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Potential analysis model for case specific quantification of the degree of eligibility of innovative production concepts in the process industry

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ABSTRACT

Several innovative production concepts are currently in the focus of the process industry. These concepts represent alternatives to conventional, established plants. If an investment need for new capacities is identified, innovative concepts seem to be promising in multiple use cases. Comparing and evaluating comprehensively both the innovative and conventional concept in every investment decision process lead to a lot more time and cost efforts in economic and ecological evaluations, though. Therefore, a potential analysis model is developed which quantifies the degree of eligibility for using a defined innovative production concept with respect to the given use case prior to evaluations. Consideration of promising production alternatives with the developed model provide a more comprehensive and accelerated investment decision process. Transformable plant designs and decentralized production are chosen exemplarily as innovative concepts. The model is based on the analytic hierarchy process (AHP). Criteria for eligibility are structured hierarchically into the three clusters market, process/plant and product/logistics. Two scenarios have been implemented to test the model with different use cases. Results indicate that the eligibility of a certain innovative production concept depends on the scenario and the given circumstances like customer locations, demand volatilities or storage costs.

1. Introduction

One innovative plant design is currently highly discussed and developed in the process industry: transformable, small scale plants. These implement continuous processes in standardized, transportable ISO-containers and offer short times to markets. In research projects like F^3-Factory or CoPIRIDE such container-plants have already been developed and demonstrated [1–3].

Modularization is regarded as the main and basic element for transformable systems [4,5]. The modular construction of standardized apparatuses and containers offers mobility, universality and scalability as well as faster development and construction times. Containers are moved to resource or customer locations and can be relocated if necessary. Products are changed by switching apparatus modules quickly and capacity is adjusted by numbering up or numbering down containers. Improved respond to temporal and regional fluctuations in demand of quantity and product portfolio is a huge advantage compared to conventional immobile and less flexible plant designs. Moreover, locating directly at customer sites leads to decentralized network concepts with less transportation efforts of products. In addition, local sourcing becomes an option that reduces the raw material transportation and overall network transportation efforts. In contrast to these benefits, lost economies of scale state the price for this higher degree of transformability.

Summing these aspects of network structure and plant design up, the production concept matrix in Fig. 1 shows four possibilities. A mostly centralized or sometimes decentralized network with conventional plants can currently be observed in industry. Switching to a transformable plant design offers two possibilities: either producing at one location and gaining the advantages of scalability and shorter times to markets or producing decentralized and benefiting additionally from mobility and customer or resource proximity. In general, network structure and plant design are independent and can be combined in each way to create such production concepts like shown in Fig. 1.

Market motivations for transformable plant designs emerge concerning shortened product life cycles, resulting in smaller windows of opportunities, and volatile markets with special regard to specialties and fine chemicals as well as pharmaceuticals [1,6]. As a further motivation, more product differentiations are considered [7]. Recent studies have shown the profitability of such transformable plant designs compared to conventional single-product or multi-purpose plants in several use cases [8–10].

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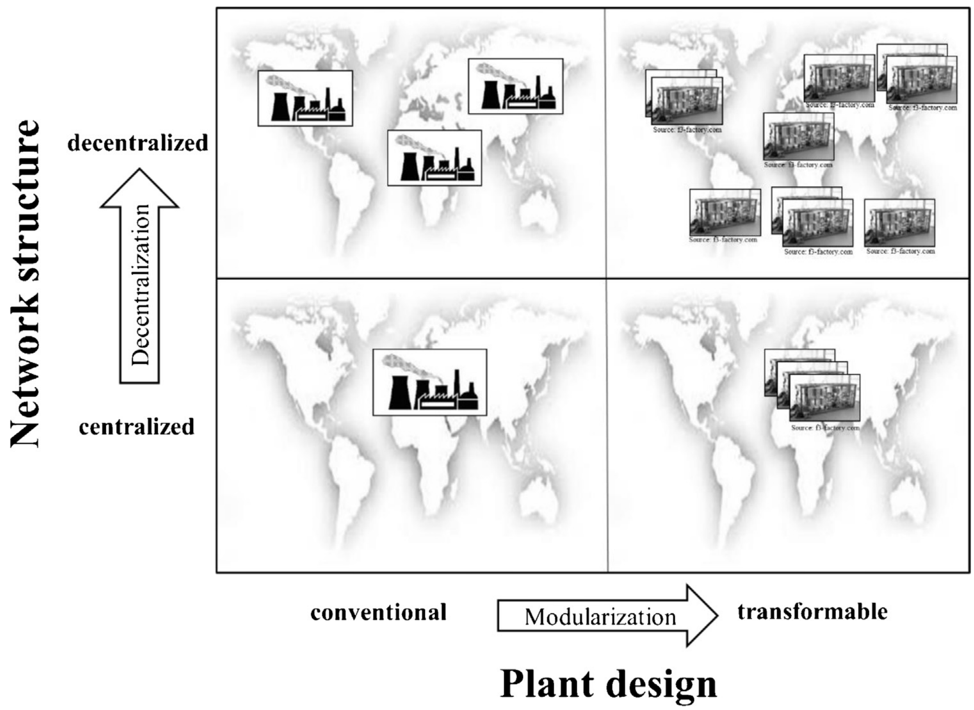

Fig. 1. Production concepts.

Moreover, real option approaches have given the provided flexibility a monetary value [11,12]. Transformable plant designs therefore offer a highly discussed production alternative to conventional large scale designs.

The intense discussions in the field of transformable production in the process industry are expressed in recent past by several related publications dealing with proper business models [13], the characterization of modular equipment [14], the development of supporting logistic concepts [15,16] and the elaboration of analysis models [17]. A comprehensive overview of existing studies in the field of transformable production in the process industry is given by Lier et al. [18].

In research and industry different kinds of transformable plant designs exist in different specifications [1,3,13–15]. Designs differ for example in using apparatus modules, process modules, container surrounding, continuous or batch production mode or standardized interfaces. Depending on the use case the same technical specifications and the same degree of transformability could be more or less useful and beneficial.

With the emersion of innovative production concepts like the one introduced new investment options for many use cases now become available. These are new circumstances in process industry as fundamental alternatives to conventional large-scale production concepts rarely existed so far and therefore have not been taken into account as investment options.

In this paper a model is presented which quantifies the degree of eligibility (DoE) of an innovative production alternative use case specific by measuring its potential prior to time and cost taking in-depth economic and ecological evaluations. The process of matching technology and use case can be basically considered in two directions. Either matching one defined technology to several use cases or matching several technologies to one use case. In this work the model is developed to tackle the first scenario, one technology to multiple use cases.

By using the model innovative production concepts can be taken into consideration every time an investment need is identified and these concepts are not discarded simply because necessary time, manpower or budget is not available. Consequently an innovative, more comprehensive and at the same time accelerated investment decision process is gained with the help of the developed model. It is designed for the very early phases of the decision process, in which information is rare. As the developed potential analysis model evaluates the eligibility of one defined technology in different use cases, it can be used not only by plant operating companies but moreover by (potential) providers of innovative production concepts as a use case screening tool in order to identify promising applications for their offered technology. The DoE depends on several market, process and product parameters like customer locations, demand volatilities, required delivery times or technical efforts for process implementation.

Such an innovative model for the determination of the DoE does not exist so far, especially not in the field of process engineering. Besides, the DoE is introduced as an innovative performance figure in this paper. The paper is structured as follows. Firstly in the subsequent Section 2 the motivation, goal and placement of the potential analysis model is elaborated. Afterwards in Section 3 the generic model is developed. This development is based methodologically on elements of the analytic hierarchy process (AHP). In Section 4 the developed model is used to set up a framework for quantifying the DoE in case of a decentralized production and a fully transformable plant design. Afterwards, in Section 5, use cases are implemented in the framework in order to present the applicability of the potential analysis model. Finally Section 6 gives a conclusion and an outlook to future research activities.

2. Motivation and goal of the potential analysis model

Several reasons can be identified for investment needs in new production capacities in the process industry [16,17]. In general, either strategy-orientated (future products, innovations) or demand-driven (current products) motivations occur. Strategy-orientated investments are a result of companies' product push or market pull strategies. Demand-driven investments are primarily essential when current capacities are not capable of providing the