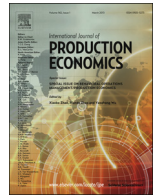




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## Manufacturing facility location and sustainability: A literature review and research agenda

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### ABSTRACT

The perspectives on the manufacturing footprint of global firms are widening from the economic aspects to also include the environmental and social aspects. Thus, sustainability is becoming an important issue for the location of manufacturing facilities. It is therefore timely to review the relevant aspects and dimensions in the extant literature to investigate the relationship between sustainability and facility location. In this paper, we aim to understand how sustainability aspects are included in decision-making concerning manufacturing facility locations and the role of location in evaluating manufacturing sustainability. We examine the literature streams on sustainability and facility location. A comprehensive search includes peer-reviewed literature from 1990 to 2011. We propose a literature classification scheme with respect to focal area and research methodology. The content analysis identifies the environmental, social and economic perspectives and factors affecting location decisions. We synthesize the findings into a framework for taking sustainability aspects into account in manufacturing facility location decision-making. We also propose a research agenda for further research on sustainable locations.

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### 1. Introduction

The facility location problem has been around for a long time. In general, it concerns the geographical positioning of facilities for a specific organizational entity, such as a company. As such, it is a strategic decision related to the configuration of the manufacturing network. As competition becomes global and the complexity of the environment in which companies operate is increasing, managing an integrated international network has become an increasingly important task for managers (Ferdows, 1997, 2009). Traditionally, the objective has been to derive a cost-optimal distribution of facilities with respect to the location of markets (customers) and raw materials (suppliers). More recently, access to skills and knowledge has been added as a major strategic factor that affects location decisions (Ferdows, 1997; Vereecke et al., 2006; Feldmann and Olhager, in press). Manufacturing companies that have more than one plant can gain insights on markets, products, and processes by managing a group of plants as a manufacturing network. In practice, this can lead to a complete reconfiguration of the manufacturing network such as in the cases of Digital (Arntzen et al., 1995) and Procter & Gamble (Camm et al., 1997). In other cases, the changes to the manufacturing network may be more incremental such as

opening up of a new facility or closing down an existing one. There may be different strategic reasons for the location decisions for different manufacturing facilities, such as access to low-cost manufacturing, proximity to market, and access to skills and knowledge (Ferdows, 1997). Thus, deciding on the “optimal” set and location of manufacturing facilities is becoming increasingly difficult.

The literature on facility location can be broadly classified into two areas: factor assessment and mathematical approaches. The factor assessment approach often has a focus on strategic issues in decision making and it can be generalized into four steps: (i) establish the critical success factors of the business, (ii) assess options for regional manufacturing configurations, (iii) define a number of potential sites, and (iv) rank the most suitable solutions (Reid and Sanders, 2010). Implicitly, economic performance has been the driver for selecting critical success factors. Also, the mathematical approaches are typically formulated as cost minimization and profit maximization problems; cf. e.g. Melo et al. (2009), Drezner and Hamacher (2004). Thus, the economic dimension of sustainability has historically dominated the location problem.

However, environmental and social issues have gained importance in recent years as organizations seek competitive advantage (Dou and Sarkis, 2010; Kleindorfer et al., 2005; Seuring and Müller, 2008). Technology and geopolitics enable and accelerate the companies to extend their manufacturing network globally. Also, the customer and supply bases are increasingly global. With wider manufacturing footprint, global markets, and global supply base,

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the question of location is becoming increasingly important, particularly for the facilities that are owned by the manufacturing company. The economic, environmental, and social dimensions make up the so-called triple bottom line (3BL) accounting report concerning the relationship of profit, people, and the planet (the 3P's); cf. Kleindorfer et al. (2005). Many authors refer to the UN Brundtland Commission (WCED, 1987) concerning the overarching objective of sustainable development; i.e. "meeting the needs of the present without comprising the ability of future generations to meet their own needs".

Consequently, it is becoming increasingly necessary for manufacturing firms to include all aspects and dimensions of sustainability in their manufacturing facility location decisions. Even when a facility is selected locally, there is need to integrate sustainability factors to reach economic, social, and environmental benefits from local innovation and collaboration with local customers and suppliers (Theyel, 2012). The right location choice can help the company gain competitive advantages and improve operational performance; not only in the short term but also in the long term. For example, environmental degradation is becoming an important concern in manufacturing industry. When manufacturers outsource to a low-cost countries, operations may be halted for months due to water scarcity, earthquakes, and thunderstorms (Economy and Lieberthal, 2007). Economy and Lieberthal (2007) propose that multinational companies should proactively implement environmental protection efforts, for instance by introducing programs to build facilities and develop technologies that are required for environmental protection. Also, corporate social responsibility (CSR) aspects concerning cultural difference and ethical values should also be taking into consideration when a manufacturing network is extending into multiple countries. Underage labor may be considered a normal means for survival in some countries, but is not ethically acceptable in many developed countries.

The research literature on the combination of manufacturing facility location and sustainability is still at an early stage but growing. Terouhid et al. (2012) found 38 papers in their review, focusing on location and siting models. Therefore, it is timely to conduct a broad analysis of the state of the art on sustainability aspects related to manufacturing facility location, by providing a systematic literature review, synthesize the findings into a framework and identifying areas for future research. In this review, we perform an independent and structured search strategy with a broader focus than Terouhid et al. (2012) and identify 81 papers (with only one common paper; Dou and Sarkis, 2010). We include both quantitative and qualitative research. An important feature in this review is that sustainability is explicitly included, such that economic aspects as well as environmental and social factors are taken into account in the decision-making process. Issues like reverse logistics and waste management are related to the facility location problem, but these areas are adequately discussed and reviewed in the existing literature; cf. e.g. Pokharel and Mutha (2009), Chan et al. (2010), Dekker et al. (2012), Van der Wiel et al. (2012). Therefore, they are outside the scope of this paper.

We first present an overview of the literature review methodology. We then present the search strategy and the classification scheme, based on a content analysis. Then, the results of the literature review are presented. Finally, we present a conceptual framework and a research agenda.

## 2. Methodology

The core idea with a literature review is to summarize the state of the art in the subject field, as a basis for identifying areas in which further research would be beneficial (Rowley and Slack,

2004). They state that literature reviews are important in: (i) supporting the identification of a research topic, question or hypothesis; (ii) identifying the literature to which the research will make a contribution, and contextualizing the research within that literature; (iii) building an understanding of theoretical concepts and terminology; (iv) facilitating the building of a bibliography or list of the sources that have been consulted; (v) suggesting research methods that might be useful; and (vi) analyzing and interpreting results. In conducting this literature review, we follow the general guidelines from Rowley and Slack (2004): (i) material collection, including (i) scanning documents, (ii) making notes, (iii) structuring the literature review, (iv) building the bibliography, and (v) writing the literature review. The research team, consisting of three researchers (two senior researchers and one doctoral student) have collaborated and interacted on all aspects of this literature review.

Below we discuss the key steps in conducting the literature review, in terms of (i) the search strategy, and the content analysis in terms of (ii) literature over time, (iii) literature across journals, and (iv) categorization with respect to topical areas as well as research methodologies; cf. Seuring and Müller (2008), Gold et al. (2010), Seuring and Gold (2012).

### 2.1. Search strategy

A comprehensive search of related research from 1990 to 2011 was applied to produce a synthesis of peer-reviewed literature. The start of the time period was chosen such that the report of the UN Brundtland Commission (WCED, 1987) served as a starting point, similar to Seuring and Müller (2008). The search strategy is based on selected databases (Business source premier, Scopus, and Web of Science), selected keywords ("sustainability" in combination with "facility location", "supply chain", or a combination of the following: "global", "international" or "network" in combination with "manufacturing", "operations", or "production"). For example, one such combination was "sustainability"+"global"+"production". We also use back-tracking to find earlier relevant sources, and forward-tracking in Web of Science to find literature that are referring to the central sources. Based on this, 140 papers were identified. Based on this list, all members of the research team made individual content analyses and evaluations. The full interrater agreement among all three researchers was 75.0% (105 papers). Consequently, 35 papers were subject to further analysis by all three researchers jointly. In the elimination process, we excluded papers that focused on only one dimension of sustainability or did not relate to facility location at all. Finally, 81 papers were identified. As a comparison, using only "sustainability" or "facility location" yields approximately 5.700 and 1.200 hits, respectively, in Business Source Premier. However, the 81 papers selected for this study have relevance for the relationship between sustainability and manufacturing facility location.

### 2.2. Literature across journals

The 81 articles we finally reviewed are distributed among 46 different international scientific journals. 10 journals account for 45 articles (see Table 1), while the other 36 articles are from 36 different journals. The highest numbers of articles are found in Journal of Cleaner Production, Ecological Economics, International Journal of Physical Distribution & Logistics Management, and International Journal of Production Research. Thus, this research area is treated in specialized sustainability journals as well as in general operations management journals.

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