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Preface

Production and inventory management is a combination of production management and inventory management. They are the exciting areas of management that have effects on the productivity of both manufacturing and service industries. This text book aims to present various perspectives of production and inventory management, both in theories and real case studies. Topics include sales and operations plan, master production scheduling, material requirements panning, distribution requirements planning, capacity planning, inventory management, inventory management: managing uncertainties, theory of constraints, waiting line theory, and lean operations.

Many examples and problems are provided in each chapter with step-by-step solutions. Exercises at the end of each chapter are provided for the readers to practice. Case studies, specifically in Thailand, help the readers to better understand the chapters and apply the knowledge in the real practices. It is hoped that this text book provides readers valuable insights to the practice and management of production, operations, and inventory.

I would like to thank my parents, my family, my friends, the institution staff, and all related person to make this text book happen.

Thanwadee Chinda

1.4 What is Covered in this Textbook?

This textbook looks at production and inventory management in various perspectives. It is organized into 11 chapters, as the followings.

- Chapter 1: Introduction to Production and Inventory Management. This chapter overviews the production management, inventory management, and uncertainties in production and inventory management.

- Chapter 2: Sales and Operations Plan (S&OP). This chapter details fundamentals of the S&OP. Different strategies used to develop the S&OP are presented, such as chasing strategy, leveling strategy, and mixed strategy.

- Chapter 3: Master Production Scheduling (MPS). This chapter considers the MPS in different production environments. Details of an MPS, including forecast demand, orders booked, ending inventory, available-to-promise, lot sizing decision, and safety stock are described in details. Managing the MPS in a dynamic environment utilizing freezing period is also discussed.

- Chapter 4: Material Requirements Planning (MRP). This chapter details key information in an MRP, including bill of materials and backward scheduling. The chapter also discusses key data used in an MRP record, including gross requirement, scheduled receipt, ending inventory, net requirement, planned receipt, and planned order. An updated MRP, when changes occur, is also presented.

- Chapter 5: Distribution Requirements Planning (DRP). This chapter considers DRP in the supply chain, and relationships between the MPS, MRP and DRP.

- Chapter 6: Capacity Planning. This chapter introduces short-, medium-, and long-term capacity plans. A number of capacity techniques, including capacity planning using overall factors, capacity bills, resource profiles, and capacity requirements planning are considered in capacity management.

- Chapter 7: Inventory Management. This chapter utilizes an and a cycle counting approach to manage inventory. To determine an ordering amount, a number of inventory models are introduced, such as economic order quantity and discounting. Reorder point and safety stock are, on the other hand, presented to determine the lead-time or ordering period necessary to avoid the stock out.

- Chapter 8: Inventory Management: Managing Uncertainties. This chapter presents indices, service level, and average inventory used to measure inventory performance. The chapter also focuses on inventory management when demand and performance cycle time are uncertain. Different policies to manage inventory are also discussed.

- Chapter 9: Theory of Constraints (TOC). This chapter explains various TOC concepts. Group scheduling and transfer batches are introduced to manage with bottleneck work centers. The TOC scheduling is also developed using processing time and workload schedules.

- Chapter 10: Waiting Line Theory. This chapter explains cost of waiting and cost of service in the waiting line theory. Different characteristics of a waiting line system are presented.

- Chapter 11: Lean Operations. This chapter discusses advantages of lean production. Various lean perspectives are pinpointed. Kanban system and Poka Yoke technique, which are the approaches in the lean production, are also discussed in details.

> **▶▶ Example 3.7** The MPS tables with a fixed lot size of 100 units and a safety stock of 25 units
>
> a) The MPS table from weeks 1–8
>
> | Product | Week | | | | | | | |
> |---|---|---|---|---|---|---|---|---|
> | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
> | F | ⟨100⟩ | ⟨125⟩ | ⟨120⟩ | ⟨40⟩ | ⟨30⟩ | 30 | ⟨25⟩ | ⟨25⟩ |
> | OB | 90 | 100 | 95 | 20 | ⟨30⟩ | ⟨40⟩ | 10 | 10 |
> | EI 100 | 100 | 75 | 55 | 115 | 85 | 45 | 120 | 95 |
> | Discrete ATP | 110 | 0 | 5 | 10 | - | - | 80 | - |
> | Cumulative ATP | 110 | 110 | 115 | 125 | - | - | 205 | - |
> | MPS | 100 | 100 | 100 | 100 | 0 | 0 | 100 | 0 |
> | Condition: Lot size = 100 units, safety stock = 25 units | | | | | | | | |
>
> At the end of week 1, the information are updated as follows.
>
> - Actual sales was 90 units.
> - Forecast demand in week 3 was reduced to 40 units. In addition, the customer cancelled orders booked in that week.
> - Forecast demand in week 9 was set at 25 units. There was no order booked in that week.
> - Freezing period was used in weeks 1–4.
>
> b) The *updated MPS* table from weeks 2–9
>
> | Product | Week | | | | | | | |
> |---|---|---|---|---|---|---|---|---|
> | | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
> | F | ⟨125⟩ | ⟨40⟩ | ⟨40⟩ | ⟨30⟩ | 30 | ⟨25⟩ | ⟨25⟩ | ⟨25⟩ |
> | OB | 100 | 0 | 20 | ⟨30⟩ | ⟨40⟩ | 10 | 10 | 0 |
> | EI 110 | 85 | 145 | 205 | 175 | 135 | 110 | 85 | 60 |
> | Discrete ATP | 110 | 100 | -10 | - | - | - | - | - |
> | Cumulative ATP | 110 | 210 | 200 | - | - | - | - | - |
> | MPS | 100 | 100 | 100 | 0 | 0 | 0 | 0 | 0 |
> | Condition: Lot size = 100 units, safety stock = 25 units | | | | | | | | |

- With the freezing period condition, the production schedule in weeks 1–4 is fixed, and no changes can be made without management approval.
- Actual sales in week 1 was 90 units, which is 10 units less than the amount expected to sell at the beginning week. This, in turn, raises the ending inventory at the end of week 1 from 100 to 110 units.

Week 2 (the first week of the updated plan)
- Maximum expected demand in this week is 125 units.
- The on-hand inventory at the beginning of week 2 is 110 units. With the freezing period condition, the production of 100 units is fixed to be produced in this week, leading to the total supply of 110+100=210 units.
- The ending inventory in week 2 is then 210-125=85 units.
- The discrete ATP in week 2 (the first week of the updated plan) is 110+100-100=110 units.
- The cumulative ATP in week 2 is also 110 units.

Week 3
- Maximum expected demand in this week is 40 units.
- With the freezing period condition, the production of 100 units is fixed to be produced in this week, leading to the total supply of 85+100=185 units.
- The ending inventory in week 3 is then 185-40=145 units. This high amount of inventory results from the freezing period condition and changes in forecast demand and orders booked in this week.
- The discrete ATP in week 3 is 100-0=100 units.
- The cumulative ATP in week 3 is 100+110=210 units.

Week 4
- Maximum expected demand in this week is 40 units.
- With the freezing period condition, the production of 100 units is fixed to be produced in this week, leading to the total supply of 145+100=245 units.
- The ending inventory in week 4 is then 245-40=205 units. This high amount of inventory results from the freezing period used in this week.

- The discrete ATP in week 4 is $100-(20+30+40+10+10+0)=-10$ units. This discrete ATP covers the orders booked from weeks 4–9, as there is no production from weeks 5–9. It could be explained that without the inventory, the production of 100 units in week 4 does not fulfill the customer orders in weeks 4–9.

- The cumulative ATP in week 4 is, however, $-10+210=200$ units, representing the total amount company can promise to the customers in the next 8 weeks (from weeks 2–9).

Week 5

- Freezing period is not considered in this week. So, if no production is scheduled in this week, the total supply amount in this week will be 205 units (i.e. ending inventory in week 4).

- The maximum expected demand in week 5 is 30 units, resulting in the stock of $205-30=175$ units is kept at the end of week 5. This is higher than the safety stock amount, confirming no production in week 5 i.e. $MPS_5 = 0$).

- No discrete and cumulative ATPs are calculated in this week, as there is no production (i.e. no positive MPS).

The updated MPS shows that the MPS of 100 units in week 7, previously scheduled at the beginning of week 1, is cancelled due to the changes of week 3's demand and the use of freezing period condition.

3.5 MPS in the Assemble-to-Order Environment

In an ATO environment, the possible combinations of end-items can be huge. The MPS therefore cannot be based on end-items. In this case, the information called *super bill* is used to manage the MPS, as it describes the related options or modules that make up the *average end-items* to satisfy each customer. This type of bill of materials is not built into a finished product, instead, it is used to plan the requirements for options and common components in their respective master schedules. Normally, it is only used for production planning purposes, not actual production, and the MPS developed from this super bill is called the *two-level MPS*.

- With the use of safety lead time of 2 weeks, the ending inventory of "rim" on week 5 becomes positive. This proves the use of safety lead time to manage with the dynamic changes.

- Based on the change in EI_5, EI_6 can be calculated as:

$$EI_6 = EI_5 + SR_6 + PR_6 - GR_6$$

$$EI_6 = 840 + 0 + 0 - 600 = 240 \; units$$

Conclusion

MRP is an important tool that creates a schedule for all components in an end-item's bill of materials based on fixed manufacturing lead times. Effective use of an MRP system allows development of a forward-looking approach to managing material flows. The MRP system provides a coordinated set of linked product relationships, which permits decentralized decision making for individual part numbers. To make the MRP useful, system records must be accurate and reflect real practices.

To develop an MRP, the company requires an accurate bill of materials that lists all subcomponents and raw materials, as well as their quantities to make an assembly and backward scheduling to properly release the date of the order.

The MRP includes six key information, namely 1) gross requirement (GR), 2) scheduled receipt (SR), 3) ending inventory (EI), 4) net requirement (NR), 5) planned receipt (PR), and 6) planned order release (PO). Safety stock and safety lead time can also be used to ensure minimum inventory at the end of each period. Various lot sizing decisions, such as fix lot size, multiple lots, lot-for-lot, minimum order quantity, and maximum order quantity can be used in the MRP production

To avoid the fluctuation of the demand that may affect the production schedules, the firm planned order is used. It is the planned order that the MRP system does not automatically change when conditions change. To adjust the production schedules during the firm planned order period, management permission is required.

Inventory Management

This chapter includes the following topics:

- What is inventory management?
- Managing inventory
- Inventory models
- Reorder point and safety stock
- Case studies

7.1 What is Inventory Management?

Inventory is the term for the goods available for sale, and raw materials used to produce goods. It represents one of the most important assets of a business because the turnover of inventory represents one of the primary sources of revenue generation and subsequent earnings for the company's shareholders.

Inventory management is a systematic approach to obtaining, storing, and profiting from non-capital assets (raw materials and finished goods). Its objectives are to achieve the right stock, at the right levels, in the right place, at the right time, and at the right cost. In other words, it aims to balance between inventory investment and customer service. Operations managers have long recognized that good inventory management is crucial. A firm cam reduce costs by reducing inventory. In contrast, production may stop, and customers become dissatisfied when a stock out occurs.

9.3 Overlap Scheduling and Transfer Batches

Lot sizes are calculated differently for bottleneck and non-bottleneck work centers. For the same product, lot sizes at different operations may be different. TOC distinguishes between a *transfer* batch and a *process* batch. Transfer batch dictates the quantity that moves from operation to another operation, while process batch represents total lot size released to the shop. In other words, a transfer batch is a fraction of a process batch. It provides a work center a flexibility to start producing an order before it is completed at the previous work center. This flexibility is referred to as *lot splitting* or *overlap scheduling*. It assists in cutting setup time, smoothing workflow, reducing flow time, and improving utilization.

Example 9.1 explains transfer batches of a production of Secure Bottles. There is an order of 1000 units, and that the production requires three operations, which are #1, #2, and #3, respectively.

▶▶ **Example 9.1**   Transfer batch for Secure Bottles

Processing times per unit for operations A, B, and C are 1, 0.5, and 0.75 minutes, respectively. If transfer and operation batches are not considered, the total time used for the 1000-unit production is 2,250 minutes, as shown in Figure 9.4.

Figure 9.4 Production time without transfer and process batches

Based on Figure 9.4, operation#1 requires 1 minute to process one unit, thus this operation finishes at the end of minute 1000th. After operation#1 is finished, operation#2 can start. It takes 500 minutes to complete 1000 units, thus this operation is completed at the end of minute 1500th. Operation#3, the last operation, can start at the end of minute 1500th, and is finished at the end of minute 2250th.

If transfer and operation batches are considered at each operation, the completion time of this production can be reduced.

Operation	Process batch (units)	Transfer batch (units)
#1	100	100
#2	200	200
#3	200	-

Figure 9.5 shows the new completion time of 1,200 minutes when transfer and process batches are used. Details are as below.
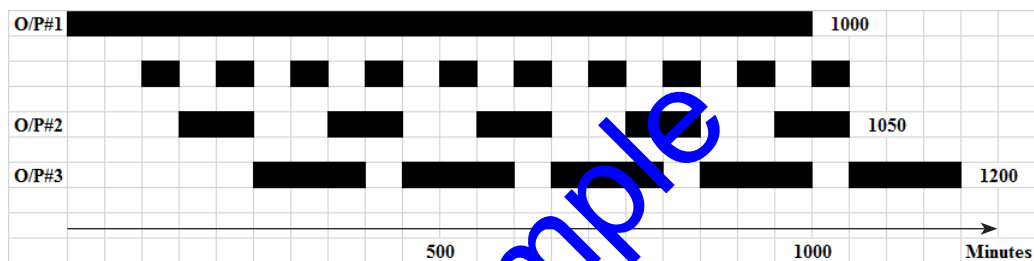

Figure 9.5 Production time with transfer and process batches

- O/P#1 is the first operation of this production. So, this operation can be proceeded from the first to the last units in one round.

- The finished time of O2P#1 is 1,000 minutes.

- O/P#1 has the transfer batch of 100 units. With the processing time of 1 minute/unit, the first batch of 100 units can then be transferred to the next operation (O/P#2) after minute 100th. The following batches are transferred to the next operation after every 100 minutes.

- After the first transfer batch arrives at O/P#2, it is processed at the processing time of half a minute per unit, and finished at minute 150th.

- The second transfer batch arrives O/P#2 at minute 200th, and is continued with the production until minute 250th.

- As the first transfer batch finishes its operation at O/P#2 at minute 150th, but the second transfer batch arrives at O/P#2 at minute 200th, this creates a 50-minute gap between these two transfer batches.

10.2 Cost of Waiting and Cost of Service

Though high customer satisfaction is required, managers must trade-off between cost of providing good service and cost of customer or machine waiting time (see Figure 10.1). To explain, manager may want a short queue so that customers do not become unsatisfied, however, he may allow some waiting if a significant savings in service balances costs.
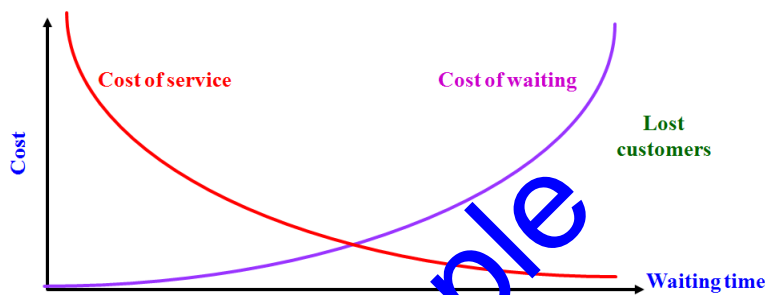

Figure 10.1 Cost of waiting and cost of service

In Figure 10.1, cost of waiting increases when customers spend longer time waiting in lines. This cost is effected in terms of customer lost due to poor service and long queues. In some service systems, such as emergency ambulance and car insurance services, the cost of long waiting lines may be intolerably high.

As the level of service improves through, for example, more staff and specific service assignment, cost of waiting decreases but cost of service increases. Managers must, therefore, attempt to provide the service that yields the lowest total cost.

10.3 Characteristics of a Waiting Line System

A waiting line system has major characteristics to consider, including population, arrival rates, service rates, and priority rules.

11.2 Lean Perspectives

Lean philosophy has covered all aspects of supply chain management. Figure 11.1 shows the traditional mass production and lean production. In lean production, coordination along the supply chain is tighten, smaller lot sizes are produced with less inventories, and goods are pulled out of plant only by customer demand. Firms following this philosophy often experience remarkable improvement in their productivity, inventory level, and quality.
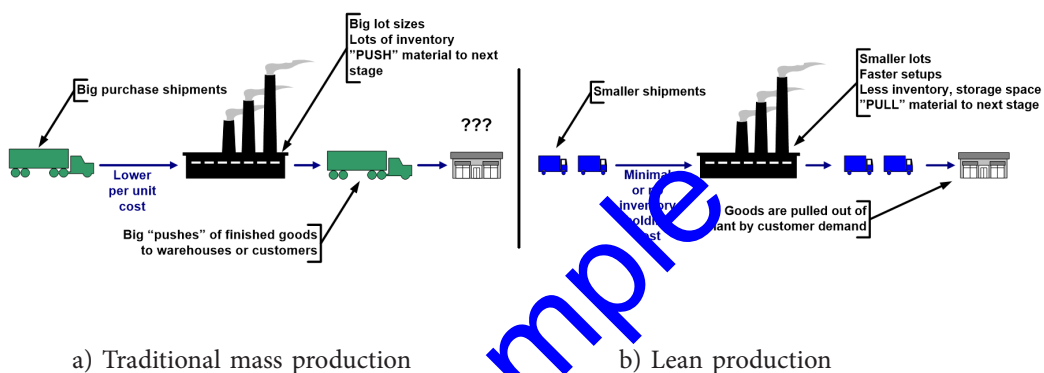

a) Traditional mass production   b) Lean production

Figure 11.1 Traditional mass production and lean production
(Bozarth and Handfield, 2013)

11.2.1 Lean Perspective on Waste

Waste is anything other than the minimum amount of equipment, materials, parts, space, and workers' time, which are essential to add value to the product. There are eight common forms of waste:

1) *Overproduction* represents unreliable processes that may cause organizations to produce goods before they are needed.

2) *Waiting* may occur when demand and supply are not matched.

3) *Unnecessary movement* may increase costs and risks of product damage.

4) *Inappropriate or overly complex process* may create waste.

5) *Unnecessary inventory* occurs when lead-time or quality is uncertain.

6) *Excess motion* is a result of poor process design.

7) *Defect* not only creates scrap or rework, but also reduces production capacity.

8) *Underutilization of employees* is the newest form of waste.

There are various techniques that can be used to manage waste, such as total productive maintenance, 5S methodology, single minute exchange of die, visual control, continuous improvement, cellular manufacturing, just in time, Kanban system, and Poka Yoke technique (Siasos et al., 2017).

11.3 Kanban Systems

Kanban is a production control system that uses containers, cards, or visual signs to control the production and movement of goods through the supply chain. It has several characteristics:

- It uses simple signaling mechanisms, such as card or empty container, to indicate when items should be produced or moved.
- It can be used to synchronize activities either within a plant or between different supply chain partners
- It is not a planning tool. Rather it is a control mechanism that is designed to pull parts or goods through the supply chain based on downstream demand.

The number of Kanban cards used in the production depends on demand, lead-time, container size, and the stability of the demand, as shown in Equation 11.1.

$$y = [D \times T \times (1 + x)]/C \qquad (11.1)$$

Where y = number of Kanban cards (cards)

   D = demand from the downstream process per unit of time (units)

   T = Time to produce and move a container of parts to the downstream demand point (or lead time)

   x = A safety factor in percentage

   C = Number of parts per container (units)

Apart from cards, other methods can be used, such as color coding of containers, designated storage spaces, and bar-coding systems.