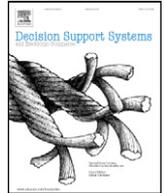




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## A review of modeling approaches for sustainable supply chain management

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## ABSTRACT

More than 300 papers have been published in the last 15 years on the topic of green or sustainable (forward) supply chains. Looking at the research methodologies employed, only 36 papers apply quantitative models. This is in contrast to, for example, the neighboring field of reverse or closed-loop supply chains where several reviews on respective quantitative models have already been provided. The paper summarizes research on quantitative models for forward supply chains and thereby contributes to the further substantiation of the field. While different kinds of models are applied, it is evident that the social side of sustainability is not taken into account. On the environmental side, life-cycle assessment based approaches and impact criteria clearly dominate. On the modeling side there are three dominant approaches: equilibrium models, multi-criteria decision making and analytical hierarchy process. There has been only limited empirical research so far. The paper ends with suggestions for future research.

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## 1. Introduction

Globalization places demands on supply chain management to reach beyond pure economic issues and matters like e.g. fair labor conditions and environmentally friendly production. This raises interest in its intersection with sustainable development, which is usually comprehended in an economic, an environmental and a social dimension (see e.g. [45]; for the link to supply chain management see [70]; [42]). Managing supply chains in a sustainable manner has become an increasing concern for companies of all sizes and across a wide range of industries. Meeting environmental and social standards along all stages of the supply chain ensures that (at least) minimum sustainability performance is reached. This more reactive approach of responding to external pressure from governments, consumers and non-governmental organizations (NGOs) [71] and media can be complemented by the development and introduction of sustainable products.

For the period 1990 to 2007 Seuring and Müller [70] reviewed a total of 191 papers. Toward the end of 2010 this list has grown to about 308 related papers which published about green and sustainable supply chain management. Yet, sorting these papers according to the research methodology employed, only 36 remain which build or use quantitative models. Hence, this paper aims at taking a longer period into account than Seuring and Müller [70], but focuses on one kind of research method, i.e. quantitative models, only. This allows detailed insights into this stream of research and should reach conclusions on how to develop it further. This small number and share

of models is in clear contrast to, for example, the neighboring field of reverse or closed-loop supply chains, where Fleischmann et al. [46] already provided a first review on “quantitative models for reverse logistics”. Furthermore, (wider) literature reviews on related fields are available: (1) closed-loop supply chains [50]; (2) green supply chains, but also with a focus on reverse logistics [73] and (3) sustainable supply chain management [70]. Recently, further reviews have been published, which address particular topics. Two examples are those on sustainable supply chain management and inter-organizational resources [48] or those relating it to a wider set of constructs in supply chain management [49]. Mollenkopf et al. [61] have emphasized the link to lean management and globalization issues in their review. Carter and Easton [42] evaluate particularly related empirical research, restricting themselves to a set of papers taken from seven journals mainly in the domain of logistics and supply chain management. Yet, such a review has not been attempted for quantitative models applied to the forward supply chain.

The aim of this paper is to summarize existing research on quantitative models for forward supply chains, thereby aiming at substantive justification as an important step in theory building [58]. This provides insights toward future research directions and needs.

The paper is structured as follows: as the study deals with a literature review, a classical section labeled as such is not provided. Instead, the paper starts by outlining the content analysis method as applied in the research process. Next, some descriptive background on the papers (e.g. years of publication, major journals) is presented. Further, the findings from the content analysis are discussed, with a particular focus on the sustainability dimensions and modeling approaches. This will lead over to the discussion of the findings and brief conclusions.

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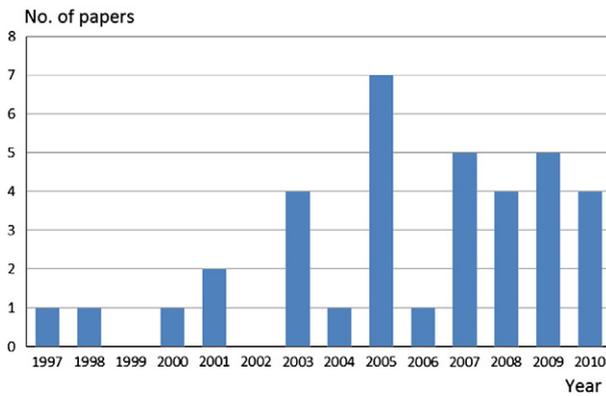


Fig. 1. Time distribution of the analyzed papers.

## 2. Describing the method and base for the literature review

This study forms part of a wider literature review at the intersection of sustainability and supply chain management. The methodology applied has already been described in detail [70]. Papers were identified by means of a structured keyword search on major databases and publisher websites (Ebsco, Springerlink, Wiley Inter-science, Elsevier ScienceDirect, Emerald Insight). Keywords such as “purchasing”, “sourcing”, “supply” and “supply chain”, and “logistics/logistical” were combined with sustainability related ones, such as “sustainable/sustainability”, “sustainable development”, “environment(al)”, “green”, “social” and “ethics/ethical”. Subsequently, papers were screened in detail in a two-step process. First, there were three issues excluded from further analysis: (1) reverse logistics and remanufacturing, as they have already been subject to self-contained literature reviews already [46,50], (2) ethical behavior of purchasing staff, and (3) public procurement. Second, the papers were unanimously assigned to one research method, where five categories were applied: modeling (the one used here), theoretical or conceptual, case study, survey or literature review.

A content analysis was conducted to systematically assess the papers [55,56,63]. Material collection has already been described by means of the literature search and reduction mode. For the analysis itself, a set of criteria is used at first for describing the sample. Then, the discussion is taken into the content analysis itself, where a mixture of deductive and inductive as well as quantitative and qualitative criteria is chosen. Respective criteria applied for the content analysis are outlined below.

### 2.1. Basic terminology

#### 2.1.1. Sustainable supply chain management (SSCM)

The definition of Seuring and Müller [70] who take standard definitions of supply chain management [59] serves as a starting point: “Sustainable SCM is the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria.”

#### 2.1.2. Quantitative modeling

According to Bertrand and Fransoo [39] this is “model-based quantitative research, i.e. research where models of causal relationships between control variables and performance variables are developed, analyzed and tested”. Such research methods are frequently

used in supply chain management research (see e.g. [38,60,57]). Subsequently, four different quantitative approaches are distinguished, which are briefly introduced, while the full justification for using them as categories is provided later in the paper.

### 2.2. Sample and descriptive analysis

The overall sample contains 309 papers in total (status papers published up to the end of 2010). Out of this sample only 36 papers apply quantitative models, thereby only contributing little more than 12% of the total number of papers.

Fig. 1 highlights the timely distribution of the 36 papers. Only two papers were published before the year 2002 [29,31,6,7,24]. There is a small peak in 2005 with seven papers, but this seems just accidental as there was no special issue which would easily explain it. In current years, there is an almost stable output with four or five papers published for each year in 2007–10 (see Fig. 1).

Regarding journals, where such papers appear most often, Journal of Cleaner Production (JCLEPRO) is the leading journal with nine papers (or 24%) published. Four papers appeared in the European Journal of Operational Research (EJOR), and three each in the International Journal of Production Economics (IJPE) and the International Journal of Production Research (IJPR), in total contributing another 27% of the sample. The rest of the papers are distributed across a range of other journals.

### 2.3. Criteria applied in the content analysis

Establishing criteria for content analysis can be based on a deductive or an inductive approach. Here, the criteria are mainly derived deductively and are based on the already mentioned literature reviews in the field (particularly [70] criteria). Yet, this would not be sufficient for addressing all relevant issues, so in some cases, criteria can only be established while working with the material. This was the case here for the assessment of the modeling approaches applied in the paper.

The following dimensions will be discussed, briefly explained and justified:

- First, the environmental, social and economic criteria or performance objectives are assessed. In a second step, the integration of environmental and/or social issues with economic objectives is analyzed. This is in line with the typical three dimensional comprehension of sustainability (see e.g. [45]) and has been discussed in the field of supply chain management before (see e.g. [71,42]).
- The modeling approach taken in the paper is described. As there was no clear starting point for this analysis, the categories were derived inductively. Three categories, i.e. life-cycle assessment models, equilibrium models and analytical hierarchy process, were used right at the start, while the other two only appeared during the coding.
- The link to empirical data forms the final dimension of the analysis [42,69]. This allows insights into the field research done toward filling the models with empirical data.

The findings from applying these dimensions are now presented.

## 3. Analysis of the papers

In the following sections, the different dimensions of the analysis will be presented. To allow easier presentation of the material, tables will be used summarizing the single dimensions as embedded in the papers. Unless stated otherwise, all figures refer to the sample of 36 papers analyzed here.

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