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Changeability of strategic and tactical production concepts

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ABSTRACT

Changes in the market entail increasing flexibility requirements in product quality and delivery. As a consequence, sales, production, and supplier networks must be able to be adapted quickly. This holds for both physical and organizational structures and processes as well as their IT support (e.g., PPC software). The paper shows what networks, facility layouts, or planning and control systems are more suitable for certain requirements than for others. The differences come to light even within a company, such as when the finished product business shows different characteristics from the semi-finished product business or the spare parts business. In some cases flexibility potentials can be utilized to align resource management to different characteristics. In other cases there still are technical, methodological, and cost constraints.

1. Introduction

Today, the ability to rapidly adjust production and distribution in response to changes in customer demand is viewed as a strategic challenge. For this reason, the changeability of production systems, for example of manufacturing plants, is being investigated at the strategic and tactical levels. This includes also the IT support of production and distribution, such as through PPC software. On changeability, see for example [1–3] as well as the comprehensive discussion in [4]. Similar challenges result also for the selection of the production networks.

This article shows that it is essential to have a clear understanding of the characteristic features that determine the choice of possible forms of the production networks, facility layouts, and planning and control systems. The features stand for market requirements with regard to quality, quantity, cost, and delivery. If these requirements change, quick adjustment in the use of resources is needed. This is possible only to some extent, depending on what the original state is and in what direction the change is required. In addition, different forms of the production types, for example, can exist simultaneously within the company.

2. Concepts for production networks

2.1. Characteristic features for choosing concepts for production networks

There are two fundamental concepts for production and distribution networks:

- In *centralized production* a product is manufactured at only one location or through a chain of single stations, one station per operation at one location. Analogously, in *centralized distribution* products are delivered to the customer directly from one or a few central warehouses.
- In *decentralized production* a product or certain operations of a product are manufactured at several locations. Analogously, in *decentralized distribution*, a company operates several warehouses, as close to customers as possible.

Expanding an idea by Abele et al. in [5], p. 170, Fig. 1 shows more centralized or decentralized concepts between two (conflicting) dimensions, taking the example of a product with four operations (or four production levels) and subsequent distribution.

Fig. 1 actually shows several different features, or decision variables, for designing production networks:

- *Demand volatility*: Items have *continuous demand* if it is approximately the same in every observation period. Items have *discontinuous* or *volatile demand* if many periods with no or very little demand are interrupted by few periods with large demand, for example ten times higher, without recognizable regularity.
- *Supply chain vulnerability*: Unplanned events can disrupt a supply chain. These disruptions can arise from either the supply chain participants or the macro-economic environment.
- *Necessity for economies of scale*: Are the manufacturing costs of the product low enough?
- *Demand for consistent process quality*: Can customer needs be satisfied despite differing process quality?

Fig. 1 shows that these four decision variables are correlated: Centralized production is an advantage for a high economy of scale as well as for a high demand for consistent process quality. Decentralized production is an advantage in the case of high demand volatility as well as in the case of high supply chain vulnerability.

Further features for designing production networks are:

- *Customer proximity*: To sell a product it can be necessary to locate the value-adding processes close to the customers.

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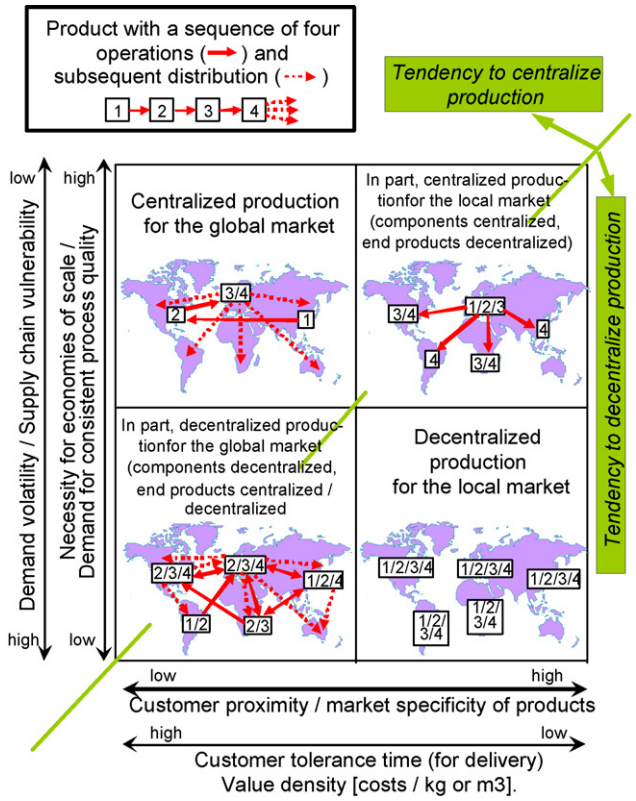

Fig. 1. Concepts for production networks in dependency upon characteristic features.

- *Market specificity of products*: Adapting products to the market is necessary for functional requirements, such as voltage, electrical connections, packaging, and documentation. But it also applies for the appearance of products in the broadest sense.
- Customer tolerance time is, according to [6], the time span the customer will (or can) tolerate from the date of the order release to delivery of the product.
- Value density, that is, item costs per kilogram or cubic meter: Transport costs are of greater consequence if value density is low than if value density is high.

Fig. 1 shows that the above four decision variables are also correlated: If customer tolerance time is high enough, there will be a tendency to centralize production, as there is also when value density is high. If high customer proximity is necessary, there will be an advantage in decentralizing production, as is also the case if high market specificity is necessary.

2.2. Different concepts for production networks and limits to changeability

The advantages that can be achieved through centralization (e.g., economies of scale or consistent process quality) stand in competition with the proximity to the customers that a decentralized configuration offers. Here, a company must make a strategic decision, which sometimes differs for each product family. Fig. 1 suggests the following production network design strategies:

- *Centralized production for the global market* is an advantage where economies of scale are strong and when there are advantages to having well-established partnerships along the supply chain. In this way, there is a greater possibility to maintain consistent process quality. Distribution takes place from the location that manufactures the last production level. Required for this is high value density as well as high customer tolerance time and low supply chain vulnerability. Examples are electronic components, consumer electronics, chemicals, pharmaceuticals, large aircraft, standard machines or facilities.
- *Decentralized production for the local market* is advantageous when high proximity to customers is required, when products must be modified for the local market, and when customer tolerance time and value density are low. The supply chain should not be strongly dependent on neither economies of scale nor qualitative differences. Examples here are household appliances, building materials (gravel, cement).
- *In part centralized production for the local market*: If semi-processed items are produced centrally, and if the last value-added steps are performed at decentralized locations, important economies of scale can be exploited, while at the same time having proximity to market. Examples here are strategies for local end production for all consumer goods, such as mass customization or "postponement."
- *In part decentralized production for the global market*: If the same items are manufactured at different locations, and if at various production levels they can be moved to different locations and distributed globally, this brings advantages in the case of volatile demand and also for a supply chain that is vulnerable to disruptions, in that the capacities in the network are utilized more evenly or can even substitute for one another. However, this makes sense only for standard products with high value density and sufficient customer tolerance time. Examples are components or end products in the automotive industry, perishable foodstuffs, or important raw materials (such as steel).

There are, of course, mixed forms of networks that lie between these four main designs. This is particularly the case when the characteristic features are not significantly pronounced on the abscissa or ordinate of Fig. 1.

When characteristic features change, it is appropriate to consider changing the production networks. For example, the production costs of cement are on the rise today (costs of energy and CO_2 emissions). This fact increases also the necessity for economies of scale. As a consequence, value density increases, so that centralized production becomes more and more an option. But that requires new cement works and added logistics infrastructure for supply of raw materials and distribution of the cement. In another case, increased demand volatility makes it necessary to produce two different engine variants at each of two locations instead of producing only one of the variants at each. Although this entails considerable investments for equipment, the result is much better use of the capacities.

In both cases the financial investments required often quickly set limits to changeability.

3. Production types and facility layouts

Within a production network, the *production type* encompasses a particular set of manufacturing technologies and methodologies, having specific importance with regard to overall production management. A production type is made up of the physical organization of the infrastructure as well as the system for planning and control.

3.1. Characteristic features for choosing production types

Fig. 2 makes it clear that choosing the appropriate production type corresponds to assessment of two market requirements, namely "volume" and "variety," and thus to the tactical decision on how to position between the two dimensions, "volume versus variety" (VVV).

The two dimensions, or decision variables, for determining production types, are defined as follows:

- *Production order batch size* (="volume") is the *order quantity* of an item. It is dependent on the market and the features of the product. *Single-item production*, or *batch size one* (i.e., only one