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# Characterization model for innovative plant designs in the process industry—An application to transformable plants

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ABSTRACT

This article presents a characterization model for describing, comparing and improving innovative plant designs based on the core idea of Quality Function Deployment. The presented model supports providers of innovative plants to develop highly customer orientated products, to offer a competitive product portfolio and to create customized solutions. Plant operator's requirements are correlated with design attributes. Radar diagrams visualize requirements attainments and indicate individual strengths and weaknesses of the design. In addition the Degree of Attraction is introduced and specified as a characteristic, comparable performance parameter among innovative plant designs.

In order to identify and classify plant operator's requirements a survey in the means of Kano's theory has been conducted. Classified requirements are weighted in order to set up the characterization model.

Transformable plant designs are applied in this work as they currently represent a highly discussed example of innovative plants in process industry. As there are several transformable designs in research and practice aiming for different purposes a morphology has been developed in order to be able to define each individual design. Using the morphology for defining design attributes in the model allows a characterization of transformable plants. It is shown that transformable designs lead to highly attractive plants.



## 1. Introduction

In the process industry transformable plant designs are currently emerging in both research and practice. Motivation for these plant designs are predominantly three main market dynamics [1]. Firstly, a rising product differentiations and the tendency to more customized products can be identified. Secondly, product life cycles are shortened in particular for fine and specialty chemicals. Thirdly, market volatilities increase and thus demand uncertainties as well as market dynamics are rising. Simultaneously to these market trends challenges concerning scale up acceleration and reducing process and plant development times are discussed from engineering and logistics points of view [2,3,4,5]. Transformable plant designs are supposed to match these market and engineering challenges [6,7].

Transformability is defined by five enablers: modularization, universality, mobility, compatibility, scalability [8]. This means a system that possesses all these enablers can be declared as fully transformable. In the former research project $F^3$-Factory demonstrators of transformable plant designs have been developed and tested [3]. Here processes were build up by using apparatus modules with standardized interfaces. Those apparatuses were implemented in ISO transportation containers (20 ft.). The container format represents an open frame and is provided with operating supplies via “backbone” infrastructure and standardized docking stations. Such a standardized container design provides short time to markets as well as a more universal production and high degree of mobility and scalability. In the visionary scenario, due to the modular equipment with standardized interfaces, processes can be assembled and converted quickly in order to produce different (e.g. customized) products. The container format supports production location shifts toward customers or resource locations and furthermore uncouples the location of assembly. Production capacity is adapted by numbering up or numbering down containers or apparatuses. Due to the high degree of standardization and the small scale container format initial investment costs and investment risks are relatively low compared to conventional world scale plants. An efficient production is realized by implementing continuous production mode. Low down times and high degrees of automation are coming along. The downside of these small scale, transformable plant designs compared to world scale plants are losses in economies of

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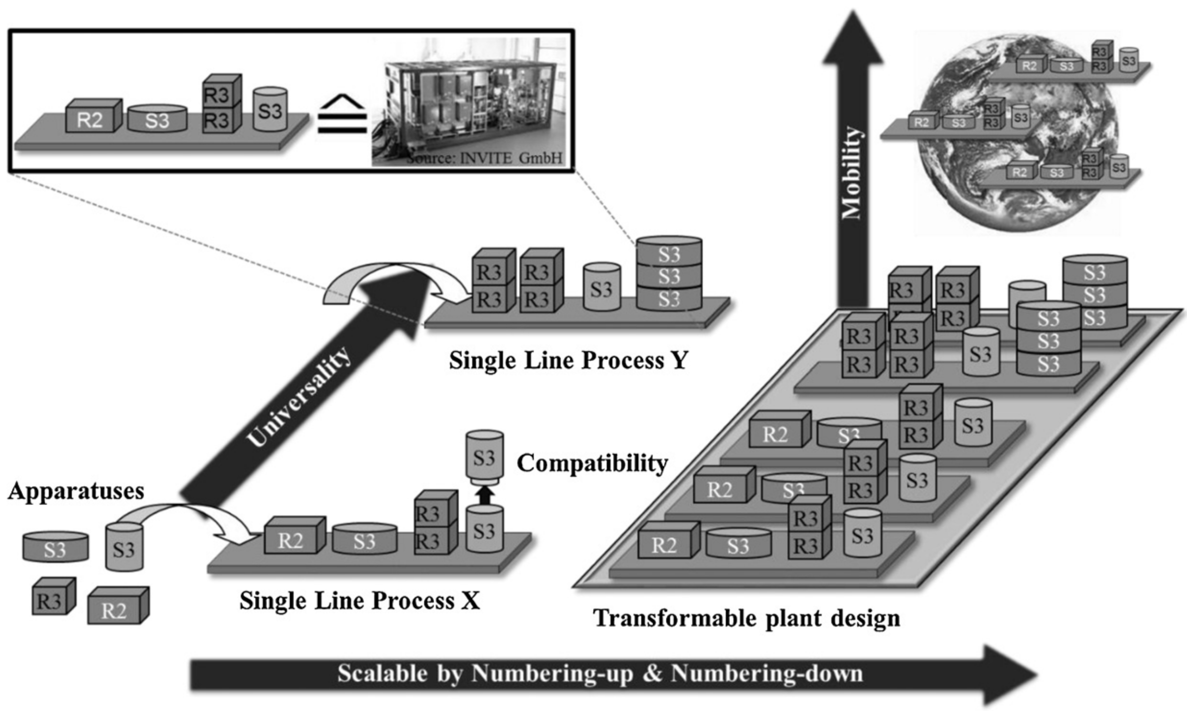


**Fig. 1.** Vision of a fully transformable plant design [1].

scale. Fig. 1 gives an overview of the described vision of a fully transformable plant design.

In addition to the established design in the F$^3$-Factory project several further plant designs heading to transformability can be identified in process industry. In the following examples are described in order to indicate that different types of transformable plant designs exist. Evonik Industries operates a transformable plant named "Evotrainer" [9]. Here the process is also integrated in an ISO transportation container (40 ft.). An area for logistics and control systems are additionally part of this longer container. But neither apparatuses are planned to be modular and standardized nor is continuous production compulsory. In contrast to these small scale plant designs (F$^3$-Factory, Evotrainer) further approaches exist in practice where large scale plants are cut and divided into container units. These units contain conventional equipment or process steps. One example for such a design is the first fully container based carbon dust plant developed by Lintec and Loesche [10]. This designs aims to provide mobility and quick, simple assembly of the plant. The EnviModul designed by EnviroChemie and modular plants designed by Zeton are further examples of partly transformable plant designs [11,12].

Summing up several different concepts for transformable plant designs exist in research and industry. The variety of examples of plant designs heading toward transformability indicates clearly that transformable plants are a significant trend in the process industry. Hereby the degree of transformability varies from design to design. In dependency of the use case and the purposes one specific design is more or less appropriate [13]. A fully transformable design, which requires a lot of engineering efforts in the beginning, is not more beneficial in every production case.

New business models will occur alongside with these highly standardized plants. Leasing models with additional services during life time like maintenance, dismounting or replacement are one option. Hereby tasks and responsibilities between plant provider, equipment manufacturer and operator will shift [14]. Each of the current market players (operator, provider and equipment manufacturer) or a new player can become provider of these new plant designs. Business types will likely change as well and will no longer be identified as project businesses but rather systems businesses. In the occurring system businesses the physical product is not explicitly designed for one single customer and transactions between buyer and seller occur during the entire product life cycle [15]. This is a fundamental change in the business of process industry.

As elaborated before different types of transformable plant design exist and are currently in the development process. In addition, due to the mentioned shifts in business types in direction to systems businesses, providers of transformable plants will be able to offer a product portfolio of several standardized types of plant designs. For this they will need a management model in order to offer and improve plant designs, which match different operators' requirements and provide a high degree of customer satisfaction. This will lead to customer loyalty and a strong market position. Using this model allows to characterize alternative plant designs. This means a comprehensive profile of strengths and weaknesses of single designs is presented to the operator. Based on this the required model enables to select the right plant design (out of the available portfolio) for the individual preferences of a particular operator. So, the existence of such a model supports the successful introduction of transformable plant designs in the process industry. Therefore such a management model (which is named characterization model in the following) is introduced and developed in this article.

Such a characterization model, which is based on the Quality Function Deployment (QFD) framework, has never been presented with application to production concepts in the process industry before (because there is no existent need in project businesses). In literature similar types of characterization models are presented in application to other investigation objects e.g. in the field of automotive, construction or hospitality [16,17,18]. (An extended overview of literature dealing with QFD applications is given by Chan and Wu [19]). In all identified applications customer requirements differ to requirements of plant operators in the process industry with regards to kind and importance. Moreover in