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# Cycle-oriented Evaluation of Production Technologies: Extending the Model of the Production Cycle

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**Abstract**

Permanently evaluating and adopting suitable production technologies due to the dynamic environment is a major challenge for producing companies. However, influencing factors that show cyclic behavior can be anticipated and are predictable to a certain extent. Thus, lifecycle models facilitate the forecast of predictable factors and assist in deriving recommendations for action timely. The developed cycle-oriented planning and evaluation approach provides a cycle stage specific technology requirements profile. The conceptual framework ascertains the suitability of established production technologies using fuzzy sets to meet the vagueness inherent in soft requirements. The presented extension of the production cycle model provides a holistic framework to identify deficits concerning properties of established production technologies proactively. This enables a continuous technology evaluation approach resulting in the timely identification of technological need for action.


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*Keywords:* Technology planning, Manufacturing process; Production planning; Cycle management

## 1. Introduction and definitions

The suitability of production technologies to fulfill a specific production task is changing over time [1, 2] depending on internal and external influencing factors of the production environment [3]. To compete within such a dynamic environment, monitoring and anticipating those influences becomes an increasingly important element of developing competitive advantages (cf. [4, 5]). In this connection, applying production technologies which fulfill current and future requirements in the best manner offers high potential for cost reduction [6] and efficiency [7]. Consequently, it is of utmost importance to permanently analyze the appropriateness of the applied production technologies. Since the development of requirements resulting from the production environment is difficult to predict, this is a major challenge for producing companies (cf. [8, 9]).

Lifecycle models assist to anticipate and monitor influencing factors that show cyclic behavior, in the following defined as temporally and structurally recurring patterns comprising defined phases [10]. The management of interdependencies of multiple cycles in terms of planning, modelling, organizing and monitoring is understood as cycle management [10]. The term “technology” denotes all emerging and established manufacturing processes [11] and techniques (including the manufacturing resource) that are required to produce a product. In this context, the combination of single technologies in order to manufacture a specific product is regarded as a technology chain [1, 12].

The objective of this novel approach is to identify a decline in the technology’s suitability proactively and to evaluate resulting opportunities earlier than the competition does. A proactive technology management approach is characterized by continuously assessing established production technologies as well as identifying, evaluating and acquiring alternatives and capabilities in advance of needs [5].


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## 2. Cycle-oriented management of production technologies

Due to a wide range of developed models and methods (cf. [13]) considerable scientific achievements were gained evaluating production technologies at a single point in time and synchronizing technology planning activities to product development (cf. [14]). The literature documents fruitful approaches focusing on the optimization (e.g. [15]) and standardization (e.g. [7, 16]) of technology chains. In the sequel, the most relevant ones with regard to the continual assessment of production technologies are briefly discussed.

### *2.1. Relevant approaches for the continual evaluation of production technologies*

A generic model to determine the monetary value of an established manufacturing technology is presented by Schuh et al. [17]. The objective of this approach is to ascertain the value-contribution of an applied or future technology to the manufacturing system.

Stauder et al. [18] developed a conceptual approach to assess the substitution risk of production systems regarding to changes in the product program. The method comprises four steps and includes suitability analysis of production systems based on previous defined scenarios.

From a strategic point of view, Reinhart & Schindler [1] and Reinhart et al. [19] presented a technology chain calendar. Based on a static multi-criteria evaluation approach (considering uncertainties of the evaluation results) the suitability of a technology chain is determined in early stages of the product development process. Greitemann et al. [13] extended this approach to a dynamic model comparing competing technology chains over the planning horizon.

In order to plan innovation activities for manufacturing, Friedrich [20] published a methodology encountering the three determined deficits in established technology planning approaches: transparency, efficiency and effectiveness. Therefore, the “footprint model” is presented (based on [12]) comprising a static requirements- and ability-profile for evaluating competing production technologies.

Directly addressing lifecycle models, Abernathy and Townsend [21] developed a descriptive model of process evolution over time. For each stage of the manufacturing process lifecycle (uncoordinated, segmental and systemic stage) important implications were derived qualitatively.

To visualize the changing suitability of a technology over time, Swamidass [2] applied Technology Characteristics Curves. The objective of the proposed method is to capture modernization opportunities as they arise during the process lifecycle. Therefore, estimated data for cost, quality and flexibility are considered defining the technology’s suitability.

Hayes and Wheelwright [22] presented the conceptual framework of the “product-process matrix”. The authors noted that the manufacturing processes have to be in line with the corresponding challenges of each product lifecycle stage.

Exploring the potential of the product lifecycle as a strategic planning framework, Magnan et al. [23] conducted empirical analysis of the most appropriate manufacturing practices within each lifecycle stage.

Considering multiple products that demonstrate different lifecycles, Ferro and Aguilar-Saven [24] presented comparative tables and recommendations supporting the decision making which manufacturing process to implement.

### *2.2. Shortcomings and the need for further research*

The review reveals three future areas of activities that are justified in the following: (1) focusing on the model of the production cycle, (2) applying a cycle-stage specific (dynamic) requirement profile, (3) enable to use value ranges for evaluating the technology’s suitability.

(1) In industrial practice, the product lifecycle from marketing perspective does not by default equal that of the duration of the production cycle of e.g. single components [9]. Aurich and Barbian [25, 26] separated the market lifecycle and production period of a product. The authors introduced the model of the production cycle (also regarded as production period) as the duration between the start of production and the end of production. Cooperating with one of the leading manufacturer of commercial vehicles, Schönmann et al. [9] quantitatively and qualitatively derived four phases of the production cycle (cf. section 3.2) to evaluate technologies.

(2) Although ascertaining the current and future suitability of a technology has major impact on replacement decisions, only a few approaches consider including established production technologies. A cycle-stage specific requirements profile for evaluating production technologies over time is not existent to the knowledge of the authors. Consequently, the timely derivation of technological need for action (e.g. declining suitability of the applied technology) has not sufficiently been addressed.

(3) As stated in section 1 the development of requirements resulting from the production environment is hardly predictable, in particular with regard to the addressed mid- and long-term planning of this approach. With that in mind, an evaluation framework needs to include and consider both types of requirements and abilities: exact values (e.g. size) and value ranges (e.g. costs) due to vagueness and uncertainty.

### *2.3. Objectives and benefits of the novel approach*

The main objective of this novel approach is to extend the model of the production cycle into a framework for evaluating production technologies proactively. This framework serves as a solid foundation for deriving technological needs systematically. Based on the cycle-stage specific technology’s requirements profile, the properties (or abilities) of the applied technology must be reflected. Deviation from the requirements profile shows technological need for action. Using the cyclical pattern of the production cycle of a product or component allows to anticipate the future progression and to proactively derive required actions.

Since there are many uncertainties related to both, the evaluation of technologies as well as the classification of cycle