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Technology foresight for sustainable production in the German automotive supplier industry

Bernadette Förster [1]

University of Paderborn, Chair of International Business, Warburger Straße 100, 33098 Paderborn, Germany

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ABSTRACT

Environmental sustainability is the new paradigm in production and entails the efficient use of resources and energy. To achieve such efficiency, a multitude of technological and process-related approaches are currently being developed. The aim of this paper is to utilize technology foresight to identify the technologies and processes, which might be relevant for sustainable production in the German automotive industry in the future. Therefore, we conducted a Delphi survey with practitioners and practice-oriented researchers concerning future technologies and their postulated effect on sustainability goals in the automotive industry. The assessments were grouped into five categories: short-term developments, uncertain short-term to mid-term developments, (certain) short-term to mid-term developments, mid-term developments, and long-term developments. These categories provide insight regarding potential drivers (cost reduction, customer demands, and legal requirements) and hindrances (costs associated with large investments) for the implementation of various technologies. Major automotive suppliers are expected to adopt new sustainable technologies faster than small and medium-sized enterprises (SMEs) since they have the financial means to make investments and sufficient production volumes for automation, and modify production arrangements more often.

1. Introduction

Technology foresight activities identify the profitability of a technology (Andersen et al., 2004; Svidén, 1988) and, at a national level, determine the areas of potential competitiveness of a country (Anderson, 1997; Cuhls, 2001; Saritas et al., 2007). The influence on sustainability plays a minor role (Liu et al., 2011). Very few technology foresight projects have sustainable technologies as a core focus (Liu et al., 2011; Weinberger et al., 2012). The neglect of sustainability issues is surprising since it is necessary to consider available resources for production, which is recognized to be a major topic for the 21st century (O'Brien, 1999; Seliger et al., 2008). Even though sustainability refers to the so-called triple bottom line of social, environmental, and economic performance (Gimenez et al., 2012), the research at hand focuses on the latter two elements: the eco-efficiency (O'Brien, 1999). In particular, we focus on the environmental sustainability accruing during the production of automobile components in manufacturing companies. Nevertheless, the elements of the triple bottom line are frequently interrelated (Bergenwall et al., 2012) and previous research determined that initiatives to enhance environmental sustainability had a positive effect on social and economic sustainability at the same time (Gimenez et al., 2012). More precisely, implementing environmentally friendly production technologies fosters corporate success (Zeng et al., 2010).

In our research, we focus on sustainable production in the German automotive industry. The automotive industry is a crucial element of the industrial sector with a large number of small and medium-sized automotive suppliers, not only in Germany. A variety of stakeholders such as customers and legislation demands a high degree of sustainability, not only from automotive companies and due to its economic relevance,

E-mail address: Bernadette.foerster@web.de.
[1] Tel.: +49 5251 60 2076.

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the automotive industry, the focus on this industry is high (O'Brien, 1999). Thus, it is ahead in sustainable production in many respects (O'Brien, 1999) and additionally demands sustainable processes from the entire supply chain, too (Koplin et al., 2007). For the automotive industry, research on the topic of sustainability is already well established. For instance, the Journal of Cleaner Production published a special issue on The Automobile Industry & Sustainability in 2007. The topic of sustainable driving is not the sole topic addressed from the perspectives of technology (Liu et al., 2011), consumer behavior (Lane and Potter, 2007), and innovation strategy (Magnusson and Berggren, 2011; Zapata and Nieuwenhuis, 2010), and future prospects (Warth et al., 2013) are likewise researched. In addition, topics such as ergonomics in production (Thun et al., 2011), use of alternative materials (Tharumarajah and Koltun, 2007; Zah et al., 2007), and lifecycle assessment are addressed (Duval and MacLean, 2007; Neelis et al., 2004). To the best of our knowledge, there is a lack of information concerning which production technologies might influence sustainable production for automotive suppliers in the future. In a Delphi survey, we collected the opinions of German automotive suppliers and academics on the expected influence of different production technologies and processes on the future of the automotive industry in order to answer the research questions:

(1) Which technologies will enable environmentally sustainable production in the future?
(2) How long will it take for the technologies to reach a certain level of adaptation in the industry or to effect sustainability?

Thus, the research at hand can be utilized by practitioners and researchers likewise to obtain insights about the upcoming developments in sustainable production in the automotive supplier industry, especially with regard to the perspective of the manufacturing companies. Based on the argumentation of the panelists for the certain expectations about the future, drivers and barriers for sustainable production technologies can be identified and possible reactions to overcome the barriers can be elaborated.

After a brief review of a literature about sustainable production, we introduce the applied methodology. Based on a literature review of previous technology Delphi surveys, we determine the structure of the Delphi tool for our purposes. We describe the survey process and discuss the survey's findings. Founded in the evaluations of the participants, we group the statements concerning various technologies and their impact on sustainable production in a timeline. We then discuss the drivers and barriers for each development, as stated by the panelists. After a conclusion of the findings, we point out limitations inherent in our research and directions for future research.

2. Towards sustainable production

An early definition of sustainability was formulated by the World Commission on Environment and Development (Brundtland, 1987) as: “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” With regard to environmental sustainability, the sustainability of a product encompasses its entire lifecycle, from design to manufacturing, and use, and disposal (Bevilacqua et al., 2007; Duval and MacLean, 2007; Neelis et al., 2004; Orsato and Wells, 2007). Gunasekaran and Spalanzani (2012) provide an overview of a literature on sustainable manufacturing along different phases of the lifecycle. The Journal of Cleaner Production published a special issue on The Automobile Industry & Sustainability, whose articles were arranged along the phases of the automotive lifecycle (Orsato and Wells, 2007).

In the complex phase of designing the product, the crucial basis for achieving sustainability is established since the product design determines the subsequent phases of the product lifecycle (Bevilacqua et al., 2007; de Ron, 1998; Gehin et al., 2008; Mascle and Zhao, 2008). The product is coupled with production via the utilized technology (de Ron, 1998). In this phase of production, the strategy of implementing innovative technologies can be utilized to increase sustainability, or the use-efficiency of the product (Seliger et al., 2008). The aim at this stage should be “to use clean technologies to reduce pollution rather than using cleaning technologies” (O'Brien, 1999, p.5). The potential starting points are manifold: Raw materials, such as metals, have different environmental impacts (Norgate et al., 2007). Light-weight materials can be utilized which can be formed with novel superplastic forming techniques (Abu-Farha and Khraisheh, 2008). Moreover, the processing machines can be optimized not only according to productivity, but also according to energy consumption which has a positive effect on the costs of energy and the environmental footprint (Bi and Wang, 2012; Rajemi et al., 2010). The toxicity of substances for ecology and humanity are detrimental impacting factors for sustainability in production (Kim et al., 2010). Metalworking fluids for instance become harmful to the environment and the health of workers when they deteriorate. To delay deterioration, their lifetime can be extended or the fluids can be reduced utilizing gas-based minimum quantity lubrication (Pusavec et al., 2010; Skerlos et al., 2008). Optimization tasks aim to find the optimal solution of the trade-off between minimizing polluting emissions and maximizing returns (Rădulescu et al., 2009).

Furthermore, the production can be organized according to certain premises and the production processes evaluated according to different criteria: The heat levels can be analyzed using pinch-analysis with the aim to find a theoretical optimum for temperature gradients between the process steps to minimize energy consumption by optimizing the energy supply, the process, or introducing recovery systems (Geldermann et al., 2007). Indices for the profile of units, such as energy, waste, or raw material, can be used for optimization purposes (Fijał, 2007) or the flow of these units can be modeled to identify avenues to sustainable production (Smith and Ball, 2012). In addition to the instruments which mainly focus on the technological aspects of the production process, the managers of a production unit have the opportunity to increase sustainability in the production process utilizing commonly known manufacturing organization approaches that have a positive effect on sustainability. The Toyota Production System (TPS) for instance is a lean manufacturing approach, which is very popular in the automotive industry and builds upon the aim to reduce eight different kinds of waste, such as overproduction, inventory, or time delays (Ohno, 1988). TPS