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Production Control – A Logistic Control Function

According to an earlier definition of American Production and Inventory Control Society (APICS), production control is defined as:

> [....] the task of predicting, planning and scheduling work, taking into account manpower, materials availability and other capacity restrictions, and cost to achieve proper quality and quantity at the time it is needed, and then following up the schedule to see that the plan is carried out, using whatever systems have proven satisfactory for the purpose.
>
> (MacKay and Wiers (2004))

As such, production control can be regarded as a logistic planning and control (LPC) function within a production environment. Therefore, we will first discuss logistics in the general sense in Section 1.1. Next, in Section 1.2, we will concentrate on basic decision elements in planning and control for logistics. Then in Section 1.3, we will discuss some specific characteristics of LPC in production, followed in Section 1.4 by an introduction of basic terminology.

1.1 Logistics

The term "Logistics" originates from the logistics on the battlefields, i.e. those activities that take care of the supply and removal of troops, equipment, and materials to and from the battlefields (see, for instance, https://www.merriam-webster.com/dictionary/logistics). The basic function of logistics is to make sure that the *transformation process* can perform its function effectively and efficiently by providing that process with the proper information, materials, and resources ("capacity"). In Figure 1.1, the material flow is shown as a double-lined arrow, going from left (*input* of materials) to right (*output* of finished products); information is shown as a single line, whereas for resources triple-lined arrows are used.

The idea of "logistics" may be applied to *any type of transformation process*. The transformation process can be a production process, turning the incoming materials

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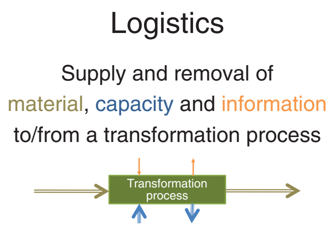

Figure 1.1 Logistics.

("raw materials") into outgoing products, using machines controlled by operators (capacity resources) and specifications ("information") determined by engineering. However, a transformation process can also be a maintenance process where a machine that went down (incoming material) is repaired, possibly using spare parts (also incoming materials). The repair can be done by a mechanic using tools and possibly other machines (capacity resources), based on maintenance instructions (=information).

The output of a transformation process doesn't have to be tangible. Also, in professional service organizations like banks or insurance companies transformation processes take place: in general not regarding the transformation of form, but the transformation of information which leads to intangible output. Within a production context, an engineering process is an example of a transformation process with intangible output. The incoming "material" would be information (so nonphysical). That information is turned into product and process specifications by engineers (capacity resources). Supporting information will be used, such as standard solutions or background information stored in databases. In hospitals, patients are the incoming "materials." Doctors, nurses, operating theaters, beds, and labs are the capacity resources used to turn sick patients into outgoing ex-patients (hopefully cured …). Finally, transportation processes can be regarded as transformation processes, the transformation being the change of location of the goods transported. Then clearly the goods to transport are the materials, using transportation documents while trucks, drivers, trains, etc. are the capacity resources.

Examples of transformation processes are given in Figure 1.2.

The logistic function aims to make sure that:

– the objects on which the transformation is performed, are available (objects such as materials, assets to be maintained, and patients);
– the resources required to perform the transformation are available (capacity resources such as machines, tools, operators, and transportation resources);
– the supporting information is available (like instructions for the transformation).

Objects, information, and resources often are *physical* by nature, but that's not necessarily true for all of them (cf. the example of engineering). For instance, software can be regarded as a resource required for a particular transformation, or particular documents may be available digitally before a process may start. It's not only the availability of objects, information, and resources that matter but also

Figure 1.2 Examples of transformation processes. Source: https://depositphotos.com/.

the removal of these items after the transformation has taken place. Making sure the output of the process (the "products") is made available for the next step is an important issue in logistics. Moreover, also getting the resources back in time and having them available for other processes is an important logistical task, either because these resources may not yet be at the place of the next process they will be used for, or because the resource cannot be used directly for a new process and will be unavailable during a certain period (e.g. because the resource needs "re-conditioning"). Sometimes even the carrier of information has to be returned to be available next time.

It will be clear that logistics is a very broad term. In many instances, publications, etc., it is often interpreted in relation to warehousing and/or transportation. In this book, we will concentrate on transformation processes that take place in production organizations (transformation of form), and thus logistics has to be interpreted with regard to physical production processes. Therefore, we will mainly use terminology from industry in this book.

1.2 Logistics Planning and Control

Logistic planning and control is all about making *decisions* on the availability and the supply of the materials, information, and capacity resources at which place and in what quantity to get the transformation process going. The two parts of logistics planning and control are:

- *Planning*: determining which jobs ("orders") should be done and setting targets on when and who should be doing what, etc.
- *Control*: starting the actual jobs, monitoring their progress, and if necessary intervening. This is also known as the *control cycle* (see Figure 1.3).

We will see later that usually more than one plan is made. These plans may all differ in time horizon (e.g. a plan for the next shift versus a plan for next year), system boundaries (one workplace versus an entire factory), and units used ("truck ZF20/13 with options X, U, and Z, planned to be produced on time 10:15" versus "120 trucks on day 15").

If we look in more detail at LPC, we can distinguish the following essential decisions (see Figure 1.4):

- Actual *planning*: setting targets for the transformation process considered, like due dates (when should the process be done) and efficiency targets.
- *Acceptance* of a job offer: a job may not be acceptable from a logistic point of view because the targets set are not possible to meet (like a too-tight due date), the materials are not (all) available, or the capacity resources required are not available (at least not within the required time frame). Only accepted jobs should be considered for release.
- *Release* of a job chosen from all the waiting accepted jobs: this requires some kind of prioritizing of the waiting jobs. Together with the release of the job, the materials used, information needed, and the capacity resources required should be released (if that is not done yet). Jobs that have been released are called "work in progress" (WIP), and the materials connected to that job are usually stored in a buffer at the workstations.
- *Progress monitoring* of the released jobs: during the progress of the transformation process, jobs may run behind schedule (or ahead of schedule). Depending on the reaction time available and the measures that might be taken, an intervention might be considered. Such an intervention can be an adjustment of the number of

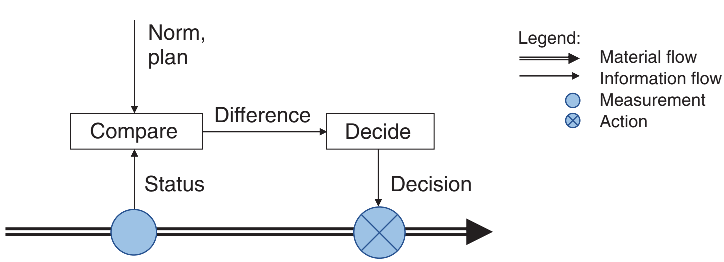

Figure 1.3 Control cycle.

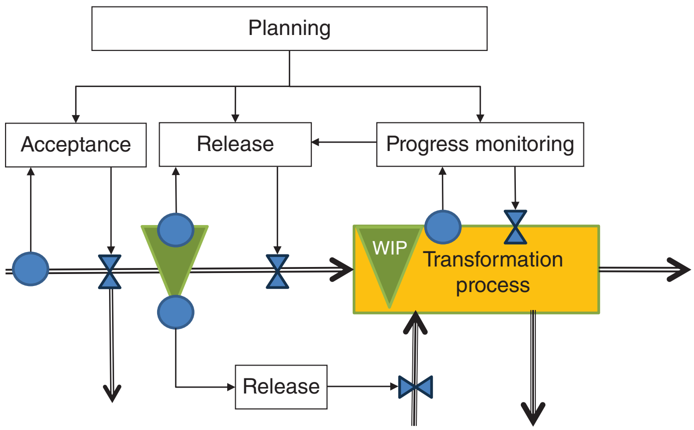

Figure 1.4 Basic decision elements of logistic planning and control.

capacity resources available (like hiring extra temporary operators) or a rescheduling of the due dates. Also, a feedback link to the release of new jobs might be considered. It might even be a change in the job specifications, for instance, in the number of products to be produced. Monitoring requires some kind of progress measurement.

Releasing new jobs, information, materials, and capacity resources (or not) and intervening in the progress of jobs that have already been released (or removing capacity and materials from the process) is the most direct way the logistic function may influence the logistic performance of the transformation process. In other words, LPC combines "jobs," "materials," "information," and "resources" to allow the transformation process to start (and finish).

1.3 Logistic Concepts in Production

Logistic Planning and Control (LPC) in the case of *production processes* (production planning and control) is the main subject of this book. Before we explain the position of LPC in a production context, it is worthwhile to describe a production process as an aspect of a *production system* as In 'Veld has introduced in his System Approach (Veeke et al. 2010). Any production system can be described in terms of the PCOI aspects (van Assen 2016; Dijkstra et al. 1997; Ribbers and Verstegen 1992):

- *Process*: the actual activities of the system, including the interrelations between these activities (like material flows) and the resources used to perform the activities.
- *Control*: the planning and control of the activities of the process, usually in terms of quality, timeliness, and costs.
- *Organization*: the division of tasks, responsibilities, and competencies in the system among people and functions ("who does what").

- *Information*: the provision and gathering of information to, in, and from the system. This information is needed for all three other aspects of the system: to support and monitor the process, to assist in decision-making and distribute decisions made, and to exchange facts, knowledge, and statuses between people and functions.

Any production system operates in an *environment*. Crucial parts of the environment of a production system are the consumer *markets* buying/using the products ("*outputs*"). These markets are the "reason for being" for the production system. The output is related to the performance the system delivers. The choices made on what to achieve in such a context from a business perspective, translated into targets for the production system, may be considered the goals of the system as defined by van Assen (2016). Other markets, then the consumer markets, that the production system has to take into account, especially from a logistic point of view, are the supplier markets providing materials and resources ("inputs"). We will call this view on production systems the MO/PCOI-view, which is short for "Markets-Output-Process-Control-Organization-Information" (see Figure 1.5). Using this model on production systems, LPC can be considered as an *aspect system* of the "control" part of the production system. It focuses on the *planning and control of the timeliness of the process*. The logistic performance is usually expressed in terms of having *the right amount of the right products at the right place at the right time*. It consists of two basic elements:

- *Delivery reliability*: the degree to which the agreed delivery specifications (in time, place, and quantity) are met.
- *Delivery time*: the time required to deliver the required items (so: how fast is delivery).

Promising a short delivery time is only wise if we're pretty sure that we'll be able to keep this promise and thus meet the due date. Otherwise, it might be better to enlarge the promised delivery time somewhat. So having a short promised delivery time usually only leads to satisfied customers if the promised delivery time is met.

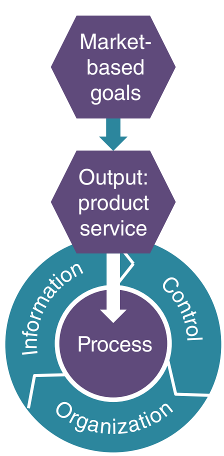

Figure 1.5 MO/PCOI-view on production systems. Source: van Assen (2016).

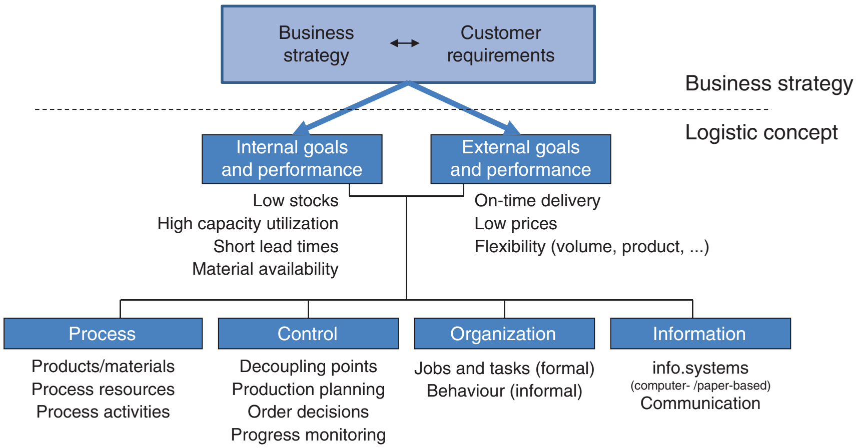

Figure 1.6 Logistic concept. Source: Adapted from Ribbers and Verstegen (1992).

Besides delivery performance, often the following two aspects are considered as well when determining the total logistic performance:

- *Flexibility of delivery*: the degree to which agreements made (like due dates) can be changed afterward without loss in delivery reliability or extra costs.
- *Logistic costs*: all costs associated with the supply of materials and capacity resources, such as inventory cost, cost of storage, and ordering cost.

In real-life situations, measuring only the delivery performance as mentioned above doesn't give an accurate and complete image. Usually, the extra costs caused by these decisions are considered. We will discuss the specific logistic costs later. This view on logistics is also known as the "logistic concept" (see Figure 1.6). The main focus of this book is the "control" part of this concept.

At this point of the discussion, it is important to understand that the logistic performance of a production process is "only" a part of the total performance of that process. Usually, the performance of a transformation process is based on three considerations:

- the quality of the product and process (*Quality*).
- the logistic performance (*Delivery*).
- the efforts that are taken to do so (*Costs*).

In this book, the focus is on logistic performance, including that part of the costs that are logistic related. The logistic performance of any production system is always the result of the choices made in the design of that system. As explained, these choices concern all four PCOI aspects of a production system. In this book, we will limit the discussion to the choices made concerning the control aspect of the system. Studying LPC of a production system requires an understanding of all aspects of the system involved. In other words, in any real-life situation, the following logic can be followed to understand the actual situation at hand:

– describe the processes, including materials, information, and resources used;
– describe the LPC structure, including all planning and control decisions;
– describe the division of tasks and responsibilities;
– describe the supporting IT systems, including the data available.

1.4 Terminology for Production Control

As already said, we will concentrate on transformation processes that take place in production organizations (transformation of the form) and thus logistics has to be interpreted with regard to physical production processes. In this section, we will define some crucial concepts used in production control (Section 1.4.1) and discuss some general characteristics of a production situation (Section 1.4.2).

1.4.1 Concepts Used in Production Control

If we consider a physical material transformation process, the transformation steps can be, for instance, bending, sawing, drilling, casting, welding, etc. which are called *operations* and are performed at *work centers* consisting of one or more (more or less) identical machines. The sequence in which the different operations are performed often is called *routing*. The routings of different products can be quite different in some production departments, whereas in other production departments, they are identical. If we have a nonphysical process, the sequence in which the different operations like for instance application, classification, calculation, and sending a mail are performed is called *workflow*. A schematic representation of a production process is given in Figure 1.7.

A *job* is a task or combination of tasks that has to be executed at a certain work center for a certain order.

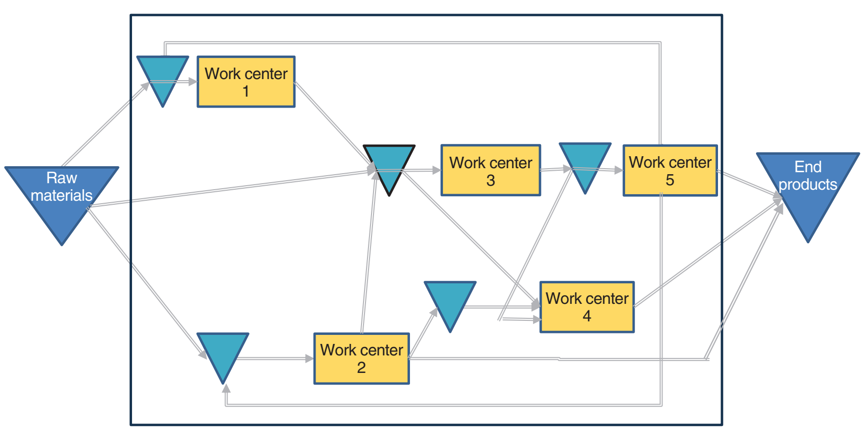

Figure 1.7 A schematic example of a production process.

An *order* is a general term that may refer to such diverse items as a purchase order, shop order, customer order, planned order, or schedule. In this book, we interpret it as a document that contains all the necessary information to produce a series of a (semifinished) product in the production department. Often several jobs have to be executed for one order. Releasing an order means that all the necessary materials, information, and/or tools have been collected and that a department can start working on the first job of that order.

The time necessary for an operation is called the *processing time*. Often an order occupies a resource longer than the processing time. For instance, at the beginning of the operation the order has to be administrated, the resource has to be set up and at the end of the operation, it might be that the product needs to be cooled down. All that time, the resource cannot be used for another order and we will call this "extended" processing time the *service time*.

We will call the *actual* time between the arrival of the order (at a work center) and the completion time of this order (at the work center) the (work center) *throughput time,* whereas the *planned* time between arrival (at the work center) and completion (at the work center), often needed for planning purposes, is called (work center) *lead time*. The lead time determines the *Due Date,* and the throughput time determines the *Completion Date*. The difference between these two dates, Completion Date – Due Date, is called the *lateness*; max(0, lateness) is called the *tardiness,* and -min(0, lateness) is called the *earliness*.

Remark: Often cycle time or lead time is used instead of throughput time. This can be confusing since cycle time is often used in certain industries (like process industries) with quite another meaning. In this book, we will use these words as described above and thus lead time is used for the planned time and throughput time for the actual time.

Delivery time is the time between the acceptance of a customer order and the delivery of this order to the customer. The transformation process is driven by *work orders* that are derived from *customer orders,* where a customer can also be the next stock point or department. Depending on the characteristics of the resources, customer orders might be merged into one work order or split into several work orders.

In Figure 1.7 we see several triangles before the operations. These triangles represent waiting lines (that lead to waiting times) that may occur since to perform the operation a decision is required or resources are required that are limited available. For instance, if at a certain work center, we need a drilling machine and we only have one drilling machine we can only start with a newly arriving order if the drilling machine is idle, otherwise this order has to wait. This leads to the situation that the time between the arrival of the order at a work center and the completion time of the order at this work center, which is called the (*work center*) *throughput* time, is larger than the processing time. In many instances, the waiting times are much larger than the operation times which implies that the throughput time mainly consists of waiting time.

1.4.2 Complexity, Uncertainty, and Flexibility

Production control in general can be very complex. Therefore, for developing a (specific) control concept, it is important to know how the production situation can be described in terms of:

a) complexity
b) uncertainty
c) flexibility

Ad a.: Complexity is among others caused by the variety of the products, variety in demand, variety in operations, variety in routings, variety in number of operations per routing, etc. High complexity requires a lot of coordination and therefore one of the main points for a concept for production control is that it should be directed to reduce the complexity. This can be done by *decomposition:* divide the total production control problem into several subproblems each with its own objective and decision-making autonomy. An example of this is the decomposition between production unit control and decoupling point control (also called goods flow control), which will be discussed later on. Other examples are the decomposition between control at an aggregate level and detail level and the decomposition between Sales and Production.

Ad b.: Uncertainty is caused by unpredictability and dynamics. We can make a distinction between uncertainty at the demand side and uncertainty at the process side. Uncertainty at the demand side can be caused by the kind of customers (end user; dealer; …), the kind of product (consumer product; professional product; …), etc., and uncertainty at the process side can be caused by the reliability of the machines, fluctuation in processing times, reliability of the suppliers, quality of the materials/ components, etc. These uncertainties influence the desired control concept for a certain production situation. For instance, if there are long-lasting machine breakdowns, the control is quite different than in case there are more or less frequent variations in the processing times.

Ad c.: Flexibility is important to counteract disturbances. Forms of flexibility are:

– multi-skilled operators
– machines that have small setup times and that easily can be changed
– commonality (using the same components in several different configurations)
– short lead times of components
– overcapacity
– outsourcing
– inventories (makes it possible to react quickly to changes in for instance demand)
– overtime, etc.

If there is a lot of flexibility, the effect of uncertainties can easily be downplayed so they don't have a large effect on the desired control concept. Making the (potential) flexibility effective might involve substantial coordination, which might affect the desired control concept.

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