ECONOMIC SUSTAINABILITY FOR MANUFACTURING SYSTEMS AND PRODUCTS
Integrated Environmental and Economic Assessment of Production Systems using a Material Flow Simulation Model

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Abstract
Manufacturing companies are under pressure to optimize both the environmental and economic sustainability of their production. However, the interdependencies between environmental and economic performance indicators are widely unexplored. Companies need a decision support tool that helps them understand these interdependencies, evaluate alternative improvement measures and make the right decision to increase overall performance. This paper presents a new approach that combines Discrete Event Simulation, Material Flow Analysis and Life Cycle Assessment in one simulation model. It unifies the economic and environmental perspective on a production system and is thus deemed to have a high potential for a more effective decision support for companies.

Keywords:
Sustainable manufacturing; environmental assessment; production simulation

1 INTRODUCTION
The concept of sustainable development has become an essential part of today’s business practice. In 1987, the United Nations defined sustainable development as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” [1]. Besides pursuing the economic goals of low costs and high profits, companies are becoming more and more aware of the environmental and social impacts of their actions. This is manifested by the growing number of sustainability reports published by companies to highlight their efforts towards sustainable development. In a study performed in 2008, already 80% of the 250 largest enterprises worldwide were publishing such reports on a regular basis as compared to 52% in 2005 [2]. Schönsleben et al. highlight this shifting manufacturing paradigm, putting companies in a strong area of conflict between the three dimensions of sustainability; economic, environmental and social [3].

Especially for manufacturing companies, environmental considerations are becoming increasingly important. In the year 2010, a study in Germany including 300 experts in factory planning identified environmental sustainability as a major trend with 73% of the experts rating this aspect as ‘important’ or ‘very important’ [4]. This trend is influenced mainly by the following driving factors [5]:

- Costs of raw materials, energy and other input factors for production are continuing to grow due to their limited availability on one hand and an increasing demand from rapidly industrializing countries as China on the other, forcing companies to increase their resource efficiency.
- Public pressure for an increased environmental performance is growing, resulting in additional regulations and imposed penalty costs for companies to cover their externalities.
- The increasing public awareness is resulting in a consumer demand for environmentally friendly products, letting environmentally friendly practices become a selling proposition.

Despite this pressure for environmentally sustainable processes, companies still remain under high cost pressure due to a rapidly increasing competition from developing low cost countries as well. Thus, they are facing the task of identifying suitable measures to improve both their environmental and economic performance. Solving this task demands a good understanding of the interdependencies between environmental and economic performance. There have been several attempts in the past to qualitatively explain these interdependencies (see [6-8] for an overview on different research studies). Under different assumptions, these studies come to contradicting results on whether or how an increasing environmental performance correlates with economic performance, showing that there is a lack of understanding of the complex interrelation between these two dimensions.

For illustrative purposes, the interdependencies of different performance indicators of a production system can be depicted as a ductwork (see Figure 1). Each indicator imposes a different amount of pressure on the fluid in the ductwork as according to its weight, thus causing a different state of the system depending on how production parameters are set. There is a good understanding of this interrelation within an independent economic or an independent environmental performance indicator system, but the interdependencies between economic and environmental indicators are still widely unexplored. For instance, it is hard to understand how the alteration of batch sizes in production might influence its CO2-emissions.

Hence, companies striving for an integrated optimization of their production processes considering both the environmental and the economic perspective need to be given a tool to help them understand what effects different improvement measures have on their production system considering both perspectives.