Abstract English

The Sustainability Assessment in manufacturing is a combination of global and political aspects, views of the mature manufacturing sector and scientific approaches. By considering these three perspectives, a one is able to gain a holistic view of the complex manufacturing system. Several relevant international standards and regional directives support the transition of the manufacturing sector to increase sustainability. The manufacturing industry is always first concerned about possible cost and time constraints when considering new approaches. Especially today, manufacturing companies are striving for more productivity, higher flexibility and more customization to meet demands of the markets. More products are manufactured for an increasing population, which may lead to increased consumption (rebound effect). Because of this, the impact of increased manufacturing and products on the global eco-system and on humans is inevitable. To effectively lower the impact of manufacturing, the carrying capacity concept must be considered. It describes the reduction of environmental impacts of goods and resources throughout the entire life-cycle at least to a level in line with the Earth’s estimated carrying capacity. One example of these carrying capacities is the recommended maximum average global temperature increase of 2°Celsius. It results in a remaining emissions of 390 -940 Gt CO₂eq and indicates a tipping point, if it is exceeded. Manufacturing must take its share and make effective sustainability-oriented decisions.

This thesis describes a holistic approach of integrating the sustainability assessment in manufacturing with its focus on highly automated production processes. A new Sustainable Manufacturing framework, the Sustainability Cone, is introduced which provides a holistic, consistent, applicable and transparent way to look at the complex system. The framework supports the integration of the life cycle approach to avoid any sub-optimization in the whole product system planning; from the provided functionality of the product to the different modules and their production system to the very last tool in the production cells.

As manufacturing simulation tools are necessary in coping with the complexity of manufacturing planning today, it becomes necessary to integrate sustainability measures in the same platform to maintain consistency and transparency. Before integration, methodological obstacles had to be resolved. Life Cycle Assessment and discrete event simulation were merged to assess manufacturing system dynamics. This approach ensures a holistic manufacturing system analysis and can immediately reflect the environmental impact performance of the system and thus support the production planners. Dynamic effects in manufacturing systems, like degree of utilization of equipment, as well as interdependencies between levels in the Sustainability Cone, can be analyzed. The approached is adjusted to the Sustainability Cone and is able to identify potential sub-optimization, and thus support rather effective solutions.

In order to support automotive companies in finding effective solutions in the highly automated processes, like the Body-in-White production, the framework “Sustainability Cone” was applied. The concept of Life Cycle Target Setting was introduced, which is essentially an activity-based top-down
allocation of target states for the whole manufacturing system. Individual Life Cycle Targets reflect
the marginal impact of each level in the Sustainability Cone, which may not be exceeded by the target
state. An algorithm, based on typically available data and process parameters as well as an alignment
to existing decision making processes in production planning (i.e. stage gate model), was developed.
The algorithm enables a consistent and transparent allocation of the target states to determine Life
Cycle Targets in the very last level of the cone. This thesis addresses all relevant levels: a robot, a
production cell and the entire production line. After integration and testing of the new framework in
current PLM systems, any sub-optimization, rebound effect or burden-shifting could potentially be
reduced and more effective solutions could be found in highly automated car manufacturing.