Aalto University
School of Science

TU-A1300
Introduction to Industrial Engineering and Management

Week 4 Pre-lecture Reading

How to Manage Production?

Production process design strives for processes that operate efficiently, without disruptions and with as little adjustments and maintain as possible. However, this is not always possible, and processes require management on a daily basis. Production management can be roughly divided into two separate tasks: 1. production planning and control, and 2. quality control. In other words: 1. how does one decide what to do, when to do it, and in which order, and correspondingly, 2. how to ensure that that which is done ends up the way it was intended.

Production planning can be examined on three different time scales. On the longest time scale, production planning answers the question of how much production and storage capacity is required, how to utilize it and where is it needed. Examples of questions to consider on this time scale include: whether to build a new factory or increase capacity through subcontracting? Where should the factory be built or the storage located? How should existing resources be developed? On the mid-length time scale, production planning includes the planning of sales and procurements. This has the following goals: only that which can be produced will be sold, everything that is promised can also be delivered, and the amount resources that is required for production is also possessed. On the short time scale, production planning answers the question of which resources will be used to which output, and when will the production take place. Here, allocation of resources, fine-tuning of capacities, scheduling of deliveries and production as well as controlling and addressing deviations, take place. While long-term planning is conceptually quite close to designing production systems, short-term planning is closer to actual production control. Production control can be built upon three separate basic principles, which are called push control, pull control, and the intermediate solution between these two, CONWIP (“constant work-in-progress”), in which the amount of work-in-progress, i.e. unfinished production, is maintained at a constant level.

In push control the flow units, as the name suggests, are pushed through the production process. In practice, this means that production is performed in batches, which are planned according to predicted demand, and they are assigned an ordering such that the production process is as economically effective as possible (e.g. from the perspective of resource efficiency and the amount of unfinished products, work-in-progress). This way, in the production system it is always clear what to produce at a given moment, what to produce next, when are raw materials, parts and components required and what can be promised to the customer as a delivery date. Correspondingly, in pull control the flow units are “pulled” through the production process. In practice, this means that production starts only when an order is received from a customer. From a process perspective, this means that demand is targeted on the final stage of the production, which gives permission to start production to the stage that precedes it, which in turn gives permission to the one before it, and so on all the way to the supplier (in certain cases – in some other cases this chain might stop earlier than at the supplier). This way, it is again clear what to produce at a given moment, what to produce next and what is the delivery date that can be promised to the customer. It is, however, important to note that due to the fact that in pull control there are no production batches from a production plan, the production system has to be able to produce the entire selection of products without significant setup times.

In practice, however, production systems are rarely purely pull controlled, because the further the pull control reaches in the production, the longer the delivery times to the customer grow. If, for example, a car manufacturing process was pull controlled all the way, then in theory, the order placed by a customer would lead to the first piece of iron ore being mined, and this piece of ore would end up in the chassis of the car, which would lead to a delivery time measured in years. In the intermediate form of push and pull control the amount of work-in-progress stays constant. This means that while the production begins from the order of a customer, demand is targeted at first stage of the product. The amount of work-in-progress is maintained at a constant level by adjusting the amount of simultaneous customer orders, so that when the amount of simultaneous orders reaches a certain point, the next customer must wait for an order to be completed before her/his order reaches production. This happens regardless of there being free capacity in the first stage of the process or not. This intermediate solution is simpler to execute than pure pull control, assuming that the products are relatively similar and only one main route of production is utilized in the process.

In addition to knowing what to produce at a given moment, what to produce next, when are the raw materials and components required and what can be promised to the customer, it is also highly relevant to production management to ensure that exactly that which was intended to be produced is also that which was actually produced. This is done by means of quality control, which we will examine by starting from the perspective of variability.

Variability, the distribution of results, as a phenomenon is based on the existence of randomness in natural processes and phenomena, and the tendency for entropy to increase in a closed system. However, production is a very goal-oriented process which requires discipline and order. As such, recognizing, understanding and eliminating, or at least minimizing, it is another integral task of production control. With regard to production, the concept of variation (deviations from intended result), can be applied, because production has an intended result, a goal – for example, an engineer has designed a particular geometry for a specific component along with intended values and a scale of tolerance – and the deviations from the intended result emerging in production can be recognized and measured. The goals of production along with deviations from these goals form a basis for the concept of technical quality, also called the 'small q'. With regard to quality development it is important to recognize the different causes of variation, because these can be fixed or improved upon through different methods. These causes can be roughly categorized in two different types: specific causes and generic causes.

Variation due to specific causes means disruptions from outside the production system, such as faulty materials or dust. They appear at a specific time in a specific location and the causes can then be recognized from the production data as 'abnormal' deviations. The causes for these deviations can be eliminated or reduced through different methods, such as quality standards based on written agreements, inspection of component deliveries and unfinished products, and actions which protect the production from external variation (i.e. closing the system). This is called quality assurance and for it, different quality management systems have been developed, such as ISO9001. Variation due to generic, or common, causes is caused by the variability of the production system itself – internal variation, meaning that even though the system is operating as it normally, without disruptions, operates, there appears some degree of random variability, so called 'normal deviation', to which a specific cause can't be assigned. This normal deviation is measured by e.g. sigma levels, i.e. how many standard deviations can fit in a given tolerance interval. 3-sigma quality has a variation of 0.4%, while in 6-sigma quality 4 flow units out of a million are faulty. Reducing variation due to generic causes requires improving the quality production capabilities of the production system itself through e.g. technological innovations.

Statistical Process Control (SPC) is a method which helps to manage the production process and the quality it produces by following how the measurements describing quality variation develop through time (or repetitions). In this depiction, the generic causes form a stable distribution around the target value. Specific causes in turn are seen as spikes in the timeline depiction of the process, or as averages of the process that are drifting away from the target. In order to differentiate specific causes from generic causes, certain warning and control levels must be assigned. When the warning level is crossed the process is still in control (producing quality within tolerance), but is clearly deviating from normal variation – something seems to be wrong (at least from a statistical perspective). When the control level is crossed, the process is no longer in control, meaning that it produces second-rate, unusable products outside of tolerance. If these errors in quality get through the production system undetected, they will lead to a negative customer experience. If the quality errors are detected in production, they will lead to adjustments, material waste and repetition of work. In complex production systems, one requirement of efficiency is that things are done right on a single attempt – there is no tolerance for bad quality.

While technical quality means a flawless performance according to assigned requirements, the term quality is also used in a wider meaning: functional quality, or 'Big Q', depicts customer experience and its possible implications to customer purchasing behavior. While technical quality is about the relation between specified intentions and measured results, functional quality means the relation between expectations and experiences. Functional quality includes challenges that don't have a technical solution, e.g. how to recognize the expectations of customers, and how are these expectations translated into features and properties of a product or a service, and how do different customers experience this product or service in different situations. In service production, quality is overall a more challenging concept, as the variety of customers creates variables in the production process. The wishes and abilities of people vary, and services are asked for when it suits them or a need arises. If closing the system from variation is not an option – the door of a barbershop can be locked, but value cannot be created without a customer – the variation just needs to be accepted. A core feature of service production systems happens to be being robust – tolerating variation.