order to avoid negative impacts on business processes - such as an insufficient range to complete a customer order -, time slots for charging and recharging must be scheduled to make sure they are sufficient for fulfilling the order.
- Tour planning: Due to range restrictions, electric vehicle are more suitable for static tours, i.e. those without changes during the distribution process. Furthermore, seasonal effects must be taken into account during the planning of tours with electric vehicles. This refers to changes in temperature and transportation volume.



- Payload: The weight of the batteries reduces the payload available for cargo. The 2014 German electro mobility law includes a special regulation for electric vehicles.: the weight of the batteries does not count towards the weight of the vehicle. As a result, drivers with a valid driving license for vehicles with less than 3,5 t are allowed to drive electric vehicles with more than 3,5 t, as long as the total weight of the vehicle reduced by the weight of the battery is not exceeding 3,5 t.

The survey has shown that user profiles in commercial transport in urban areas cannot be derived from a company's industry sector. Hence, the relationship between companies of a particular industry sector and their suitability for using electric vehicles was not found. Quite the contrary, the results of the survey suggest a correlation between the dominant purposes of transport and their user profile. The question how companies are using their vehicles - i.e. for transporting textiles or parcels - is more important to answer the question whether this company can utilize electric vehicles within their business processes than the affiliation to a certain type of company or industry sector.

In the course of the survey three user profiles in commercial transport were identified:

- Pick up, deliver and transport of goods (commercial freight transport)
- Consulting, assistance, assembling, repair services and transport of passengers (business passenger transport)
- Other business transactions (both business passenger and freight transport fields)

The first profile, “pick up, deliver and transport”, belongs to the commercial freight transport sector and is characterized by smaller companies with an annual turnover of less than two million Euros, which have only one location or branch. The majority of these companies are buying their vehicles rather than leasing or rent them. The most common types of vehicle for this type of company are compact cars as well as vans and small transporters. Employees in these firms typically do not work in shifts but on average 5 days a week with 9 to 10 hours a day. These companies typically use static route planning methods, and their daily round tours (milk runs) are less than 100 km long. Furthermore, their business is not influenced by seasonal ups and downs. Larger LSPs described in the previous topic are also investing in BEV but are not considered in the present survey.

The second user profile “consulting, assistance, assembling, repair services and transport of passengers” belongs to the business passenger transport sector. The main purpose for using vehicles within this profile is to transport employees to a certain location, where they execute specific services, such as construction workers on a construction site or craftsmen and plumbers at a private household. This user profile is characterized by the utilization of small, compact vehicles (with little payload), which are bought by the company, and as well static and dynamic approaches in route planning. Employees are running heterogeneous tours, which are on average less than 100 km long.

In contrast to the user profiles mentioned before, companies belonging to the third user profile, (both commercial freight and passenger transport “other business transactions”), are characterized by differing vehicle ownership structures. Companies with this user profile have leasing contracts

for their vehicles, which are small and compact cars, and their tour structure varies. Due to their business purpose, these companies run smaller tours, in average with less than 50 km.

One limitation when trying to identify the user profiles of the most representative industry sectors in regard to the city of Berlin is the number of participants in the survey. No clear and valid statement concerning the match of users' profiles and characteristics to the specific requirements of electric mobility could be formulated. Nevertheless, the user profiles identified can be understood as indicators. Despite the survey's limitations, the data was consistent enough to identify the most important characteristics for electric mobile transport within the urban commercial traffic of Berlin. The criterion of range was shown to be the most important one. Although the survey does not allow for a conclusive statement about the daily driven distance, a tour length of less than 100 km is seen as sufficient to utilize an electric vehicle in distribution. Furthermore, it can be assumed that the criterion of payload is the second most important one. Particular in the commercial transportation of goods, the payload directly affects the usability of electric vehicles. Regarding business passenger transport, the payload showed to be an insignificant issue as individuals' transport is at the focus of this profile. To organize multi-shift operations, there is not enough data available to identify a trend. In regard to route planning, the data shows that most companies rely on static routing. In addition, the survey has shown that the attitude towards a more sustainable transportation is most positive within the user profile of "consulting, assistance, assembling, repair services and transport of passengers".

## 5 Conclusions

Innovations in supply chain sustainability hold a large potential to reducing companies' carbon footprint and their impact on peoples' lives. Among the most cited by companies worldwide are those related to improvements in equipment and vehicles. In the consumer goods industry, pressure from clients is clearly one of the main drivers for encouraging changes through the entire supply chain. As verified in the paper on hand, more efficient and cleaner E&V are being implemented by LSPs and retailers and, to a lesser extent, by manufacturers. This result is not particularly surprising as LSPs and retailers are the ones that implement most of the transportation and warehousing processes. In the meantime, logistics activities are typically outsourced by manufacturers as their core activities are developing and producing consumer goods. Nonetheless, one unexpected result was the lack of integration and collaboration between business partners in consumer goods supply chains. During the present research, the absence of co-operative projects specifically related to E&V implementation was clear when checking and analyzing documents from companies recognized as among the "greenest" companies in the world. Although Beiersdorf turned out to collaborate more closely with their LSPs, the primary goal was to increase data transparency and measure overall emissions. Initiatives related to co-operative development or investments in E&V were absent. It appears that LSPs have been shouldering the risk themselves when investing in new technological solutions for decreasing emissions on logistics activities, such as battery electric vehicles.

Regarding users' profiles of BEV, it became evident that distribution activities with short routes in regard to the distance and little payload lend themselves to being performed with electric vehicles. Well-planned routes as well as the factoring in of charging and recharging times support this suitability of technology and task. The survey has shown that the purpose of using the vehicle rather than the industry sector of a certain company is the significant variable for the usage of electric vehicles.

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# Environmental Sustainability Standards in Transport Alliances

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In 2012 about 23 percent of worldwide carbon dioxide emissions were caused by transportation. Therefore, it is desirable to improve the environmental sustainability of the transportation sector. In Germany a major part of road transportation is operated by small and medium sized enterprises (SME). They often lack the resources to identify and implement sustainability initiatives. However, to be able to compete with the big players SME tend to establish cooperations, so-called transport alliances. This paper presents an approach supporting the assessment and selection of sustainability measures within transport alliances.

A literature review was conducted investigating measures to improve environmental sustainability as well as their environmental and economic impacts. Based on these findings focus group discussions and interviews were carried out in order to develop a concept that enables a company-specific selection of sets of measures. About 130 measures were identified and rated with respect to their environmental and economic capability. These findings were then used to develop a demonstrator program that supports both selecting measures and reporting the results.

**Keywords:** Transport, General Cargo Alliances, Sustainable Process Improvements, Environmental Sustainability

## 1 Introduction

Increasing scarcity of resources and growing pressure from politics and public to reduce carbon dioxide emissions draw more attention to environmental sustainability (Weber, et al., 2011, p. 15; Bretzke and Barkawi, 2012, p. 77). One focus area is the logistics sector (Lochmahr and Boppert, 2014, p. 23): Transport alone causes 23 percent of energy-related carbon dioxide emissions, 75 percent thereof emitted by cars and trucks (International Energy Agency, 2014, p. 54). Additionally, rising commodity prices motivate logistics companies to improve their sustainability standards. In Germany a major part of road transportation is operated by small and medium sized enterprises (SME): According to government figures, more than 95 percent of the companies engaged in freight transport employ less than 50 people (Bundesamt für Güterverkehr, 2012, p. 6). To be able to compete with the big players SME establish transport alliances. These cooperations permit a further reaching transportation network. As a result SME are able to offer a huge number of transport relations and destinations. Moreover, they have the chance to enhance load factors of their transport vehicles by consolidating shipments (Rieck, 2008, p. 115).

A current topic for transport alliances is the optimization of their networks with respect to environmental sustainability. Existing disparities, e.g. with respect to company size and maturity level of sustainability experiences (Hunt and Auster, 1990), inhibit a one size fits all approach. Furthermore, gross profit margins within the general cargo sector are very low (Bollig, 2015) and SME often lack the resources to implement effective sustainability actions.

This publication reports preliminary results of a larger research project with the ultimate goal of developing and enforcing environmental sustainability standards within transport alliances both on strategic and operational level. Therefore, this paper presents an approach that supports the assessment and selection of sustainability measures within transport alliances while considering the specifics of participating companies. The results were used to build a software demonstrator that supports the selection, comparison and performance control of different measures within the transportation network.

## **2 Method**

As it was crucial to gain a deep understanding of strategy development processes and problems occurring during implementation, qualitative research methods were chosen. Accordingly, the results stem from literature reviews, expert interviews, and focus group discussions.

### **2.1 Literature Review**

Before new concepts and ideas are developed it is necessary to gain a profound knowledge about the topic and preceding research (Booth, Papaioannous and Sutton, 2012, p. 3). Different ways of doing a literature review exist. All forms of reviews can be assigned to a continuum mounted between the poles of narrative review and systematic review. While systematic reviews are highly structured and follow rigorous standards, narrative reviews follow no defined method and appear in a variety of styles (Jesson,

Matheson and Lacey, 2011, pp. 10–11). The literature conducted here follows a broad research question: There is no limitation on the amount of processes that should be optimized nor is the kind of measures predetermined. Besides, the appraisal of the results is variable and the synthesis qualitative. Therefore, a narrative review approach is sufficient (Cook, Mulrow and Haynes, 1997, p.378). The research questions are practically oriented. Hence, not only journal contributions but also project reports, handbooks, and practitioner publications were considered. The review results were used as basis for further research and the development of the software demonstrator.

## 2.2 Expert Interviews

In qualitative research interviews are the primary data collection technique (Cooper and Schindler, 2008, p. 170). Three types of interviews can be distinguished: unstructured, semi-structured and structured interviews (Cooper and Schindler, 2008, p. 171).

In this case semi-structured interviews were conducted. While doing semi-structured interviews the interviewer is supported by a guideline that simplifies focusing on the topic (Mitchell and Jolley, 2010, p. 277). Sustainability is a broad topic with different possible directions of research. The guideline helped to focus only on environmental sustainability aspects. Two in-depth interviews (more than two hours each) were conducted with special focus on the software concept. The questions were formulated openly to give the interviewees the chance to answer independent of any restrictions.

After introducing the topic, the interviewees were asked to specify their requirements with respect to the software demonstrator. The researchers then presented the actual structure of the software and asked for feedback. Next, the underlying data was discussed. The interviewees commented on the catalogue of measures and on the possibilities to categorize them. Afterwards, an early approach to evaluate the measures was discussed. Finally the interviewees were asked to identify dependencies between the different measures. These results were simultaneously noted down on a flipchart and organized as a matrix.

### 2.3 Focus Group Discussion

Focus Group discussions are used to collect qualitative data through interactions between the participants. The researcher plays an active role through the selection and composition of the group and the moderation of the discussion (Morgan, 1996, p. 130). A focus group typically consists of 6 to 10 participants, who discuss experiences, feelings and ideas on a specific topic (Cooper and Schindler, 2008, p. 178).

For this project four focus group discussions were conducted (n1=8, n2=10, n3=9, n4=6). The majority of participants took part in more than one meeting. Nearly all of the participants represented small and medium enterprises that are doing business in the general cargo sector and participate in at least one transport alliance. All of the participants were familiar with the concept of environmental sustainability and eager to contribute their knowledge to the project. For every session care has been taken that at least two persons from academia attended to record the discussion results.

An initial workshop was conducted to introduce the project as well as the participants to each other. The organizational structure of a typical transport alliance and the decision processes within the organization were discussed to identify potential cooperative environmental optimizations. Within the second focus group session findings from the initial literature review were presented. Subsequently, the attendees were asked to discuss the existing catalogue of measures as well as the classification. Additionally, by using marking points, the participants were asked to rate measures that were most suitable for a transport alliance from their point of view. Both the third and fourth discussion sessions were used to develop and validate a software concept. During the third meeting the moderator focused on the interrelations between the different identified measures. To support the discussion, a matrix of the different groups of measure was used to identify connections between them. Within the fourth session an early version of the software was presented. The focus group attendees were asked to comment on the software concept as well as on the already existing modules of the software.

### 3 Results

By using the aforementioned research methods different results were generated that were all brought together within a software demonstrator. These results include a catalogue of measures to improve environmental sustainability within transport alliances as well as an evaluation of these measures.



### 3.1 Catalogue of Measures

A process model of general cargo transport was designed and validated with the focus group (see Figure 1). The model was used to define basic conditions and requirements.

The catalogue of measures should only contain measures that aim at helping logistics companies to improve the execution of these processes. During the literature review more than 100 measures were identified. These measures were grouped into different categories and subcategories. The two main categories used were "transport" and "location/facility", where most of the processes besides transportation take place. A third category, mobility of employees, was built during focus group discussion. Every category contains different sub-categories, like vehicle, information, employees or cooperation (see Figure 2 and Figure 3).

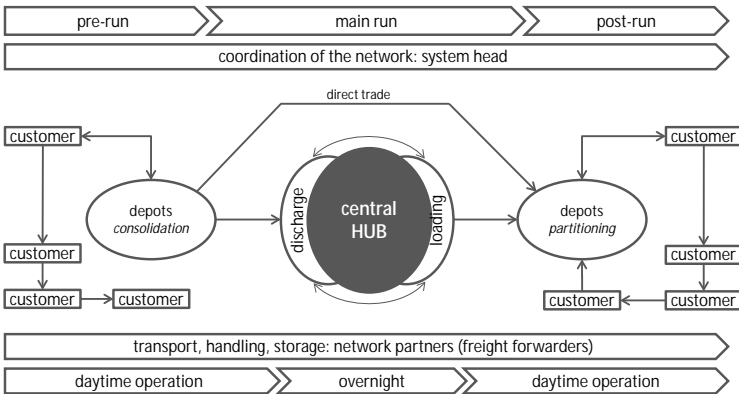


Figure 1 Process model of general cargo transport

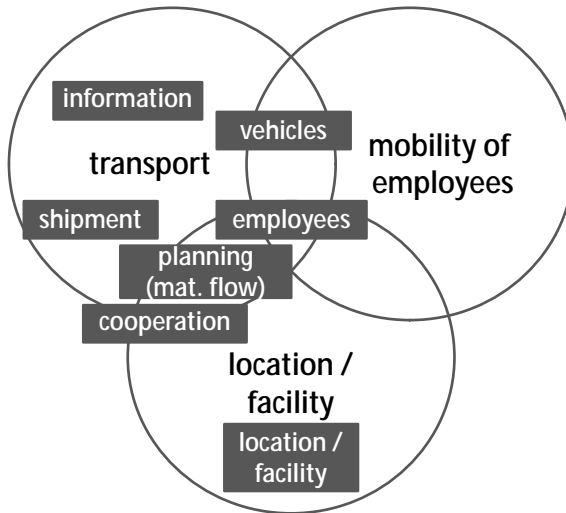


Figure 2 Systems of Categories (1)

During one focus group discussion the catalogue of measures as well as the categorization were reviewed and extended by the practitioners. They also selected most suitable measures by placing marking points on a flipchart. After finalization the catalogue contains 125 measures. All of them are categorized and equipped with a short description. Besides the categorization the measures were matched with key performance indicators from a preliminarily designed catalogue. This catalogue allows users to filter by the indicator they want to optimize. By using key performance indicators the overall reduction of resource consumption and increase of environmental credibility can be measured. The catalogue contains different indicators, for example "total energy used within the network", "water consumption of the network", "paper consumption of the network", "waste production"

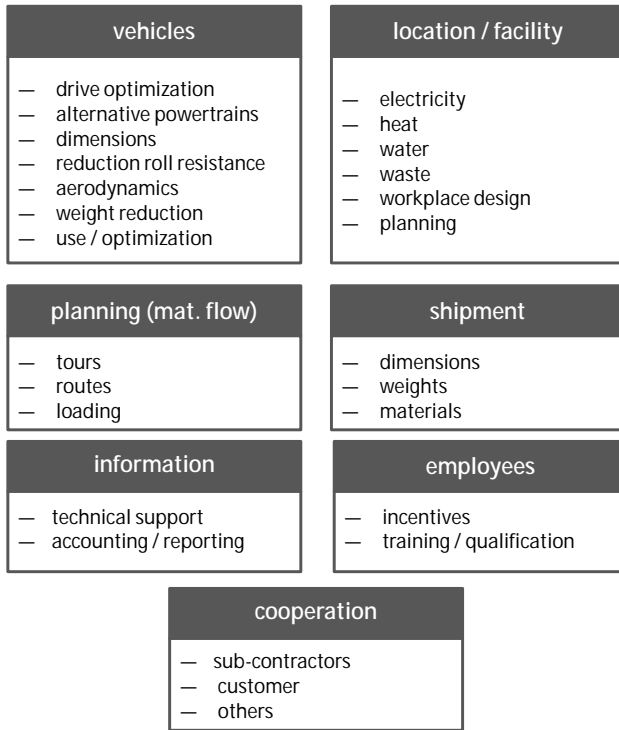


Figure 3 Systems of Categories (2)

and "carbon dioxide emissions". The indicator "total energy used within the network" is further subdivided into "fuel consumption of the commercial vehicle fleet" and "stationary energy use of the whole organization".

### 3.2 Economical and Ecological Evaluation of Measures

Based on an extensive literature review and the focus group discussions the effects of every method were collected and illustrated by practical examples. In summary, the results are as follows:

Approximately 80% of the measures can be used to directly reduce consumption of resources (input). They help to reduce consumption of fuel, heat or power as well as fresh fiber paper or water. The ecological effects can be measured directly by the savings through reduction of resource consumption. At the same time the output of emissions can be reduced. However, it is more difficult to estimate changes in output than input differences. Additionally, more than 8% of the measures listed don't reduce resource consumption but replace conventional energy sources with renewable energies. Examples are thermal power stations, alternative drives or photovoltaic systems. Measuring ecological effects is possible by calculating the share of renewable energies in comparison to the whole energy consumption. 7% of the measures that were found can't be used to reduce energy consumption, but they are helping the user to find and quantify optimization potentials (for example CO<sub>2</sub>-Footprint calculations, environmental certificates, and environmental management systems); for this kind of measures it is not possible to quantify effects. The remaining 5 % of the measures only reduce the output: Particulate filters for vehicles, for example, reduce harmful emissions. The following list shows the economical and the environmental evaluation of the Top 5 ranked measures:

### **3.2.1 Top 1: Consolidating shipments**

Even though, consolidation is – besides the expansion of the network – the main aim for alliances, there is a potential for further optimization. SME can increase utilization rate of their trucks by reorganization of the hub structure or by prolongation of service times. It is even possible to reduce empty runs by consolidating different shipments. In Germany the share of empty runs is approximately 20%. Accordingly, a reduction potential of 2.6 billions of vehicle kilometers and more than 2.2 million tons of carbon dioxide emissions is estimated (VDA, 2008, p. 9).

### **3.2.2 Top 2: Location planning (HUBs)**

During strategic planning of a freight network, the definition of the number and locations of HUBs is essential. In principle hub and spoke structures are more efficient than grid networks, because the average utilization rate of vehicles is higher. On the one hand organizational expenses in hub and spoke structures are lower on the other hand investments in construction and operation of the facilities have to be considered (Wlček, 1998, pp. 31–33). A higher vehicle utilization rate within hub and spoke networks reduces the amount of vehicle-kilometers traveled and greenhouse gases emitted. The level of savings depends on the network structure.

#### **Top 3: Reduction in water consumption**

Fresh water is a limited resource and therefore particularly worth protecting. It is estimated that in the middle of the current century in the worst case seven billion people in 60 countries will suffer from shortage of water. In the best case two billion people in 48 countries will not have access to enough fresh water. (Bundeszentrale für politische Bildung, 2010)

Simple activities to reduce water consumption are for example renewal of shower heads or perlators. Additionally, a reduction of the cold water pressure is possible. Both measures don't require high investments. (Bode, et al., 2011, p. 7)

### **3.2.3 Top 4: Systems for tire pressure monitoring**

With an optimal tire pressure a reduction of fuel consumption is possible. Estimates of the reduction potential vary between 3% and 8% (Wittenbrink, 2010, p. 16; VDA, 2008, p. 23). By decreasing consumption of fuel users are able to save 1,000€ on average for each truck (Stuhlmeier, 2014). Investments per truck are around 900€ (Wittenbrink, 2010, p. 16).

### **3.2.4 Top 5: Auditing processes for subcontractors**

By auditing subcontractors problems can be identified. This helps to find solutions and optimization potentials. A comprehensive auditing also includes environmental factors.

The research showed that the possibility to quantify the effects varies: For one part of the measures it was possible to estimate the effects in a generic way. Thus, the transfer to actual implementation scenarios is deemed possible. Examples are measures for vehicle optimization. Most of them result in fuel savings that have a quantifiable impact on the fuel costs as well as the carbon dioxide emissions. For other measures a generic quantification of effects was not possible. However, general statements could be made with respect to the interrelations between those measures and their impacts. One example is the use of special procurement and distribution

strategies like “Vendor Managed Inventory”. There is evidence that by employing such a strategy transport kilometers could be reduced (Lohre, Bernecker and Gotthardt, 2011, pp.48-49). However, the amount of reduction depends on the specific situation and network design. Therefore, the economical and ecological evaluation of measures should only be used as an indication. Practitioners are advised to carry out an individual rating of measures before starting the implementation. It is recommended to utilize cost-benefit-analysis or benefit analysis to evaluate the situation specific benefits and costs.

### **3.3 Software Demonstrator Design**

The final result of the research project is a software demonstrator. On the one hand the software aims at supporting the decision processes of finding suitable optimization measures. On the other hand it will enable transport alliances to monitor sustainability efforts within their network.

For the first goal it was necessary to build a database model to group all the information gathered. The categorization and the links to key figures were used as filters. A listing of adequate measures was displayed. Each method is accompanied by a description as well as the economical and ecological evaluation. Furthermore, users are able to select measures they already applied in practice to track their success. For this purpose the software asks for an overall rating. In addition the user is allowed to write comments on the problems, financial aspects or other related topics. The data is then exchanged within the transport alliance. Based on the information from every participant a best practice database can be built.

The measures are ranked by the individual ratings and their frequency of use. Accordingly, the software enables sharing experiences among the network partners. Furthermore, the network coordinator gets data of the sustainable progress within the alliance.

In addition, users are able to track key performance indicators for the measures in use. By entering the changes of input and output as well as necessary investments they are able to review their own progress. If users are willing to share their data they can even benchmark themselves with other users.

## 4 Discussion

For making progress in terms of sustainable development it is essential to be aware of the necessity for sustainable actions. Sustainability has to be integrated into the management system. Once there is a change in company culture regarding sustainability, measures can be applied to improve sustainability. Therefore, the overall research project started with implementing sustainability standards on a strategic level. The search for adequate measures on the operational level showed that there are multiple options to improve sustainability by changing behavior. For a comprehensive sustainability concept investments are necessary. In most cases these investments will payback within a short period of time.

It is impossible to find generic solutions that work for every company: In practice transport alliances don't start on the Greenfield but use existent assets of their participants. Accordingly, the initial situation has to be con-



sidered when improving sustainability. Therefore, this research project delivers no rigid procedures but an extensive catalogue of measures. Based on the given information every user should be able to find the solution that best fits his needs. On purpose the catalogue of measures contains possibilities that differ in various aspects. They affect different processes within transport alliances and influence various key performance indicators. Some of the measures can be implemented with low effort while others need more resources.

Especially small and medium enterprises often lack extensive resources. Nevertheless, to ensure progress regarding these sustainable measures transport alliances are able to support their network partners during implementation of these. In most cases the network coordinator functions as consultant or financier. Besides that it is possible to use the power of the network during negotiations with business partners. Truck leasing conditions, for example, are cheaper for the whole network than for individual freight forwarders. Furthermore, the selection of different vehicle variants can be limited to environmental friendly types.

The approach presented above goes beyond other projects in this field of research. In the past several authors developed guidelines and catalogues of measures to improve sustainable logistics (Lohre, Bernecker and Gotthardt, 2011; Bode, et al., 2011). However, they all focused on individual companies and most of them concentrate on only one aspect (e.g. sustainable logistics buildings).

The software developed focuses on the network idea and allows for sustainable improvement within the whole alliance. By building a network-specific best practice database every user can profit from the experience of

the others. Furthermore, the developed software concept functions as fundament for a network wide green controlling and therefore exceeds the idea of providing guidelines and support in choosing the right way of improving sustainability.

## 5 Conclusion

The discussions with practitioners have revealed a general willingness to improve environmental sustainability as long as investments amortize within a few years. The engagement of top management as well as of network coordinators is essential for a sustainable development. Margins within the logistics sector are very low. As a result economic factors outweigh environmental issues in most cases. Therefore, the approach presented above supports an economic assessment of possible measures. Besides that it provides help for choosing the right action.

This project identifies a lot of opportunities and possibilities to improve environmental sustainability in the logistics sector. However, practitioners – especially small and medium enterprises – often lack personal capacity and financial resources to find the right solution for their own business. A generic solution that works for every company remains elusive. Therefore, the software aids by implementing a best practice catalogue of measures. Based on the information, exchange of experiences should be encouraged and decisions for individual best solutions should be prepared. Furthermore system leaders struggle to align sustainable development of every single partner no matter what size or intention. Using the software it is possible to control and coordinate the partners.

## 6 Further Research

Based on this research project another issue in the field of environmental sustainability in logistic networks arose. In future, companies are forced to report all emissions that are caused by their value-adding processes, even those, which are caused by subcontractors (known as scope-3-emissions). That means logistics service providers will be responsible for the emissions of their subcontractors, who are often very small (< ten employees). Because of their limited resources and possibilities those subcontractors have to be supported in calculating carbon dioxide emission. Taking this situation into account new research questions arise, such as "How can logistics service providers support their subcontractors in reporting carbon dioxide emissions? How to integrate key performance indicators from subcontractors into the existing reporting? How to ensure data privacy and protection?"

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# Assessing the Diffusion of a City Logistics System Based on Low Emission Vehicles

*Anna Corinna Cagliano, Giulio Mangano, Carlo Rafele and Giovanni Zenezini*

City logistics (CL) has recently emerged as a comprehensive and coordinated approach to reduce the negative impacts of last mile logistics, making urban freight distribution more sustainable from both an economic and an environmental point of view. Assessing the viability of CL initiatives is necessary to comprehend the relevant aspects that can support their adoption by private stakeholders. This work focuses on a new CL system relying on low emission vans for a large city in Northern Italy. A System Dynamics simulation model has been developed in order to assess the potential diffusion of the system at issue and understand the main factors that either stimulate or hinder it. Behavioral, economic, and environmental issues that characterize urban freight distribution are taken into account. A sensitivity analysis has been performed to test the robustness of the model and to predict the CL system behavior when its underlying parameters change. The outcomes show that the new system is feasible and allow suggesting some policies to encourage its adoption.

**Keywords:** System Dynamics, Diffusion Model, Low Emission Vehicles, Sustainable City Logistics

## 1 Introduction

In recent years problems caused by the increasing freight transportation demand within cities, such as pollution and congestion, have led both researchers and public authorities to concentrate their efforts on City Logistics (CL) initiatives. CL has been defined as "the process of totally optimizing urban logistics activities by considering the social, environmental, economic, financial and energy impacts of urban freight movement" (Taniguchi et al., 2001). CL fosters the development of integrated logistics systems where all the stakeholders are coordinated to reduce negative effects on citizens. Thus, a CL model should be planned and managed with the aim of improving the quality of life of communities, while at the same time carrying no disadvantages to both public and private operators. In literature, there is a substantial amount of works focusing on the positive and negative impacts of urban freight distribution from an operational and economic point of view, taking into account the effects on both public and private stakeholders (Figliozzi, 2010; Browne and Gomez, 2011).

Several policies can be implemented to reduce the negative impacts of CL, such as restricting or even banning commercial vehicles from circulating in city centers, using reserved lanes for goods vehicles, load factor control, and road pricing (e.g. congestion charge) for charging the entrance in restricted areas (Visser, Van Binsbergen and Nemoto, 1999; Witkowski and Kiba-Janiak, 2012).

CL initiatives often include also the partial or total substitution of existing commercial vehicles with low emission ones, mainly electric or hybrid vehicles. However, in order to make these initiatives sustainable for private



stakeholders it is necessary to understand the main factors for the adoption of such kind of vehicles. In fact, private companies do not always follow up on the efforts made by municipalities to stimulate the diffusion of low emission vehicles (Trip and Konings, 2014). In addition, investing in electric commercial vehicles turns profitable only under certain operational conditions (Gries, et al., 2014).

In order to contribute to the existing body of literature on the factors for adopting low emission vehicles, a model assessing the diffusion of a CL system based on electric and hybrid vehicles in the city of Torino (Italy) is here proposed, by taking into account all the typical operational factors of a freight distribution system. As a matter of fact, current literature on CL lacks studies that analyze the diffusion of low emission commercial vehicles by focusing on the operational aspects of the associated logistics systems. Economic and environmental costs and benefits of the proposed system are compared with the existing CL system, which mostly uses traditional diesel powered vehicles. The results of the simulation and the consequent sensitivity analysis allow to identify some factors that might drive the adoption and diffusion of this distribution system.

System Dynamics (SD) methodology is applied for the development of the model. The SD approach was originally introduced in the 1960s at Massachusetts Institute of Technology to study the evolution over time of complex systems composed by numerous and heterogeneous variables and nonlinear connections between them (Forrester, 1961). The variables and parameters of the model are based on reviews of similar case studies, interviews with the main stakeholders in the CL system at issue, as well as

detailed data on the characteristics of the vehicles that were provided by the main manufacturer of commercial vehicles involved in the research. The paper is structured as follows. In Section 2 the relevant literature on SD modelling is reviewed, in order to understand which aspects should be represented in a model of a CL system and to provide the theoretical background for the selected diffusion model. In Section 3 the main aspects of the methodology are explained. The development of the model is presented in Section 4 and its calibration is proposed in Section 5. The results of the simulations and of the sensitivity analysis are discussed in Section 6 and 7. Finally, the authors propose some interpretations of the results along with policy implications and concluding remarks in Section 8.

## **2 Modelling the Diffusion of Low Emission Vehicles with SD**

The literature review aims to identify the main variables that should constitute a sustainable urban freight distribution system and their relationships. Thus, the variables retrieved literature will form the background for developing the model.

Seitz and Terzidis (2014) focus on the adoption of low emission heavy goods vehicles. The authors highlight the importance of having both a potential market and an efficient refueling network for the diffusion of such vehicles. Ardila and Franco (2013) investigate the Colombian market and show that good communication is more effective than fiscal policies to encourage low emission private transportation. Struben and Sterman (2008)

study the diffusion and competition between low emission vehicles, in particular electric and hydrogen ones. They find that a critical mass dependent on economic and behavioral factors should exist in order to adopt alternatives technologies. In particular, the word of mouth appears to be crucial for stimulating diffusion.

Some authors have focused specifically on the diffusion of electric and hybrid vehicles. Shepherd, Bonsall and Harrison (2012) build on the work of Struben and Sterman to examine the adoption factors for hybrid plug-in and electric vehicles in the United Kingdom considering a 40-year time span. The sensitivity analysis reveals that word of mouth, average vehicle lifetime, and emission rates might influence adoption more than other aspects such as incentives or specific technical features. Lastly, the model developed by Gorbea, Lindemann, and de Weck, (2011) takes into account fuel prices fluctuation, incentives, network effects (e.g. word of mouth), operational costs, and ownership costs in order to model the adoption of light hybrid and electric vehicles.

The model developed in the present work is based on the SD representation of the Bass diffusion model (Bass, 1969) developed by Sterman (2000), which provides also the theoretical background for other existing models in the CL arena, mainly aimed at studying the adoption of low emission vehicles (Struben and Sterman, 2008; Park, Kim, and Lee, 2011). However, there is a lack of works investigating the diffusion of these vehicles by taking into account the main operational CL aspects. In fact, SD models in this field usually focus on the impact of policies, operating and acquisition costs of vehicles, and other traditional adoption factors such as word of mouth or advertising. Therefore, the aim of this work is to integrate such factors

together with the aspects that define urban freight distribution systems, such as freight demand, daily vehicle routes, and distance travelled.

### 3 SD Methodology

This section presents the SD methodology as discussed by Forrester (1961) and Sterman (2000). From a methodological point of view, three main elements compose a SD model: Causal Loop Diagrams, Stock and Flow Diagrams, and equations representing the relationships between variables. The Causal Loop Diagram (CLD) is a qualitative and graphical representation of variables and their mutual connections. These connections are depicted through feedback loops, both negative (balancing) and positive (reinforcing) ones. Feedback loops, or causal loop, are best defined as closed sequences generated by causes and effects triggered between variables. In particular, reinforcing loops connect variables that are positively linked: for each increase in one variable within the loop, the growth generated in the linked variables originates an additional increase in the first variable. The opposite process happens for balancing loops: the increase in the value of one variable causes changes in the values of the linked variables that then result in a decrease in the value of the first variable. It is worth noting that CLDs do not include equations. Stock and Flow Diagrams (SFD) are made up of four funding elements: stocks, flows, auxiliary variables, and connectors. Stocks are cumulated quantities given by the difference between the inflow and the outflow of a process. They can represent accumulations of goods, money, customer orders, etc. over time. Flows can be physical, eco-

nomical or informational quantities that either increase (inflows) or decrease (outflows) the value of a stock. Auxiliary variables can be either constant or variable over time. In the second case they are functions of stocks, flows or other auxiliary variables. Connectors represent the relationships between the previous mentioned three elements. Finally, the equations of a SD model can be either algebraic or differential in nature, they are independent from one another, and are functions of the state of the system in the previous time steps. They can define for instance the values of flows connecting stocks or the stock levels.

## 4 Model Development

In the next sections, the detailed structure of the SD model together with its main feedback loops is presented.

Since the SD approach does not allow flows of different elements (e.g. different kinds of adopters) to be easily modelled and simulated as flowing together out of the same stock (e.g. the total number of potential adopters), it is assumed that any retail store operating in the city of Torino, also named commercial unit (C.U.), which adopts the new distribution system makes an exclusive choice on the type of vehicle. For this reason, two configurations of the model have been developed: the first one for the adoption of electric vehicles (variables marked with the prefix E) and the second one for the adoption of hybrid vehicles (variables marked with the prefix H). A second assumption has been made on the type of adopters. In fact, the adoption by the C.U.s is considered as a direct consequence of the

adoption by logistics providers. Hence, the population stock of the diffusion model is composed by the potential C.Us that could be served by the new CL system.

The software Vensim® DSS by Ventana Systems is used to develop the model; simulations cover a time period of 120 months with a time step equal to one month.

#### 4.1 The General Structure of the Model

The model presents a general structure divided into four conceptual parts developed according to pertinent literature and agreed with the van manufacturer:

- Number of vehicles in the system and associated number of kilometers travelled (Figliozzi, 2010; Egilmez and Tatari, 2012; Trip and Konings, 2014), which are estimated based on some operational and demand factors depicted in Section 4.2.
- Savings in CO<sub>2</sub> emissions (Egilmez and Tatari, 2012; Trip and Konings, 2014). Only CO<sub>2</sub> emissions are included in the model since the level of PM<sub>10</sub> emissions is significantly lower. In fact, according to the van manufacturer estimates, the PM<sub>10</sub> emissions for traditional vehicles are on average 0.03 g/km, while the CO<sub>2</sub> emissions are approximately equal to 275 g/km.
- Total vehicle cost savings (Armenia, et al., 2010; Gorbea, Lindemann, and de Weck, 2011; Shepherd, 2014). They include the acquisition cost (amortization), the fuel cost, the maintenance cost (e.g. tire replacement), and the insurance cost. These savings stimulate the adoption of the new distribution system.

- Charging station costs (Clement-Nyns and Haesen, 2010). The charging stations are not part of a public infrastructure but they are located within the premises of the logistics providers or the C.U. suppliers.

The model also takes into account possible public contributions for purchasing the vehicles and the charging stations. These contributions are dependent on the savings in the level of CO<sub>2</sub> emissions generated by the CL system.

The dynamics of the four parts of the model are represented via some feedback loops detailed in Section 4.3. Due to space constraints the paper only describes the main aspects characterizing the developed SD model. The complete model structure as well as the associated equations are available from the authors.

## 4.2 The Sub-Models

Three sub-models compose the SD model providing a detailed and thorough representation of its general structure. The first one is named “Electric/Hybrid TO BE” sub-model and assesses the vehicles diffusion by comparing the new system with the traditional one, whose operating variables are in turn estimated in the “AS IS Model (DIESEL)” sub-model. Then, the “C.U. adoption Electric/Hybrid” sub-model studies the adoption process of the C.U.s and is directly linked to the first one.

#### 4.2.1 “Electric/Hybrid Model TO BE”

As mentioned above, this sub-model aims at representing causes and effects that lie behind the diffusion of electric and hybrid vehicles within the new distribution system.

The number of vehicles depends on a variety of factors such as:

- The quantity of goods delivered, equal to the average monthly freight demand of each C.U. multiplied by the number of adopters. The latter is taken from the “C.U. Diffusion Electric/Hybrid” sub-model.
- The monthly utilization factor of the vehicle, calculated in the model as the reciprocal of the number of monthly routes necessary to serve the C.U.s.
- The increase in the number of vehicles generates both a reinforcing and a balancing loop.

As the number of vehicles in the new distribution system increases, the total number of kilometers they travel increases as well. If the operating costs for hybrid and electric vehicles are lower than for traditional vehicles, one can say that for each increase in the total amount of kilometers travelled savings are generated in comparison with the traditional system (simulated in the AS IS sub-model). Consequently, such savings generate more adoptions of electric and hybrid vehicles, closing a reinforcing loop.

On the contrary, the more the vehicles the more the total investment in charging stations leading to increased investment costs, which negatively affect the adoption (balancing loop). The higher the initial investment



costs, for instance because of higher purchasing costs or lower public contributions, the greater the effect of the balancing loop and the disincentive to the adoption of the new distribution system.

#### **4.2.2 “C.U. Adoption Electric/Hybrid”**

This sub-model studies the dynamics of the adoption process of the C.U.s. In the developed model, the adoption process takes place as a consequence of different factors:

- The advertising performed by the vehicles themselves, which will carry a sign stating that they are part of an eco-friendly distribution system.
- Formal advertising campaigns.
- Word of mouth actions between adopters and non-adopters.
- Observation of the cost savings generated by the new distribution system.

As a matter of fact, non-adopters are stimulated to adopt in order to take advantage of the lower operating costs comparing with the traditional distribution system. In this way, they are able to offer lower distribution fares to their customers, avoiding the possibility of decreasing their market share because of customers turning to the adopters of the new CL model.

#### **4.2.3 “AS IS Model (DIESEL)”**

The present sub-model was developed to make comparisons between the new and the traditional logistics systems. It is indeed the simplest part of the SD model.

In each time step the operating costs of a traditional system are calculated for the same number of vehicles and kilometers travelled as in the new system. Taxation costs are calculated for traditional vehicles by adding a carbon tax and an ownership tax. Operating costs and taxation costs makes up for the total costs of the AS IS system.

### 4.3 Analysis of the Main Feedback Loops

The adoption of the new distribution system through the obtained savings, in terms of both CO<sub>2</sub> emissions and operating costs, gives rise to interesting



Figure 1 Effect of CO<sub>2</sub> savings on adoption

feedback loops involving all the sub-models. Figure 1 shows the positive impact of the savings in polluting emissions on the adoption. As Adoption from Savings in Cost increases, the number of adopting C.U.s increases (C.U. Adoption Rate) generating more freight and transportation demand in the distribution system (Total C.U. Demand; Total # Monthly New km). Consequently, when the number of kilometers travelled increases also the value of Total CO2 Saved grows in comparison with a traditional distribution system, increasing in turn the value of the variable Initial Public Contribution for Plugin. The higher this contribution the lower the cost carried by private



Figure 2: Effect of savings in operating costs

operators to buy charging stations (Plugin Total Cost) and the higher the savings (Savings in Investment Costs and Total Cost Savings). As a consequence of these economic benefits generated by the positive impact of the CO<sub>2</sub> emissions, Adoption from Savings in Cost increases, closing a reinforcing loop.

Figure 2 depicts the effect on the adoption of the variable Savings in Operating Costs. If this variable increases, the variables Total Cost Savings as well as Adoption from Savings in Cost increase. As mentioned above, the total transportation demand grows, together with the number of necessary vehicles (# Vehicles). If logistics providers and C.U. suppliers used the same number of traditional vehicles to fulfil the C.U. demand (D. # Vehicles), they would bear the costs related to the taxation of the vehicles, which include ownership taxation and carbon tax (D. Total Monthly Vehicle Taxes). Since these types of taxation are not due for electric and hybrid vehicles, the associated savings increase the value of Savings in Operating Costs, closing another reinforcing loop.

During the first months of the simulation savings in operating costs are lower than investment costs, hence the sum is negative and the adoption is lagging. As the number of C.U.s and kilometers travelled increases, then savings turn positive stimulating the adoption process.

## 5 Model calibration

In order to carry out the simulation runs, it is necessary to provide the input values for the parameters that contribute to define the base case for the sensitivity analysis (Section 7). The values here presented for each sub-

model are retrieved from the data provided by the van manufacturer and the logistics operators involved in the research as results of their investigations of the Torino area as well as previous similar studies. Also, the numerical values in the next sections are related to parcel delivery and frozen food since these are the product categories investigated in the present work.

### **5.1 Input Parameters of the Sub-Model “Electric/Hybrid Model TO BE”**

The first set of parameters is related to the C.U.s and the necessary routes to serve them. The variable Average Distance b/w C.U. has been estimated assuming a higher value in case of C.U.s located outside the city center restricted area (ZTL - Zona a traffico limitato) than for C.U.s located within ZTL because there is a lower density of commercial establishments outside ZTL. In particular, this parameter is equal to 0.04 km/C.U. in ZTL and 0.9 km/C.U. outside ZTL. On the contrary, the value of the parameter Setup Distance (average distance travelled by a vehicle from the depot to the first visited C.U. and from the last C.U. back to the depot) is higher in case of ZTL than for the outside areas since warehouses are usually located far from city centers. Setup Distance is equal to 9.5 km when talking about ZTL C.U.s and equal to 5.5 km for C.U.s located outside ZTL. C.U. Monthly Demand is equal to 0.44 t/C.U. for parcel delivery and to 24.2 ton/CU for frozen food. C.U. Monthly Delivery Factor is a dimensionless parameter and is equal to 4 for both the types of vehicles.

The second set of parameters deals with the features of the vehicles. Monthly Vehicle Utilization Factor is equal to 0.05 for electric vehicles and

0.06 for hybrid vehicles for parcel delivery. The vehicles associated with frozen food have a Monthly Vehicle Utilization Factor equal to 0.024 for electric ones and to 0.025 for hybrid ones. The carrying capacity is 1.4 t/vehicle for both the types of vehicles. Operating Unit Cost is equal to 1.7 €/km for electric vehicles and 1.6 €/km for hybrid vehicles and represents the operating cost of the vehicle before public contribution. Public Contribution Factor, meaning the contribution for purchasing low emission vehicles, is equal to € 0.005 for each gram of CO<sub>2</sub> saved.

The third set of parameters considers CO<sub>2</sub> emissions. CO<sub>2</sub> Emissions per km is estimated equal to 74.7 g/km for electric vehicles and 180 g/km for hybrid vehicles (Element Energy Limited, 2012), while CO<sub>2</sub> Emissions per km AS IS is set at 356.5 g/km. Both Well-to-Tank (WTT) and Tank-to-Wheel (TTW) emissions are included in the model.

The fourth and last set of parameters of this sub-model is related to the plugin units:

- Plugin Unit Cost: 7,000 €/unit
- # Vehicle per Plugin Unit: 4 vehicles/unit (electric) and 8 vehicles/unit (hybrid)
- Public Contribution Factor for Plugin: 0.001 €/(g\*unit).

## 5.2 Input Parameters of the Sub-Model “C.U. Adoption Electric/Hybrid”

The input values for the adoption sub-model have been assumed to be the same for both the types of vehicles. These values are set intentionally low in order not to overestimate the impact of the parameters on the adoption process, which would lead to unfeasible outcomes.

The parameters Contact Rate, Adoption Fraction and Advertising Effectiveness have been estimated equal to 0.1, 0.04 and 0.08 respectively (unit of measure 1/month). Emulation Contact Rate, which defines how frequently a potential adopter observes the benefits obtained by an adopter, is set equal to 0.14.

The potential C.U. adopters are equal to 2,462 and 120 for the parcel delivery and frozen items distribution system with electric vehicles, and to 9,538 and 1,380 for the same distribution systems based on hybrid vehicles. These values are different because the distribution with electric vehicles is supposed to take place only in ZTL while the distribution with hybrid vehicles is adopted just by the C.U.s located outside ZTL.

### **5.3 Input Parameters of the Sub-Model AS IS Model (DIESEL)**

The variable D.Operating Unit Cost defines the operating cost for a diesel vehicle and it is estimated equal to 1.6 €/km. D. Ownership Vehicle Tax and D. Carbon Tax are used to calculate the total taxation costs for a traditional diesel vehicle. The first one is computed on a monthly basis and it is equal to 6.67 €/vehicle; the second one is dependent on the emission levels (g/km) characterizing a specific kind of vehicle and is not associated with the actual use of the vehicle (e.g. kilometer travelled), it is also computed on a monthly basis and it is equal to  $1.0 (\text{€*km})/(\text{Vehicle*g})$ .

## 6 Simulation

This section shows the results of the simulation runs of the SD model. Simulations are based on the database resulting from the study carried out in the Torino area by the van manufacturer and the other research partners. In particular, the adoption of the new distribution system is assessed in terms of C.U.s and number of vehicles. Two scenarios are discussed: one scenario considers electric vehicles within ZTL and the other shows the adoption of hybrid vehicles for deliveries to C.U.s located outside ZTL.

### 6.1 Inside ZTL: Electric Vehicles

The entire stock of parcel delivery C.U.s at issue adopt the distribution system in a 51 month period, being served by a total number of 40 electric vehicles as shown in "Figure 3" and "Figure 4".

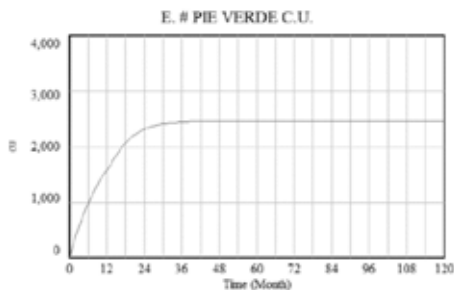


Figure 3: C.U.s. diffusion for parcel delivery



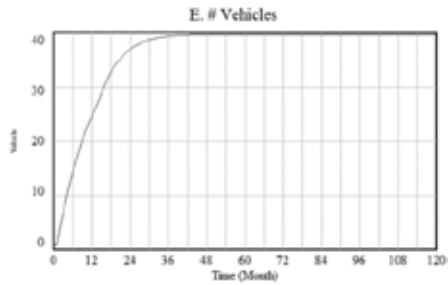


Figure 4: Electric vehicles diffusion for parcel delivery

Also the simulations show that the 120 CUs related to frozen items join the new configuration within 3 years and they are served by 26 vans ("Figure 5" and "Figure 6").

Finally, simulations prove that in the case of parcel delivery the total cumulated cost savings in ten years are around € 2 million. In the frozen food case, starting from the ninth month the savings become positive up to 1 Million €.

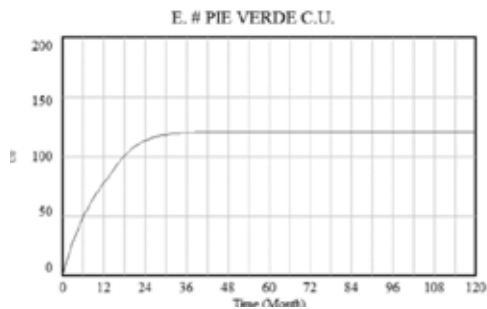


Figure 5: C.U.s. diffusion for frozen food

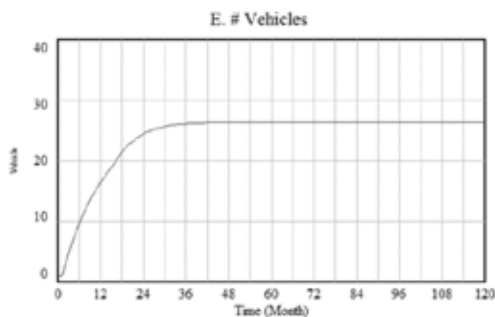


Figure 6: Electric vehicles diffusion for frozen food

## 6.2 Outside ZTL: Hybrid Vehicles

In this scenario, market saturation in the parcel delivery sector is reached in 47 months. The 9,538 C.U.s are served by 181 hybrid vehicles, each of them performing on average 16 monthly routes. The saturation for the 1,380 C.U.s in the frozen food market is got in 48 months. Overall, 279 vehicles are necessary.

This configuration achieves total cost savings equal to € 10 million, turning positive from the fourth month of simulation on for both the product categories under study.

## 7 Sensitivity Analysis

The aim of the sensitivity analysis is to reveal how the outcomes of the model vary when the main input parameters change. This objective is instrumental not only to understand the dynamics of the diffusion process

and highlight the most important stimulating factors, but also to validate the robustness of the SD model at issue (Sterman,2000).

In this section the sensitivity of the main elements of the model, namely the number of vehicles, the number of adopting C.Us, and the total savings, to changes in the input parameters is investigated. In the following sub-sections the results of the three most significant scenarios, which rely on both univariate and multivariate sensitivity analysis, are proposed.

The analysis was performed with Vensim DSS, which allows varying the input parameters according to a selected probability distribution. The software executes a fixed number of simulations, usually 200, calculating the output variables for each value of the input parameter. In the next figures the thin black line represents the base case, while the grayscale bands are the confidence bands where the output values can be found with probabilities equal to 50%, 75%, 95%, and 100%.

### **7.1 Multivariate Sensitivity Analysis on Advertising Effectiveness, Emulation Contact Rate and Contact Rate**

In this scenario the dynamics of the adoption process changes as three parameters, Advertising Effectiveness, Emulation Contact Rate, and Contact Rate, vary between 0 and 0.4 [1/month] according to a standard normal distribution. "Figure 7" presents the total cost savings trend for the new distribution system with electric vehicles in the parcel delivery market. In the first months of the simulation period, the advertising and the emulation effects drive the adoption and the associated savings. When a considerable number of C.Us has already started being served by the new CL system the

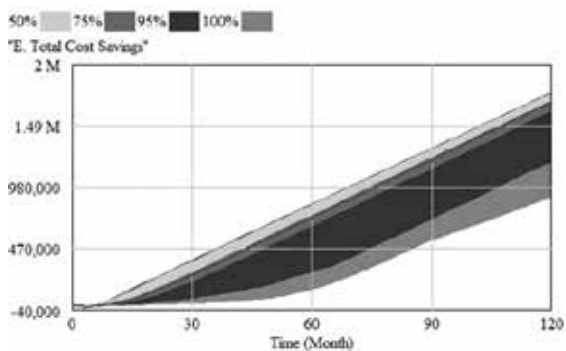


Figure 7: Sensitivity analysis on Advertising Effectiveness, Emulation Contact Rate and Contact Rate on the total cost savings – electric vehicles for parcel delivery

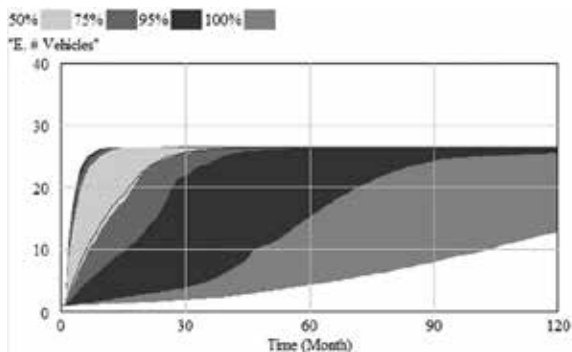


Figure 8: Sensitivity analysis on Advertising Effectiveness, Emulation Contact Rate and Contact Rate on the total cost savings – electric vehicles for frozen food

word of mouth action becomes relevant in order to furtherly stimulate the diffusion.

For the frozen food market, 120 months of simulation are not enough to reach the saturation when the values of all the three parameters are low ("Figure 8").

## 7.2 Univariate Sensitivity Analysis on Monthly Vehicle Utilization Factor

In this scenario, the parameter Monthly Vehicle Utilization Factor changes according to a uniform distribution varying between 0.015 and 0.06.

This range of values was calibrated to obtain a number of routes per day ranging from 0.76 to 3, feasible values for the product categories at issue.

For parcel delivery, with a Monthly Vehicle Utilization Factor equal to 0.06, a total of 46 electric vehicles are necessary to serve all the C.U.s. On the contrary, with 3 routes per day (Monthly Vehicle Utilization Factor = 0.015) a total number of around 12 vehicles is required ("Figure 9"). For both the output variables analyzed, namely the number of vehicles in the system and the total cost savings, significant variations as the values of the selected input parameters change are observed. For instance, the variable Total Cost Savings takes maximum values ranging from around € 500,000 to € 2 million in case of parcel delivery ("Figure 10").

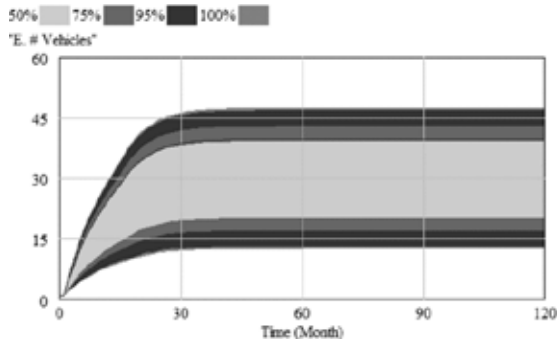


Figure 9: Sensitivity analysis of Monthly Vehicle Utilization Factor on the number of electric vehicles for parcel delivery

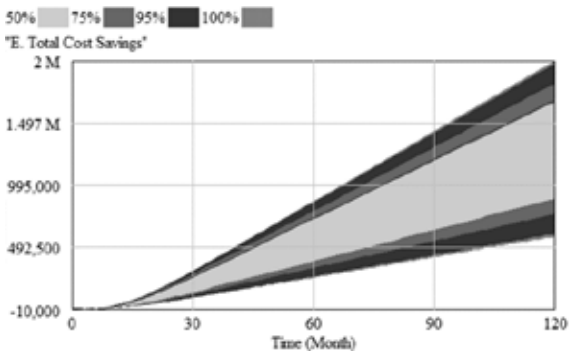


Figure 10 Sensitivity analysis of Monthly Vehicle Utilization Factor on the total cost savings - electric vehicles for parcel delivery

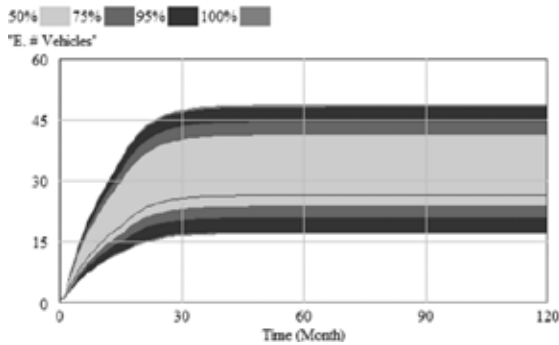


Figure 11 Sensitivity analysis of Monthly Vehicle Utilization Factor on the number of electric vehicles for frozen food

Similarly, for the frozen food market a Monthly Vehicle Utilization Factor equal to 0.045 requires 50 vehicles to serve all the C.Us ("Figure 11"). On the contrary, a Monthly Vehicle Utilization Factor equal to 0.015 leads to around 15 vehicles.

### 7.3 Multivariate Sensitivity Analysis on Public Contribution Factor, Public Contribution Factor for Plugin and D. Carbon Tax Factor

The degree to which public contribution can support and influence the adoption of the new distribution system is here assessed.

All the three input parameters follow a standard normal distribution. Public Contribution Factor ranges from € 0 and € 0,009; Public Contribution Factor for Plugin ranges from € 0 and € 0.003, while D. Carbon Tax Factor can take values from € 0.1 to € 2.

As expected, the public contribution dependent on the CO<sub>2</sub> emission reduction is able to lead to a significant increase in the total cost savings of

the distribution system because this contribution has a direct impact on the adoption from savings. Moreover, the analysis shows moderate indirect effects of the public contribution on word of mouth actions.

The same sensitivity analysis was performed excluding the parameter D. Carbon Tax Factor. In this case, the positive effects mentioned above are weakened, meaning that public intervention is more effective on the adoption if it comprises both incentives for low emission vehicles and taxes for traditional vehicles.



## 8 Discussion and Conclusion

This work studies the dynamics of the adoption of electric and hybrid commercial vehicles to perform freight distribution activities in the city of Torino (Italy). The analysis has been conducted through the SD approach since it appears to be very useful to describe the behavior of a complex system and its associated variables. The simulations and sensitivity analyses show that a new urban freight distribution system with low emission vehicles is feasible both for the city center restricted area (ZTL) and for the whole city.

In fact, by focusing on two different fields of application, namely parcel delivery and frozen food, in both the areas the market saturation is reached within the simulation time horizon, and in particular within 51 and 36 months for electric vehicles and 47 and 48 months for hybrid vehicles. Moreover, the model simulation reveals that the new distribution system could bring significant savings over ten years, equal to around € 2 and 1 Mln for electric and € 10 Mln for hybrid vehicles

Such results are due to two main factors. First, the involved technology can be considered mature, in terms of costs (the difference in operating costs between low emission and traditional vehicles is less than 10 cents per km) and in terms of operating time of the batteries that now allow for a whole trip to be completed without being recharged. Second, the involvement of the public sector could significantly support the diffusion of low emission freight distribution systems. In the model, such involvement includes both disincentives to traditional vehicles and incentives to low emission ones. In

particular, the CO<sub>2</sub> emission gap between the two types of vehicles is calculated: the higher this gap, the higher the public contribution. This leads private operators to adopt the new system.

The sensitivity analyses performed show that the most determinant aspects for the diffusion process are the same for electric and hybrid vehicles and for both the product categories. Advertising Effectiveness, Public Contribution, Initial Public Contribution for Plugin and Plugin Unit Cost are the most influential variables for stimulating the diffusion process. As a matter of fact, the total cost savings deriving from the distribution with low emission vehicles are moderate, because of the low gap in operating costs and the necessary investment in charging stations. This means that the economic aspect is less relevant to the diffusion process than the awareness of adopting an eco-friendly freight distribution system.

Therefore, results of the simulations and sensitivity analyses imply that this new freight distribution system should be implemented based on structured advertising campaigns aiming at delivering the real environmental and operational benefits of such a CL model, on a public intervention and on consolidated and mature technologies. Only with these pillars it is in fact possible to reach a complete diffusion in reasonable times. Future research efforts will be directed towards further validation of the model and to its application to other cities.

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Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and Supply Chain Management. HICL provides a creative environment, which attracts researchers and practitioners from all over the world.



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