

Henny Van Ooijen and Corné Dirne

# Production Control in Practice

A Situation-Dependent Decisions Approach





## **Production Control in Practice**



# **Production Control in Practice**

A Situation-Dependent Decisions Approach

*Henny Van Ooijen*

*Corné Dirne*

## Authors

### *Prof. Dr. Henny Van Ooijen*

Eindhoven University of Technology  
Tielseweg 5  
4116 EB Buren  
The Netherlands

### *Prof. Dr. Corné Dirne*

Fontys University of Applied Sciences  
Rondom 1  
5612 AP Eindhoven  
The Netherlands

**Cover Image:** © akinbostanci/Getty Images

■ All books published by **WILEY-VCH** are carefully produced. Nevertheless, authors, editors, and publisher do not warrant the information contained in these books, including this book, to be free of errors. Readers are advised to keep in mind that statements, data, illustrations, procedural details or other items may inadvertently be inaccurate.

**Library of Congress Card No.:**  
applied for

**British Library Cataloguing-in-Publication Data**  
A catalogue record for this book is available from the British Library.

**Bibliographic information published by the Deutsche Nationalbibliothek**  
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at <<http://dnb.d-nb.de>>.

© 2024 WILEY-VCH GmbH, Boschstraße 12, 69469 Weinheim, Germany

All rights reserved (including those of translation into other languages). No part of this book may be reproduced in any form – by photoprinting, microfilm, or any other means – nor transmitted or translated into a machine language without written permission from the publishers. Registered names, trademarks, etc. used in this book, even when not specifically marked as such, are not to be considered unprotected by law.

**Print ISBN:** 978-3-527-35344-6  
**ePDF ISBN:** 978-3-527-84590-3  
**ePub ISBN:** 978-3-527-84589-7  
**oBook ISBN:** 978-3-527-84588-0

**Typesetting** Straive, Chennai, India

## Contents

**Preface** *xi*

### **Part I Production Control in General** 1

#### **1 Production Control – A Logistic Control Function** 3

- 1.1 Logistics 3
- 1.2 Logistics Planning and Control 6
- 1.3 Logistic Concepts in Production 7
- 1.4 Terminology for Production Control 10
  - 1.4.1 Concepts Used in Production Control 10
  - 1.4.2 Complexity, Uncertainty, and Flexibility 12
- References 13

#### **2 Horizontal and Vertical Decomposition** 15

- 2.1 Horizontal Decomposition 16
- 2.2 Vertical Decomposition 22
- 2.3 Types of Release Triggers 25
  - 2.3.1 Just-in-Time Versus Just-in-Case 25
  - 2.3.2 Push Versus Pull in Logistics 28
- 2.4 An Example of Decomposition 30
- References 32

#### **3 Planning and Control in Production Units** 33

- 3.1 Production Control in General 33
- 3.2 Basic Forms of Production 35
  - 3.2.1 Process-Wise Production 35
  - 3.2.2 Mass Assembly/Flow Production 36
  - 3.2.3 (Repetitive) Small Series Production (Also Called Job-Shop) 36
  - 3.2.4 (Repetitive) Project-Wise Production 37
  - 3.2.5 Throughput Time Production Units 37
- References 39

## **4 Framework for Logistic Planning and Control in Production Systems 41**

- 4.1 General Framework 41
- 4.2 Position of this Book 45
- References 46

## **Part II Planning and Control of Decoupling Points 47**

### **5 Decoupling Point Control 49**

- 5.1 Decoupling Point Control – An Introduction 49
- 5.2 Performance Measures for Decoupling Point Control 53
- 5.3 Demand and Forecasting 58
  - 5.3.1 Demand Pattern 59
  - 5.3.2 Forecasting Methods 60
    - 5.3.2.1 Time Series-Related Forecasting for Stationary Demand 63
    - 5.3.2.2 Time Series-Related Forecasting for Demand with a Trend 67
- 5.4 Order Size 71
  - 5.4.1 Optimal Batch Size in Case of Fixed Order Size 72
  - 5.4.2 Relaxation of Assumptions 75
    - 5.4.2.1 Known or Predicted Demand Variation 75
    - 5.4.2.2 Quantity Discount 78
    - 5.4.2.3 Minimum Order Quantity 79
    - 5.4.2.4 No Variable Order-Related Costs 79
    - 5.4.2.5 Interdependencies of Order Sizes – Not BOM Related 80
    - 5.4.2.6 Interdependencies of Order Sizes – BOM Related 81
  - 5.4.3 Single Period Problem 83
- Appendix 5.A The Wagner-Whitin Algorithm 84
- Appendix 5.B Example Impact Advanced and Optimal Approach for Determining Batch Sizes 87
- Appendix 5.C Newsvendor Problem 87
- References 90

### **6 Reorder Point Decoupling Point Control Systems 93**

- 6.1 General Discussion of Reorder Point Systems 93
- 6.2 When to Order? 96
  - 6.2.1 Continuous Review 97
  - 6.2.2 Periodic Review 99
    - 6.2.3 The Reorder Level – Continuous Review 100
    - 6.2.4 The Reorder Level – Periodic Review 107
- 6.3 How Much to Order? 109
  - 6.3.1 Fixed Amount 109
  - 6.3.2 Maximum Level 109



6.3.2.1	( <i>s, S</i> )	109
6.3.2.2	( <i>R, s, S</i> )	110
Appendix 6.A	Table of the One-Sided Standard Normal Distribution	110
Appendix 6.B	Table Standard Normal Loss Function	112
Appendix 6.C	Reorder Level Determination in Case of a General Distribution	113
6.C.1	Discrete Demand	113
6.C.2	Continuous Demand	115
6.C.3	Determining the Reorder Level	116
	References	116
<b>7</b>	<b>MRP Decoupling Point Control Systems</b>	<b>117</b>
7.1	General Discussion of MRP Systems	117
7.1.1	Material Requirements Planning (MRP-I)	117
7.1.2	Manufacturing Resources Planning (MRP-II)	119
7.1.2.1	Engine	119
7.1.2.2	Front End	120
7.1.2.3	Back End	121
7.2	When to Order	122
7.3	How Much to Order?	125
7.4	Discussion on MRP-Related Issues	128
7.4.1	Dealing with Uncertainty	128
7.4.2	Bill-of-Materials Versus Bill-of-Distribution	130
Appendix 7.A	MRP Formulas	132
7.A.1	Rescheduling Assumption	132
	References	133
<b>8</b>	<b>Systems Using Echelon Stock (ESC, LRP)</b>	<b>135</b>
8.1	General Discussion of Systems Using Global Norms	135
8.1.1	Discussion on ROP and MRP	136
8.1.2	Echelon Stock Control Systems	137
8.1.3	Line Requirements Planning	138
8.2	When and How Much to Order?	139
8.2.1	When and How Much to Order in Echelon Stock Systems?	139
8.2.2	When and How Much to Order in Line Requirements Planning Systems?	139
8.3	Discussion on Echelon Stock Systems	142
	References	143
<b>9</b>	<b>Choosing an Appropriate DPC System</b>	<b>145</b>
9.1	General Considerations	145
9.2	Advantages/Disadvantages of the Different DPC Systems	146
9.2.1	Bullwhip Effect	147
9.3	Which Decoupling Point Control System to Use?	150
	References	157

**Part III Production Unit Control 159**

- 10 General Discussion of Production Control Decisions 163**
  - 10.1 Priority Control 164
  - 10.2 Capacity Allocation 165
  - 10.3 Work Order Release/Work Order Detail Planning (Scheduling) 166
  - References 168
  
- 11 Production Control for Deterministic, Static Production Situations (Scheduling) 169**
  - 11.1 Sequencing Orders Without Delivery Date (Throughput Time Oriented) 170
    - 11.1.1 Work Orders with One Operation and Work Centers with One Machine 171
      - 11.1.1.1 Relation Between Work-in-Process and Throughput Time 171
      - 11.1.1.2 Minimization of the Average Throughput Time 171
      - 11.1.1.3 Minimization of Weighted Average Throughput Time 171
    - 11.1.2 Work Orders with One Operation and Work Centers with Parallel, Identical Machines 172
      - 11.1.2.1 Minimizing the Makespan 172
      - 11.1.2.2 Minimizing the Average Throughput Time 172
    - 11.1.3 Work Orders with Multiple Operations and Work Centers with One Machine 173
      - 11.1.3.1 Minimizing the Makespan for a Flow Shop with Two Operations 174
      - 11.1.3.2 Minimizing the Makespan for a Flow Shop with More Than Two Operations 176
  - 11.2 Sequencing Orders with a Delivery Date (Reliability Oriented) 178
    - 11.2.1 Minimizing the Average Lateness 179
    - 11.2.2 Minimizing the Maximum Tardiness 179
    - 11.2.3 Minimizing the Number of Tardy Orders ( $N_T$ ) 179
    - 11.2.4 Minimizing the Average Tardiness 181
  - 11.3 Relaxing Assumptions 183
    - 11.3.1 Orders with Sequence-Dependent Set-Up Times 183
    - 11.3.2 Sequencing Orders with Different Routings 184
    - References 185
  
- 12 Flow Process Production 187**
  - 12.1 General Description 187
  - 12.2 Main Control Attention Points of Flow Process Production 189
    - 12.2.1 General 189
      - 12.2.2 Cycle Time Determination 190
        - 12.2.2.1 A Stable Level of Demand 191
        - 12.2.2.2 Variable Demand 194
        - 12.2.2.3 Different Cycles on One Production Line 196

- 12.3 Production Control Decisions for Flow Process Production in MTS Situations 196
  - 12.3.1 Sequencing 196
  - 12.3.2 Capacity Allocation 197
  - 12.3.3 Work Order Release 197
- 12.4 Production Control Decisions for Flow Process Production in MTO Situations 197
  - 12.4.1 Sequencing and Work Order Release 198
  - 12.4.2 Capacity Allocation 200
- 12.5 Application 200
  - References 204
  
- 13 Mass Assembly Production 205**
  - 13.1 General Description 205
  - 13.2 Main Control Attention Points of Mass Assembly Production 207
    - 13.2.1 Pure Flow Production 208
      - 13.2.2 Variants of Pure Flow Production 209
        - 13.2.2.1 Different Processing Times 209
        - 13.2.2.2 Variable Processing Times 211
        - 13.2.2.3 Different Products (Needing Different Materials and/or Resources) 211
          - 13.2.2.4 Disturbances at the Work Centers 212
          - 13.2.2.5 No Availability of Efficient Technology 212
          - 13.2.2.6 A Variety of Routings (Some Operations Are Skipped) 213
      - 13.2.3 Quantitative Models for Analyzing the Effect of Buffers 214
        - 13.2.3.1 Two Stations Without Failures 215
        - 13.2.3.2 More Than Two Stations Without Failures 216
        - 13.2.3.3 Two Stations with (Time-Dependent) Failures 216
        - 13.2.3.4 More Than Two Stations with (Time-Dependent) Failures 218
      - 13.2.4 Cross Training 219
    - 13.3 Production Control Decisions for Mass Assembly Production 220
      - 13.3.1 Sequencing 220
      - 13.3.2 Capacity Allocation 220
      - 13.3.3 Work Order Release 221
    - 13.4 Application 222
      - References 224
  
  - 14 Small Series Production 227**
    - 14.1 General Description 227
    - 14.2 Main Control Attention Points of Small Series Production 229
      - 14.2.1 Fundamental Results from Queueing Theory 230
        - 14.2.2 Throughput Time-Related Aspects 236
          - 14.2.2.1 Production Layout 236
          - 14.2.2.2 Measures Based Upon Insights from Queueing Theory 236
          - 14.2.2.3 Customer Differentiation 238
        - 14.2.3 Lead Time Reliability Related Aspects 239

14.2.3.1	Due Date Determination Rules	240
14.2.3.2	The Effect of the Value of the Slack on the Delivery Reliability	246
14.2.3.3	Internal Versus External Due Date	248
14.3	Production Control Decisions for Small Series Production	248
14.3.1	Throughput Time	249
14.3.1.1	Sequencing	249
14.3.1.2	Capacity Allocation	252
14.3.1.3	Work Order Release/Work Order Detail Planning	256
14.3.2	Lead Time Reliability	259
14.3.2.1	Sequencing	259
14.3.2.2	Capacity Allocation	262
14.3.2.3	Work Order Release	263
14.4	Application	263
Appendix 14.A	Short-Term Capacity Adjustment	265
Appendix 14.B	Flexible Batching	267
Appendix 14.C	The Effect of Workload Control in Case There Is a Relationship Between Productivity and Workload	268
	References	271
<b>15</b>	<b>(Repetitive) Project-Based Production</b>	<b>273</b>
15.1	General Description	273
15.2	Main Control Attention Points of Project-Based Production	275
15.2.1	Construction of a Network	276
15.2.1.1	Terminology	276
15.2.1.2	Duration of the Activities	279
15.2.1.3	Critical Path and Project Duration in Case Activity Times Are Deterministic	279
15.2.1.4	Slack	281
15.2.1.5	Uncertainty in Project Duration Due to Stochastic Activity Times	282
15.2.1.6	Realistic Estimates of the Activity Times	284
15.2.1.7	Activity on Node Networks	284
15.3	Production Control Decisions for Project-Based Production	286
15.3.1	Sequencing	286
15.3.2	Capacity Allocation (and Scheduling)	286
15.3.2.1	Resource Loading	286
15.3.2.2	Resource Leveling	286
15.3.2.3	(Constrained Resource) Scheduling	287
15.3.3	Work Order Release/Project Scheduling	289
15.3.3.1	Work Order Scheduling	289
15.3.3.2	Work Order Release	290
15.4	Application	291
	References	295
	<b>Index</b>	<b>297</b>

## Preface

In the 1980s–1990s of the past century Bertrand, Wortmann, and Wijngaard published the book “Productiebeheersing en Materials Management” (in Dutch), which was unique in its approach to the discussion of production control (see further on). This book is no longer edited, but from a lot of sources, we heard that the material, and the way it is discussed, are still very interesting and relevant. Therefore, we decided to “upgrade” this book. It is extended, updated, and written in English. Moreover, we tried to make it as practical as possible. Therefore, we will not discuss the latest, most sophisticated research concerning the different decision functions since these are often difficult to understand, or to implement, for practitioners. Moreover, here holds: the first blow is half the battle, that is, with only simple methods already a lot (cost) benefits are obtained. The target audience is students at a bachelor level and practitioners with some experience working in the field of (production) logistics.

In our daily life, we can observe lots of transformation processes. We can group them into:

- (a) Transformation of form or content
- (b) Transformation of time
- (c) Transformation of place

In this book, we will discuss the transformation of the form (production) and the transformation of time (inventory) with an emphasis on operational control. We will concentrate on transformation processes that take place in production organizations or professional service organizations (insurance companies, banks, etc.). In these organizations, we deal with the production of tangible or intangible products and the stocking of raw materials, intermediate components, and products produced. We will mainly use terminology from industry, but the concepts can easily (with some creativity) be translated into professional service organizations.

We decompose the complex production control problem in supply chains into several less complex subcontrol problems. This leads to a decoupling point control (material coordination) problem and one or more production unit control (capacity coordination) problems.

We distinguish several characteristic control situations, and for each of them, we discuss the control aspects where we will use the same format for discussion for

all the goods flow and production situations: first a general discussion of the control situation, next a general discussion of the relevant decision functions and then a detailed discussion of each decision function for the control situation we consider. This is one of the unique points of this book. The fact that we distinguish several characteristic situations and discuss for each of them the relevant decisions led to the inclusion of “situation-dependent” in the subtitle.

The books we know on production control discuss this from a technical point of view (LP, queuing theory, dynamic programming, etc.) or a functional point of view (aggregate planning, materials requirement planning, etc.). The kinds of production systems considered are limited, often only transfer lines (or flow lines) and assembly systems are discussed. This book is *different* from other books on Production Planning or Production Control in the sense that especially the (basic) control decisions are discussed for the different characteristic Decoupling Point Control and Production Unit Control situations that we distinguish. These control decisions are not discussed, for instance, from a mathematical point of view, but are based on the main decisions that have to be taken in the situation considered. This is another unique point of this book. That is why we added a “decisions approach” in the subtitle.

The book consists of three parts: production control in general, decoupling point control for the flow of goods between units, and production unit control.

In the first part, we will discuss general aspects of production planning. We will discuss the terminology used in this book and the way we look at production control. For the latter, we will discuss our typology of production situations found in practice leading to several characteristic production situations, and we discuss how we decompose the complex production control problem in supply chains.

In the second part, we will discuss the different coordination and material supply control mechanisms that are relevant to supply chains. We first start by discussing some general aspects and then give a typology of the different control mechanisms. Moreover, we discuss the decisions that, in general, have to be taken. Next, each control mechanism is discussed in more detail in a structured way.

In the third and last part, we discuss each of the production situations from our typology and the way production should be controlled. We do this in a structured way taking in Part I distinguished control decisions as a starting point. At the end of each section, we illustrate the way of production control using a (stylized) practical example.

Much of the material on which the book is based is relatively old, but since most of the decision functions are already extensively discussed and/or exactly solved, new research on these functions does not necessarily bring new insights. A few decision functions (like for instance the work order release function) don't have unique “solutions” and are therefore still the subject of research. Where relevant, we extended the discussion of control decisions with newly developed material. Again, the main contribution of this book is the *structured way* in which *the different production control decisions* in the different *characteristic situations* are discussed.

The book is meant for a broad range of readers: bachelor students from universities of applied sciences, academic bachelor students, and practitioners. Parts of the book discuss in more detail the determination of results or technicalities of methods; these have a blue background and are especially meant for academic bachelor students.

We are grateful to Will Bertrand, Hans Wortmann, and Jacob Wijngaard for paving the road for us with their book, for the lessons we learned from them during the time we were colleagues, and for their permission to use (part of) their material.

*Henny Van Ooijen*

Buren, The Netherlands

*Corné Dirne*

Eindhoven, The Netherlands





## Part I

### Production Control in General

In this part, we will discuss the subject of this book and we will give some basic concepts and terminology. Production Control can be discussed from a different number of viewpoints: quality, economics, technology, logistics, etc. In this book, we will take the viewpoint of logistics. We start in Chapter 1 with a discussion of the logistic aspects of planning and control, both in the general sense and in the context of production. In Chapter 2, the complicated control problem will be decomposed in two ways: a vertical decomposition and a horizontal decomposition, leading to several (hierarchical) control problems that are much easier to handle. Moreover, in this section, we will also discuss the different release triggers. Next, in Chapter 3, we discuss planning and control aspects in Production Units, and subsequently, in Chapter 4, a general framework for (logistic) planning and control in productions and the position this book (using this framework) will be highlighted.

### Content

1. Production Control – A Logistic Control Function
  - 1.1 Logistics
  - 1.2 Logistics Planning and Control
  - 1.3 Logistic Concepts in Production
  - 1.4 Terminology for Production Control
    - 1.4.1 Concepts Used in Production Control
    - 1.4.2 Complexity, Uncertainty, and flexibilityReferences
2. Horizontal and Vertical decomposition
  - 2.1 Horizontal Decomposition
  - 2.2 Vertical Decomposition
  - 2.3 Types of Release Triggers
    - 2.3.1 Just-in-Time Versus Just-in-Case
    - 2.3.2 Push Versus Pull in Logistics
  - 2.4 An Example of DecompositionReferences
3. Planning and Control in Production Units
  - 3.1 Production Control in General
  - 3.2 Basic Forms of Production

*Production Control in Practice: A Situation-Dependent Decisions Approach*, First Edition.

Henny Van Ooijen and Corné Dirne.

© 2024 WILEY-VCH GmbH. Published 2024 by WILEY-VCH GmbH.

3.2.1 Process-Wise Production

3.2.2 Mass Assembly/Flow Production

3.2.3 (Repetitive) Small Series Production (Also Called Job-Shop)

3.2.4 (Repetitive) Project-Wise Production

3.2.5 Throughput Time Production Units

References

4. Framework for Logistic Planning and Control in Production Systems

4.1 General Framework

4.2 Position of this Book

References

# 1

## 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

## Logistics

Supply and removal of  
material, capacity and information  
to/from a transformation process



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

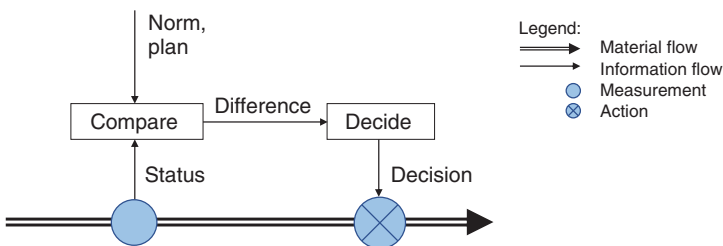
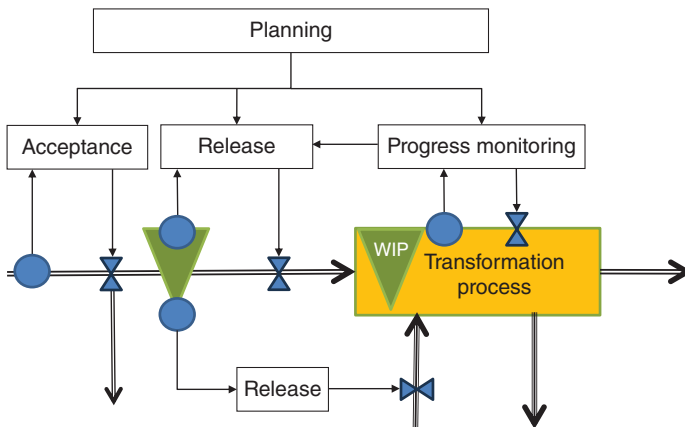


Figure 1.3 Control cycle.



**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 Versteegen 1992):

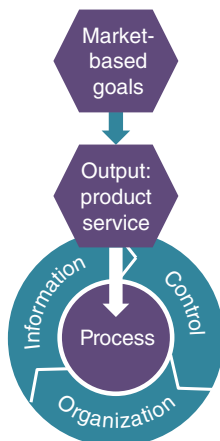
- *Process*: the actual activities of the system, including the interrelations between these activities (like material flows) and the resources used to perform the activities.
- *Control*: the planning and control of the activities of the process, usually in terms of quality, timeliness, and costs.
- *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:

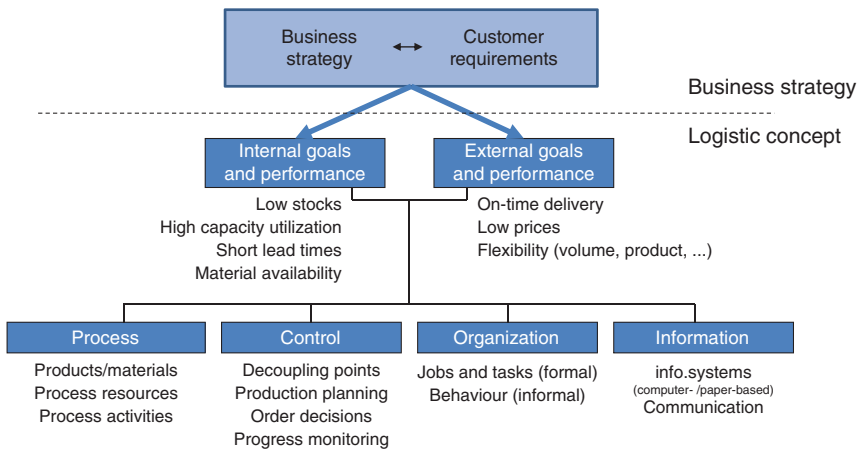
- *Delivery reliability*: the degree to which the agreed delivery specifications (in time, place, and quantity) are met.
- *Delivery time*: the time required to deliver the required items (so: how fast is delivery).

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.

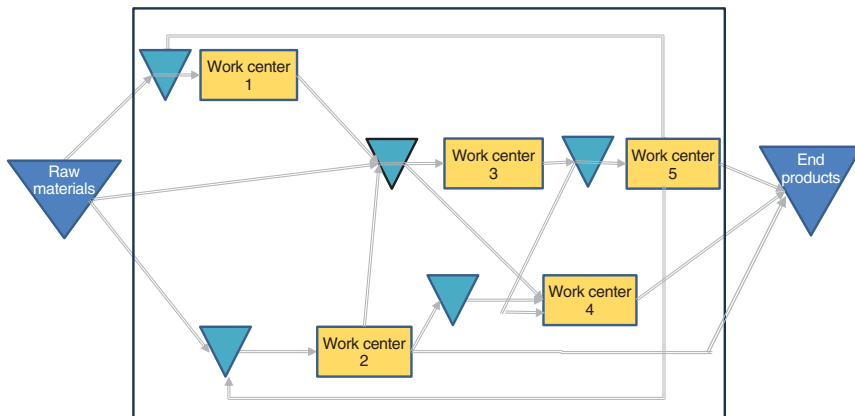
## 1.4 Terminology for Production Control

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*;  $\max(0, \text{lateness})$  is called the *tardiness*, and  $-\min(0, \text{lateness})$  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.

## References

- van Assen, M.F. (2016). *Operational Excellence*. (in Dutch). Koninklijke Boom uitgevers.
- Dijkstra, L., Dirne, C.W.G.M., Govers, C.P.M. et al. (1997). *Samenwerking in ontwikkeling: productontwikkeling door uitbesteder én toeleverancier*. (in Dutch). Kluwer Bedrijfsinformatie.
- MacKay, K. and Wiers, V.C.S. (2004). *Practical Production Control: A Survival guide for Planners and Schedulers*. J Ross Publishing and APICS.
- Ribbers, A.M.A. and Verstegen, M.F.G.M. (1992). *Toegepaste logistiek*. (in Dutch). Kluwer.
- Veeke, H.P.M., Ottjes, J.A., and Lodewijks, G. (2010). *The Delft Systems Approach – Analysis and Design of Industrial Systems*. Springer-Verlag London Ltd.

