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APPLICATION OF LIFE CYCLE ASSESSMENT TOOLS TO SUSTAINABLE PRODUCT DESIGN AND MANUFACTURING

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Abstract. *Sustainable design and manufacturing must address economic, societal, and environmental dimensions simultaneously over the product life cycle, e.g., manufacturing, use, and end-of-life. While decision support tools have been developed to assist designers in creating more sustainable products, there is a dearth of tools for addressing the sustainability impacts of manufacturing during engineering design. To respond to this need, this paper examines how designers and planners can address key sustainable manufacturing measures such as energy use, resource consumption, waste production, and occupational health. As an illustration, the functional and life cycle performance of several alternatives for a steel component are analyzed. A sensitivity analysis is performed to identify the product and process variables with the greatest effect on the overall life cycle impact. Finally, the analysis considers how changes in the product/process design impact production economics and measures of sustainable performance.*
Keywords: Life cycle assessment, Sustainability, Design, Manufacturing, Steel products

1. **Introduction.** Sustainability considerations are gaining prominence in corporate decision making. Sustainability reports are proliferating, but implementation of sustainability principles presents a challenge; its definition can vary depending on the perspective of the decision maker. From a technological perspective, sustainability is "... the design of human and industrial systems to ensure that humankind's use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment" [1].

Numerous strategies, frameworks, and tools have been devised to reduce negative environmental impacts and avoid unsustainable design practices. More than a decade ago, the primary goals of environmentally responsible design were stated as follows [2]:

- reduce energy and material (hazardous and nonhazardous) content,
- develop products that can be reused by follow-on consumers,
- create product features that promote remanufacturability/demanufacturability, and
- select materials that are recyclable.

Today, the shift to sustainable design of products, processes, and services requires a comprehensive understanding of intertwined economic, social, and environmental effects associated with any decision to prevent the transference of negative impacts from one life cycle stage to another (Figure 1). The life cycle analyst must consider whether a study should be production-specific (cradle-to-gate) or product-specific (cradle-to-grave). Often, life cycle studies have been hampered by poor data quality, uncertainties, and