Aalto University
School of Science

TU-A1300
Introduction to Industrial Engineering and Management

Week 3 Pre-lecture Reading

What is an Effective Production System?

The effectiveness of a production system is easily perceived as a feature of the number of goods it produces in a unit of time i.e. throughput. In this sense, an assembly line that produces a car every 20 seconds is perhaps the culmination of effectiveness. However, effectiveness must be considered in relation to what the production system produces. Although it makes sense to produce cars on an assembly line, this doesn't mean that it necessarily makes sense to produce, for example, chairs or bicycles on an assembly line. Instead, it makes sense to look at effectiveness as a trade-off between throughput and flexibility. A production system with high throughput is rarely flexible, and vice versa – but both can be economically effective. The relationship between throughput and flexibility, or trade-off, can be viewed through 4V of operations and management (Volume, Variety, Variation and Visibility), the first two of which are often perceived as at least partially mutually exclusive.

Volume can be considered the most important factor that defines the planning and controlling of the production system. When the production volume is high enough, a company can invest in specialized expensive equipment that has a high throughput, and this investment is worthwhile because the cost is spread over more of the products it produces, that is, economies of scale are achieved. In some industries, especially in the process industry, it's not vice to begin production, until one can be reasonably sure that the production volume can be kept high enough. However, there are two things to consider when using specialized equipment. First, the use of such production equipment often requires that every product produced is nearly identical. Unlike in a car made in an assembly line, a car part that is made in a workshop can be machined again if it doesn't fit on the first try. High-volume products are thus very standardized, and tolerances are generally very strict. High-volume manufacturing has very high throughput and able to compete with production cost. In high-volume production, demand must be high and homogeneous.

Flexibility is the Achilles heel of high-volume production systems because it is challenging to produce products tailored to the customer's needs.

When the variety of products increases, the throughput of a production system decreases. The increasing product portfolio has two significant effects. Firstly, production resources can no longer be as specialized, but one resource must be able to produce multiple products. Secondly, the management of the production becomes more difficult, and the time it takes to make one single product increases. Let's compare fast food and gourmet restaurants. The gourmet restaurant is likely to have a much broader menu, longer response times, and requires more skillful and flexible resources, i.e. top chefs. Fast food restaurants, on the other hand, produce food at a fraction of the price compared to gourmet restaurants at a larger volume.

Variation in demand also impacts the relationship between throughput and flexibility of a production system. Demand variation is very challenging because it makes the managing of production capacity difficult. In some cases, particularly in labor-intensive sectors, production capacity can be adjusted very flexibly, for example by hiring additional workers when the demand spikes. However, in the case of production machines, where capacity is not as easily adjustable, the company has a couple of options. Firstly, it can hold the same throughput, and produce excess stock to inventory when demand is low, and then deplete the inventory when demand is high. Secondly, if the production system is flexible enough, the company can produce complementary products on a seasonal basis; such as rakes in the summer and snow shovels in the winter. Alteration of the price is another way to smooth out the peaks in demand. In practice, several, of these methods can be used to control the variation of demand. However, service production is different, because services cannot be stored, meaning that demand fluctuations have to be dealt with resource flexibility. Service production systems can be further subdivided into systems where the customer waits for the resource and into systems where the resource waits for the customer.

The visibility of a customer in a production system increases the need for flexibility. This has

given rise to the idea of dividing service production systems into two - a back office and a front office. In simplified terms, a company can seek both flexibility and efficiency at the same time, by placing service-related tasks that can be standardized apart from the tasks where customers are involved and need high flexibility.

If the customer is part of a company's production system, the company has resources that it doesn't fully control. This causes variation in the production system. In a closed system (e.g. factory), the aim is to continuously reduce variability by getting rid of it. However, even in a closed production system, there is often customer-induced variation, even though the customer itself is not part of the production. This variation is due to the customer's individual wishes, which can be taken into consideration at different stages of production. This is associated with the concept of order penetration point (OPP). Order penetration points are divided into the following four types:

1. Deliver-to-order (DTO) or make-to-stock (MTS), where the production has taken place without knowing who the final customer is.
2. Assemble-to-Order (ATO), where the product is assembled on the customer's request
3. Make-to-order (MTO), where production doesn't start before the customer order arrives
4. Engineer-to-order (ETO), where product design starts when the customer order is confirmed.

This last category includes, for example, cruise ships. The earlier a product is identified to the customer, the more flexible the production must be, and the more challenging it is to make it more efficiently. On the other hand, more added value can be generated for the customer. Indeed, combining customization and high throughput into the same production system is probably the long-term dream of every factory manager. And even though they are presented here in principle as mutually exclusive, things can be done to improve both at the same time:

(1) Appropriate production control, e.g. making product in sound order and with cogent coordination can improve throughput.

(2) Sensible design of the production system can result in the lesser time needed for changing the product that is been produced (i.e. setup time) and lower production response time.

(3) Modular product design can both give the customer options and place the variation in production to the assembly stage. When considering the effectiveness of a production system, the utilization rate plays a central role. The higher the utilization rate, the more productive the resource is (provided it produces something that has value). However, the utilization rate of a single resource is a slightly more complex concept. There is usually a significant difference between the theoretical and actual utilization rate of a resource, which must be considered when designing a production system. This difference is due to a number of factors, such as service and maintenance, and the set-up time. The resource with the highest actual utilization rate decides the capacity of the whole production system (i.e. is the bottleneck). For this reason, it is a good idea to ensure that the utilization rate of this resource remains as high as possible, so the resource never has to wait for the completion of earlier production stages. If a production system produces many different products, the additional challenge is that the bottleneck may be different for different products, which must be taken into account in production control.