Controlling Automated Manufacturing Systems

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Contents

Preface

This book is intended as an introduction to production planning and control of automated manufacturing systems. As such, it links together two diverse fields of interest: in the area of production planning and control there is a large body of work completed in analytical models, computer structures and overall systems; equally, for the hardware and detailed control aspects of the equipment used (for example, NC machines, robots, etc), comprehensive studies have also been completed. To cover each area fully would result in a work of several volumes. Instead, this book stresses the important elements of both areas that are vital to effective production planning and control of the whole automated manufacturing system.

Overall, the book presents a viable production planning and control structure for an automated manufacturing system. This structure has been designed to tie in, where possible, with existing more traditional production engineering and production management approaches, that may well already be firmly established within an organization. Detailed mathematical treatments have been avoided in favour of describing fundamental structures; but adequate references have been given for those eager to pursue more detailed aspects.

A strategy for the tremendously important area of production planning and control for automated manufacturing systems is provided. Feasible and effective approaches are described and their application and implementation is discussed.

Chapter 1 provides a brief introductory definition of an automated manufacturing system, and outlines a few of its most characteristic features and most significant areas of application.

Chapter 2 describes the particular requirements that automated manufacturing systems impose on the production planning and control system.

Chapter 3 explains the background against which a production planning and control system for automated manufacturing systems can be implemented. Included are brief overviews of master production scheduling, materials requirements planning, and job shop scheduling. Analytical and heuristic approaches that can be used to aid master production scheduling and job shop scheduling are reviewed.

In Chapter 4, the structure of the production planning and control system for an automated manufacturing system installation is given. In this book, the structure is divided into four hierarchical levels for production planning and control purposes. These four levels are the factory, shop, cell and equipment levels.

The following four chapters deal with each of these levels in turn, and Chapter 9 provides a conclusion to the book with a brief analysis of likely future trends in the development of automated manufacturing systems.

CHAPTER 1
Introduction

Rapid improvements in both computer hardware and software have made possible a dramatic shift towards automated manufacture. Complete mini factories can now operate with limited human involvement; such automated manufacturing systems rely on effective control procedures for their operation.

Conventionally, manufacturing can be divided into three major categories:

1. Flow or mass production
2. Batch manufacture
3. Jobbing manufacture

Flow or mass production is concerned with producing a limited range of products in high volume (for example, car assembly). Batch manufacture deals with a much larger product range than flow manufacture, but the products tend to have lower volumes and repeat orders are expected. Jobbing manufacture produces what may be termed 'one-offs', that is, there is no expectation that there will be repeat orders for the products. Jobbing manufacture is characterized by a high product-type range but a low volume.

In Western industrialized countries, the proportion of manufacturing output is greatest for batch manufacture; it is usually taken to be somewhere in the region of 70 per cent of total manufacturing output. This book therefore focuses most of its attention on batch manufacturing.

One frequently quoted aim of automated manufacturing systems is to raise the efficiency level of batch manufacture to the level of flow manufacture, and this can be greatly eased if an effective production planning and control system is used.

What is an automated manufacturing system?

A variety of terms have been used to describe highly automated manufacturing facilities, including:

Flexible manufacturing systems.
Computer integrated manufacturing systems.
Automated manufacturing systems.

Each of these terms, which tend to be used more or less interchangeably, describes a highly automated, integrated manufacturing facility. Purists may argue that the present generation of automated manufacturing systems are not particularly adaptable (see later) and should not therefore be labelled flexible manufacturing systems. These purists may also argue that a full computer integrated manufacturing system should include design, manufacturing, control and financial computer systems, and that automated manufacturing systems that do not contain all of these should not be labelled computer integrated manufacturing systems. Overall, therefore, it is perhaps safer to restrict the terminology to 'automated manufacturing systems' and this terminology is followed throughout the book.

Over the past few years a variety of attempts have been made to define an automated manufacturing system. A definition given by Draper Labs (1983) is perhaps a good starting point:

> 'a computer-controlled configuration of semi-independent work stations and a material handling system designed to efficiently manufacture more than one part number at low to medium volumes.'

The definition given by Groover (1980) is a more detailed one which gives some insight into the overall structure of automated manufacturing systems (although he does use the term FMS):

> 'An FMS consists of a group of processing stations (usually NC machines) connected together by an automated work part handling system. It operates as an integrated system under computer control. The FMS is capable of processing a variety of different part types simultaneously under NC program control at the various work stations . . . The work parts are loaded and unloaded at a central location in the FMS. Pallets are used to transfer work parts between machines. Once a part is loaded on to the handling system it is automatically routed to the particular work stations required in its processing. For each different work part type, the routeing may be different and the operations and the tooling required at each work

station will also differ. The co-ordination and control of the parts handling and processing activities is accomplished under command of the computer.'

This definition highlights the central role of the computer in co-ordinating and controlling the activities of the automated manufacturing system; this co-ordination and control function is fundamental to the overall automated manufacturing system efficiency.

Some other points arising from Groover's definition should be stressed. First, the simultaneous processing of a variety of part types is mentioned. This infers the careful co-ordination of different sections of the automated manufacturing system, so that part types can be passed from one section to another. Second, Groover indicates that each part type may have a different route, so planning and controlling the movement of a number of different part types through different routes may be a complex problem.

One frequently quoted aim of an automated manufacturing system for batch manufacture is to lower the cost of discrete part manufacture so that the cost more nearly resembles that of flow manufacture. This is achieved by several features of an automated manufacturing system:

1. Part programs can be downloaded to NC machines relatively easily.
2. Lead times can be reduced.
3. Levels of equipment usage can be raised.

The latter two features are, in particular, dependent on the provision of an adequate and effective production planning and control system.

WHAT IS FLEXIBILITY?

Automated manufacturing systems can perhaps achieve their greatest potential when they are designed to be flexible. This flexibility can take a number of forms, including:

(i) *Volume flexibility* – the ability to handle changes in the production volume of a part.
(ii) *Re-routeing flexibility* – the ability to have a number of routes through the system for each part in order to enable, for example, machine breakdowns to be dealt with.
(iii) *Part flexibility* – the ability to handle a wide variety of parts including the ability quickly to adapt the system to handle a new part.

Including this kind of flexibility into the design of an automated manufacturing system can greatly increase costs; it is perhaps not surprising that many modern automated manufacturing system installations are not particularly flexible. The Ingersoll Engineers' survey (1982) found that for the installations they investigated, compatible part numbers were, on average, restricted to eight and that the proportion of all components in the plant that passed through the automated manufacturing system was approximately four per cent. This fairly limited role for automated manufacturing systems is likely to change over the next few years as the second generation of system facilities come on stream. These second-generation automated manufacturing systems offer a much greater degree of flexibility in the production range.

Automated manufacturing systems have traditionally been associated with metal machining, thereby containing a number of direct numerical control (DNC) machine tools. Recently, much attention has been focused on other areas in which the concepts inherent in automated manufacturing systems can achieve major benefits. One such area is in electronic assembly, where a flexible assembly line can be built to handle a number of different assembly tasks. With good design of the flexible assembly line, new assembly tasks can be readily incorporated.

Why is production planning and control important?

Reduced lead times, low work-in-progress, low inventory levels and high facility usage are extremely important for *any* manufacturing system; consequently, production planning and control is important for all manufacturing systems. However, it becomes increasingly important in an automated manufacturing system for two major reasons. First, one of the significant advantages of automated manufacturing systems is that manufacturing lead times (ie the time taken to manufacture a part) can be shorter than in conventional manufacture. It is not unusual to find lead times for a part of six weeks in conventional manufacture being reduced to eight hours when that part is manufactured in an automated manufacturing system. These shortened lead times mean that the production planning and control function becomes much more important, since activities must be scheduled and controlled more closely to achieve these reduced lead times. Whereas in conventional manufacture, for example, waiting for specialized tooling can be tolerated, in an automated manufacturing system this delay is unacceptable; the specialized tooling has to be available as and when needed, otherwise lead times escalate.

The second reason for the importance of production planning and control in an automated manufacturing system is the high cost of most of these systems (several million dollars being typical), meaning that high system usage becomes an important factor. Most automated manufacturing systems probably aim at an average usage across the whole system of 85-95 per cent whereas 40-60 per cent is typical for conventional manufacture. The achievement of this high usage is, again, aided by an effective production planning and control system.

Effective production planning and control is tremendously difficult in both conventional manufacture and in automated manufacturing systems. This is because typical batch manufacture involves planning and controlling a large number of jobs through many machines/processes, posing an exceedingly difficult combinatorial problem.

The degree of difficulty in planning and controlling production in an automated manufacturing system is greater than that in conventional manufacture due to the two major factors indicated above. In particular, the requirements of short lead times (meaning that tooling, machines, transport and inspection must be available when needed), and the desire to achieve high usage of the automated manufacturing system, mean that there is a need for a much more sophisticated planning and control system.

CHAPTER 2

Automated Manufacturing Systems and Production Planning and Control

Introduction

The complexity of the problem of production planning and control for batch manufacture in both conventional and automated systems has been stressed: again, any automated manufacturing system will underachieve unless there is high quality production planning and control. The results of poor production planning and control can be severe, with high work-in-progress levels, high lead times and poor system usage. The latter aspect is important when one bears in mind the high cost of these automated manufacturing systems; the only way in which they can be justified is if they demonstrate the good rate of return associated with high usage.

This chapter gives some background to the special production planning and control characteristics that automated manufacturing systems require. The first aspect discussed is that data availability, quality and immediacy are fundamentally different from that found in conventional manufacturing systems; the greater accuracy in the data available to decision makers from automated manufacturing systems could therefore lead to better decisions.

There are, however, several other factors which can complicate the production planning and control system for automated manufacturing systems. These include: short manufacturing lead times; the consideration of engineering details; the greater emphasis placed on system usage; the need to integrate with existing software systems; and the need to generate detailed instructions. These factors are described in turn and their impact on the production planning and control function is discussed.

Factors affecting production planning and control

An automated manufacturing system differs considerably from its conventional counterpart. These differences lie not only in the manufacturing hardware, but also in the software and communication aspects, as well as in the provision of sensors and other monitoring devices. This means that automated manufacturing systems have the mechanisms to be closely monitored and controlled, so that production planning and control can be done with more certainty about the actual state of the manufacturing process than in conventional manufacturing systems.

Nearly all automated manufacturing systems contain some provision for communication within the system. In many cases this communication is achieved by direct linkage of elements of the system. In other cases a network will be used, so that the same transmission medium can be used for a variety of communications.

Overall, therefore, automated manufacturing systems are likely to produce a large amount of data that can be used for production planning and control. This data is likely to be produced automatically and is likely to have higher accuracy than that produced by conventional manufacturing systems. Furthermore, this data is likely to be up to date since there should be little elapsed time between the data being generated and it being received by the production planning and control systems.

Decisions made in such an environment can, therefore, be better for three reasons. First, a greater amount of data is available since it is generated automatically. Second, the data produced automatically is likely to be more accurate than that produced by human labour although, of course, a system should be protected against totally ridiculous data being produced by faulty equipment. Third, the data can reach the decision-making areas faster than in conventional systems.

Although decisions can be made under better conditions than in conventional systems, some features of automated manufacturing systems can result in more complex problems to be solved. These features are:

1. Manufacturing lead times are shorter.
2. Engineering details need to be considered.

