II. Summary

Concerns about the extensive use of natural resources, an increasing population and increasing wealth has put sustainability on the agenda for many governments, companies and other institutes. It was the World Commission on Environment and Development who stated the definition for 'sustainable development' in 1987 as follows: *"Development that meets the needs of the present without compromising the ability of future generations to meet their needs"* (WCED, 1987). Five years later, in 1992, at the Rio Summit the Agenda 21 was published by the United Nations Commission on Environment and Development which stated: *"Achieving the goals of environmental quality and sustainable development will require efficiencies in production and changes in consumption patterns in order to emphasize optimization of resource use and minimization of waste".* The role of the production industry was explicitly stated in the Agenda 21. After many years of the worldwide introduction of 'sustainability', many companies still experience difficulties with achieving sustainable development. According to Jovane (2009) the problem with the manufacturing sector and sustainable development continues as "Manufacturing consumes an increasing amount of natural resources". The goal of this literature study is to review the Delft Systems Approach as a method to approach sustainable development in industrial systems. The main research question is: Is the Delft Systems Approach an applicable approach towards sustainable development in industrial systems?

According to many authors including Kidd (1992), Munn (1992) and Bell (2008) there is a lack of a single definition for sustainability which holds for everyone. Kidd argues "there is not, and should not be, any single definition of sustainability that is more logical and productive than other definitions" (Kidd, 1992). It is argued by Bell: "People differ in the environmental, social and economic conditions within which they have to live, and having a single definition that one attempts to apply across this diversity could be both impractical and dangerous" (Bell, 2008). However, as follows from the roots of sustainability by Kidd (1992), there is consensus on the three dimensions of sustainability, these include; environmental, economical and social aspects. Sustainable development should include these aspects. For sustainable development the Bellagio Principles are introduced by Hodge and Hardi (1997), these include among other principles, the need for a clear definition, a holistic approach and a method to measure the progress. The method for Cleaner Production introduced by the United Nations Environmental Program (UNEP) argues to evaluate possible production methods on all sustainable aspects. Since sustainability includes many aspects, Espinosa, Harnden et al. (2008) state: "There is wide acceptance of the need for a more holistic approach to sustainability". The systems theory, in special the Delft Systems Approach, is discussed as a possible holistic approach. According to Veeke et al. (2008) the conceptual models used by the Delft Systems Approach offer complete freedom with respect to physical interpretation. It is shown that the Delft Systems Approach

has models for every aspect and uses main process criteria to define the systems' objectives and define key performance indicators in order to measure the systems performance. The models are the steady-state model, the process-performance (PROPER) model, and the innovation model. Bikker states that the main process criteria are based on the systems objectives. The criteria *effectiveness, productivity* and *quality of work* can be regarded as direct objectives for measurements for the systems' sustainable performance in respectively the sustainable aspects *environment, economy* and *sociology.* Whereas the other main process criteria, *flexibility and innovative potential*, can be regarded as less sustainable objectives for the systems. The criteria for *control,* both internal and external, is always necessary in a system.

Concluding, the Delft Systems Approach has shown its applicability towards sustainable development. The Delft Systems Approach is a holistic approach and therefore is able to include all aspects of an industrial system and all aspects of sustainable development. The indicators, stated at the Bellagio Principles, exist in the Delft Systems Approach as main process criteria and the derived key performance indicators. Since the main process criteria are based on the objectives of the system, they includes the three aspects of sustainability, also known as environmental, economical and social aspects. As the systems objective can differ, it is stated that the main process criteria, and the derived key performance indicators, can be adjusted towards this objective. The innovation model can be used to identify the sustainable demands. In the last phase of the innovation model both the PROPER model and steady-state models are used in order to measure the new systems' performance according to the main process criteria. Due to all the iterative loops, the innovation model uses evaluation like the Cleaner Production method. Finally it should be noted that the total freedom of the holistic systems approach together with the immaturity of the knowledge of the different sustainable aspects for industrial systems can lead to problems in achieving sustainable development. If the sustainable goal is not precisely stated, the systems approach will not be able to achieve the demanded sustainable development as it would be impossible to adjust the main process criteria properly. Therefore it is suggested to focus further research on the specific sustainable aspects in relation to industrial systems.