Journal of Manufacturing Systems 42 (2017) 29–43

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

Real options-based evaluation model for transformable plant designs in the process industry

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ARTICLE INFO

Article history:
Received 14 March 2016
Received in revised form 18 July 2016
Accepted 14 November 2016

Keywords:
Transformable plant design
Process industry
Flexibility
Model development
Economic assessment
Real options analysis

ABSTRACT

Transformable plant designs are emerging in the process industry as an alternative production concept to conventional large-scale plant designs. While transformable plant designs come at the disadvantage of higher costs per unit due to lower scale effects and higher investment costs per capacity unit installed, their major advantage are the flexible choices of capacity, product, and location which allow for quick adjustments to market changes. The value of such flexibility is not captured in traditional methods of investment appraisal such as the net present value method. When using these methods flexible technologies may appear less attractive than they actually are. More recently, the real options approach has been proposed as a tool to value investments in flexible technologies. In this paper we present an evaluation model for the economic assessment of investments in transformable plant designs that is able to capture different kinds of flexibility in a setting with multiple sources of uncertainty. The implementation of the model in two case studies shows that the flexibility value is a significant driver of the overall value of transformable plant designs.

1. Introduction

Innovative plant designs for the process industry are currently not only discussed in academia but also tested in industrial applications [4,8,18]. Similar to flexible or reconfigurable systems in discrete manufacturing (for a review of such systems see [11] and [3]), such innovative plants are designed to provide flexibility that allows producers to quickly react to changing market conditions. Conventional large-scale, tailor-made single- or multi-product plant designs no longer seem fit to cope with strategic challenges such as shortened product life cycles, increasing product differentiation, and increasing competitive pressures in highly volatile markets. Such conditions are found, for instance, in the markets for fine and specialty chemicals [19].Transformable plants are designed to tackle these challenges by providing a modular structure that offers flexibility[1] in three dimensions: (1) scalability of production capacity, (2) adaptability of the production process, and (3) mobility [20,23,37]. Fig. 1 shows the vision of a fully transformable plant design with flexibility in each of these dimensions.

(1) Scalability of production capacity: At each production site capacity can be varied by adding or removing modules. Scaling by adding or removing modules, named numbering up or down respectively, largely reduces scaling times compared to large-scale plants. Another way of scaling production capacity is the use of different size modules.
(2) Adaptability of the production process: The apparatuses in transformable plants are standardized in size and interfaces. This high degree of standardization provides for compatibility and supports quick reconfigurations of the production process. In a visionary scenario, apparatuses can be switched and replaced quickly like Lego™ bricks. Consequently, production processes for a number of different products can quickly be set up with a transformable plant. Thus, the universal use of

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[1] In the literature on transformable plants flexibility and transformability are distinguished. While flexibility is limited to changes within pre-determined corridors, a plant is considered to be transformable if the limits of these corridors can be changed (e.g. [26]). The real options literature, on the other hand, makes no such distinction. Any possibility for managers to react to new information is described as managerial flexibility. This includes both strategic changes, e.g. new investments, and operating changes, e.g. adjustments to ongoing projects. In this paper we use the term flexibility in the more general meaning common in the real options literature. In this sense the most important feature of a transformable plant is that it is flexible (rather than transformable) in a number of ways.

http://dx.doi.org/10.1016/j.jmsy.2016.11.001

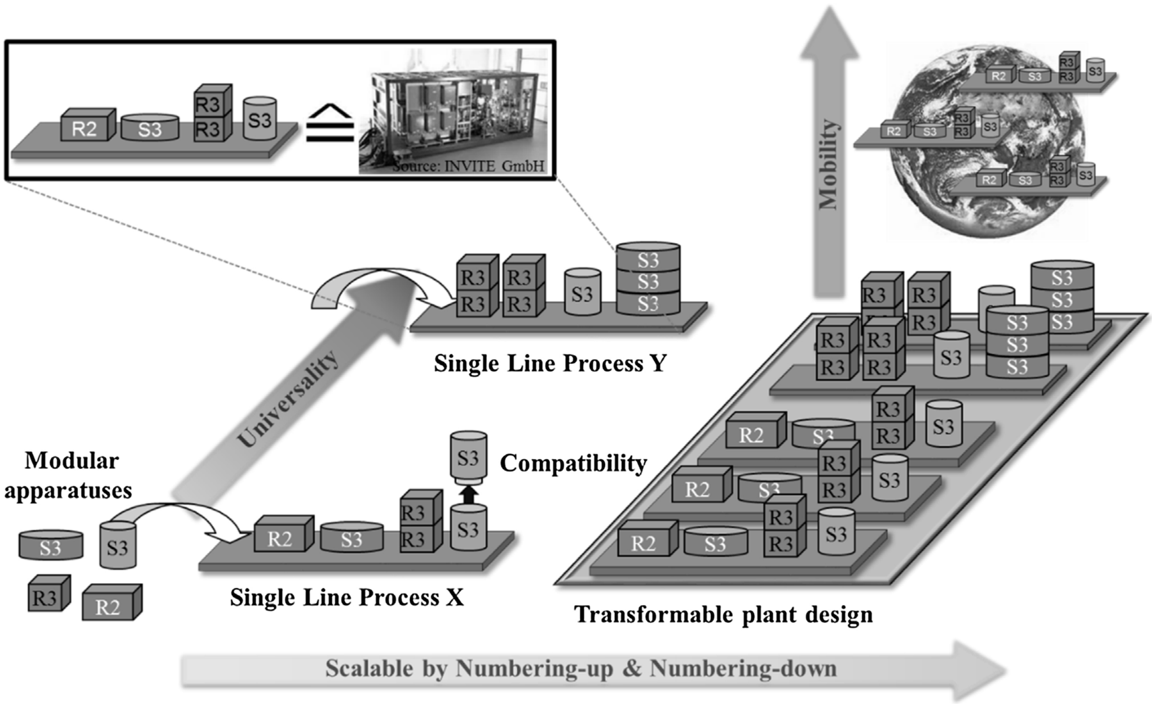

Fig. 1. Vision of a fully transformable plant design [23].

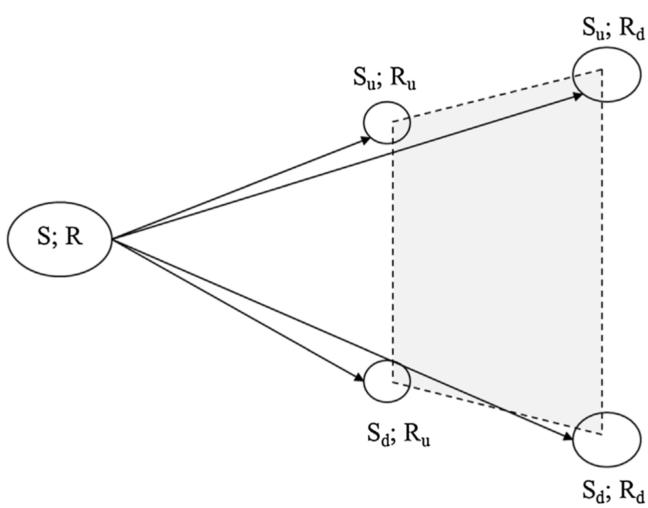

Fig. 2. 1-Step Pyramid.

production units supports a larger product portfolio than large-scale production sites.

(3) Mobility: By placing transformable plants in ISO transportation containers a very high degree of mobility can be achieved. Such production containers can be placed in proximity of either customers or resources resulting in less transportation efforts. In addition, even production during transportation might be an option in the future.

Beyond the level of single apparatuses, standardized production containers are an option for modular design as well. Such containers can be considered as process modules with an entire production process placed in each container. They appear advantageous in terms of quick capacity scaling and mobility. Instead of reconfiguring a process on site, a container with the entire process on board can quickly be moved to the site.

Small-scale, transformable plant designs not only offer flexibility. They can also significantly reduce investment risks and shorten times to market as single apparatuses and even entire process containers are designed and built far quicker than a large-scale plant.

The use of transformable plants may possibly lead to changes in market designs. In particular, supporting business models such as lease offers for single apparatuses or process containers are likely to emerge. With such new models, the roles of current market players (operator, manufacturer, designer) will change and providers of production modules will become new market players [21]. Additional services such as remote control, maintenance or transportation of modules might be offered.

The major disadvantage of small scale, modular designs is the loss of economies of scale. Due to this loss both the overall investment and the operating costs per unit will be higher when production capacities are eventually built up to the dimensions of conventional world scale plants.

For economic evaluations of transformable, small-scale plant designs and comparisons to conventional, large-scale designs, net present value (NPV) analyses have already been carried out [7,20,24,28]. For growing markets, the results of these analyses can be summarized as follows: Modular plant designs lead to faster amortization times due to low initial investment costs and quick market entries. In the course of operations, however, conventional large-scale plants catch up due to economies of scale. Accordingly, at some point in time the overall economic advantages can switch back from small-scale, modular design to large-scale, conventional design [23].

From investment theory it is well known that the NPV method does not fully capture the value of flexibility (e.g., [34], i.e. it neglects the major advantage of transformable designs). As an alternative approach, methods developed for the valuation of financial options have been proposed. While originally focused on the value of strategic investments, the application of such methods has repeatedly been suggested for the valuation of flexibilities in operations as well (e.g., [17,12,33,14]; for an overview see Bengtsson [2]). More recently, Amico et al. suggested the application of the real options