Three basic methods of calculating the ATP quantities:

1. Discrete Available-to-Promise [(on hand + supply – ordered) per period]
2. Cumulative Available-to-Promise *without look ahead*
3. Cumulative Available-to-Promise *with look ahead*

Discrete Available-to-Promise

1. Add the beginning inventory to the MPS [planned production] for period 1, subtracting the committed customer orders (CCOs) from period 1 up to but not including the period of the next scheduled MPS.
2. For all subsequent periods, there are two possibilities:
   - If no MPS has been scheduled for the period, the ATP is zero.
   - If an MPS has been scheduled for the period, the ATP is the MPS minus the sum of all the CCOs from that period up to the period of the next scheduled MPS.
3. If an ATP for any period is negative, the deficit must be subtracted from the most recent positive ATP, and the ATP quantities must then be revised to reflect these changes.

TIME FENCING

Because MPS is the plan that drives the business, even small changes in the MPS can cause major changes in the detailed production schedule and the material plan, creating nervousness and instability throughout the organization. To minimize the impact of the inevitable changes in MPS that will occur, many companies have adopted a time fencing policy separating the planning horizon into a firmed time period and a planned time period. This means that the business agrees that it will not change the MPS within a given window of time (e.g., the first six weeks of the plan).

- **Firmed Time Period:** From the current date out several weeks into the future
  - A firm time fence is established at the outer limit of this period to signify when changes can no longer be made automatically or without prior approval.
  - The planning system or master production scheduler is not allowed to automatically make changes in the firmed time period, only recommend changes.

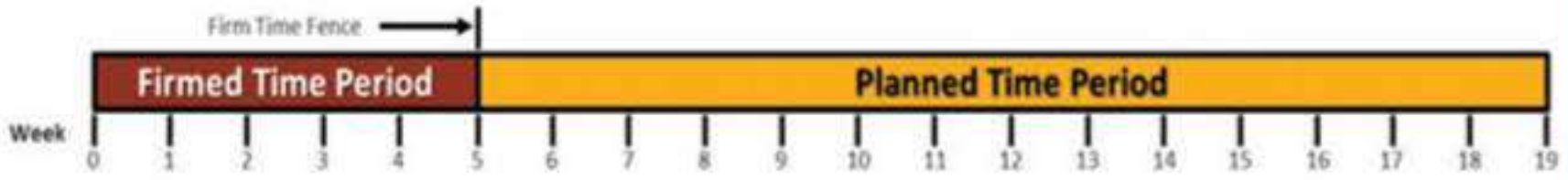
- Recommended changes must be reviewed and approved by an authorized person(s) who will then initiate the appropriate action.

- **Planned Time Period:** From the end of the firmed time period to the end of the planning horizon

  - The planning system or the master production scheduler can create or make changes to planned orders in this time period based on the data and planning logic determined by the company, without prior approval.

  - Figure 3.5 illustrates an example.

FIGURE 3.5



(McLaury, 2016)

While this time fencing policy may help to minimize the nervousness and instability in the MPS created by changes, it can be extremely difficult to stick to as there is a tradeoff between maintaining the stability and effectiveness of the plan, and supporting a customers' urgent requirements.

BASIC PRODUCTION STRATEGIES

The three basic production strategies that companies use to complete the production plan are the level production strategy, the chase production strategy, and the mixed production strategy.

1. **Level Production Strategy:** Relies on a constant output rate while varying inventory and backlog according to fluctuating demand. This strategy may be adopted in cases where the changeover is long, or it's inefficient to stop/start. The company relies on variable finished goods inventory and backlogs to meet demand. This strategy works well for make-to-stock firms. Examples include plywood, steel, light bulbs, razors. **Example**: The established stable workforce has a capacity to produce 50 units per demand time period. If customer demand decreases, the workforce is kept stable and excess inventory is produced. If the demand increases, the workforce is kept stable and the incremental demand is satisfied through any available excess inventory or by accepting a backlog (i.e., unfulfilled customer demand) until such time as there is sufficient excess inventory to supply the shortfall (see figure 3.6).

FIGURE 3.6

Customer Demand	Workforce	Finished Output of Goods or Services	Backlog or Inventory
10	Constant Number of Workers	50	40 Inventory
20	Constant Number of Workers	50	30 Inventory
80	Constant Number of Workers	50	30 Backlog get shortfall from inventory

(McLaury, 2016)

2. **Chase Production Strategy:** Adjusts capacity to match demand. The company hires and lays off workers to match the finished product output to fluctuating demand. Finished goods inventory remains constant. This strategy works well for make-to-order firms. Examples include airplane companies, because of their lengthy training time. Union employees are sent back to the union hall, waiting to be recalled and collect unemployment in the interim. Another example is workers who harvest crops. **Example**: The established stable workforce has a capacity to produce 20 units per demand time period. If the demand drops to 10 units, the company would fire/lay off up to half the workforce. If the demand increases to 30 units, the company would hire up to an additional 50% to meet demand (see figure 3.7).

FIGURE 3.7

Customer Demand	Workforce	Finished Output of Goods or Services
10	Fire	10
20	Stable Workforce	20
30	Hire	30

(McLaury, 2016)

Mixed or Hybrid Production Strategy: Maintains stable core workforce while using other short-term means such as overtime, subcontracting, and part-time helpers, to manage short-term demand. Examples include construction companies and retail stores at holiday season (see figure 3.8).

FIGURE 3.8

Customer Demand	Workforce	Finished Output of Goods or Services
10	Stable Workforce	10
20	Work Overtime	20
50	Work Overtime & Outsource some Output	50
80	Overtime, Part Time Help and Outsource	80

(McLaury, 2016)

BILL OF MATERIALS

The **bill of materials (BOM)** is a document that shows an inclusive listing of all component parts and assemblies, and the quantity of each, needed to produce or assemble a single unit of a parent item. "It is used in conjunction with the master production schedule to determine the items for which purchase requisitions and production orders must be released. A variety of display formats exist for bills of material, including the single-level Bill of Materials, indented Bill of Materials, modular (planning) Bill of Materials, transient Bill of Materials, matrix Bill of Materials, and costed Bill of Materials. . . The Bill of Materials may also be called the formula, recipe, or ingredients list in certain process industries."[1]

The following are different types of bills of material used in supply chain planning:

- **Single Level Bill of Materials:** Display of components that are directly used in a parent item, together with the quantity required of each component (i.e., the planning factor). Shows only the relationships one level down.[1]

- **Multilevel Bill of Materials:** Display of all the components directly or indirectly used in a parent, together with the quantity required of each component (i.e., the planning factor). If a component is a subassembly, blend, intermediate, for example, all its components and all their components also will be exhibited, down to purchased parts and raw materials.[1] This is often presented as an indented bill of materials.

- **Planning Bill of Materials:** "An artificial grouping of items or events in bill-of-material format used to facilitate master scheduling and material planning. It may include the historical average of demand expressed as a percentage of total demand for all options within a feature or for a specific end item within a product family and is used as the quantity per in the planning Bill of Materials."[1]

Example of How the BOM Is Used: The recipe for baking a cake includes a list of ingredients and the instructions on how to actually combine those ingredients to make a cake. The list of ingredients is the bill of materials, which in this example might include 4 cups of flour, 1 cup of water, 4 eggs, 1 cup of sugar, etc. The bill of materials tells you which ingredients and how much of each ingredient you need to produce each individual "cake."

In this example the cake is an independent demand item, and the ingredients are dependent demand items, defined as follows:

Independent Demand: Demand for an item that is unrelated to the demand for other items (e.g., a finished product or spare/service parts). The demand for finished products generally comes from the external customer, is independent from other items, and may therefore need to be forecasted. It can be affected by trends, seasonal patterns, and general market conditions.

For example, if we have been selling 10 cakes per week for the past few months, we can use this information to create a forecast of how many cakes we expect to sell for the next few weeks/months. This estimate/forecast for the independent demand item (i.e., cake) becomes the basis for determining how many cakes we will produce in our production plan to satisfy the projected demand.

Dependent Demand: Demand that is directly related to, or derived from, the bill of materials structure for other items or finished products (a raw material, component part, packaging material, subassembly, etc.) used in making a finished product or parent item. Dependent demands are calculated and should not be forecasted.

For example, if we are going to bake a cake, and the BOM states that we need 4 cups of flour for one cake, the total amount of flour that we need is entirely dependent on how many cakes we are going to make. Flour is one of the dependent demand items of the cake, which is the independent demand

item in this example. If we plan to make 10 cakes per week, and per the BOM we need 4 cups of flour for each cake, we will need 40 cups of flour in total each week to make the planned 10 cakes per week. No forecast or estimation is needed for the flour because we can calculate exactly how much we need based on the planned number of cakes.

Example: Single Level Bill of Materials

FIGURE 3.9

Independent Demand - The external demand for an item that is unrelated to the demand for other items (e.g., finished product). The demand for these items is forecasted and can be affected by trends, seasonal patterns, and market conditions.

Dependent Demand - the internal demand for items that are assembled or combined to make up the final product (e.g., component parts). Demand for these items is calculated based on the demand of the final product in which the parts are used, by using the planning factor.

Table	Quantity Per *
Leg	4
End	2
Side	2
Top	1
Hardware Kit	1

* Planning Factor

(McLaury, 2016)

Figure 3.9 is a single level BOM showing that for every table that is produced, 4 legs, 2 ends, 2 sides, 1 top, and 1 hardware kit are required. The finished product (i.e., the table) is an independent demand item forecasted based on anticipated external demand. The component parts (leg, end, side, top, and hardware kit) are dependent demand items in which the demand is calculated based on the number of tables that are planned for production.

Example: Multilevel Bill of Materials

FIGURE 3.10

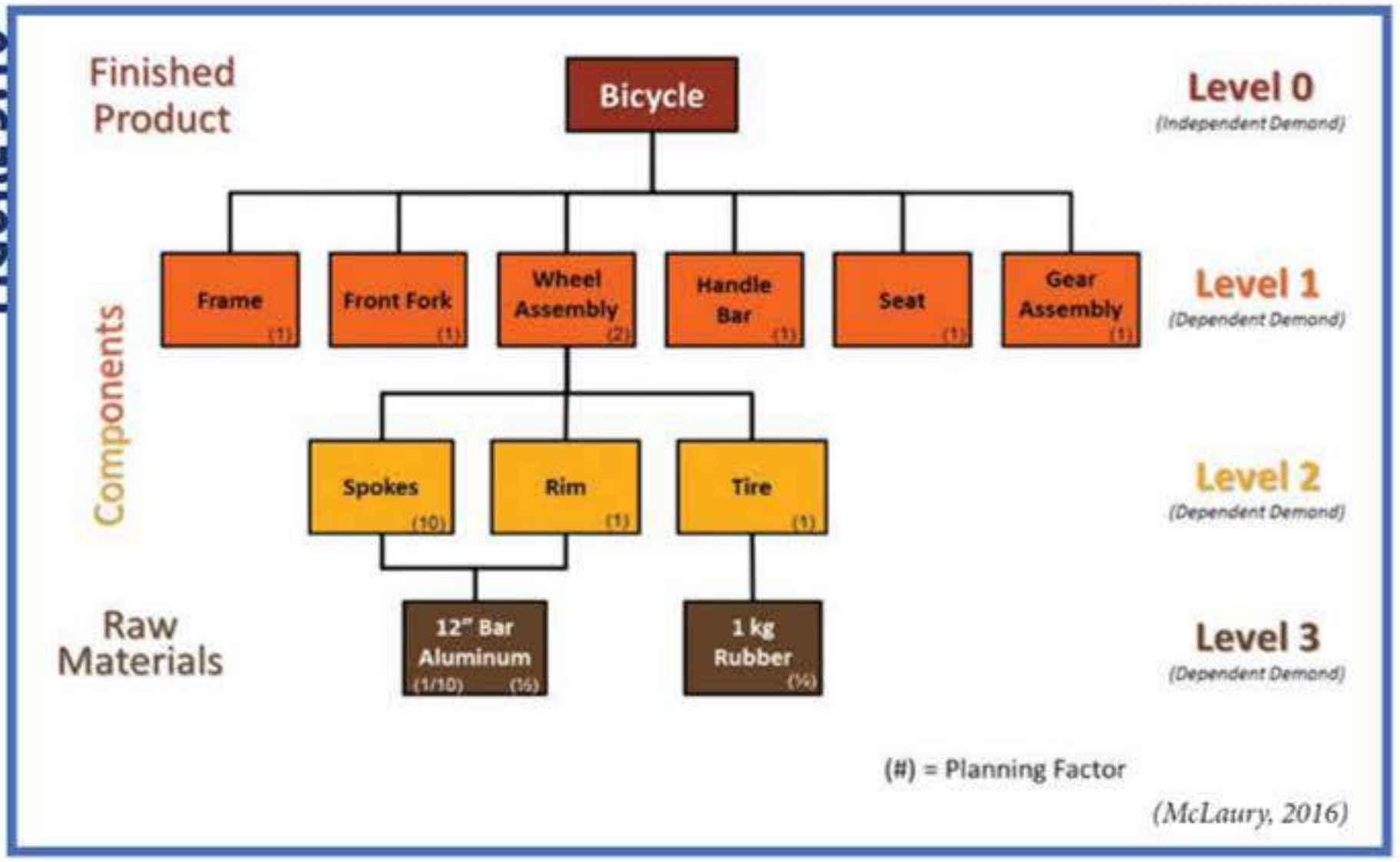


Figure 3.10 is a multilevel BOM showing the parent and component relationships and the specific units of each component (i.e., the planning factor) needed to produce one unit of the parent item. In this example, the parent item (i.e., finished product) is the bicycle and all of the other items are component parts of the bicycle. Some of the component parts such as the wheel assembly also have their own component parts such as the spokes, rim, and tire. The bicycle is Level 0; the wheel assembly is Level 1; the spokes, rim, and tire are Level 2; and so forth.

MATERIAL REQUIREMENTS PLANNING

"Material Requirements Planning (MRP) is a set of techniques that uses Bill of Materials data, inventory data, and the master production schedule to calculate requirements for materials. It makes recommendations to release replenishment orders for material. Further, because it is time-phased, it makes recommendations to reschedule open orders when due dates and need dates are not aligned. Time-phased MRP begins with the items listed on the MPS and determines (1) the quantity of all components and materials required to fabricate those items and (2) the date that the components

and material are required. Time-phased MRP is accomplished by exploding the Bill of Materials (see Key Terms Used In MRP), adjusting for inventory quantities on hand or on order, and offsetting the net requirements by the appropriate lead times."[1]

The authorized MPS is a critical input to MRP, which is the next planning level below the MPS. The MRP uses the MPS, bill of materials data, and inventory records to calculate specific requirements for materials in specific time frames. The MPS tells the MRP what the company plans to build and when. The MRP logic then uses this information along with the BOM and the inventory data to calculate the materials needed to build the products in the schedule and plan the procurement or production of those materials in quantity and in time to meet the schedule. Notice that as we move from the business plan down through the aggregate production plan, MPS, and then MRP, we progressively become more specific and detailed, as well as more immediate in terms of the planning horizon.

Key Terms Used in MRP

- **Gross Requirement:** A time-phased requirement prior to netting out on-hand inventory and lead-time

- **Net Requirement:** The unsatisfied item requirement for a specific time period: gross requirement for period minus current on-hand inventory

- **Projected On-Hand Inventory:** Projected closing inventory at the end of a period: beginning inventory minus gross requirements, plus scheduled receipts plus planned receipts from planned order releases

- **Planned Order Release:** A specific order for a specific item and quantity to be released to the shop or the supplier

- **Firmed Planned Order:** A planned order that can be frozen in quantity and time so that the MRP computer logic cannot automatically change when conditions change; established by the planner or supply chain manager to prevent system nervousness (This can aid planners working with MRP systems to respond to material and capacity problems by firming up selected planned orders.)

- **Scheduled Receipt:** A committed order awaiting delivery for a specific period

- **Time Bucket:** Unit of time or time period used in MRP (e.g., days, weeks, months)

- **Parent:** Item generating demand for lower-level components

- **Components:** Parts demanded by a parent
- **Planning Factor:** The number/quantity of each component or material needed to produce a single unit of the parent item
- **Explosion:** The process of converting a parent item's planned order releases into component gross requirements
- **Pegging:** Relates the gross requirements for a component part to the planned order releases of the parent item, so as to identify the source(s) of the item's gross requirements (Pegging can be thought of as active where-used information.)
- **Lot Size:** Order size for MRP logic
- **Safety Stock:** "A quantity of stock planned to be in inventory to protect against fluctuations in demand or supply. Over planning supply versus demand can be used to create safety stock."[1]

MRP Input

In order for the MRP logic to work, the following data are required:

1. The independent demand information (i.e., finished product forecast from the MPS)
2. Parent-component relationships from the BOM
3. Inventory status of the final product and each of the components and materials
4. Released, firmed, or planned order releases for the final product and each of the components and materials

MRP Output

MRP systems have capabilities of providing management with a wide range of outputs. These typically include:

1. **Planned orders:** a schedule indicating the amount and timing of future orders
2. **Order releases:** authorizing the execution of planned orders
3. **Changes to planned orders:** revisions of due dates or order quantities, including the cancellation of orders if necessary

4. **PERFORMANCE-CONTROL REPORTS:** measure deviations from plans such as deliveries and stockouts, as well as providing info that can be used to assess cost performance

5. **PLANNING REPORTS:** predict future inventories, procurement contracts, and data for future assessment of material requirements

6. **EXCEPTION REPORTS:** recognizes inconsistencies within the report such as errors in overdue or late orders, etc.

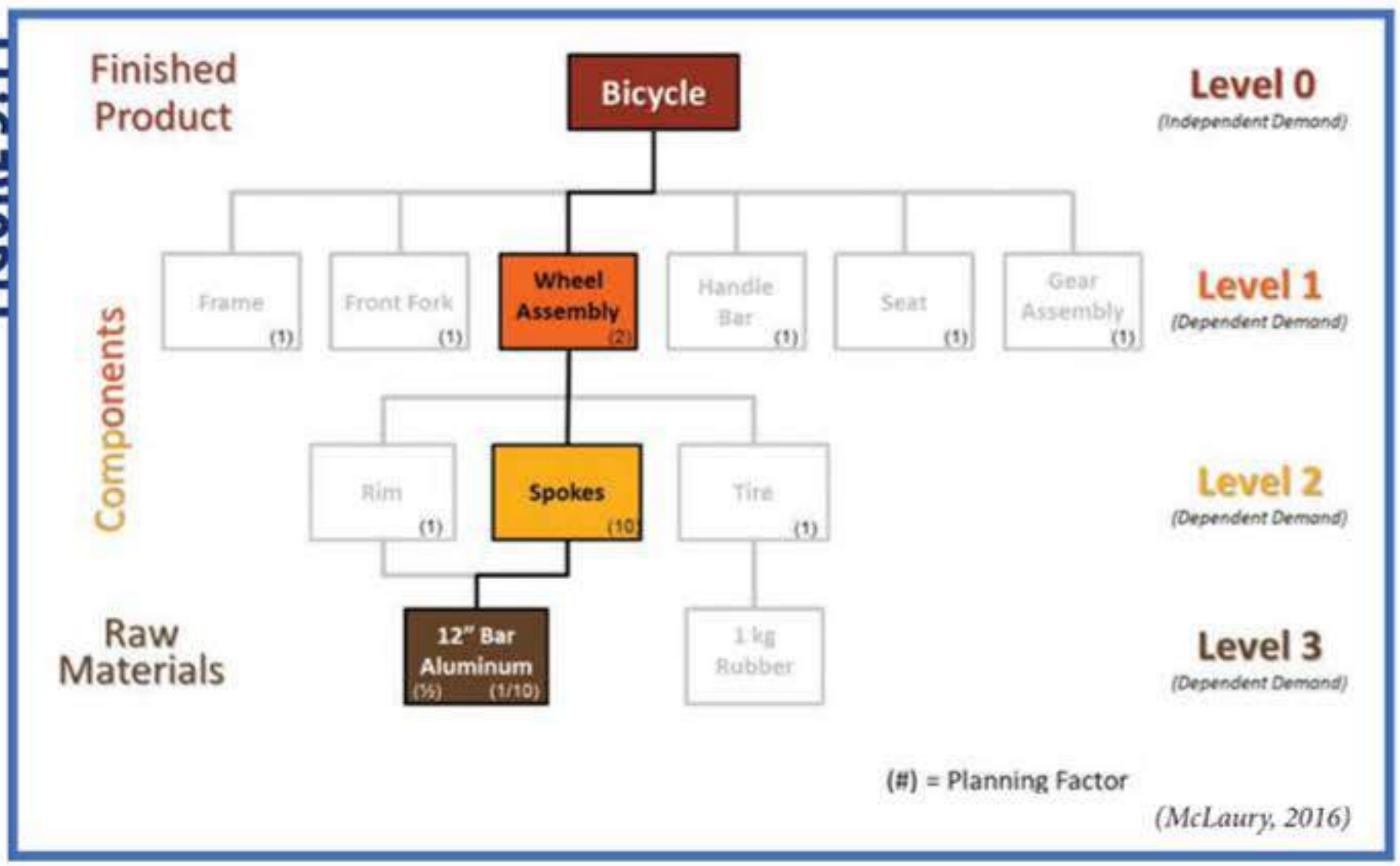
Advantage: MRP provides detailed planning information for all products and materials.

Disadvantages: MRP results in loss of visibility, which is especially acute for products with a deep BOM, and it ignores capacity and shop floor conditions.

Example: Material Requirements Planning

Figure 3.11 highlights part of the BOM for a bicycle, which will be used to demonstrate how the MRP is determined. To illustrate, each bicycle (finished product) requires 2 wheel assemblies. Each wheel assembly requires 10 spokes. Each spoke requires 1/10 of a 12-inch bar of aluminum.

FIGURE 3.11



(McLaury, 2016)

In figure 3.12, the bicycle and each of these component parts are entered into a simple MRP template along with their relevant planning information, including independent demand forecast, scheduled receipts, beginning inventories, lot sizes, lead times, safety stock requirements, and the like, to be planned for the next eight weeks.

FIGURE 3.12

Example

	Beg Inv	Week 1	2	3	4	5	6	7	8
Bicycle Model A - Level 0									
Gross Requirements *(independent demand - forecasted)*		10	10	20	0	20	0	0	20
Scheduled Receipts *(placed order confirmed by supplier)*			10						
Planned Delivery *(not yet placed or confirmed by supplier)*				20		20			20
Projected on-hand Inventory *(must include safety stock)*	30	20	20	20	20	20	20	20	20
Planned Order Release *(to allow LT for supplier to deliver)*		20		20			20		
Lot Size = 10 ; LeadTime = 2 ; Safety Stock = 15									
				"MRP explosion"					
Wheel Assembly – Level 1 (Plan Factor = 2)									
Gross Requirements *(dependent demand - calculated)*		40		40			40		
Scheduled Receipts *(placed order confirmed by supplier)*		40							
Planned Delivery *(not yet placed or confirmed by supplier)*				36			40		
Projected on-hand Inventory *(must include safety stock)*	4	4	4	0	0	0	0	0	0
Planned Order Release *(to allow LT for supplier to deliver)*		36			40				
Lot Size = L-F-L ; LeadTime = 2 ; Safety Stock = 0									
Spokes – Level 2 (Plan Factor = 10)									
Gross Requirements *(dependent demand - calculated)*		360			400				
Scheduled Receipts *(placed order confirmed by supplier)*		380							
Planned Delivery *(not yet placed or confirmed by supplier)*					380				
Projected on-hand Inventory *(must include safety stock)*	100	120	120	120	100	100	100	100	100
Planned Order Release *(to allow LT for supplier to deliver)*				380					
Lot Size = 380 ; LeadTime = 1 ; Safety Stock = 100									
12" Bar Aluminum – Level 3 (Plan Factor = 1/10)									
Gross Requirements *(dependent demand - calculated)*				38					
Scheduled Receipts *(placed order confirmed by supplier)*									
Planned Delivery *(not yet placed or confirmed by supplier)*				50					
Projected on-hand Inventory *(must include safety stock)*	20	20	20	32	32	32	32	32	32
Planned Order Release *(to allow LT for supplier to deliver)*			50						
Lot Size = 50 ; LeadTime = 1 ; Safety Stock = 20									

(McLaury 2018)

Bicycle Model A (Level 0):

The gross requirements (i.e., finished product forecast) for the bicycle has been entered for each week. There is a beginning inventory of 30 bicycles already in stock and a scheduled receipt for 10 units confirmed for delivery in Week 2. For Week 1, start with 30 units of beginning inventory, and subtract the gross requirements of 10 units in Week 1, leaving a projected on-hand inventory of 20 units at the end of Week 1. For Week 2, start with the 20 units at the end of Week 1, and subtract the 10 units of gross requirements for Week 2, and add the scheduled receipts of 10 units in Week 2 to end the week with 20 units. For Week 3, start with 20 units at the end of Week 2, and subtract the 20 units of gross requirements in Week 3. This would end Week 3 with zero (0) units; however, this item has a safety stock policy of 15 units, so an order must be planned to bring the projected

week-ending inventory up to a least 15 units. As this item also has a lot size of 10 units, orders must be placed in increments of 10 units. Consequently, a delivery of 20 units must be planned (i.e., planned delivery) for Week 3 bringing the projected on-hand Inventory at week end to 20 units. The lead time for this item is 2 weeks, so the planned delivery of 20 units must be released to the supplier in Week 1 (i.e., planned order release) for delivery in Week 3. Each of the succeeding weeks 4 through 8 follows the same logic.

Wheel Assembly (Level 1):

The gross requirements for the wheel assembly (dependent demand item) are calculated directly from the planned order releases of the bicycle (i.e., the parent item) as the wheel assemblies must be available to produce the bicycles when the planned orders for the bicycles are released (see red arrows in figure 3.11). As there are 2 wheel assemblies required for every bicycle produced (i.e., the planning factor), the gross requirements for the wheel assemblies in Week 1, Week 3, and Week 6 are 40 units each. There is a beginning inventory of 4 wheel assembly units already in stock, and a scheduled receipt for 40 units confirmed for delivery in Week 1. For Week 1, start with 4 units of beginning inventory, and subtract the gross requirements in Week 1 of 40 units, and add the scheduled receipts in Week 1 of 40 units, to end the week with 4 units of projected on-hand inventory. For Week 2, there are no gross requirements, scheduled receipts, or planned deliveries in Week 2, so the projected on-hand inventory of 4 units is carried forward. For Week 3, start with 4 units at the end of Week 2, and subtract the 40 units of gross requirements in Week 3. Because demand exceeds available supply resulting in a shortage of 36 units, a delivery must be planned for Week 3. The lot size is lot-for-lot (LFL), meaning that any quantity can be ordered. In addition, there is no safety stock requirement for this item, so the planned delivery in Week 3 can be established at 36 units to resolve the projected shortfall. The lead time for this item is 2 weeks, so the planned delivery of 36 units must be released to the supplier in Week 1 (planned order release) for delivery in Week 3. Each of the succeeding weeks 4 through 8 follows the same logic.

Spokes (Level 2):

The gross requirements for the spokes (dependent demand item) are calculated directly from the planned order releases of the wheel assembly (i.e., the parent item), as the spokes must be available to produce the wheel assemblies when the planned orders for them are released (see red arrows in figure 3.11). As there are 10 spokes required for every wheel assembly produced (i.e., the planning factor), the gross requirements for the spokes in Week 1 are 360 units, and in Week 4 are 400 units. There is a beginning inventory of 100 spoke units already in stock, and a scheduled receipt for 380 units confirmed for delivery in Week 1. For Week 1, start with 100 units of beginning inventory, and subtract the gross requirements in Week 1 of 360 units, and add the scheduled receipts in Week 1 of 380 units, to end the week with 120 units of projected on-hand inventory. For Week 2 and Week 3, there are no gross requirements, scheduled receipts, or planned deliveries, so the projected on-hand

inventory of 120 units is carried forward. For Week 4, start with 120 units at the end of Week 3, and subtract the 400 units of gross requirements in Week 4. Because demand exceeds available supply resulting in a shortage of 280 units, a delivery must be planned for Week 4. The lot size is 380 units, and there is a safety stock requirement of 100 units for this item, so the planned celivery in Week 3 can be established at the 380 unit lot size to resolve the projected shortfall, and end the week with the 100 units of safety stock required. The lead time for this item is one week, so the planned delivery of 380 units must be released to the supplier in Week 3 (planned order release) for delivery in Week 4. Each of the succeeding weeks 5 through 8 follows the same logic.

12-Inch Aluminum Bar (Level 3):

The MRP calculations for the 12-inch aluminum bar follows the same logic as for the spokes.

MRP Process

The MRP process can be done manually, but it is usually computer based, because it is an iterative process and can be quite extensive depending on the number of items to be planned during each cycle. Most companies have a software package that will handle this calculation, whether it is a Microsoft Excel type spreadsheet application, or an ERP system such as SAP. Companies run MRP at least once per month and most run MRP much more frequently, up to and including daily. The planning horizon also varies among companies. It can be as short as three months and as long as multiple years.

CAPACITY PLANNING

Capacity is defined as the capability of a system to perform its expected function. Capacity planning is "the process of determining the amount of capacity required to produce in the future. This process may be performed at an aggregate or product-line level (resource requirements planning), at the master-scheduling level (rough-cut capacity planning), and at the material requirements planning level (capacity requirements planning)."[1] Organizations must balance the production plan with capacity.

Capacity planning is essential to determining optimum utilization of resource and it plays an important role in the decision-making process (e.g., decisions to extend existing operations, modification to product lines, starting new products). This directly impacts how effectively the organization deploys its resources in producing products. Effective capacity planning is dependent upon such factors as production facility layout, design and location, product line or mix, production technology, human resources, operational structure, and external supply structure.

Standard Steps in the Capacity Planning Process:

1. Estimate future capacity requirements.
2. Evaluate existing capacity and facilities and identify gaps.
3. Identify alternatives for meeting requirements.
4. Conduct financial analyses of each alternative.
5. Assess key qualitative issues for each alternative.
6. Select the alternative to pursue that will be best in the long term.
7. Implement the selected alternative.
8. Monitor results.

The following are the major capacity planning tools:

Resource Requirement Planning (RRP): "Capacity planning conducted at the business plan level. The process of establishing, measuring, and adjusting limits or levels of long-range capacity. Resource planning is normally based on the production plan but may be driven by higher level plans beyond the time horizon for the production plan (e.g., the business plan). It addresses those resources that take long periods of time to acquire. Resource planning decisions always require top management approval."[1]

Rough-Cut Capacity Planning (RCCP): "The process of converting the master production schedule into requirements for key resources, often including labor; machinery; warehouse space; suppliers' capabilities; and, in some cases, money. Comparison to available or demonstrated capacity is usually done for each key resource. This comparison assists the master scheduler in establishing a feasible master production schedule. Three approaches to performing RCCP are the bill of labor (resources, capacity) approach, the capacity planning using overall factors approach, and the resource profile approach."[1] RCCP is a gross capacity planning technique that does not consider scheduled receipts or on-hand inventory quantities when calculating capacity requirements. It is a statement of the capacity required to meet gross production requirements.

RCCP verifies that sufficient capacity is available to meet the master schedule. It is used to both balance required and available capacity and negotiate changes to the master schedule and/or available capacity. The master schedule can be adjusted by changing master schedule dates and increasing or

decreasing master schedule quantities. Capacity can be adjusted by adding or removing shifts, using overtime or temporary labor, and adding or removing equipment.

Capacity Requirement Planning (CRP): "The function of establishing, measuring, and adjusting limits or levels of capacity. The term capacity requirements planning in this context refers to the process of determining in detail the amount of labor and machine resources required to accomplish the tasks of production. Open shop orders and planned orders in the MRP system are input to CRP, which through the use of parts routings and time standards translates these orders into hours of work by work center by time period. Even though rough-cut capacity planning may indicate that sufficient capacity exists to execute the MPS, CRP may show that capacity is insufficient during specific time periods."[1] There is an old adage, "the devil is in the details," and CRP is where the detailed production plan is vetted against available and planned capacity to ensure that the plan can really be executed.

CRP uses the information from the RCCP, plus MRP outputs on existing inventories and lot sizing. The result is a load report or load profile for each work center to help plan production requirements. This will indicate where capacity is inadequate or idle, allowing for imbalances to be corrected by adjustments in labor or equipment or the use of overtime or additional shifts.

DISTRIBUTION REQUIREMENTS PLANNING

"The function of determining the need to replenish inventory at branch warehouses. A time- phased order point approach is used where the planned orders at the branch warehouse level are 'exploded' via MRP logic to become gross requirements on the supplying source. In the case of multilevel distribution networks, this explosion process can continue down through the various levels of regional warehouses (master warehouse, factory warehouse, etc.) and become input to the master production schedule. Demand on the supplying sources is recognized as dependent, and standard MRP logic applies."[1]

Distribution requirements planning (DRP) is designed to optimize the movement of inventory in a multi-warehouse environment so that demands can be met effectively and efficiently without relying on excessive inventory. Companies that use DRP include those in wholesale or manufacturing that have regional demand supplied by one or more warehouses or manufacturing plants. DRP enables supply transfers from one warehouse to another, rather than having to issue a purchase order to an external supplier, or initiate a production order in a manufacturing plant. Suggestions are based on the closest warehouse in a chain of supplying warehouses, resulting in stock being supplied from oversupplied warehouses to undersupplied warehouses with a demand.

Key elements of DRP include:

- Forecast demands
- Current inventory levels
- Target safety stock
- Recommended replenishment quantities
- Replenishment lead times

DRP works by either a push or a pull method. The push method sends goods down through the network based on a forecast. This method generally has lower costs because shipments are planned and stored centrally; however, service levels can suffer if central planning is too far removed from the actual demand. The pull method uses the fulfillment of actual customer orders to move the inventory down through the network. This provides more availability for customers because local management controls the availability of the goods; however, managing distribution inventory can be difficult because small changes in customer demand can generate large swings in demand higher up the network, due to the bullwhip effect.

ENTERPRISE RESOURCE PLANNING SYSTEMS

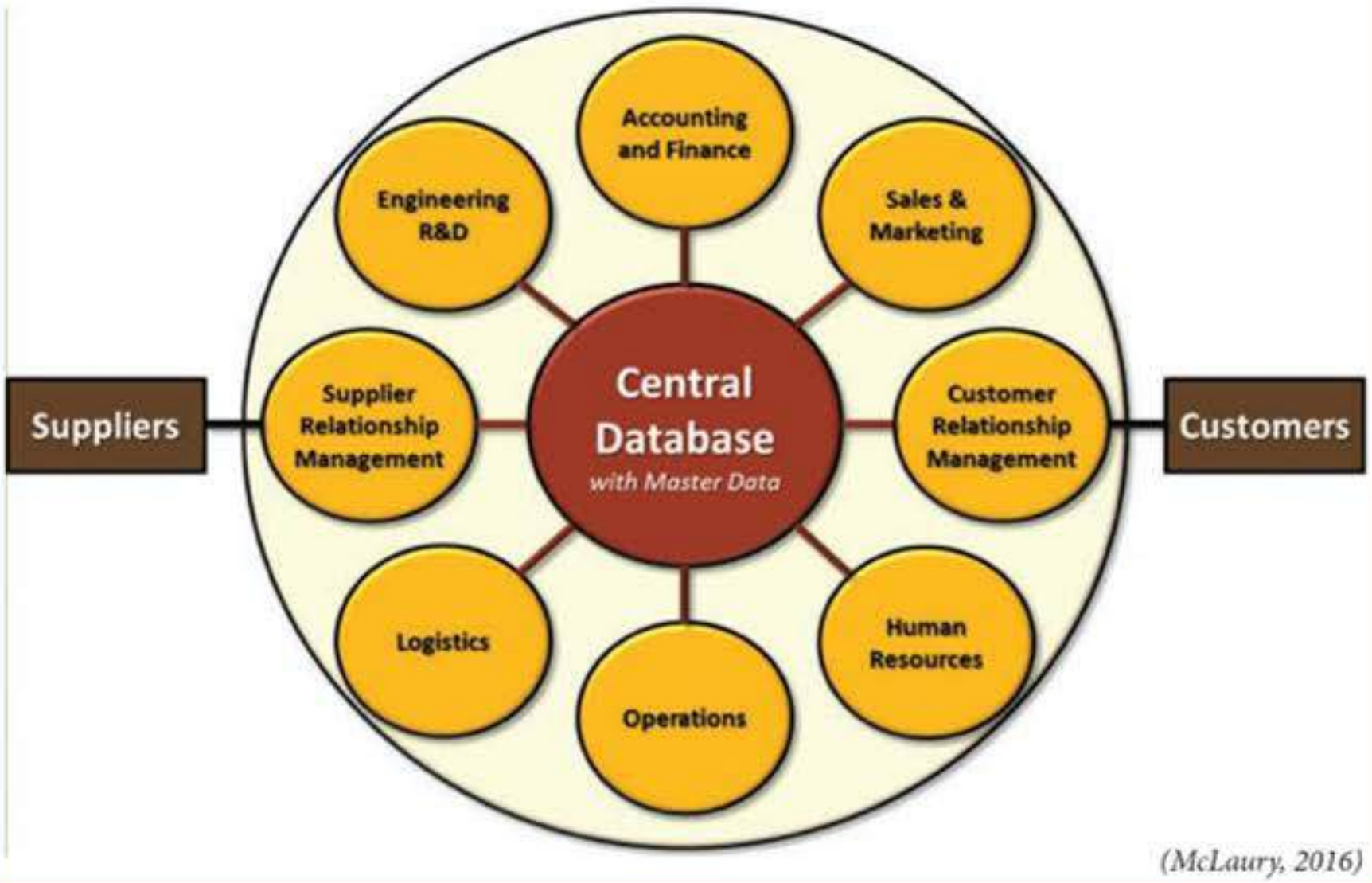
An enterprise resource planning (ERP) system is a "framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage."[1]

An ERP system automates and integrates core business processes such as taking customer orders, scheduling operations, and keeping inventory records and financial data. ERP systems can drive huge improvements in the effectiveness of any organization by:

- Assisting in defining business processes and ensuring there is compliance throughout the supply chain
- Protecting critical business data through well-defined roles and security access
- Enabling a company to plan the workload based on existing orders and forecasts
- Providing the tools to give a high level of service to customers
- Translating data into decision-making information

To realize the full benefits of an ERP system it should be fully integrated into all aspects of the business from the customer facing front end, through planning and scheduling, to the production and distribution of products to the end customer.

FIGURE 3.13



(McLaury, 2016)

The basic goal of using an enterprise resource planning system is to provide one central repository for all information that is shared by all the various supply chain functions to improve the flow of data across the organization (see figure 3.13).

ERP software typically consists of multiple enterprise software modules, which can be purchased as part of a system or individually, based on what best meets the specific needs and technical capabilities of the organization. Each ERP module is focused on one area of business process.

Major ERP applications include:

- Accounting and Finance
- Customer Relationship Management
- Human Resource Management

- Manufacturing
- Supplier Relationship Management
- Supply Chain Management

Advantages:

- The added visibility offered by the ERP system leads to more efficient and effective use of the firm's resources and reduced supply chain inventories.
- It helps to standardize manufacturing processes.
- It measures performance and communicates via a standardized method.

Disadvantages:

- It takes substantial time and capital investment to implement.
- The ERP system is complex.
- Firms tend to adapt existing processes to meet the functionality or capabilities of the ERP system, which may not be the most optimal for the firms' business.

ERP System Developers

- **Large Enterprise ERP:** SAP, Oracle, Microsoft
- **Mid-Market ERP:** Infor, QAD, Lawson, Epicor, Sage, IFS
- **Small Business ERP:** Exact Globe, Syspro, NetSuite, Visibility, Consona, CDC Software, Activant Solutions

ERP Implementation

There are two basic types of ERP implementation:

1. **Best-of-breed:** Companies pick the best application for each individual function for their particular business needs regardless of the supplier/software developer, and then integrate the various systems together.

- **Advantage:** Companies can obtain the best system for each function to meet the specific needs of the company.

- **Disadvantages:** Software may not integrate well; may not be able to take advantage of upgrades and enhancements as each will require a reintegration.

2. **SINGLE INTEGRATOR SOLUTION:** Companies evaluate and pick a single vendor for all the desired applications.

   - **Advantages:** Functions are already integrated, tested, and debugged. No compatibility issues or data translation issues. Can take advantage of system upgrades and enhancements more easily than the best-of-breed solution.

   - **Disadvantages:** Single integrator software solutions are generally costly, and require a significant number of resources, people, and time to implement. Companies may be paying for functionality that they do not need. It may not be the best solution for individual functions.

Major causes of ERP implementation problems include:

- Lack of top management commitment
- Lack of adequate resources
- Lack of proper training (both initial and ongoing)
- Lack of communication
- Incompatible system environment

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Chapter 4

Inventory Management

CHAPTER OUTLINE

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Categories of Inventory
Inventory in the Service Industry
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Inventory Management
Inventory Stocking Levels
Inventory Costs
Inventory Investment
Independent and Dependent Demand
Inventory Policy
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Summary

INTRODUCTION

A key decision in any product-based supply chain is how much inventory to keep on hand. Maintaining adequate finished product inventory allows a company to fill customer orders immediately, and maintaining adequate materials inventory allows a company to support manufacturing operations and the production plan while avoiding delays. Failing to manage inventory adequately can lead to significant issues and inefficiencies throughout the supply chain, including dissatisfied customers, lost sales and revenue, and higher costs, just to name a few. Inventory is usually one of the company's largest assets, so careful management of that asset is an essential business requirement.

INVENTORY

Inventory represents the quantities of goods and materials that are held in stock. APICS defines inventory as "those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies), and customer service (finished goods and spare parts)."[1]

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Inventory includes finished product(s), all the materials used for production, and all of the other materials and supplies needed to run a business (office and break room supplies, spare parts for equipment, cleaning and maintenance supplies, etc.). Most companies segregate their production inventory from their nonproduction inventory. They may even have separate procurement groups that individually handle the buying activities for production versus nonproduction items.

Inventory Is an Asset and Potentially a Liability

While inventory can be one of a company's largest assets, it can also be a significant liability if it is not managed well. Some inventory may be necessary to maintain operations and ensure that products are available when customers demand them, but too much inventory ties up capital that could otherwise be used for purposes such as research and development, marketing and sales, stockhold-

er dividends, salary increases, and so forth. Too much inventory can be a liability if it becomes unusable due to expiration, obsolescence, damage, or spoilage. In addition, the more inventory a company holds, the more space that must be used, and space costs money whether a company owns and maintains its own warehouse or rents space from an outside public or contract warehouse. In addition to storage costs, a company may also have to pay for utilities, security, insurance, taxes, and the like, to hold inventory. Simply put, the more inventory a company holds, the more costs are generated.

CATEGORIES OF INVENTORY

There are four main categories of inventory:

- Raw Materials
- Work in Process (WIP)
- Finished Goods
- Maintenance, Repair, and Operating (MRO) supplies

Raw Materials are "purchased items or extracted materials that are converted via the manufacturing process into components and products."[1]

Any company that produces a product generally starts with some type of raw material, component part, or starting material. There are entire strategies around the question of how much raw material a company should hold in inventory. Do they want to buy it from their supplier and have it delivered to their operation just in time for when it is needed? Or do they want to buy and hold a larger quan-

tity for strategic reasons? Companies might be willing to increase costs by storing excess inventory if they fear there may be a potential shortage of the material or suspect that there is an upcoming price increase and want to buy at the current lower price. The ultimate decision for how much raw material to buy and when could lie at either end of the spectrum or anywhere in between.

Work in Process (WIP) is "a good or goods in various stages of completion throughout the plant, including all materials from raw material that has been released for initial processing up to completely processed material awaiting final inspection and acceptance as finished goods."[1] Work-in-process inventory is sometimes also referred to as "work-in-progress" inventory.

Due to the range of potential stages of completion that WIP encompasses, and the fact that materials in WIP may be in a state of continuous transformation, many companies view WIP as the "black hole" of inventory as they may not have very good or very timely visibility into this part of their inventory.

Best practice generally suggests minimizing the amount of work-in-process inventory in the manufacturing area, because too much WIP may clutter up the physical space and impede the process flow. In a LEAN manufacturing environment, which will be discussed in Chapter 8, the WIP inventory should be so minimal that it is almost immaterial.

Because it can be time consuming to calculate the amount of WIP inventory, determine the percentage of completion, and assign a cost to WIP, it is also a standard practice in many companies to minimize the amount of WIP inventory on hand just prior to the end of a reporting period.

Finished Goods are "those items on which all manufacturing operations, including final testing, have been completed. These products are available for sale and/or shipment to the customer as either end items or repair parts."[1] Merchandise owned by a retailer that is sitting on the shelf or in the stockroom, ready for immediate sale and delivery to its customers, is considered finished goods. There is no remaining work to prepare these items for the consumer.

From a cost perspective, finished goods are usually worth much more than raw materials or WIP, because all of the material, labor, and overhead costs are fully applied to finished goods.

The amount of finished goods inventory that a company decides to maintain is a strategic decision:

- Companies can decide to operate a **make-to-order** supply chain where the finished goods are not produced until a customer order is received, and the raw materials may not even be ordered from the supplier(s) in advance. Once the customer order is received, the materials are ordered/delivered, the finished goods are produced, and the product shipped to the customer immediately upon production. Little to no finished goods inventory is maintained by the manufacturer in a make-to-order supply chain strategy.

- Companies can alternatively decide to operate a **make-to-stock** supply chain where product is produced prior to receipt of a customer order. A forecast and demand plan are created for the finished goods based on anticipated demand. The raw materials are ordered in advance and the finished goods are produced against the production plan, which is based on the anticipated demand, and then held in inventory until a customer order is received. Significant amounts of finished goods inventory can sometimes be maintained by the manufacturer in a make-to-stock supply chain strategy when large demand is forecast.

Each of these strategies, and variations of these strategies, involves making trade-offs among inventory investment, operating costs, and customer service.

Maintenance, Repair and Operating (MRO) supplies are "items used in support of general operations and maintenance such as maintenance supplies, spare parts, and consumables used in the manufacturing process and supporting operations."[1] These are materials that you need to run the manufacturing operation and the business but do not end up as part of the finished product. Some MRO items are consumed during the process of converting raw materials into finished goods (e.g., oil for the manufacturing equipment). Other MRO items are used to facilitate the manufacturing operation (cleaning supplies, spare parts, etc.), and still other MRO items may be used to facilitate the company's administrative activities (office supplies, coffee for the break room, etc.).

MRO inventory is separate from production inventory, but it is just as important. It needs to be stored and accounted for similarly to production items. As companies need MRO items to run their operations, a shortage of one or more of these items may cause a supply disruption. Frequently these items are expensed at the time they are purchased, and there may be a separate function, group, or individual who plans and orders these MRO items from those who plan and order production items.

INVENTORY IN THE SERVICE INDUSTRY

Companies in the service industry do not maintain inventory of services, because services are basically produced and consumed immediately upon demand. Companies in the service industry can, however, maintain inventory of "facilitating products," which are those items that are used to help facilitate the service being provided. For example, a car rental service provides the vehicles necessary to offer the rental service. The rental vehicles are facilitating products that can be inventoried in advance of providing the rental service. Restaurants offer dining services that involve preparing and serving the food, providing the seating area, ambiance, cleanup, parking and valet, among other amenities. Restaurants cannot inventory the actual dining service; they can only begin the service when the customers arrive. Restaurants can, however, inventory the food, tableware, and other elements of the dining operation as these are facilitating products necessary to provide the dining ser-

vice. Restaurants can even prepare some of their meal options in advance such as salads or deserts (i.e., inventory these facilitating products so they are ready to go when the customers arrive for the dining service). Supply chains in the service industry will be covered in more detail in Chapter 12.

FUNCTIONS OF INVENTORY

There are four basic function of inventory, or reasons why companies hold inventory:

1. To meet customer demand (cycle stock)
2. To buffer against uncertainty in demand and/or supply (safety stock)
3. To decouple supply from demand (strategic stock)
4. To decouple dependencies in the supply chain

1. To Meet Customer Demand:

- Meeting customer demand is the purpose of "cycle stock."
- Maintaining finished goods inventory allows a company to immediately fill customer orders. A customer places an order which can then be shipped/delivered to him or her from the available inventory.
- Maintaining raw materials inventory helps a company ensure that the necessary materials will be available to begin or continue the production plan/schedule uninterrupted.
- To facilitate meeting customer demand, companies may develop inventory deployment strategies to ensure that the product is available when and where the customers want it. Inventory deployment strategies range from having all of the available inventory centrally located to having the inventory geographically dispersed to multiple locations (e.g., distribution centers or retail outlets). The more dispersed the inventory is, the more likely it will be that a higher level of inventory will be needed to ensure adequate availability at all locations for all customer demand.

2. To Buffer against Uncertainty in Demand and/or Supply:

- A company may decide to maintain some inventory of finished goods and/or raw materials due to uncertainty in demand. In the absence of actual customer orders, the company may

create a sales forecast (i.e., estimate demand based on the information that it has about what customers may want). The demand plan is not likely to be 100% accurate. If the estimates are on the low side (i.e., under-forecasted for any reason), and there is more demand than expected, the company will not be able to satisfy all of the demand unless it has proactively created a buffer or "safety stock" of finished goods inventory from which to satisfy this unanticipated demand. Similarly, the company may decide to create a safety stock of raw materials in addition to, or in place of, finished goods safety stock to buffer for any unanticipated demand.

- A company may also decide to maintain some inventory of finished goods and/or raw materials due to uncertainty in supply. Unexpected disruptions in supply can create a shortage, which leads to unfulfilled demand and/or interrupted production plans and schedules. Suppliers, whether internal or external, may be late with delivery for any number of reasons or deliver a quantity less than what was ordered, leading to a shortage. Even raw materials or finished goods delivered on time and in full may be effected by quality problems and be unusable or unsalable. Because of the uncertainty of supply, some companies may proactively decide to create a buffer or safety stock of raw materials and/or finished goods inventory from which to satisfy demand in the event of a disruption and shortage.

- This is the purpose of "safety stock": an incremental quantity of stock kept in inventory to protect against fluctuations in either demand or supply or a combination of both. Safety stock will be detailed later in this chapter.

3. To Decouple Supply from Demand:

- There are a number of reasons why a company may want to buy an amount of raw materials or produce an amount of finished goods that differs from what is specifically required by the demand plan. This can result in inventory being held.

- One reason to hold inventory may be to achieve economies of scale in purchasing, manufacturing, and/or transportation. A company may receive a price break or discount from a supplier for buying a larger quantity than is specifically required, or receive a lower per unit transportation cost for transporting a larger quantity in a truckload volume than in a less-than-truckload volume. If the price break, discount, or lower per unit transportation cost is sufficient to offset the extra

holding cost incurred as a result of the additional inventory, then the decision to buy the larger quantity is justified. Inventory can also be used as a hedge against price increases.

- Another reason to hold inventory may be the decision to manufacture a finished product in full production lots rather than smaller quantities, because it may be more economical, more efficient, offer more consistent and better quality control, or be more appropriate for equipment operating requirements.

- In each of these examples the additional quantity purchased or manufactured results in inventory that may be held for some period of time before it is used or sold.

4. To Decouple Dependencies in the Supply Chain:

- Inventory can be held between dependent operations in manufacturing to decouple the dependency of the operations. Sequential operations in manufacturing are dependent upon previous operations (i.e., production steps), to continue the manufacturing process. If there is a disruption of an upstream (previous) operation due to a material shortage, labor issue, equipment problem, etc., then all downstream (subsequent) operations will also be disrupted. If some inventory of materials or work in process is maintained between operations, then operations downstream from the disruption may be able to continue the manufacturing process for some period of time, perhaps even until the disruption is resolved. This inventory helps to decouple some of the dependencies in the supply chain.

- Inventory can also be used to smooth or level demand requirements when demand is irregular, seasonal, and so forth. For example, if a company manufactures and sells seasonal products such as snow blowers or lawn mowers, the demand for those products is likely to peak during the season and fall off significantly in the off-season. It may be very inefficient for the company to adjust manufacturing capacity to match the demand in each season. The company may decide to adopt a level production strategy where they establish a steady manufacturing output rate based on the anticipated annual volume. The company can build up inventory when demand is low, keeping workers busy during slack times, so that when demand picks up, the increased inventory can be slowly depleted through normal in-season sales and the company does not have to react by increasing production. The company can avoid excessive overtime and the hiring, training, and other associated labor costs associated with hiring more workers to meet the increased demand. It can also avoid layoff costs and the potential loss of skilled workers in the off-season associated with production cutbacks. This strategy might even prevent the idling or shutting down of facilities.

This type of level production strategy is designed to smooth the peaks and valleys in demand, allowing the company to maintain a constant level of output and a stable workforce.

The steady manufacturing output rate means that the company will overproduce against demand in the off-season in order to create inventory to meet the higher demand in-season when it will be underproducing against demand. By shifting demand requirements to earlier time periods and leveling the demand, inventory levels throughout the year vary significantly. If inventory levels could not fluctuate in this way, the manufacturing output—and associated labor, materials, and costs—would need to fluctuate.

This tactic is commonly used by retailers who routinely build up inventory months before the demand for their product peaks (e.g., at Halloween, at Christmas, the back-to-school season).

INVENTORY MANAGEMENT

Inventory Management is defined as "the branch of business management concerned with planning and controlling inventories."[1] Inventory management can help a company be more profitable by lowering the cost of goods sold and/or by increasing sales.

Small cost reductions from the application of sound inventory management principles can result in a significant increase in net income. Efficient inventory processes during the production phase of a product's life simultaneously reduce costly work stoppages and inventory storage costs. Reducing the amount of finished inventory that is held in stock reduces storage costs for the item. So long as the production and distribution channels for a given product are efficient, these inventory savings translate into more profit while selling the product for the same price. The stated advantages of maintaining smaller inventories are predicated on the notion of having sufficient supply as inventory management must balance two competing considerations: (1) reduce the amount of inventory held in stock, and (2) ensure there is enough inventory to satisfy customer demand.

Effective inventory management balances these two considerations to achieve the stated goals of lowering costs and increasing sales. Although sales are still tied to demand, customers cannot satisfy their demand if an item is out of stock. Not having product available for customers when they place orders is one of the self-defeating mistakes a company can make. There are some products customers do not expect to receive immediately, but any stockout adds delays in delivering a finished product to the customer or adds cost to the manufacturer. If manufacturing supplies are out of stock, the company may have to expedite delivery of materials, expedite new production, spend extra money working overtime, and use premium modes of transportation, to satisfy the customer demand. Any of these remedies effectively negate any cost savings generated from maintaining lower inventory levels, and not investing in one of these costly solutions will likely lead to upset customers, effectively decreasing future sales.

Balance in inventory management is crucial. Effective inventory management can yield decreased costs and/or increased sales, but sometimes companies may opt to concentrate on one end or the other and accept the potential trade-offs of their inventory decision:

- If a company's supply chain strategy is to operate an **efficient capabilities model**, the company can choose to maintain a somewhat more reduced level of inventory held at a centralized location, which may potentially be more remote from the customer(s). This strategy decreases the overall inventory costs, but increases the risk of a customer service issue.

- If a company's supply chain strategy is to operate a **responsive capabilities model**, the company can choose to maintain a somewhat higher level of inventory held at multiple decentralized locations which may potentially be closer to the customer(s). This strategy increases the overall inventory costs, but reduces the risk of a customer service issue occurring.

So, what is the right amount of inventory? The answer to that question is, "It depends." There are many factors that go into determining the right amount of inventory for a particular company/product. It depends on the supply chain strategy and setup, the type of product(s), customers' expectations, customer service objectives, product shelf life, among other factors.

INVENTORY STOCKING LEVELS

As introduced earlier in this chapter, there are various levels of stock held by companies to meet customer demand, to buffer against uncertainty in demand and/or supply, to decouple supply from demand, and to decouple dependencies in the supply chain (see figure 4.1).

The three main inventory stocking levels are:

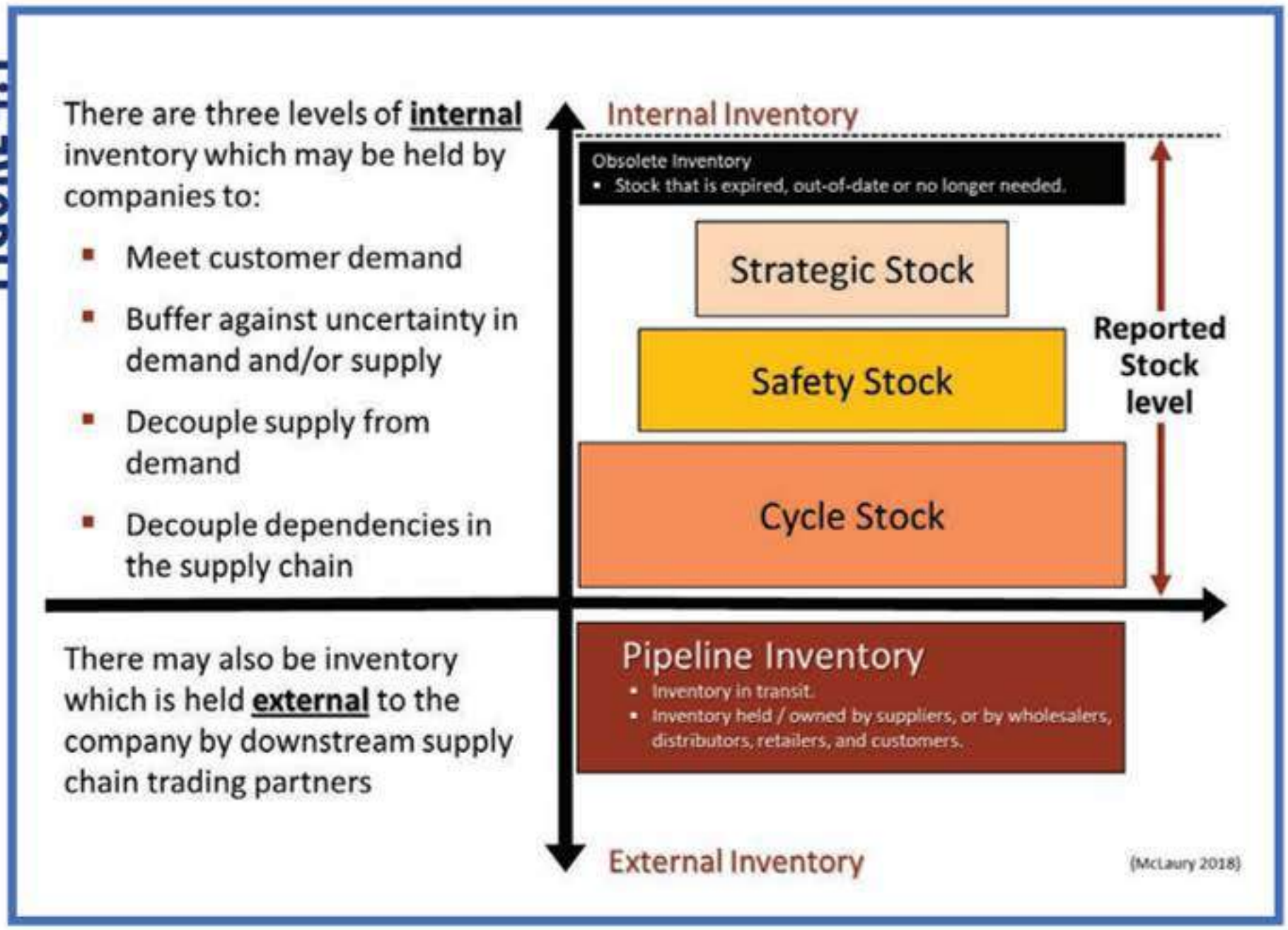
- Cycle stock

- Safety stock

- Strategic stock

In addition, pipeline inventory, which is external to the company, may have an impact on decisions that companies make about how to manage and control their inventory resources.

FIGURE 4.1



Cycle Stock

Cycle stock is the most active component of inventory. It is the inventory that a company builds to satisfy its immediate demand. Cycle stock "depletes gradually as customer orders are received and is replenished cyclically when supply orders are received."[1] The amount of cycle stock that a company holds is dependent on various factors, including anticipated and actual demand in the immediate time period, supply replenishment lead time, and supply replenishment order quantities. Unless a company is operating in a pure make-to-order type environment, companies carry some amount of cycle stock.

Safety Stock

Safety stock is "a quantity of stock planned to be in inventory to protect against fluctuations in demand or supply. Over planning supply versus demand can be used to create safety stock."[1]

Among the functions of inventory are protection against higher than anticipated demand, late delivery of replenishment supplies, and poor quality of a supplier's products. It is very common for

companies to carry safety stock when demand and/or lead time are not constant. Safety stock, also known as "buffer stock," is inventory that is above and beyond what is actually needed to meet anticipated demand. Generally, the higher the level of inventory a company maintains, the better the company's customer service will be as there will be a higher likelihood that a customer's order can be filled immediately from existing inventory. Safety stock can be centrally located or geographically dispersed depending on where companies anticipate the variability in demand or supply to occur.

Planning for finished goods safety stock requires three steps:

1. Determine the likelihood of a stockout using a probability distribution (e.g., forecast accuracy/error).

2. Estimate demand during a potential stockout period.

3. Decide on a policy concerning the desired level of stockout protection (i.e., desired service level).

Companies operating in a make-to-stock environment will generally maintain some amount of safety stock whether based on a management decision or on a safety stock determination formula. There are many different ways of setting or calculating safety stock.

Setting Safety Stock Levels by Management Decision/Policy

Each of the following may be based on experience, judgment, intuition, or historical data:

1. Specifying some dynamic forward demand coverage (2 weeks, 4 weeks, etc.)

2. Establishing and maintaining a fixed quantity of safety stock inventory

3. Setting safety stock based on an ABC analysis of products in the company's portfolio (explained later in the chapter in "Other Types of Inventory Systems")

Calculating Safety Stock via Formula

1. (Maximum daily usage – Average daily usage) × Total replenishment lead time
2. k × □LT × (1.25 × MAD)

Where:

k	Desired customer service level (safety factor). Derived from a normal distribution curve. Sample values for k are 2.33 for 99%, 2.03 for 98%, 1.64 for 95%, etc.
□LT	The square root of the lead time necessary to fully replenish inventory.
1.25 x MAD	MAD = mean absolute deviation of the difference between the actual demand and the forecast demand. The absolute forecast error expressed as a unit quantity. The value *1.25 x MAD* represents an adjusted increase in the MAD by 25%. The increase helps to define the safety stock that is needed in case of unexpected demand. Any demand increase above 25% would not be covered. The value of the constant can vary from company to company and even item to item.

Strategic Stock

Strategic stock, also known as "anticipation stock," is additional inventory above and beyond cycle stock and safety stock. Cycle stock and safety stock are both maintained continuously to support demand and the ongoing uncertainty in both demand and supply. Strategic stock is generally used for a very specific purpose or future event and for a defined period of time (i.e., neither continuous nor ongoing).

There are many potential reasons that a company may decide to carry some strategic stock: hedging a currency exchange, taking advantage of a price discount, protecting against a major short-term disruptive event in supply, taking advantage of a major business opportunity, and/or providing for lifecycle changes (seasonal demand, new product launch, transition protection or bridging, etc.). Companies do not routinely carry strategic stock, and many companies never carry strategic stock, which is why it is depicted as a smaller box in figure 4.1.

Strategic stock can also be the result of smoothing or leveling the demand requirements when demand is irregular, seasonal, and the like. Shifting supply plans forward from peak demand periods to off-peak demand periods to maintain a level production strategy produces a strategic stock (i.e.,

a temporary increase in inventory levels). This is also sometimes called "build stock," "seasonal inventory," or "seasonal stock."

Pipeline Inventory

The first three types of stock in the upper half of figure 4.1 (cycle stock, safety stock, and strategic stock) are inventory, which is internal to the company. In the lower half of figure 4.1 you will see pipeline inventory, which is external to the company.

Pipeline inventory is "inventory in the transportation network and the distribution system, including the flow through intermediate stocking points."[1] Pipeline inventory is in-transit, either out to the distribution channels or already out in the market being held by wholesalers, distributors, retailers, and even consumers. The ownership of this inventory has been transferred to the company's downstream trading partners/customers, but pipeline inventory may still influence decisions the company makes regarding how it manages and controls its internal inventory.

Companies make inventory decisions regularly to remain competitive and to maintain their inventory strategy. In addition to factors such as the type of distribution network and the type and nature of the finished products in the supply chain, a company should consider all of the inventory in the supply chain holistically (i.e., internally and externally) when determining how much safety stock and/or strategic stock to hold.

- If pipeline inventory is high, it might be less critical for the company to maintain higher levels of safety and strategic stocks. A short-term supply disruption causing a temporary backorder (i.e., an unfilled customer order or commitment) to intermediary customers such as wholesalers and distributors might not necessarily turn into a major market stockout, because there is a lot of inventory moving downstream.

- Conversely, if pipeline inventory is low, any issue that happens in the marketplace will likely have a larger and more immediate impact on the overall supply situation and, therefore, more safety and/or strategic stock may be warranted.

Obsolete Inventory

A company may also experience some level of obsolete inventory. These are "inventory items that have met the obsolescence criteria established by the organization. For example, inventory that has been superseded by a new model or otherwise made obsolescent. Obsolete inventory will never be used or sold at full value. Disposing of the obsolete inventory may reduce a company's profit."[1] Simply put, obsolete inventory is stock that is expired, damaged, or no longer needed. Writing this obsolete inventory off of the books and disposing of it may be a difficult decision to make as all or part of the obsolete product's value may be lost. Unusable inventory does, however, take up space and cost money to maintain, so it may be better to absorb the loss as soon as an item has met the obsolescence criteria than delay and continue to lose money on storage and related fees. However, there may be a cost associated with the actual disposal of the obsolete inventory, depending on the type and method of disposal. Some companies may find ways to donate this inventory to a nonprofit organization if it has any remaining value, which not only helps the nonprofit but also avoids disposal costs and may result in a tax benefit for the company.

INVENTORY COSTS

The categories of costs associated with inventory are described as follows:

Direct Costs are expenditures that are directly traceable to the volume of units produced. Examples are labor, materials, and expenses specifically related to the production of a product.

Indirect Costs are expenditures that cannot be traced directly to the volume of units produced. Examples are depreciation, administrative expenses, overhead, MRO items, buildings, equipment, and utilities. Indirect costs may be either fixed or variable and are typically allocated to a cost object as defined by individual company policy.

Fixed Costs are expenditures that do not vary with the volume of units produced. Examples are rent, property tax, and salaries of certain personnel, all of which are independent from the output. Fixed costs are frequently time related (i.e., paid on a weekly, monthly, or annual basis). They are generally referred to as overhead costs. Fixed costs are, however, not permanently fixed; they are fixed only for the relevant period of time.

Whether a company manufactures 1 unit, 100 units, or 1,000 units, a manufacturing facility is needed. The cost is fixed in the immediate time period regardless of how many units are produced. Even if no units are produced, there is still a cost for the building, depreciation, insurance, security, maintenance, and so forth. The building represents a fixed cost no matter whether the building is owned

or leased by the company. However, in the long run, the fixed cost may change as the building depreciates, the lease expires and is renewed, etc. At that point it will become a new or revised fixed cost.

Variable Costs are expenditures that vary directly with a change of even one unit in the volume produced. Examples are direct labor and materials consumed, sales commissions, and allocated overhead. Variable costs rise as production increases and fall as production decreases. Generally, the cost of goods sold (COGS) are variable costs.

Order Costs are the direct labor cost incurred when a purchaser places an order. Order costs are "used in calculating order quantities, [they are] the costs that increase as the number of orders placed increases. It includes costs related to the clerical work of preparing, releasing, monitoring, and receiving orders, the physical handling of goods, inspections, and setup costs, as applicable."[1] Every time an order is placed, regardless of the quantity of the order, there is a cost associated with processing the order.

Carrying Costs are "the cost of holding inventory, usually defined as a percentage of the dollar value of inventory per unit of time (generally one year). Carrying cost depends mainly on the cost of capital invested as well as the costs of maintaining the inventory, taxes and insurance, obsolescence, spoilage, and space occupied. Such costs vary from 10 percent to 35 percent annually, depending on type of industry. Carrying cost is ultimately a policy variable reflecting the opportunity cost of alternative uses for the funds that have been invested in inventory."[1] Carrying costs are also called "holding costs."

Hidden Costs of Inventory

Having too much or too little inventory on hand can create hidden costs that will negatively impact a company. Companies need to be aware of these hidden costs.

Financial resources tied up in too <u>much</u> inventory are not available for other purposes (e.g., research and development, marketing and sales, shareholder dividends and salary increases). Excess inventory makes meeting customer demand easier, but it might also be masking underlying problems with the supply chain. Moreover, excess inventory sitting on shelves means quality control issues may take longer to uncover, eventually leading to future inventory and manufacturing costs.

Too <u>little</u> inventory, on the contrary, leads to production disruptions due to unavailability of materials, which can cause loss of sales and revenue from dissatisfied customers, cancelation of orders, idle workers and equipment, extra machinery setups, loss of quantity discounts on purchases, and more. Longer replenishment lead times and reduced responsiveness to customers ultimately yield lower sales.

INVENTORY INVESTMENT

As discussed earlier in this chapter, inventory is typically a significant asset for a company, but it can be a liability as well. Companies should measure inventory investment routinely to ensure that their inventory practices do not adversely affect their competitiveness. Two common measures companies use are **absolute inventory value** and **inventory turnover**.

Absolute Inventory Value is defined as "the value of the inventory at either its cost or its market value. Because inventory value can change with time, some recognition is taken of the age distribution of inventory. Therefore, the cost value of inventory is usually computed on (1) a FIFO, i.e., first in first out basis, meaning that the oldest inventory is used/sold first, (2) a LIFO, i.e., last in first out basis, meaning the newest inventory is used/sold first, or (3) a standard cost basis, to establish the cost of goods sold."[1] Absolute inventory value is the cost of all finished goods and materials a company has on hand. This value may be required for reporting on financial statements such as a company's balance sheet.

Inventory Turnover is "the number of times that an inventory cycles, or 'turns over,' during the year. A frequently used method to compute inventory turnover is to divide the average inventory level into the annual cost of sales. For example, an average inventory of $3 million divided into an annual cost of sales of $21 million means that inventory turned over seven times."[1] (See figure 4.2.) Generally, the more turns, the better. The more times inventory is replenished, the less opportunity there is for it to expire, become obsolete, spoil, or become damaged. Inventory turnover measures the speed with which inventory passes through an organization or supply chain. It is a measure of managerial prowess. If a company can turn inventory over very quickly, it likely means that it is converting raw material expenditures into sales revenue very quickly, utilizing the inventory asset to generate income very efficiently.

FIGURE 4.2

$$\text{Inventory Turnover Ratio} = \frac{\text{Cost of Goods Sold (COGS)}}{\text{Average Inventory @ Cost}}$$

aka, Cost of Sales or Cost of Revenue

(McLaury, 2016)

INDEPENDENT AND DEPENDENT DEMAND

INDEPENDENT DEMAND is "the demand for an item that is unrelated to the demand for other items. Demand for finished goods, parts required for destructive testing, and service parts requirements are examples of independent demand."[1] Independent demand is usually based on actual customer orders or some type of forecast, which by its nature creates some uncertainty and variability. The potential for variability is even greater when there is a lack of collaboration with customers. The uncertainty is a key driver in determining what inventory management model to use. Independent demand items are typically managed using a "replenishment philosophy" (i.e., reordered when the currently inventory diminishes to a predefined level). These inventory ordering models are stochastic or deterministic and include fixed-order quantity and fixed-time period order quantity, which are discussed later in this chapter.

DEPENDENT DEMAND is "demand that is directly related to or derived from the bill of material structure for other items or end products. Such demands are therefore calculated and need not and should not be forecast. A given inventory item may have both dependent and independent demand at any given time. For example, a part may simultaneously be the component of an assembly and sold as a service part."[1] Inventory management and determination for dependent demand items is considerably different from independent demand items, because there is significantly less uncertainty and variability. The variability for a dependent demand item is directly related to how much variability there is for the end item, from which its demand is derived. Dependent demand items are typically managed using a "requirements philosophy" (i.e., only ordered as needed based on higher level components or products). These inventory ordering models include material requirements planning, kanban, and drum-buffer-rope.

INVENTORY POLICY

An inventory policy is "a statement of a company's goals and approach to the management of inventories."[1] Inventory policies establish target inventory levels for all products and materials and the methods and systems used to achieve and maintain target goals.

Inventory policies address the fundamental inventory concerns:

1. When to review inventory?
2. When to order replenishment inventory?
3. How much inventory to order?

When to review inventory

There are two basic approaches of inventory reviews that determine when replenishment orders must be placed, and each involves some trade-offs:

- **Continuous Review:** In this method, inventory levels are continuously reviewed. As soon as the inventory/stock falls below a predetermined level (i.e., reorder point), a replenishment order is triggered. A continuous review system is more costly to conduct than a periodic review system, but it potentially requires less safety stock because inventory is constantly monitored and replenishment actions are taken more quickly.

  Advantages: Continuous inventory review systems allow for real-time updates of inventory, which can make it easier to know when to replenish. This method also facilitates accurate accounting, because the inventory system can generate real-time costs of goods sold.

  Disadvantages: The continuous inventory review system is costly to implement. The hardware and software necessary to run the system can be expensive to purchase, install, and maintain.

- **Periodic Review:** In this method, inventory levels are reviewed at a set frequency (weekly, monthly, etc.). At the time of review, if the stock levels are below the predetermined level (i.e., reorder point), then an order for replenishment is placed, otherwise no action is taken until the next cycle. This method segments the inventory items into review "buckets" (i.e., time periods), making it easier to manage when using a manual process, when the number of items involved is extremely large, or when constraints exist. A periodic review system is less expensive to implement and operate than a continuous review system. However, since inventory items are only reviewed periodically, there is a greater risk of inventory dropping well below the reorder point trigger between review points and there is a corresponding greater potential need for safety stock.

  Advantages: Periodic inventory review systems reduce the time spent analyzing inventory, which allows more time for other aspects of running the business. These systems are less expensive than continuous counterparts.

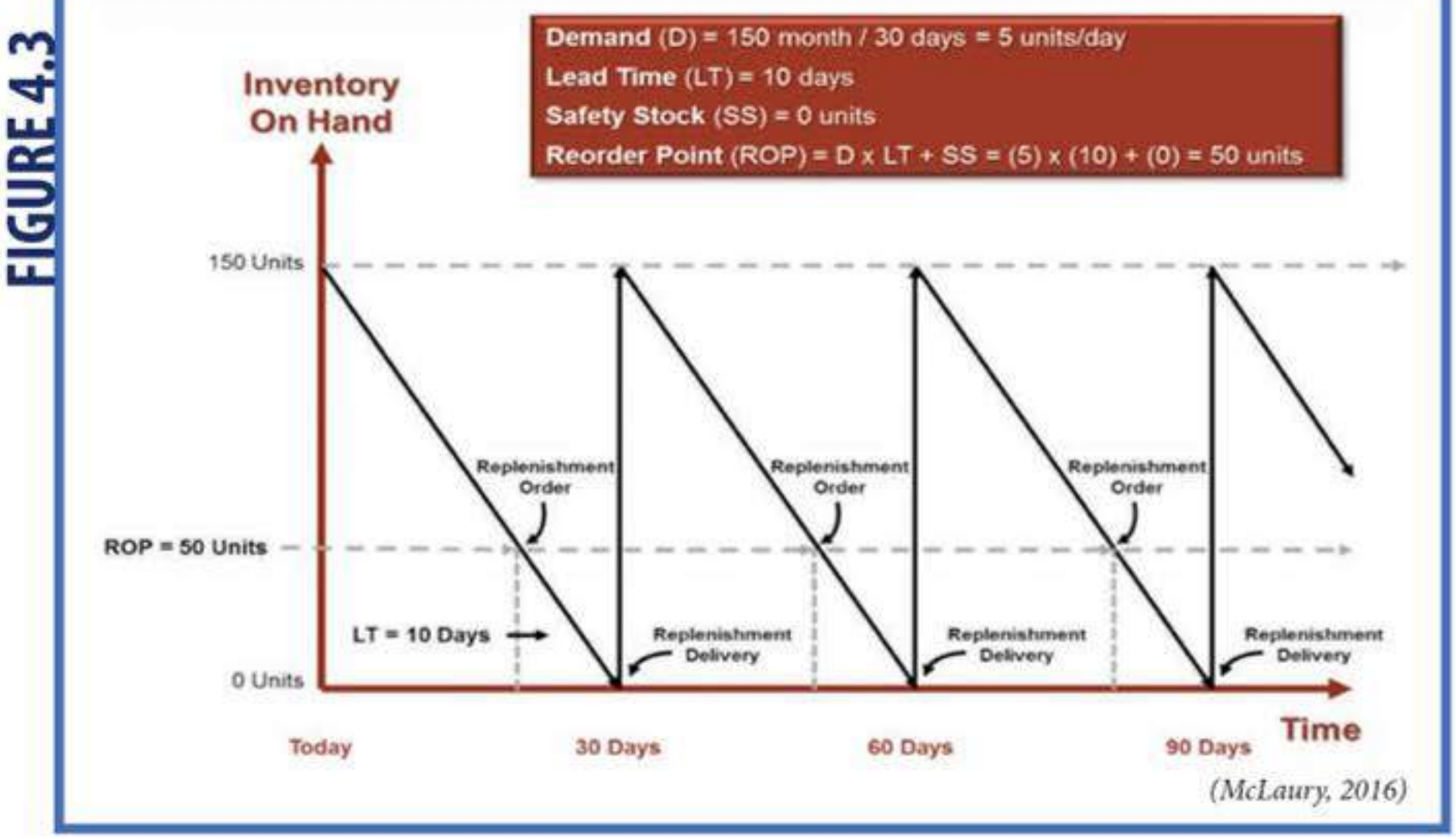
Disadvantages: It may not provide accurate inventory counts for businesses with high sales volume. You must make assumptions between inventory review periods regarding inventory counts, which can make it difficult to determine when reordering items is necessary. It also can make inventory accounting less accurate.

When to order replenishment inventory

Most, if not all, inventory replenishment systems use some type of predetermined reorder point to trigger a replenish order. A reorder point is "a set inventory level where, if the total stock on hand plus [the stock] on order falls to or below that point, action is taken to replenish the stock. The order point is normally calculated as forecasted usage during the replenishment lead time plus safety stock."[1] The reorder point is the lowest inventory level at which a new order must be placed to avoid a stockout. This means that the reorder point is set at the level of remaining inventory that is sufficient to cover all of the demand that is projected to occur during the lead time necessary to receive the replenishment supply.

Reorder Point without Safety Stock: If the replenishment lead time is 10 days, and the projected demand is 5 units per day, the reorder point should be set at 50 units of remaining inventory. When inventory drops down to 50 units, a replenishment order is triggered for delivery in 10 days: 5 units of demand per day x 10 days of lead time needed for replenishment = reorder point of

FIGURE 4.3

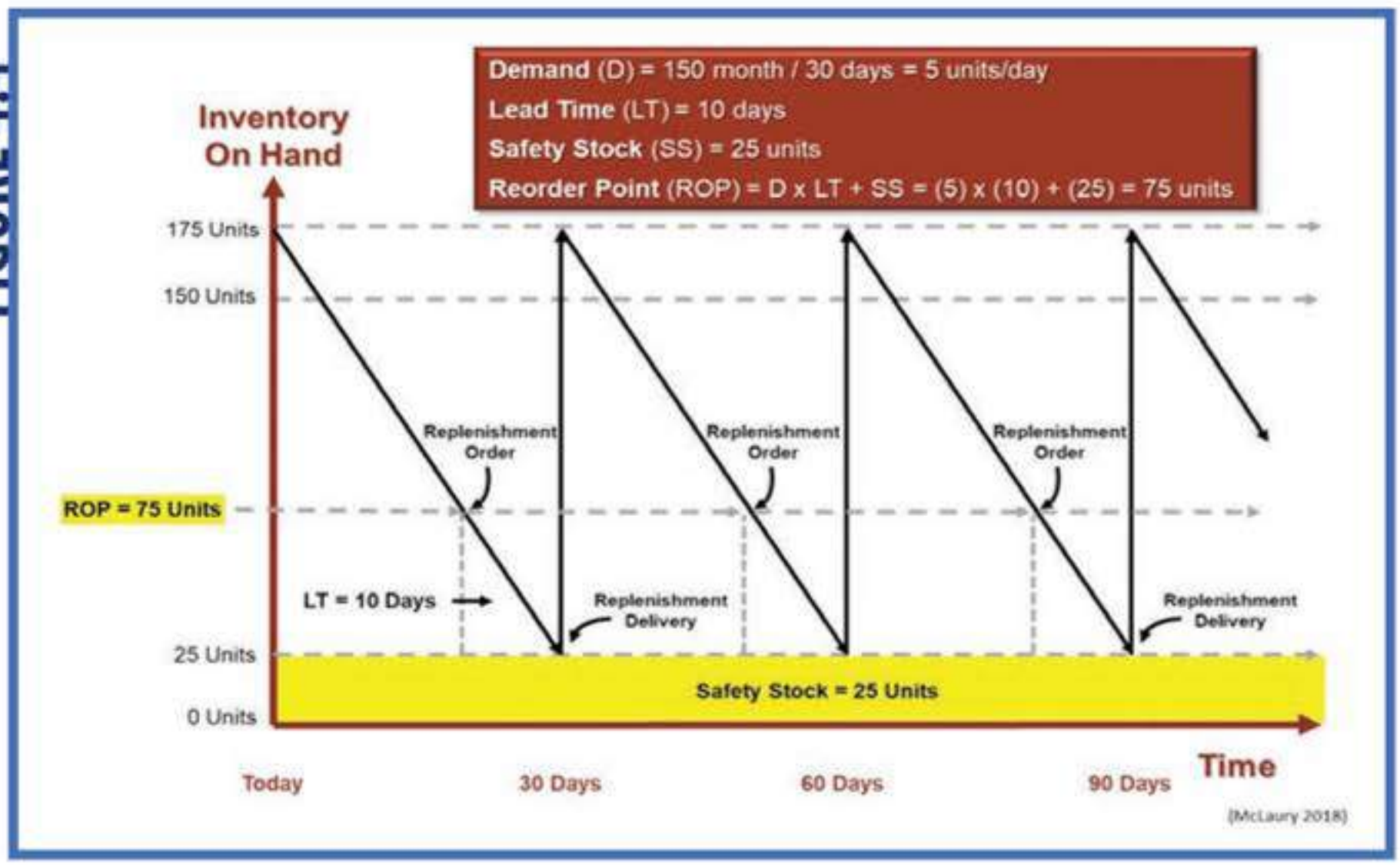


(McLaury, 2016)

50 units of remaining inventory. (See figure 4.3.) In this example the replenishment order will be delivered to the company just as the inventory drops to zero but not after, avoiding a stockout. If the replenishment order is placed after the remaining inventory drops below 50 units, then the company will likely run out of stock before the replenishment order is received 10 days later.

Reorder Point with Safety Stock: If the replenishment lead time is 10 days, and the projected demand is 5 units per day, **and the company has a desired safety stock of 25 units**, the reorder point should be set at 75 units of remaining inventory. When inventory drops down to 75 units, a replenishment order is triggered for delivery in 10 days: 5 units of demand per day x 10 days of lead time needed for replenishment + safety stock of 25 units = reorder point of 75 units of remaining inventory. (See figure 4.4.) In this example the replenishment order will be delivered to the company 10 days after the order is placed when there are still 25 units remaining in inventory. This safety stock of 25 units will help to ensure that a stockout is avoided by protecting for an upside in demand (i.e., > 5 units/day) during the time it takes to replenish the inventory, a late delivery of the replenishment order from the supplier (i.e., > 10 days to deliver), or potentially both. If the replenishment order is placed after the remaining inventory drops below 75 units but before inventory drops below 50 units, the safety stock will help to mitigate the risk of a stockout before the replenishment order is received 10 days later. If the inventory drops below 50 units before the replenishment order is placed, the safety stock will have been consumed and the company will likely run out of stock before the replenishment order is received 10 days later.

FIGURE 4.4



How much inventory to order

The two most common inventory ordering system categories are:

- Fixed-Order Quantity
- Fixed-Time Period

Fixed-Order Quantity is "an inventory system, such as Economic Order Quantity, in which the same order quantity is used from order to order. The time between orders (i.e., order period) then varies from order to order."[1] In this fixed-order quantity model, inventory is monitored on a continuous basis. When the inventory position drops to a predetermined reorder point, the same predetermined fixed-order quantity is placed.

This approach would be similar to an individual driving a car and paying attention to the fuel gauge. When the fuel gauge shows that fuel is depleted down to a predetermined level (e.g., ¼ of a tank remaining), the person pulls into the nearest fuel station to refill the tank (i.e., replenish the fuel inventory) back to the full level again. The reorder point for fuel is ¼ of a tank and the fixed-order quantity is ¾ of a tank, the amount needed to restore the fuel inventory to the full level. The time interval between refills may vary depending on how much driving is done and, therefore, how much fuel is burned. The reorder point and the order quantity are both fixed, however.

Fixed-Time Period Quantity is "a method of inventory planning that measures actual inventory levels at regular intervals of time; either an order is placed every time, or a check of inventory levels is made and an order placed if needed. Often the quantity ordered varies from period to period as inventory is restored to a predetermined level."[1] This model may also be referred to as the "min-max inventory model" (i.e., when inventory reaches the minimum allowable level, the item is reordered to its maximum allowable level).

In this model, inventory levels are checked in fixed-time intervals rather than continuously like in the fixed-order quantity model, and the quantity ordered varies based upon the inventory position when checked versus a target level. The review interval and the target inventory level are set based on factors and criteria determined by the company. Inventory is then checked at the prescribed intervals (e.g., every week), and the remaining inventory at that point in time is measured against the target inventory level. If the actual inventory is below the target inventory level, an order is placed with a quantity necessary to restore the inventory level back to the target level. The amount of inventory ordered will potentially vary from period to period based on the remaining inventory at each time interval checked.

The formula for this model is:

Q = R – IP
Where:
Q = order quantity
R = target inventory level
IP = inventory position

This method would be similar to a person who drives a car and only checks the fuel gauge every fifth day. If the fuel gauge shows that fuel is anywhere below a full tank remaining, the person pulls into the nearest fuel station to refill the tank (i.e., replenish the fuel inventory to the full level again). The target fuel inventory level is a full tank, and the reorder quantity will vary with each fifth-day check depending on how much driving is done and, therefore, how much fuel was burned between the fixed-time period intervals. This approach might be adopted when an individual knows that normal driving will never take his or her car to a dangerously low fuel level in the given time period. This person would likely not pick a time interval of 10 days if that time period might lead to an empty tank (i.e., a stockout).

The biggest difference between the fixed-order quantity method and the fixed-time period quantity method is in the timing and quantities of the orders placed.

With the fixed-order quantity method, inventory is checked on a continual basis and the system is set up to place orders as needed, regardless of time since last reorder. This system has an advantage of providing greater system responsiveness, but it also requires administrative processes to be in place to operate on a continual basis.

With the fixed-time period order quantity method, an unexpected surge in demand could lead to a stockout, because the inventory level is not checked on a continuous basis. This system, therefore, potentially requires carrying more safety stock inventory than the fixed-order quantity system.

ECONOMIC ORDER QUANTITY MODEL

Economic Order Quantity (EOQ) is "a type of fixed order quantity model that determines the amount of an item to be purchased or manufactured at one time. The intent is to minimize the combined costs of acquiring and carrying inventory."[1]

EOQ is a quantitative decision model based on the trade-off between the inventory carrying costs and the order costs. The objective of this model is to find the point of intersection of these two

costs in order to find the order quantity that bears the lowest total cost to meet projected demand. The optimal order quantity will become the quantity for every order placed until the next EOQ is calculated. It is important to note that the EOQ is a real calculation, but its worth is limited because the variables do not hold true over time. The calculation is still good as a baseline for ordering, but a supply chain manager will need to make adjustments.

The basic EOQ formula is:

$$EOQ = \sqrt{\frac{2 \times \text{Order Cost} \times \text{Annual Demand Volume}}{\text{Annual Carrying Cost \%} \times \text{Unit Cost}}}$$

EOQ = The square root of 2 *times* the Order cost *times* the Annual demand volume *divided* by the Annual carrying cost percentage *times* the Unit cost.

Order Costs (which were defined earlier in this chapter) are costs that are incurred each time an order is placed. These costs include order preparation costs, order transportation costs, and order receipt processing costs. Order costs are not impacted by the volume of inventory being ordered, only by the number of orders being placed per year.

Annual Demand Volume is the projected cumulative quantity of the item to be consumed/sold over the course of a year.

Carrying Costs (which were defined earlier in this chapter) are "the cost of holding inventory, usually defined as a percentage of the dollar value of inventory per unit of time (generally one year)." These costs include the cost of capital (i.e., the interest paid on borrowed money, or the lost opportunity cost of the money used to buy the inventory), taxes on the inventory held in storage, insurance, obsolescence, and physical storage. Carrying costs vary depending on how much inventory is bought and held. The annual carrying cost percentage is the carrying cost computed for a year and then expressed as a percentage of the cost of the inventory item. Companies typically adopt a standard such as 20% to use for this calculation.

Unit Cost is the total expenditure incurred by a company to produce, store, and sell one unit of a particular product or service. Unit costs include all fixed costs, or overhead costs, and all variable costs, or direct material costs and direct labor costs, involved in production.

Demand volume and the carrying cost must both be expressed in annual quantity terms for the formula to produce the desired results.

EOQ Example:

Order Cost	$25 per order
Annual Demand Volume	5,000 units
Annual Inventory Carrying Cost (%)	20% per year
Unit Value @ Cost	$5 per unit

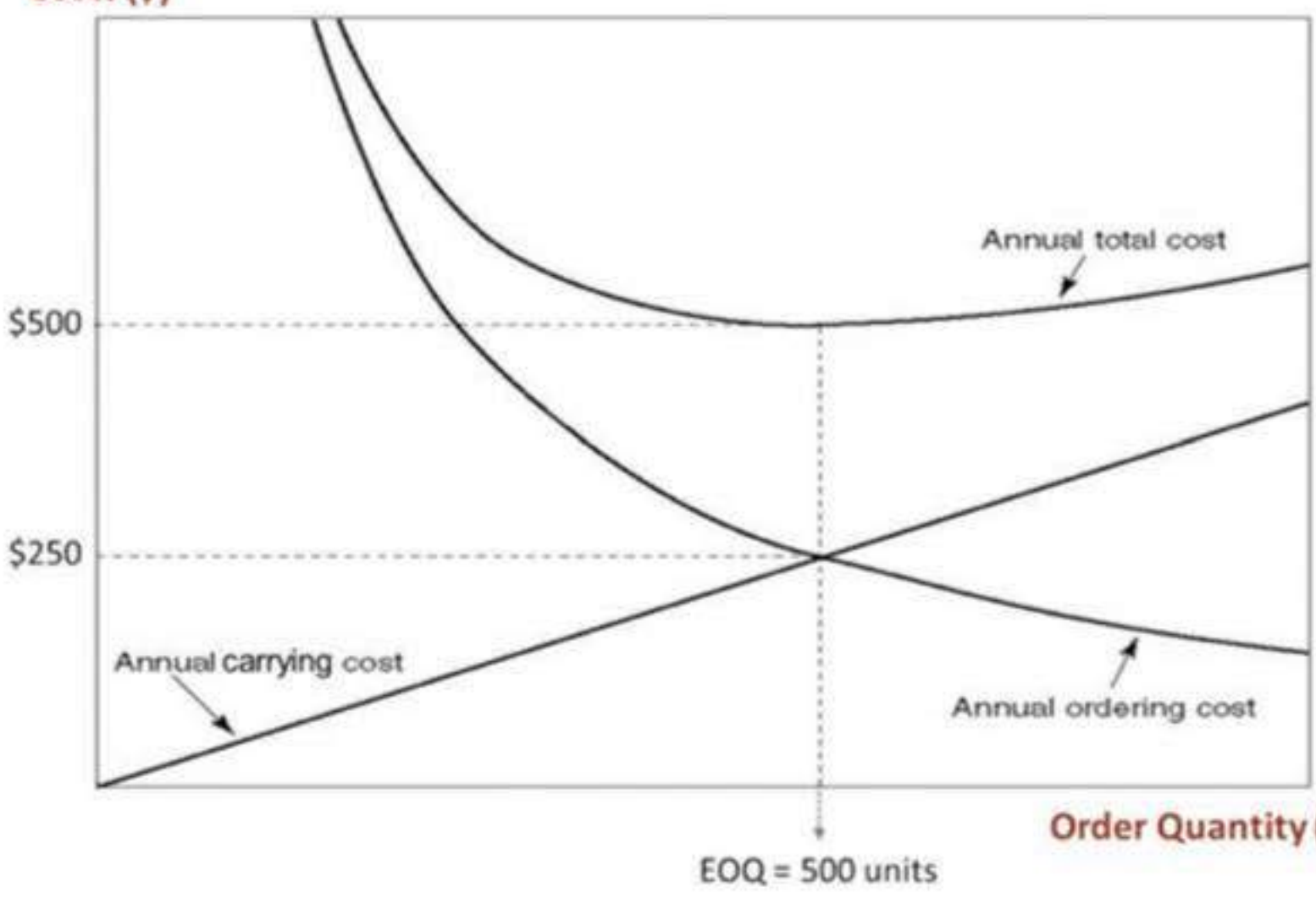
$$EOQ = \sqrt{\frac{2 \times 25 \times 5{,}000}{0.20 \times 5.00}} = \sqrt{\frac{250{,}000}{1}} = \sqrt{250{,}000} = 500$$

Proof:

Annual Order Cost is (5,000/500 x $25.00) = 10 x $25 = $250

Annual Carrying Cost is [500/2 x (5 x 0.20)] = 250 x 1 = $250

FIGURE 4.5



(McLaury, 2016)

Explaining the EOQ Graph

The EOQ graph (figure 4.5) displays the relationship between ordering cost and carrying cost. The Total Cost line is, in fact, the sum of these two costs (i.e., the sum of the other lines). The Carrying Cost line shows the costs for holding inventory based on the number of items held. As more items are held (moving right on the x-axis), the carrying costs also rise. The *Ordering Cost* line shows how much it costs per item for orders of different quantities. As the size of each order increases (again, moving right on the x-axis), the cost per item decreases. Unlike carrying costs, ordering costs cannot be represented with a simple straight line.

The Order Cost line does not typically begin with a zero value (touching the y-axis) as there are no order costs until an order is placed. If the order is for a single unit, the line would begin at 1 on the x-axis. If there are minimum order requirements, the line would start at this minimum quantity. As this line moves toward the right, it will consistently get lower as the ordering costs are shared by more and more items in the order, but the line will never reach zero ($0). There is a point of diminishing return, however, and this is why the Total Cost line eventually turns back up: The savings generated by placing a larger order no longer offset the carrying costs of the additional items.

The EOQ is specifically targeted at finding the point of greatest return, where the savings generated by larger orders combined with the carrying costs for those items is the lowest. As described earlier, this point is the intersection of the Carrying Cost and Order Cost lines. To the left of this point, carrying costs are lower, but the price per item is significantly higher. To the right of this intersection, the carrying costs for the items are higher, but the order costs have decreased slightly, failing to offset the increased carrying costs. It is important to note that the EOQ generates an idealized value that may not be possible in the real world (i.e., fractions of items or quantities not allowed by manufacturers). Moving just a little to the left or right of the intersection will still allow a company to realize much of the savings from identifying an EOQ.

Assumptions of the EOQ Model

The EOQ model involves some assumptions that must hold true for the model to deliver the desired results:

- The model must be calculated for one product at a time.
- The demand must be known and constant throughout the year.
- The delivery replenishment lead time is known and does not fluctuate.

- Replenishment is instantaneous. There is no delay in the replenishment of the stock, and the order is delivered in the quantity that was demanded (i.e., in one whole delivery).
- The purchase price (i.e., unit cost) is constant and no discounts or price breaks are factored into the model.
- Carrying cost is known and constant.
- Order cost is known and constant.
- Stockouts are not allowed

Practical Considerations of EOQ

As mentioned earlier, the assumptions outlined above rarely hold true over time in the real world. Supply chain managers typically need to consider aspects that might alter the way they use the EOQ model. Some of the more practical considerations which supply chain managers must consider include the following:

- **Volume Economies of Scale:**
  - Individual Item Purchase Price Discounts. These discounts provide a lower perunit cost when larger quantities are ordered. If the volume discount is sufficient to offset the added cost from carrying additional inventory, then ordering a larger volume may be a desirable option, assuming obsolescence will not be an issue. To facilitate this decision, enterprise resource planning (ERP) systems must be programmed with quantity discount logic to work with the EOQ formula to determine optimum order quantities.
  - Multiple-Item Purchase Price Discounts. EOQ is calculated for one product at a time and does not consider any discounts for multiple item purchases, which would lower the unit cost of an item. If you purchase a combination of items from a supplier you may be able to take advantage of a volume discount based on the total volume across all the items purchased rather than just an individual item's volume.
  - Transportation Freight-Rate Discounts. Carriers generally offer a rate discount for larger volume shipments. A general rule of thumb for transportation is that the larger the shipment, the lower the cost per unit. Ordering a larger quantity may mean that you can take advantage of full truckload shipment rates, which will lower the per unit transportation costs. These adjustments will vary the order cost at different order quantities, which is not accounted for in the standard EOQ model.

- **Constraints:**
  - Limited Capital. The EOQ model may generate an order quantity that the company does not have sufficient available funds to purchase at one time. Capital limitations, which the model does not consider, may require that supply chain managers reduce the order quantity.
  - Storage Capacity. Similar to limited capital, the EOQ model may generate an order quantity that the company does not have sufficient storage capacity to handle at one time. Storage capacity limitations, which the model does not consider, may also require that supply chain managers reduce the order quantity.
  - Transportation. The nature of the item being transported may dictate the need for specialized or dedicated transportation, which may in turn impact the quantity per order. Certain commodities may be susceptible to time, temperature, contamination, or other types of issues necessitating the use of dedicated transport conveyances to prevent commingling of products in a conveyance. Other products may be very high value and susceptible to theft requiring dedicated transport conveyances to ensure a direct (i.e., nonstop) secure delivery. In these cases, supply chain managers may want to increase order quantities to fill up the conveyance and to also make fewer shipments per year.
  - Obsolescence. The EOQ model may generate an order quantity that would create spoilage or obsolescence based on the item nearing or reaching the end of its lifecycle before consumption, because too much was ordered at one time. To resolve this issue, ERP systems may also include additional programming to determine the maximum order quantity for an item reaching the end of the product lifecycle.
  - Production Lot Size. The supplier may require the company to order an item in full production lot sizes, particularly if the supplier does not have any other customers for that item. Similarly, the company may want to order an item in full production lot sizes, for various reasons (to ensure a consistent quality, due to the lot size of a key raw material, etc.).
  - Unitization (i.e., buying in full pack, case, pallet configurations). Similar to production lot size, the supplier may require the company to order an item in full pack, case, or pallet configurations, particularly if the supplier does not have any other customers for that item. Similarly, the company may want to order an item in full pack, case, or pallet configurations for various reasons of its own.

As a result of these and other considerations, companies may calculate EOQ for use as a baseline and make management decisions on how the output is used in practice. Management overrides may be necessary in response to some of the considerations outlined above.

OTHER TYPES OF INVENTORY SYSTEMS

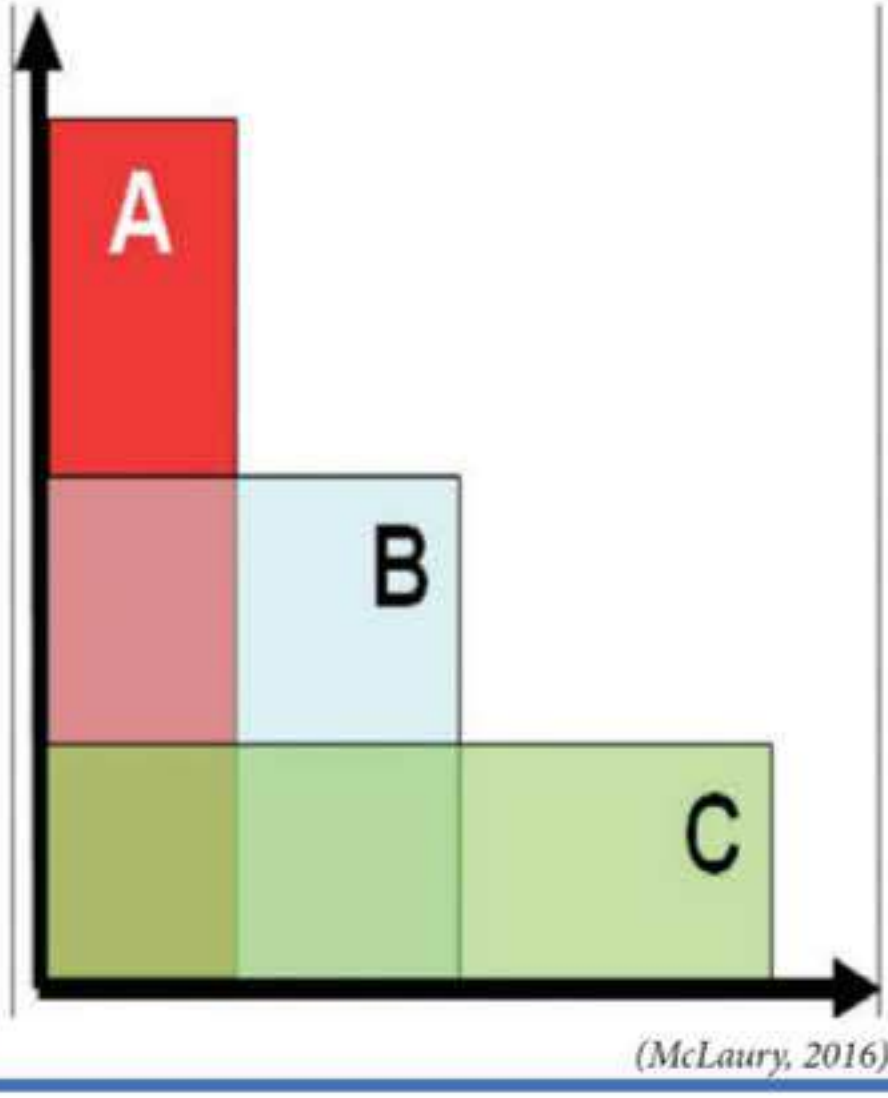
The following are other types of inventory systems that are essentially variations on the continuous and periodic review methods:

- **ABC system** is a type of inventory system that utilizes some measure of importance to classify inventory items and allocate control efforts accordingly. This system takes advantage of what is commonly called the 80/20 rule, which holds that 20% of the items usually account for 80% of the value. The ABC classification is typically in decreasing order of annual dollar volume (price multiplied by projected volume) or other similar criteria. The ABC principle states that effort and cost can be saved by applying less stringent controls on low volume/value items than that which is applied to high volume/value items. This principle is applicable to inventory, purchasing, sales, and the like. Not all items/products are equal, just like not all customers and not all suppliers are equal. Some are more important than others. An ABC classification helps to identify which inventory items are more important and which ones should receive the majority of efforts in optimizing inventory.

The typical breakdown of an ABC classification is as follows (figure 4.6):

- Category A contains the most important items and typically represents 10% to 20% of the items and 50% to 70% of the value.
- Category B contains moderately important items, and typically represents 20% of the items and 20% of the value.
- Category C contains the least important items, and typically represents 60% to 70% of the items and 10% to 30% of the value.

FIGURE 4.6

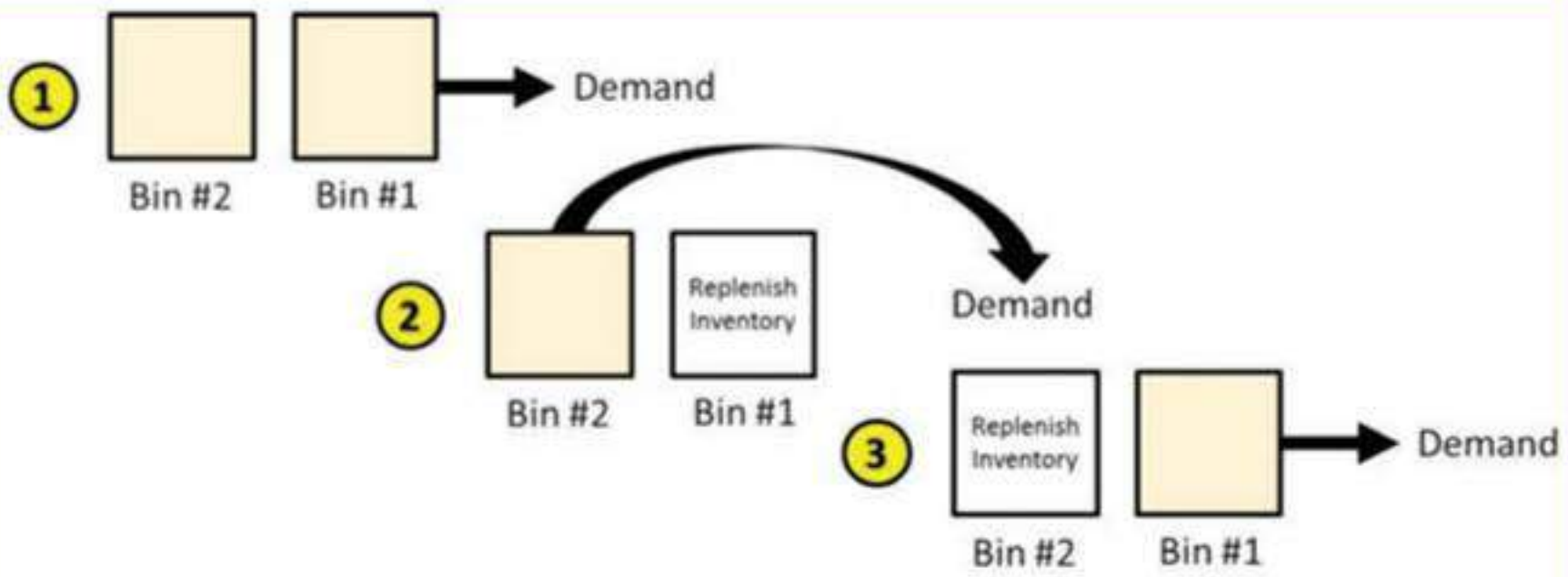


(McLaury, 2016)

- **Bin systems** is a type of inventory system that uses either one or two bins to hold a quantity of the item being inventoried (figure 4.7). It is mainly used for small or low value items. When the inventory in the first bin has been depleted, an order is placed to refill or replace the inventory.

The second bin is set up to hold enough inventory to cover demand during the replenishment lead time so as to last until the replacement order arrives.

FIGURE 4.7



(McLaury, 2016)

- **Target stock level** (TSL) is a type of periodic inventory review system. TSL is the level of inventory that is needed to satisfy all demand for a product or item over a specific time period.
  - TSL = [Demand × (Lead time + Review time)] + Safety stock
  - In a min-max inventory system, the TSL is the equivalent of the maximum.
  - It is equal to the order point plus a variable order quantity.
  - It is also known as an order-up-to-inventory level.
- **Base stock level systems** are a type of inventory system that triggers a replenishment order whenever a withdrawal is made from inventory.
  - Replenishment order quantity is equal to the quantity withdrawn from inventory.
  - This will maintain the inventory at a base stock level.
  - It is used primarily for very expensive items (e.g., airplane engines).
- **"Single-period" inventory model** is a type of inventory system in which inventory is only ordered for a one-time stocking. The objective is to maximize profit.

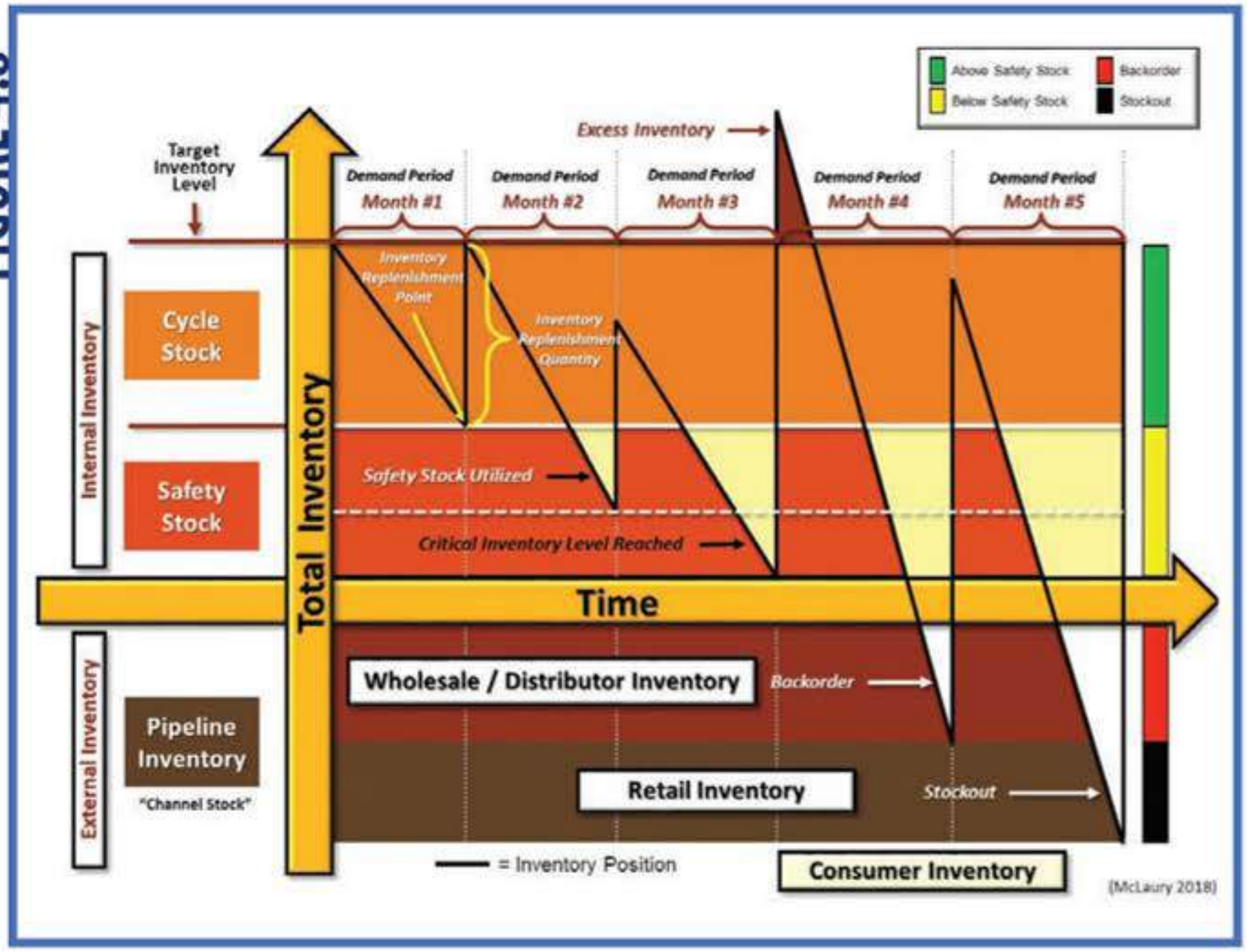
- Often referred to as the newsboy or newsvendor problem, because newspapers are usually printed only once per day in a certain quantity and immediately become obsolete when the next issue is printed the following day. Magazines suffer similar short product lifespans.

- This model is used by vendors preparing for a very small sales window (e.g., fireworks for the Fourth of July, Christmas trees, Halloween costumes, Easter decorations).

STOCK LEVELS AND REPLENISHMENT

Figure 4.8 looks rather complicated and can be intimidating, but it illustrates how the various types of stock relate to the process of supply and demand under a dynamically increasing demand pattern. For illustrative purposes, figure 4.8 represents finished goods only.

FIGURE 4.8



The top half of the figure shows the internal inventory, which consists of cycle stock and safety stock, while the bottom half of the figure shows the external pipeline inventory (or channel stock) divided

into Wholesale, Retail, and Consumer inventories for illustrative purposes. These stock levels comprise the total inventory as indicated by the vertical axis. The horizontal axis represents time moving forward from left to right.

Month #1: Starting near the top left of the diagram, the current inventory is exactly at the Target Inventory Level to begin the Demand Period for Month #1. As time moves forward through Month #1, inventory is depleted at a constant rate (as indicated by the black diagonal line) exactly as anticipated by the demand plan, and Month #1 ends by depleting the entire Cycle Stock as planned. Replenishment lead time is one month, and an inventory replenishment order was placed earlier according to the demand plan. The inventory replenishment order quantity is equal to the projected demand for the following month and is the Target Inventory Level. This projected demand is represented by the peak at the beginning of Month #2. The replenishment order arrives on time and returns the inventory back up to the target inventory level to begin the demand period for Month #2.

Month #2: As time moves forward through Month #2, inventory is depleted at a rate greater than anticipated by the demand plan and all of the Cycle Stock and some of the Safety Stock is used to meet customer demand. **As this is the very purpose of maintaining safety stock inventory, this is perfectly acceptable. In fact, if safety stock is never used to adjust for the uncertainty in demand, then safety stock is not needed and should be eliminated**. An inventory replenishment quantity equal to the projected demand was placed at the beginning of the month. The replenishment order arrives on time; however, since actual demand was greater than projected demand and necessitated use of some of the Safety Stock, the replenishment order quantity is not sufficient to return the inventory to the target inventory level to begin the demand period for Month #3. The demand might not be adjusted yet in order to see if the increase in demand was temporary or might be persistent, or the projections might be adjusted even without longitudinal data.

Month #3: As time moves forward through Month #3, inventory is again depleted at a rate greater than anticipated by the demand plan. All of the Cycle Stock and all of the Safety Stock is used to fill the unexpected volume of customer demand. Again, as this is the purpose of safety stock inventory, this is still acceptable. Month #3 ends at a critical point as all of the internal inventory (i.e., Cycle Stock and Safety Stock) has been depleted. Recognizing that the company might be under-forecasting projected demand, in the absence of any additional or collaborative information about why demand is increasing, an inventory replenishment order is placed at the beginning of Month #3 to arrive at month-end, but for a quantity significantly larger than previous orders. The replenishment order arrives on time; however, since a significantly larger quantity was ordered than in previous months, the replenishment order quantity returns the inventory to a level in excess of the target to begin the demand period for Month #4. The black line at the end of Month #3 is above the target inventory level indicating that inventory is above, or in excess of, target.

Month #4: As time moves forward through Month #4, inventory is now being depleted at a rate even more significant than the previous two months. The company is now forced to use all of the Cycle Stock and all of the Safety Stock, and there are now Wholesaler/Distributor orders that cannot be filled as inventory is insufficient to satisfy the demand. The black line at the end of Month #4 is dipping into the Wholesale/Distributor inventory, indicating unfulfilled demand. These unfulfilled customer orders are known as "backorders."

Wholesalers/Distributors can/will continue to sell their pipeline inventory to their downstream supply chain partners (i.e., Retailers and Consumers) until their stocks are depleted as well. At this critical point, customer service has been negatively impacted as the company's immediate customers (i.e., Wholesalers/Distributors) have unsatisfied demand.

Again, recognizing that they may be under-forecasting demand, the company placed an inventory replenishment order at the beginning of Month #4 to arrive at month-end for a quantity similar to what was ordered at the beginning of Month #3. The replenishment order arrives on time; however, since actual demand was once again significantly greater than projected demand and all Excess, Cycle, and Safety Stock were depleted, leaving the product on backorder with the Wholesalers/Distributors, the replenishment order quantity is not sufficient to return the inventory to the target inventory level to begin the demand period for Month #5. The black line at the end of Month #4 stops below the target inventory level.

Month #5: As time moves forward through Month #5, inventory is again being depleted at the accelerated rate experienced in Month #4 and all internal and external inventory, including Wholesaler/Distributor and Retailer inventory, is fully depleted, creating a stockout in the marketplace. A stockout is the most serious inventory situation as it means that there is no inventory available anywhere internally or externally to support any further demand. At this point, customer service is significantly and critically impacted at all levels. Damage to the brand and the company reputation may occur, and business may be lost to competitors. Lost business may be temporary until replenishment inventory is available, or this lost business might be permanently lost to competitors.

Collaborative Planning, Forecasting and Replenishment (CPFR): Figure 4.8 illustrates the scenario for inventory chasing demand, reacting to an increasing demand pattern without any additional information or collaboration with your trading partners to know what is really happening. CPFR is "a collaboration process whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers. Collaboration encompasses business planning, sales forecasting, and all operations required to replenish raw materials and finished goods. A process philosophy for facilitating collaborative communications."[1] It is a process designed to avoid or mitigate the type of situation depicted in figure 4.8. CPFR helps an organization to be proactive and get out in front of the situation before it spirals out of control.

INVENTORY OPTIMIZATION

All of the methods and approaches mentioned in this chapter look to optimize the inventory held by a company. The optimization point is the intersection of inventory costs and customer service goals, and this point will be varied for different companies based on their capacities and philosophy. Identifying the appropriate inventory buffers is essential in realizing a company's mission, but these buffers can be set for individual sites or for an entire system. In single-echelon inventory optimization, a distribution site is treated essentially as an island that holds needed inventory to meet the needs of its customers, separate from upstream components. In multi-echelon inventory optimization (MEIO), inventory needs are established across various sites and levels of the supply chain, upstream and downstream, to meet the needs of the entire system's customers. MEIO initiatives typically reduce inventory by 10% to 30% while improving service levels, resulting in dramatically improved profitability and more satisfied customers. MEIO involves identifying many variables and constants, but the result is significant information for improving inventory operations.

INPUTS:

- **Desired Service Level** is normally a user provided input. The desired service level depends on the item in question: its sales attributes, demand, profitability, and associative relationship to the other items. Users normally define groups of items that have similar attributes and desired service levels.
- **Demand** is the historical and projected demand for the item.
- **Supply** is the historical and projected supply of the item.
- **Supply Lead Time** is the historical lead time of the supplies. The lead time may vary for every order that is fulfilled even when using the same item/vendor/distribution center combinations. This time-series data allows for the variability of such lead time and helps the inventory optimization engine determine the probability that a specific projected supply will be realized on the needed date.

OUTPUTS:

- Recommended safety stock levels
- Recommended safety stock locations
- Recommended reorder levels
- Recommended order quantities

Benefits:

- Inventory can typically be reduced by 10% to 30% by rightsizing inventory held at all stages (i.e., echelons) of the supply chain.
- MEIO programs normally reduce overall inventory while meeting or improving service levels.
- Decreasing the amount of on-hand inventory frees up capital that would otherwise be tied up in inventory.
- The total logistics burden includes costs for warehousing, insurance, labor, expedited shipping, and so forth. Eliminating inventory removes its associated logistics cost, which can amount to 10% of inventory value.
- Obsolete inventory is a write-off that represents lost revenue. Most companies can expect to save a portion of the COGS of optimizable obsolete inventory. Savings can range from a few percentage points to substantially higher for companies with many new product introductions or high rates of product churn.
- Shortages and stockouts can be reduced. These inventory issues lead to both fulfillment delays and permanently lost revenue due to cancelled orders. Lowering the lost order rate results in higher revenue generation. MEIO can reduce the percentage of permanently lost orders within the optimizable inventory by a significant amount.

INVENTORY CONTROL TOOLS

Many inventory control tools exist in today's market. Those that incorporate barcode tracking or radio frequency identification (RFID) tagging generally offer the most flexibility and ease of use.

Barcode Systems

Barcode systems help businesses and organizations track products, prices, and stock levels for centralized management in a computer software system allowing for incredible increases in productivity and efficiency. The lines and patterns on a barcode are actually representations of numbers and data, and their use allows basic information about a product to be read by an optical scanning device, a barcode scanner, easily and automatically. The scanner is connected to a computer system that supplies information to the scanner (e.g., the price of the item in a grocery store), and receives information from the scanner (i.e., the product sold) and, therefore, removes it from inventory. The

computer control of the barcode system vastly reduces the time it takes to record necessary information and eliminates the potential for human data entry error.

Barcodes started out with simple one-dimensional (linear) designs, consisting of basic black lines that could only be read by specially designed barcode scanners. However, today barcodes come in many shapes and sizes and a wide range of designs; many can even be read by mobile phones and other devices. The barcodes can be classified in one of two categories: linear (1D) and two dimensional (2D).

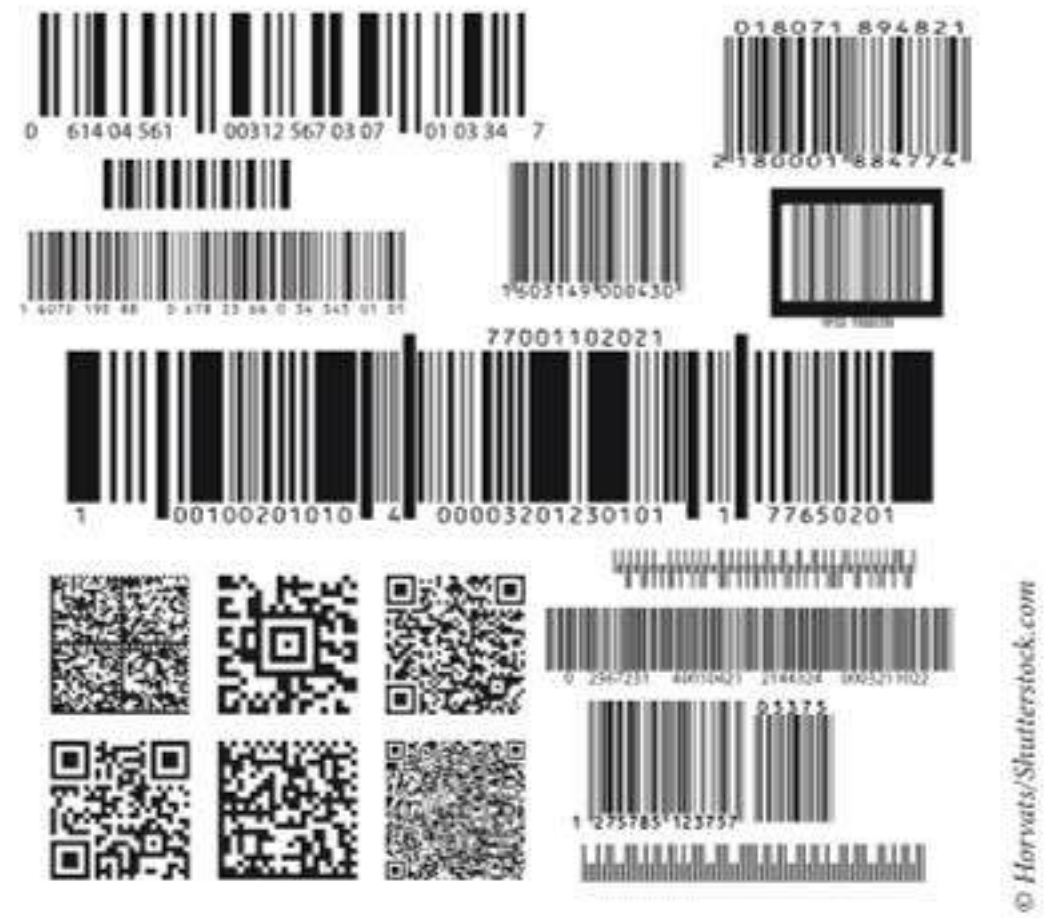
Linear (1D) Barcodes are "a series of alternating bars and spaces printed or stamped on parts, containers, labels, or other media, representing encoded information that can be read by electronic readers. A bar code is used to facilitate timely and accurate input of data to a computer system."[1]

Barcoding is "a method of encoding data using bar code for fast and accurate readability."[1]

Barcoding inventory is a quick and efficient way of monitoring stock levels. Data error rates for barcoding are significantly less than those for manual methods, and efficiency rates are higher as less time is required not only to set up initial data, but also to gather and generate reports.

Linear barcodes do have some limitations: they are one dimensional, can only be read horizontally, and can only hold a maximum of 85 characters. The 1D barcode is nearing the end of its lifespan. As 2D scanners become more affordable and newer technology becomes more accessible, the linear barcode will become obsolete.

2D Barcodes are graphical images that store information both horizontally and



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vertically. As a result of that construction, 2D barcodes can store over 7,000 characters, allowing transmission of almost two paragraphs of information.

By moving to 2D barcodes, businesses are able to convey much more complex information, like expiration dates and serial numbers, without the need for any additional scanning. 2D barcodes allow users to customize the data captured and the way it is stored. This flexibility increases the ability of organizations to achieve their specific goals and create a database catered to their needs.

2D barcode scanners are much more versatile than linear barcode scanners in that they can scan from any angle. They can also scan multiple barcodes in one scan.

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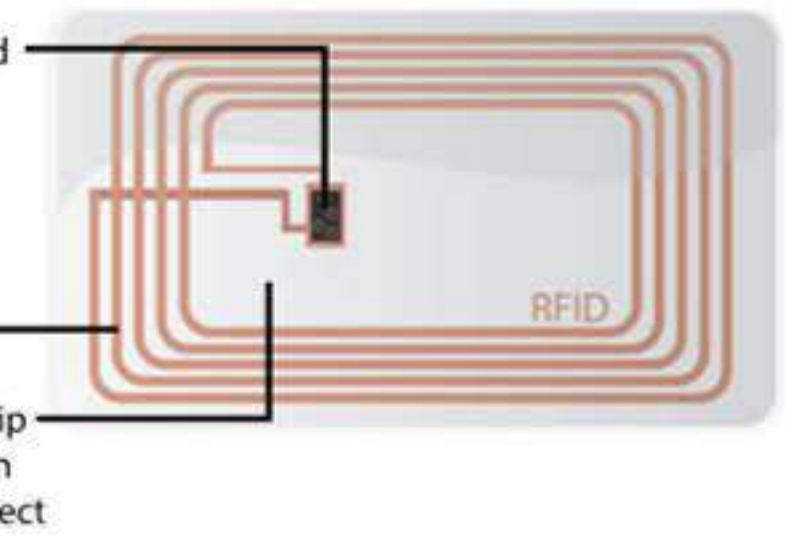
A barcode reader (or barcode scanner) is an electronic device that can read barcodes and transmit the data to a computer. These might be handheld cordless devices, corded devices that attach directly to a PC's USB port, or computers with integrated laser scanners.

A basic inventory tracking system consists of software and a barcode scanner. Inventory items (e.g., finished products or raw materials) have barcode labels affixed so that when an item is removed from stock, the barcode can be scanned in order to reduce the available count in the inventory tracking software, instead of having to enter the information manually. Real-time access to location, quantity, destination, and so forth, allows inventory managers the flexibility to make the decisions outline earlier in this chapter.

Radio Frequency Identification

Radio frequency identification (RFID) is the successor to the barcode. RFID is "a system using electronic tags to store data about items. Accessing these data is accomplished through a specific radio frequency and does not require close proximity or line-of-sight access for data retrieval."[1] The RFID tags can be either active or passive. An active RFID tag broadcasts information and contains its own power source. A passive RFID tag does not send out data and is not self-powered. Electromagnetic energy is transmitted from the reader in order to obtain the information from passive tags. As the tags pass through/near the reader, the reader pulls information from the tag (e.g., a security tag on a product that sends a signal when it passes through a reader at the front of a store).

The biggest advantages that RFID has over barcodes is that RFID does not require direct line of sight to read a tag, it can provide much more information, and the information on the tag is updatable.



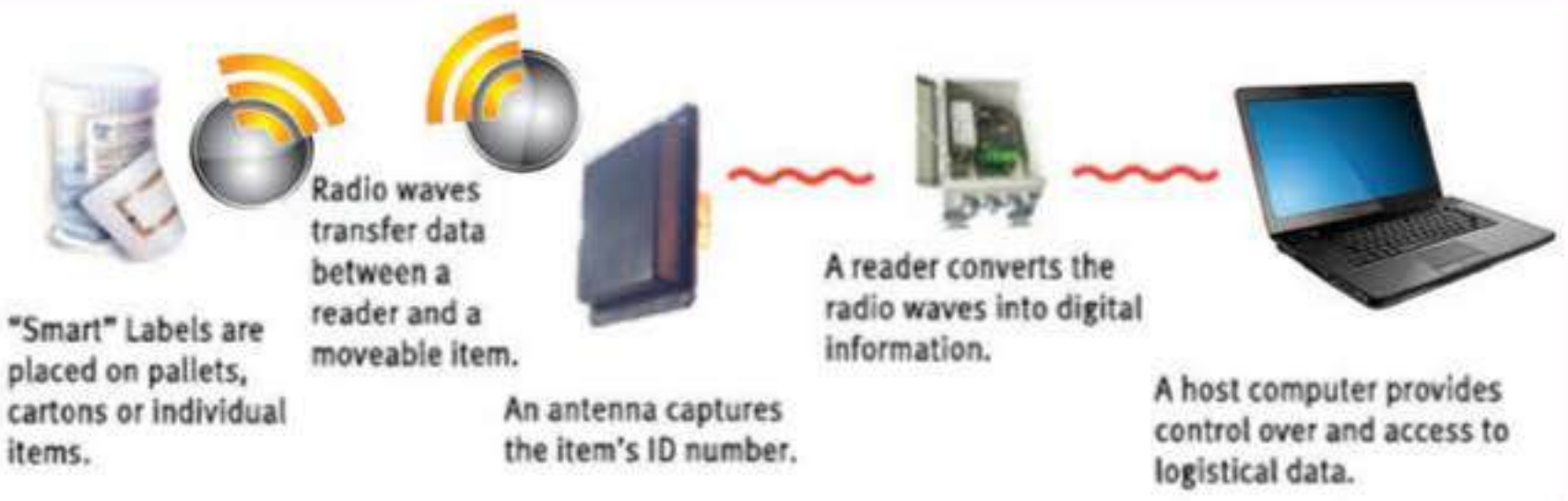
RFID works like a barcode, but unlike the barcodes you see in retail stores that have to pass in front of scanners to be identified, an RFID tag is triggered by a radio frequency from an antenna and transmits informaiton back via radio frequency through the antenna to a reader that converts it into digitial informaton for use by a software package (see figure 4.9). Significantly more information can be programmed onto an RFID tag than can be relayed with a linear barcode. A linear barcode usually provides a product code or serial number, whereas an RFID tag can include more and different kinds of information such as lot number, expiration date, and even manufacturing instructions.

RFID tags have excellent potential for warehousing and asset tracking, because they can relay information over a longer distance (up to 100 meters in some cases), making it possible to know exactly how much of something you have in real time, and reducing the risk of miscounted inventory.

Some of the ways RFID can be utilized in the supply chain include:

- **Materials Management:** Goods can be counted and logged automatically as they enter the supply warehouse. Items, cases, and/or pallets traditionally used barcodes, which workers

FIGURE 4.9



(McLaury, 2016)

had to scan indiviudally when receiving them in the warehouse. With RFID, those items can be read all at once by a portal reader placed at the dock door as they are unloaded from the truck. Unloading an inbound container which may take a least a couple of hours to individually scan, sort, and count, may take less than 30 minutes with RFID-tagged cartons.

- **Manufacturing:** Assembly instructions encoded on RFID tags can provide information to computer-controlled assembly devices even while the product is moving down the line in production.

- **Distribution:** Shipments leaving the distribution center can automatically update the enterprise resource planning (ERP) system to trigger an invoice to the customer, notify the customer of delivery tracking information, and initiate a replenishment order with the supplier.

- **Retail Store:** Use of these tags can eliminate checkout lines. If a grocery store tagged every item with an RFID tag, shoppers could place items in their carts and then simply roll the cart past the reader to complete their purchase. If that shopper has a store card with an RFID tag, the reader could even automatically charge the customers card. Just like with barcodes, RFID systems could update inventory as soon as a purchase is complete; however, the RFID tags could also help employees idenitfy products customers took off the shelf and then placed onto a different shelf after changing their minds. These misplaced products are still technically in the store inventory because they have not left the store, but they have been effectively removed since customers will not find them until they are placed back where they belong. RFID tags could alert a reader to an incorrect position and even inform an employee about where it belongs, information a barcode cannot supply.

Unfortunately, RFID hasn't yet gained much traction due mainly to the high cost of the tags, which cost as much as $0.20 each, compared to barcodes, which costs a fraction of a penny each. The other major hurdle facing mass adoption of RFID technology is that in order to reap the real rewards of RFID, the entire end-to-end supply chain must implement RFID technology. At its current price, this is an extremely expensive endeavor that requires purchasing new equipment at every level of the supply chain.

Software

The backbone of inventory management in any organization is the inventory control software that maintains the systemic record of product location, quantity, inventory transactions, and resupply orders. While some organizations are small enough to use a spreadsheet as their primary inventory management tool, most are using databases with a menu-driven user interface. Some organizations use off-the-shelf software, while others have internal development teams. Business model differences call for different solutions.

Hardware

The software requires input to manage the inventory. Servers, desktops, dumb terminals, RF devices, asset tags, RFID tags, scannable barcode label printers, and point of sale devices can all play a role as an inventory management tool. Selecting the right tools to balance labor versus infrastructure is part of the art of inventory management.

MEASURING INVENTORY PERFORMANCE

Companies use several measurements specifically for analyzing inventory:

- **Units:** the number of units available
- **Dollars:** the amount of dollars tied up in inventory
- **Days/Weeks/Months of Supply:** (Avg. on-hand inventory) / (Avg. usage)
- **Inventory Turns:** (Cost of goods sold) / (Average inventory at cost)

Inventory turnover is a measure of operational efficiency. Specifically, it tells you how many times inventory is being sold and purchased over a given time period. A low turnover rate may indicate overstocking, obsolescence, or deficiencies in the product line or marketing effort.

It is important to note that every dollar saved in inventory drops right to the bottom line as pure savings. It's a dollar-for-dollar savings for the company. Any dollar not spent on inventory is a dollar that can be invested in research and development, marketing and sales, dividends for shareholders, to take as profit, and so forth. This immediate effect on the bottom line is one reason why companies measure their inventory continuously and try to reduce their inventory investment as much as possible. Effective inventory management can potentially generate a significant amount of savings.

Other related measures that can indicate how well an inventory management system is working include the following:

- **Service Level** is "a measure (usually expressed as a percentage) of satisfying demand through inventory or by the current production schedule in time to satisfy the customers' requested delivery dates and quantities. In a make-to-stock environment, level of service is sometimes calculated as the percentage of orders picked complete from stock upon receipt of the customer order, the percentage of line items picked complete, or the percentage of total dollar

demand picked complete. In make-to-order and design-to-order environments, level of service is the percentage of times the customer requested or acknowledged date was met by shipping complete product quantities."[1]

- **Order Fill Rate** is "a measure of delivery performance of finished goods, usually expressed as a percentage. In a make-to-stock company, this percentage usually represents the number of items or dollars (on one or more customer orders) that were shipped on schedule for a specific time period, compared with the total that were supposed to be shipped in that time period. In a make-to-order company, it is usually some comparison of the number of jobs or dollars shipped in a given time period (e.g., a week) compared with the number of jobs or dollars that were supposed to be shipped in that time period."[1]

- **Line Item Fill Rate** is the total number of line items filled divided by the total number of line items ordered. This metric applies to products or orders that contain multiple products.

SUMMARY

- Inventory serves a useful purpose in the supply chain; however, companies can help minimize the need for inventory by carefully managing those factors that drive inventory levels up. Every dollar saved in inventory drops right to the bottom line as pure savings.

- There are four main categories of inventory: raw materials; work in process (WIP); finished goods; and maintenance, repair, and operating (MRO) supplies.

- There are four basic function of inventory: to meet customer demand (cycle stock), to buffer against uncertainty in demand and/or supply (safety stock), to decouple supply from demand (strategic stock), and to decouple dependencies in the supply chain.

- There are three main inventory stocking levels: cycle stock, safety stock, and strategic stock.

- Pipeline inventory may have an impact on decisions that companies make about how to manage and control their inventory resources

- There are six categories of costs associated with inventory: direct costs, indirect costs, fixed costs, variable costs, order costs, and carrying costs.

- Inventory items can be divided into two main types: independent demand and dependent demand items. The systems for managing these two types of inventory differ significantly:

  - The two classic systems for managing independent demand inventory are continuous review and periodic review systems.
  - The systems for managing dependent demand inventory are material requirements planning, kanban, and drum-buffer-rope.

- The reorder point is the lowest inventory level at which a new order must be placed to avoid a stockout. The reorder point is set at a level of remaining inventory that is enough to cover all of the demand that is projected to occur during the lead time necessary to receive the replenishment supply.

- The economic order quantity (EOQ) minimizes total annual order costs and carrying costs. Even if all the assumptions don't hold true in the long term, the EOQ gives a good indication of whether or not current order quantities are reasonable.

- Inventory optimization is finding optimal inventory strategies and policies related to customer service and return on investment over several echelons of a supply chain.

- Inventory control tools help to facilitate the management of inventory, improving efficiency and reducing errors.

- Measuring inventory performance is essential as companies cannot improve what they do not measure. Companies measure their inventory in an effort to reduce their inventory investment and generate savings.

REFERENCE

[1] *APICS Dictionary* (14th ed.). (2013). Chicago, IL: APICS. www.apics.org

SOURCE

Chapter 5

Purchasing Management

CHAPTER OUTLINE

Introduction
Defining Procurement and Purchasing
The Basic Purchasing Process
Financial Significance of Purchasing
Make versus Buy Decision
Supplier Selection
Organization of Purchasing
International Purchasing
Government and Nonprofit Purchasing
World-Class Procurement

INTRODUCTION

"Purchasing is a managerial activity that goes beyond the simple act of buying. It includes research and development for the proper selection of materials and sources, follow-up to ensure timely delivery; inspection to ensure both quantity and quality; to control traffic, receiving, storekeeping and accounting operations related to purchases."[1]

Purchasing has become a critical function within most organizations, responsible for spending as much as half of the revenues that the company receives from sales, in order to obtain the materials and services necessary for the company to succeed. More money is often spent on the purchase of materials and services than for any other expense.

In business today, the purchasing function has evolved into a core competency within most companies, performing the vital role of finding and developing suppliers, and bringing in external expertise that can be highly valued by the company.

DEFINING PROCUREMENT AND PURCHASING

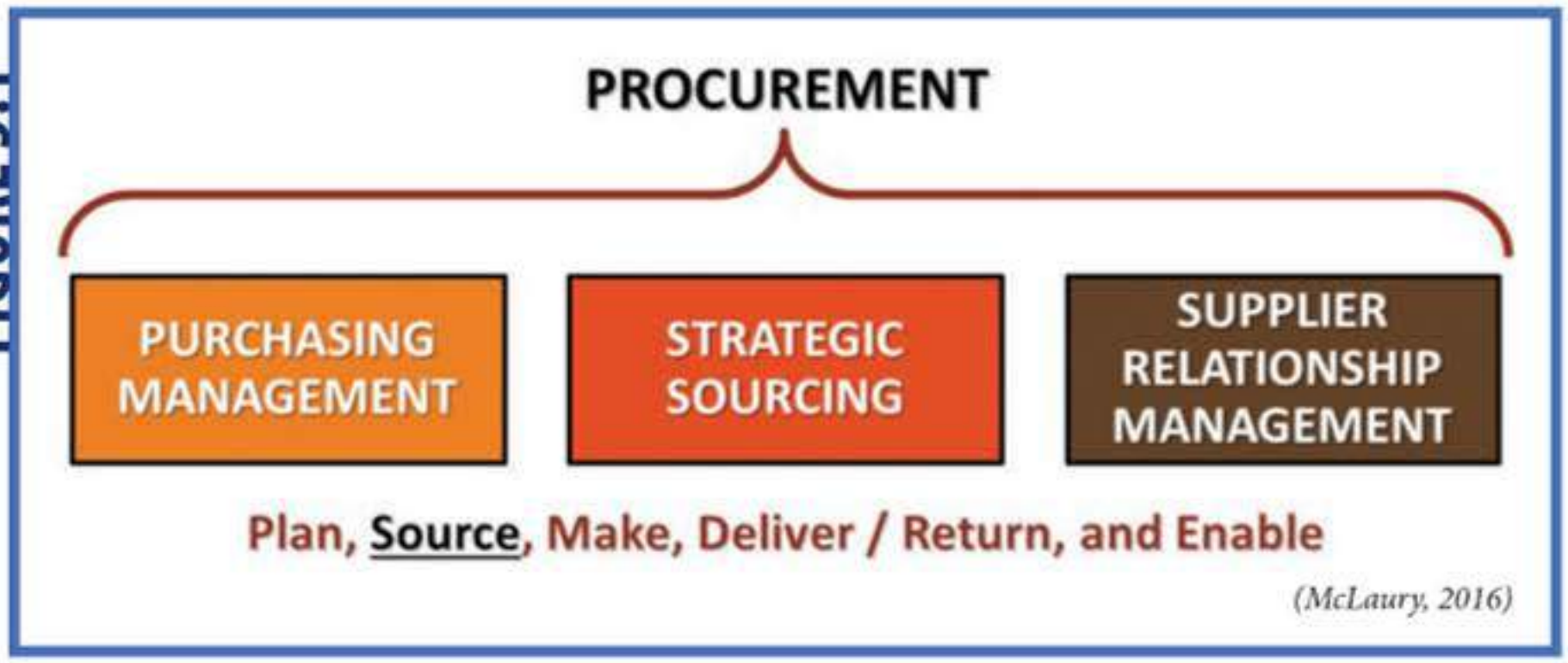
PROCUREMENT: The process of selecting and vetting suppliers, negotiating contracts, establishing payment terms, and the actual purchasing of goods and services.

- Procurement is concerned with acquiring all of the goods, services, and work that is vital to an organization.
- Procurement is the overarching or umbrella term within which the functions of purchasing management, strategic sourcing, and supplier relationship management can be found (see figure 5.1).

The objectives of a world-class procurement organization are:

1. To support the organization's goals and objectives
2. To support operational requirements
3. To manage the procurement process and the supply base efficiently and effectively
4. To develop strong relationships with key suppliers
5. To develop strong relationships with other functional groups within the organization

FIGURE 5.1



PURCHASING: The action of obtaining merchandise, capital equipment; raw materials, services, or maintenance, repair, and operating (MRO) supplies in exchange for money, or its equivalent.

- Purchasing is the process of how goods and services are ordered.
- Purchasing is typically described as the transactional function of procurement for goods or services.

PURCHASING is also a term commonly used in industry to represent the function of, and the responsibility for, procuring materials, supplies, and services for an organization.

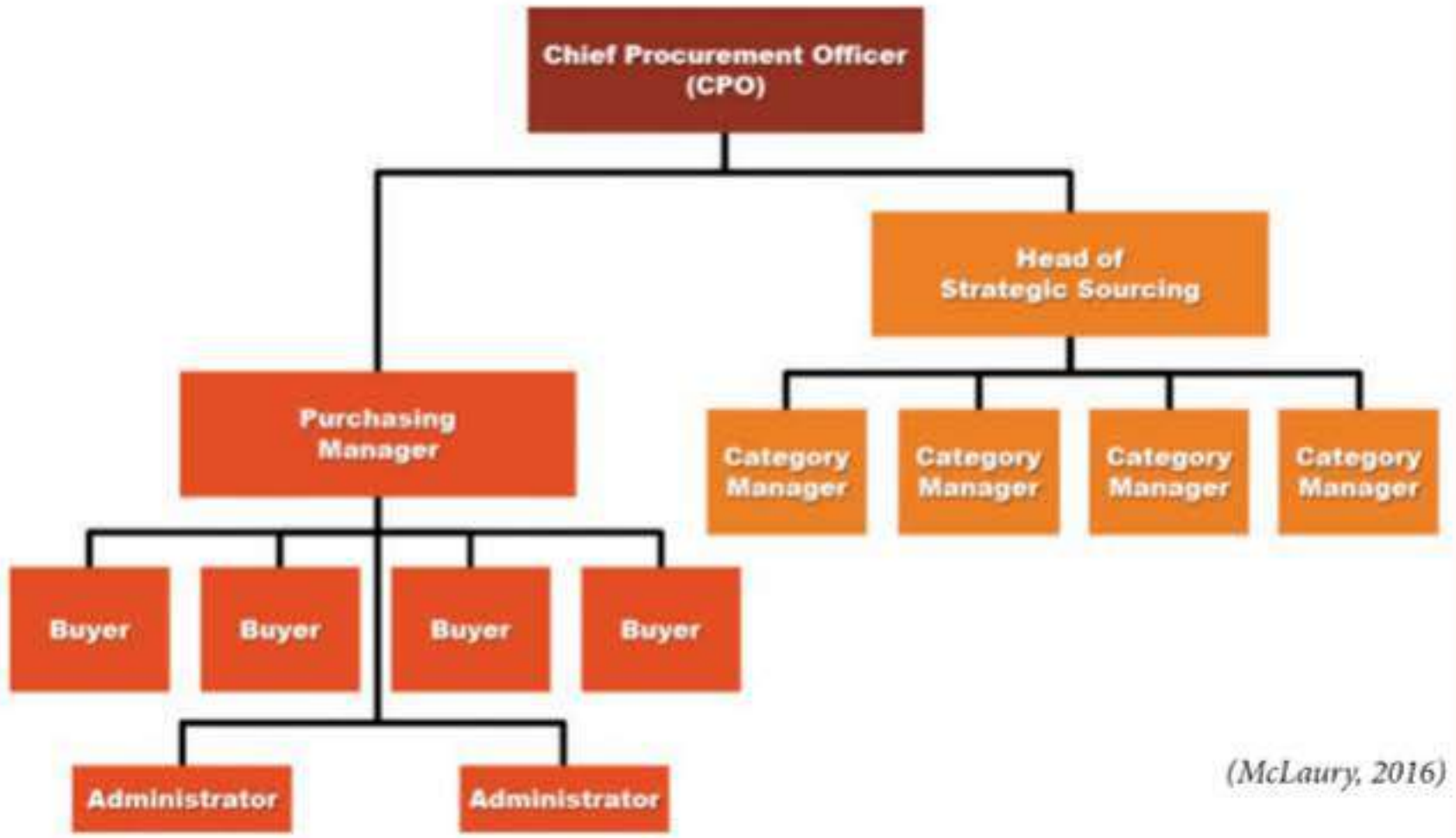
- It can be a separate department or organization within a company, or it can be part of the supply chain management department or organization within a company.
- Many companies have a Chief Procurement Officer or Chief Purchasing Officer as part of their executive leadership team. See figure 5.2.

Purchasing Terms

The following are some key purchasing terms and definitions used in this text:

- **E-PROCUREMENT:** The business-to-business purchase and sale of supplies and services over the Internet.
- **MERCHANTS:** Wholesalers and retailers who purchase for resale.

FIGURE 5.2



(McLaury, 2016)

- **Industrial Buyers:** Individuals within an organization who purchase raw materials for conversion into products, and/or purchase services, capital equipment, and MRO supplies.

- **Contracting:** A term often used for the **acquisition of services**

- **Supply Management:** A newer term that encompasses all acquisition activities beyond the simple purchase transaction.

  – The "Identification, acquisition, access, positioning, and management of resources an organization needs or potentially needs in the attainment of its strategic objectives." *Institute of Supply Management (ISM)*

- **Request for Information (RFI):** "An inquiry to a potential supplier about that supplier's product or service for potential use in the business. The inquiry can provide certain business requirements or be of a more general exploratory nature."[1]

- **Request for Proposal (RFP):** A detailed low-level capabilities evaluation document that is used to precisely determine a supplier's capability and interest in the production of a customized product or service.

- **Request for Quote (RFQ):** A document generally used to solicit bids from interested and qualified suppliers for goods or services that the organization needs to obtain.

- **Bid:** A tender, proposal, or quotation submitted in response to a solicitation from a contracting authority.

- **Competitive Bidding:** Offers submitted by multiple individuals or firms competing for a contract, privilege, or right to supply specified services or merchandise.

- **Purchase Requisition:** Document that defines the need for goods and/or services. An internal document. Does not constitute a contractual relationship with any external party.

- **Purchase Order (PO):** The buyer's offer to the supplier to acquire goods or services. Becomes a legally binding contract only when accepted by the supplier.

The Role of Purchasing in an Organization

The primary goals of purchasing are to:

1. Ensure an uninterrupted flow of materials and services for the company.

2. Obtain materials and services at the best value, meaning the best quality at the best prices, with the best service, in the most economic order quantities.

3. Secure reliable alternative sources of supply as necessary to manage risk.

4. Optimize customer satisfaction by using the knowledge and expertise of the supply base to provide high quality at the lowest total cost.

   - Actively seek better materials and reliable suppliers

   - Work with the expertise of strategic suppliers to improve quality and materials and finished goods

   - Involve suppliers and purchasing personnel in new product design and development efforts

5. Maintain good relationships with suppliers.

THE BASIC PURCHASING PROCESS

The industrial purchasing process can vary from one organization to another, but there are some key common elements, and a number of inputs, interfaces, communications, and outputs involved in the process.

The process usually starts with a demand for a material, component, or a service and progresses through the following steps:

1. A need is identified, and a **purchase requisition** is created/issued.
   - Request for goods or services submitted to the procurement/purchasing organization for action.
   - Typically initiated by a user within an organization.
2. Obtain authorization as necessary.
   - A purchase requisition may be routed to an authorized approver(s) depending on the type of material or service being requested and/or the dollar value of the request.
   - Multiple authorizations, in a prescribed sequence, to various management levels of the organization, may be necessary if the value exceeds a specific predetermined threshold.
3. Identify and evaluate potential suppliers.
   - May be determined from a list of company-approved suppliers.
   - Alternatively, may use a **request for information** (RFI) to collect information from potential suppliers on their capabilities and interest in supplying the material or service.
4. Make supplier selection.
   - If the buyers already knows which supplier they will buy the item from, move to the next step.
   - If not, a **competitive bidding** process may be initiated. A request for proposal (RFP) or a request for quotation (RFQ) may be issued to qualified suppliers, to identify proposed alternatives for supplying the desired material or service, and to obtain price and availability information.
     a. Buyer issues a **RFP** for items that have not been previously purchased, or not purchased from a specific supplier being evaluated. Supplier(s) provides the proposal to supply the item(s) including price and delivery.

b. Buyer issues a **RFQ** for routine or repeat purchased items. Supplier(s) provides a price and delivery quote on the specific item(s) requested.

- A supplier is selected from the RFP or RFQ **bids** received based on criteria determined by the buyer, including price, availability, quality, delivery costs.

5. A **purchase order** (PO) is created and delivered to the supplier.

   - A PO is generated and forwarded to the supplier to inform the supplier of the intent to purchase.

   - The purchase order will identify the item(s) to be procured, the quantity required, the requested delivery date(s), and the price to be paid. It will also identify the delivery location and any terms and conditions that relate to the order.

   - The PO is the buyer's formal offer to the supplier to obtain the item(s).

   - The PO becomes a binding contract only when accepted by supplier.

6. Supplier confirmation of the PO

   - The supplier formally agrees to supply the item(s) per the specifications, terms, and conditions described on the PO.

   - The PO then becomes a legally binding contract between the buyer and the supplier for the item(s) specified.

7. Fulfillment

   - The supplier ships/delivers the item(s) to the buying organization as per the PO.

8. Receipt of goods

   - Once the item(s) arrives at the designated location, the buyer will typically conduct some form of receipt process where the item(s) are checked to ensure that they conform to the details of the PO, including quality and quantity.

   - A confirmation of receipt may also be sent to the supplier.

9. Invoice

   - Supplier prepares an invoice for the item(s) ordered and transmits to the buyer. The invoice either accompanies the item(s) or is sent separately.

10. Reconciliation

    - The invoice may need to be reconciled to the purchase order and goods receipt before payment is made. This step is sometimes referred to as a "three-way match."

11. Payment

    - Invoice payment processed using an appropriate payment method assuming the item(s) is received and meets all of the criteria established on the PO.

12. Reclamation of taxes

    - In some situations, the supplier will be obligated to charge a tax, but the buyer may be eligible to retain some or all of the tax based on corporate status.

13. Close out the PO

    - If the PO has been received complete, and all terms and conditions have been met, then it should be closed out in the purchasing system (whether manual or automated).

14. Analysis

    - Measurements of the efficiency and accuracy of the procurement process.

    - Specific PO data and information captured and used during periodic supplier performance meetings.

In leading procurement organizations, every step will be completed, although some will be completed automatically by the e-procurement system using defined rules, particularly for low-dollar value or nonstrategic purchases

e-Procurement

The "electronic" requisitioning, receiving, and reconciliation of the received goods, e-procurement involves the automation of the nonstrategic and transactional activities that would otherwise consume the majority of a buyer's time. It provides increased enterprise level visibility of all purchases.

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The term describes the automation through web-enabled tools of many elements of the purchasing process including:

- The issue, collection, and analysis of bids
- Execution and analysis
- Award of business via reverse auction

e-Procurement tools typically automate all or part of the following processes:

- Solicitation development tools (i.e., RFI, RFP, RFQ)
- Reverse auctions

e-Procurement may not work well for every type of purchase. Examples include the procurement of critical items that are only available through a few suppliers; where procuring an item involves complex negotiations; or where the potential to lower costs through an e-procurement process is minimal.

Advantages of an e-Procurement System

- **Time savings:** A reduction in the time between recognizing the need for an item and the release and receipt of an order for that item
- **Cost savings:** Lower overhead costs in the purchasing area
- **Accuracy:** A reduction in errors; a virtual elimination of manual paperwork and paperwork handling
- **Real time:** Improved communication both within the company and with suppliers
- **Mobility:** Access to purchase requisition and purchase order information through the use of mobile devices and the internet, allowing actions to be taken regardless of where a person is located at any given time
- **Trackability:** The ability to track the status of purchase requisitions, orders, and information
- **Management:** Allows purchasing personnel to spend less time on processing of purchase orders and invoices, and more time on strategic value-added purchasing activities

- **Benefits to the suppliers:** Customer orders can be received and confirmed faster by the supplier, and receipts and invoices can be processed faster by the buyer, facilitating the supplier's receipt of revenue.

Small Value Purchases

Purchases of small value, noncritical items may take as much time to process as purchases of higher value, critical items. In an effort to minimize the amount of valuable purchasing resource time spent on small value purchases, there are some tools and techniques that companies can use to reduce this processing time and cost. These tools and techniques will allow the purchasing group to transfer some of the routine transactional purchasing activities for small value purchase to users or others within the company, thereby freeing up time for these valuable purchasing resources to work on more critical or strategic purchasing activities.

- **Credit Card/Corporate Purchasing Card (P-card):** A form of company charge card that allows goods and services to be procured without using a traditional purchasing process

- **Blanket or Open-End Purchase Orders:** A purchase order that the buyer negotiates with its supplier, which can incorporate multiple delivery dates over a period of time (often a year). It is typically used for frequently needed expendable goods. Once negotiated, authorized users within the buyer's company can arrange for the necessary items, quantities, and delivery dates directly with the supplier.

- **Blank Check POs:** A term used to describe a situation in which an usually high level of trust is afforded to the supplier by the buyer. The supplier can supply items to the buyer as needed without confirming pricing in advance. This may be used when the buyer is not exactly sure what item(s) will be needed and cannot, therefore, create a blanket PO.

- **Petty Cash:** An accessible amount of money kept by an organization for expenditure on small items. A typical example of when this might be used is a company sending someone out with petty cash to buy coffee and donuts for a business meeting.

- **Stockless Buying or System Contracting:** An arrangement in which a supplier holds the items ordered by the buyer in its own warehouse, and releases them when required by the buyer.

- **Standardization and Simplification of Materials and Components:** The concept of limiting the alternatives or options of some small value purchases in order to maximize the volume and potentially obtain better pricing. Example: creating a catalog or listing of a set number and type of office supplies to be order from a supplier.

- **Accumulating Small Orders to Create a Large Order:** The concept of volume consolidation for small value purchases. Example: having an administrator collect all of the individual departments' office supply needs throughout the month and placing one monthly order for delivery rather than allowing multiple deliveries.

- **Using a Fixed Order Interval:** Establishing a set schedule with a supplier to deliver a predetermined amount of inventory of an item. Example: water supplier delivers a fixed number of water bottles for the water cooler in a department on a fixed time schedule (e.g., delivers two 10-gallon water bottles to the XYZ Department every Monday morning).

FINANCIAL SIGNIFICANCE OF PURCHASING

Purchasing activities can have a significant and profound impact on the financials of an organization. The following are a few examples of the financial significance of purchasing.

Profit-Leverage Effect

The profit-leverage effect states that a decrease in purchasing expenditures directly increases profits before taxes (assuming no decrease in quality or purchasing total cost). The bottom line impact is a dollar saved is a dollar of profit to be used for such things as shareholder dividends, employee pay increases, investments, company reinvestments in R&D, or marketing and sales, among others.

- As shown in figure 5.3, a 10% cost reduction generates significantly more profit before taxes than does a 10% sales increase.

FIGURE 5.3

PROFIT LEVERAGE EFFECT

		Baseline Simplified P&L	Increase Sales 10%	Decrease COGS 10%
Sales		$1,000,000	$1,100,000	$1,000,000
Cost of Goods Sold (COGS)	50%	($500,000)	($550,000)	($450,000)
Administrative Costs	45%	($450,000)	($495,000)	($450,000)
Profit Before Tax		$50,000	$55,000	$100,000
% Change			10%	100%

- A **10% Cost Reduction** generates significantly more Profit Before Tax than does a **10% Sales Increase**.
- This is one of the main reasons that Procurement Managers are under significant pressure from senior management to **reduce purchase costs**.

- This is one of the main reasons that procurement managers are under significant pressure from senior management to reduce purchase costs.

Return on Assets Effect

Return on Assets (ROA) Effect states that with the exact same number/value of assets, a decrease in purchasing expenditures significantly increases the return on those assets compared to a comparable increase in sales. A high ROA indicates managerial prowess in generating profits with lower spending.

FIGURE 5.4

RETURN ON ASSETS EFFECT		Baseline Simplified P&L	Increase Sales 10%	Decrease COGS 10%
Sales		$1,000,000	$1,100,000	$1,000,000
Cost of Goods Sold (COGS)	50%	($500,000)	($550,000)	($450,000)
Administrative Costs	45%	($450,000)	($495,000)	($450,000)
Profit Before Tax		$50,000	$55,000	$100,000
Assets		$500,000	$500,000	$500,000
Return on Assets		10%	11%	20%

[Profit Before Tax ÷ Assets = ROA]

- a **10% cost reduction** generates a significantly higher **Return on Assets (ROA)** than does a **10% sales increase**, given the same number/value of assets.

[McLaury 2018]

- As shown in figure 5.4, a 10% cost reduction generates a significantly higher ROA than does a 10% sales increase, given the same number/value of assets.

Inventory Turnover Effect

Inventory is an asset but it also represents financial capital tied up and not available for use in other parts of the business. The purchasing function in an organization is frequently responsible for supply management and therefore plays a large part in the amount of inventory the company holds.

- Inventory turnover represents the number of times the company sold through inventory in a given time period.

- It is the costs of goods sold (COGS) divided by the average inventory.

- A high turnover ratio is beneficial because it means the company is generating sales efficiently to sell inventory.

- A low turnover ratio is unfavorable as it means the company is not selling through products efficiently. The company is likely making/buying too much inventory for demand and/or the company is throwing out expired or unsalable products.

Total Cost of Ownership

TOTAL COST OF OWNERSHIP (TCO) is the sum of all the costs associated with every activity of the supply stream.[1] The four elements of cost are quality, service, delivery, and price (QSDP).

TCO is the sum of the cost elements in QSDP (i.e., Quality + Service + Delivery + Price).

- Each element of QSDP has an impact on the TCO.

- The main insight that TCO offers is that the acquisition cost is often a very small portion of the total cost of ownership.

Procurement professionals recognize that although the purchase price of an item remains very important, it is only one part of the total cost of ownership. Other factors beyond purchase price must also be considered when making the decision to buy an item. This makes sense when you consider that acquisition costs account for only 25% to 40% of the total cost for most products and services. The balance of the total cost includes operating, training, maintenance, warehousing, environmental, quality, and transportation costs as well as the cost to recover the product's value later on.

Factors to consider:

- **Quantity discounts** may be offered as an inducement to encourage buyers to purchase larger quantities.

- **Cash discounts** may be offered for prompt payment of invoices.

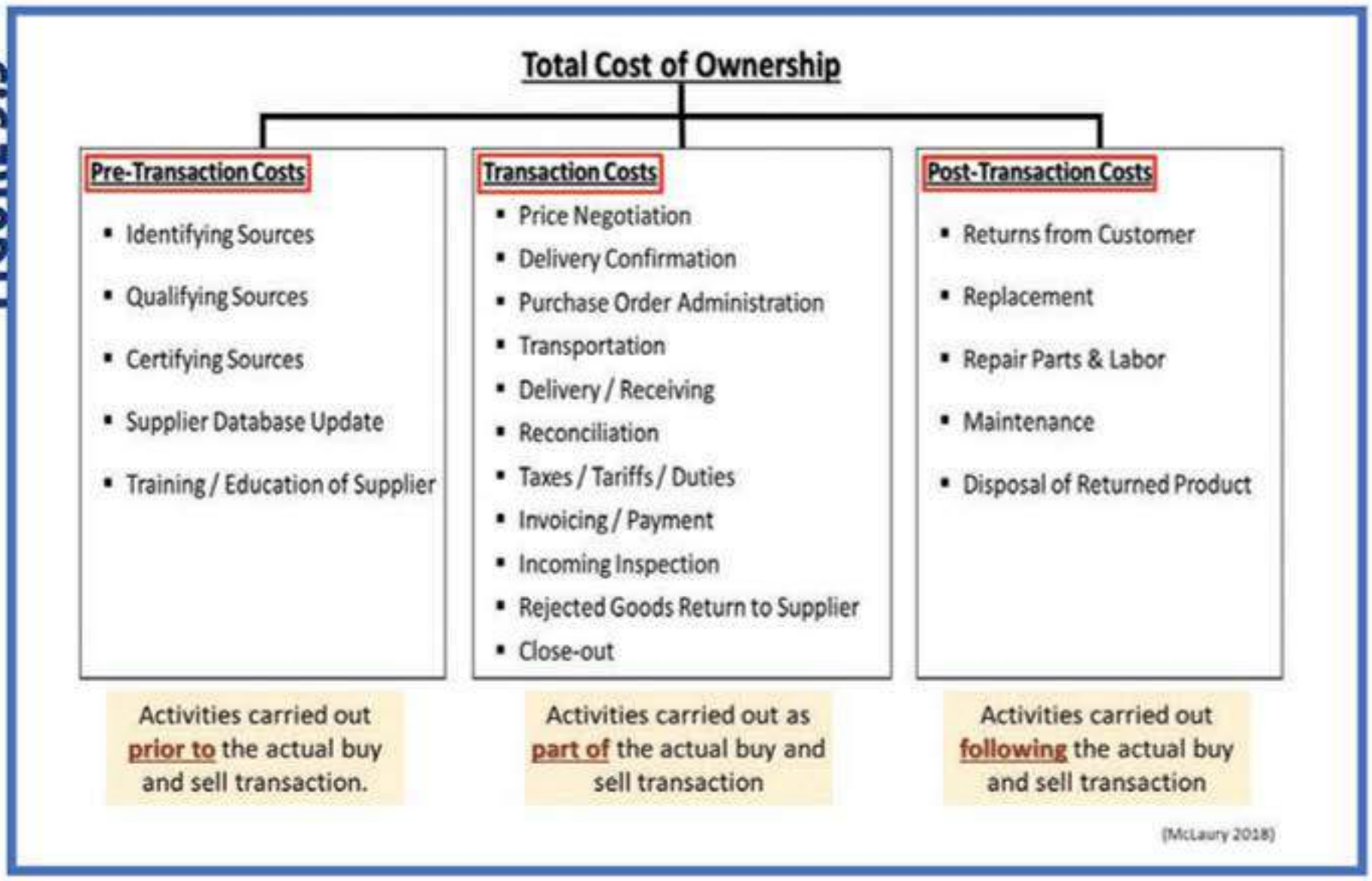
- **Value-added services** may also be offered. Services may include special delivery, special packaging, preparation of promotional displays, and subassembly operations in a supplier's plant.

- **Administrative expenses** are associated with the procurement activity itself such as screening potential suppliers, negotiation, order preparation, and order transmission.

- **Poor supplier quality** costs related to defective finished goods, scrap, rework, recycling, or recovery of materials must also be considered, as well as related warranty administration and repair costs.

The elements comprising the TCO can be viewed in three categories: pre-transaction costs, transaction costs, and post-transaction costs (see figure 5.5).

FIGURE 5.5



Pre-Transaction Costs involve all of the activities carried out prior to executing the actual buy and sell transaction; and all of the costs associated with identifying a need, finding and qualifying sources, site visits, inspections/audits, administratively establishing new sources of supply, and any approvals necessary.

Transaction Costs involve all of the activities carried out as part of the actual buy and sell transaction. These costs include the purchase price, placing and managing the order, transportation, tariffs and duties, incoming inspections, rejected product handling, late deliveries, missing documentation, expediting, and invoice processing/payment.

Post-Transaction Costs involve all of the activities carried out following the actual buy and sell transaction. All of the costs associated with defective/rejected finished products, field failures, repair, replacement or warrantee costs, loss of customer goodwill, and so forth.

MAKE VERSUS BUY DECISION

The make versus buy decision is the act of deciding whether to produce an item internally or buy it from an external supplier. Make versus buy is a strategic decision and every company must decide what and how much they want to make versus buy. Some companies want to produce as much as they can internally, while others are content to buy most, if not all, of their materials externally. Factors to consider in the decision include costs, available capacity, proprietary and/or specialized knowledge, quality considerations, skill requirements, volume, and timing.

- **MAKE:** Producing (i.e., manufacturing) materials or products internally (i.e., in operations owned by the company).

- **BUY/OUTSOURCE:** Buying materials and/or components from suppliers instead of making them in-house (i.e., buying from a third-party external source).

In determining the make-or-buy decision, it is important to analyze all of the expenses associated with developing the capability to make a product, in addition to all of the expenses associated with buying the product. The assessment should include qualitative and quantitative factors. It should also consider only relevant expenses.

- **QUANTITATIVE** factors primarily involve the incremental costs of making or purchasing the component, such as the availability of manufacturing facilities, needed resources, and manufacturing capacity. Fixed and variable costs can be determined with certainty or by estimation.

- **QUALITATIVE** factors are more subjective and include such things as control over quality, the reliability and reputation of the potential suppliers, and the impact of the decision on customers and suppliers.

Reasons for Making

Following are some of the more common reasons companies cite for the decision to make an item rather than buy it.

- To protect proprietary technology
- No competent supplier exists
- Better control over continuity of supply
- To achieve an overall lower cost
- Better quality control
- To use existing idle capacity and/or labor
- Better control of lead time
- More control of transportation and warehousing cost
- Quantity not sufficient to interest a supplier
- Political, regulatory, environmental, or social

Reasons for Buying (or Outsourcing)

Following are some of the more common reasons companies cite for the decision to buy an item rather than make it.

- If it is a nonstrategic item
- If it provides a cost advantage, especially for components that are nonvital to the organization's operations. Suppliers may provide the benefit of economies of scale
- If insufficient capacity is an issue, where a firm may be at or near capacity and subcontracting from a supplier may make better sense
- When temporary capacity constraints are a factor; the concept of "extended workbench," which involves short-term supplementing internal capacity with external capacity during time of constraint or overloaded work centers
- Lack of expertise, such as when a firm may not have the necessary technology and expertise
- Quality concerns, meaning suppliers may have better technology, process, skilled labor

- To achieve multisourcing strategy, using an external supplier in addition to an internal source
- Inventory considerations, such as when a company opts to have the supplier hold inventory of the item or the materials required to produce the item
- Brand strategy, where the company can take advantage of a supplier's brand image, reputation, and popularity

Outsourcing Risks and Benefits

There are some risks associated with outsourcing to consider:

- Potential loss of control over production decisions, intellectual property, etc.
- Increased reliance on suppliers, moving strategic direction away from manufacturing and toward external supply
- Increased need for supplier management: more suppliers means more supplier management activities

There are also some benefits of outsourcing to consider. These include allowing companies to:

- Concentrate on their core competencies by outsourcing noncore competencies.
- Reduce staffing levels, for the staff no longer needed due to shifting work volume to external supply.
- Reduce internal management problems, from the reduced staffing levels.
- Accelerate reengineering efforts by tapping into the knowledge and expertise of external suppliers to add to the company's knowledge and expertise.
- Improve manufacturing flexibility, from the potential use of the capacity from the work now shifted to an external source of supply.

Additional Make versus Buy Concepts

- **In-sourcing** (also known as back sourcing): This involves reverting back to in-house production when external quality, delivery, and services do not meet expectations.

- **Co-sourcing**:

    1. The sharing of a process or function between internal staff and an external provider
    2. Using dedicated staff at an external provider that work exclusively under your control and direction

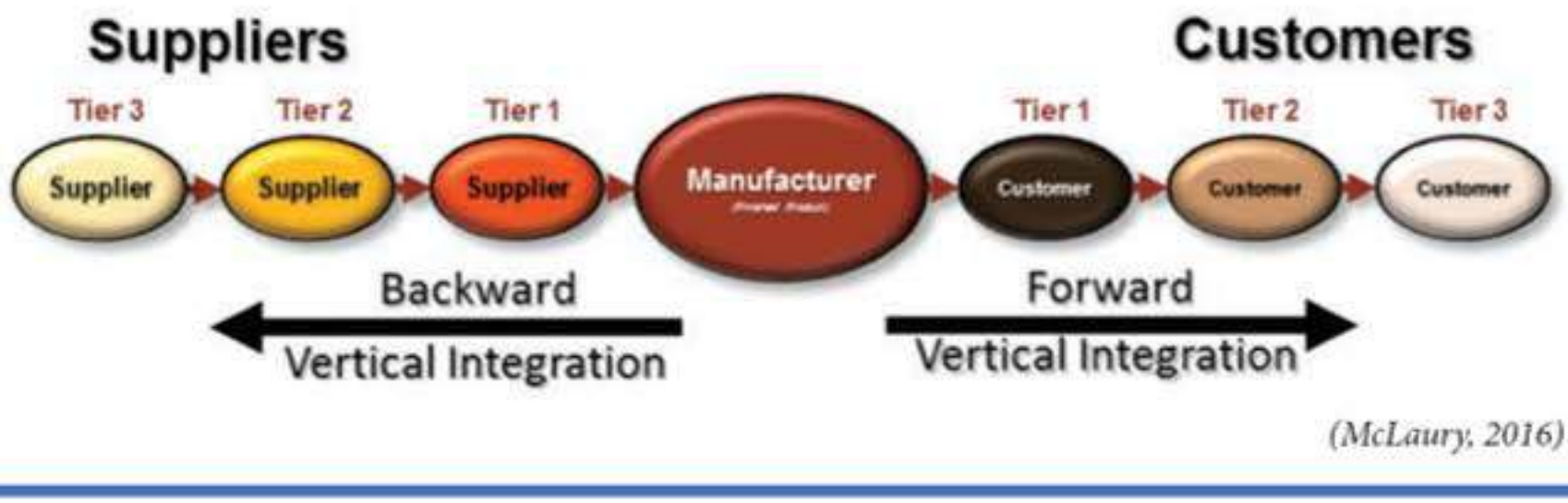
Other Types of Make versus Buy Decisions

The following are two types of strategic make versus buy decisions beyond just individual products or materials, involving larger aspects of the company. Refer to figure 5.6.

- **Backward Vertical Integration:** Refers to a company acquiring one or more of its suppliers. **Example:** a manufacturer buying the key supplier of a critical material to take ownership of this aspect of its supply chain.

- **Forward Vertical Integration:** Refers to a company acquiring one or more of its customers. **Example:** a manufacturer buying a wholesaler/distributor to take ownership of this aspect of its supply chain.

FIGURE 5.6



(McLaury, 2016)

SUPPLIER SELECTION

Supplier selection is typically conducted by a cross-functional team led by the purchasing function. It may involve members of the company's financial group, quality group, risk management group, manufacturing department, engineering group, among others.

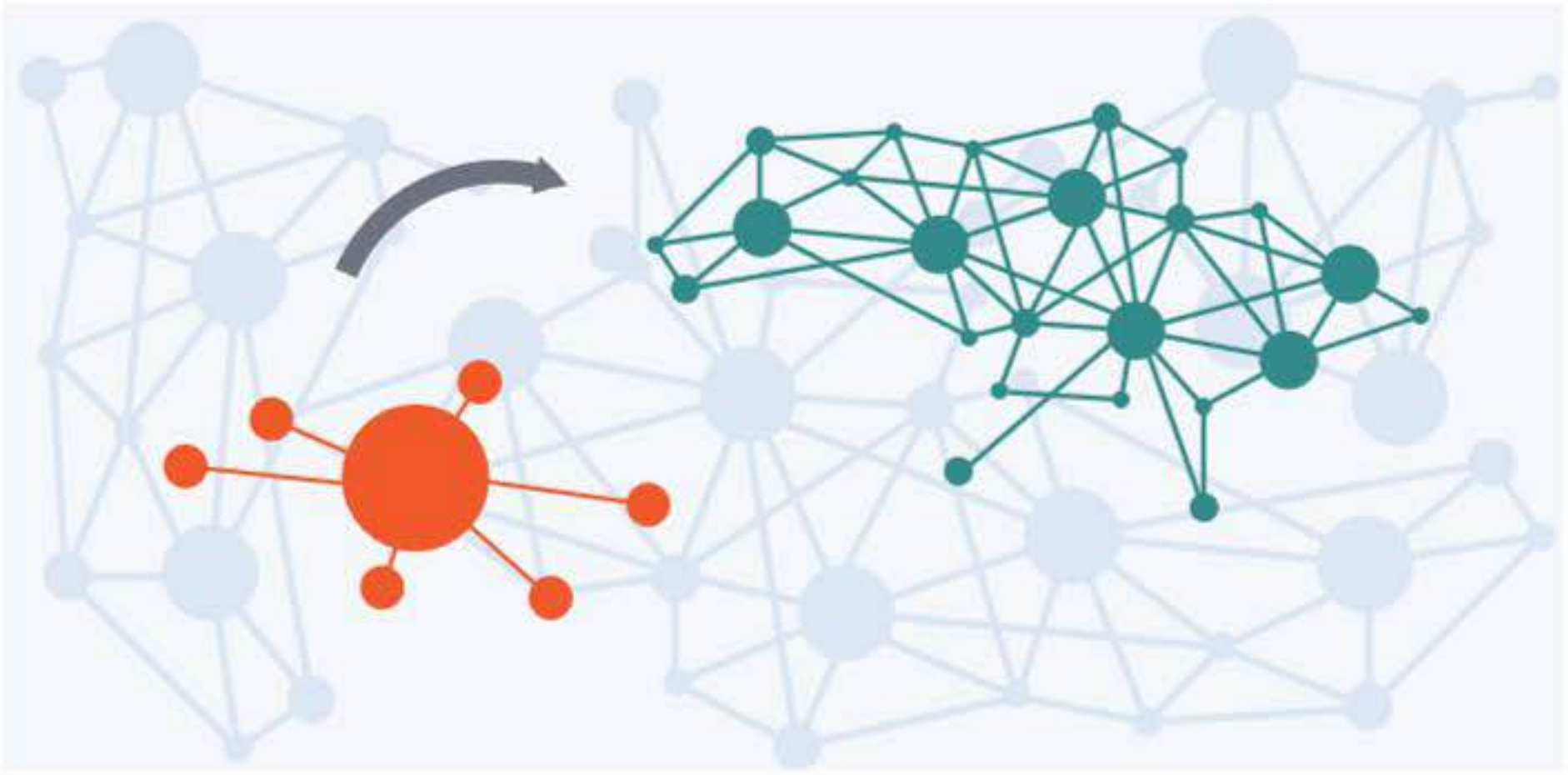
The process of selecting suppliers is complex and should be based on multiple standard criteria using evaluation forms or scorecards. The following are some commonly used supplier selection criteria:

- Product and process technologies
- Reliability
- Quality
- Order system and cycle time
- Cost
- Willingness to share information
- Capacity
- Service
- Communication capability
- Location

ORGANIZATION OF PURCHASING

The way in which a purchasing department is structured is directly dependent on the way in which the company operates. There is no ideal organization for purchasing, but most companies will organize the purchasing function so as to maximize its impact, and to generate more value for the company and the end customers.

The three general organization structures presented in this text are centralized purchasing, decentralized purchasing, and a hybrid purchasing structure.



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