IENG/MANE 332 lecture notes

Reference: PRODUCTION, Planning, Control, and Integration by SIPPER & BULFIN

Chapter 2: MARKET-DRIVEN SYSTEMS

1 INTRODUCTION

The classical management theories described earlier brought ever increasing levels of achievement to the industrial process for many years. The American leadership position and its competitive edge started declining in the mid-1960s. However, it took sometime to realize that different approaches were required to face the new industrial environment. This slow, uncoordinated process was carried out by individual companies, researchers, consultants, and professionals. Change occurred at two major sites: japan and America. Now these changes are converting to a single process.

The Japanese approach brought to light the weaknesses of American companies. It was natural for Americans to observe how Japan became a leading industrial power. Number of American industrialists and professionals visited Japan to study their systems, and large groups of Japanese consultants flooded western industries offering their services and advice, this phenomenon started in the early 1970s, reached its peak in the early 1980s, and to a certain extent is still occurring today. The content of this phenomenon is indicated by many Japanese production terms that have become part of the American jargon, e.g., *kanban, jidoka, poka yoka, and kaizen.*

Americans reached to the Japanese resurgence in three phases. The first reaction was the surprise of finding an industry notorious for bad quality outselling American products. Also, Japan had more advanced facilities and more forward-looking management concepts. Then came admiration. İn this phase was the feeling among many that Japan could do it better, and so the tendency was to *imitate* Japanese industry rather than *innovate* at home. Recently American industry moved to the third phase, sobriety, or to rephrase it, back to scale. Many of the Japanese successes are based on either American technology or management techniques. The latter were transferred to Japan in the early 1950s as part of the MacArthur Plan. Those technique covered a spectrum of topics such as methods and quality and were championed by Deming, Juran, and others. The difference was that Japanese professionals listened and implemented but American industry ignored those ideas. For whatever reasons, today we see a resurgence of doing things “the American way” i.e., by innovation rather than imitation.

in America there was soul searching to identify the reasons for the decline, to suggest remedial action, and to develop techniques to regaining the competitive edge in the future. In the latter stages of this soul searching. Americans adopted and embedded the Japanese approach into traditional American production systems. As a result, an impressive array of research, books, and reports were generated by individuals or committees. There is no consensus in these results as to why things happened and what should be done in the future; however, a consensus is indicated on the following.

- Existing classical management theories (Chapter 1) are inadequate to cope with many problems of the present and future environment.
- Certain concepts exist that will be a part of any future theory.

We make a strong statement here by claiming that the management theories and techniques that have been used for a long time- over a century in some cases- need to be updated. The environment from which they emerged has been totally transformed. On the other hand, the substitute theories are in a state of flux. Many ideas, concepts, and techniques have been proposed but have yet to become a unified theory of production management. New industrial concepts are a mix; some are old concepts that were honed and re-emerged, some are concepts replacing the old ones, and some are totally new. We provide our view of the major emerging production management concepts. These idea form the foundation for cutting edge management techniques. We embed these concepts in a platform we call the *wheel of competitiveness*. İn the rest of this chapter, we discuss this platform, the new production environment that supports market driven systems, and finally world class manufacturing.

2 THE WHEEL OF COMPETITIVENESS

The wheel of competitiveness, shown in figure 2-1,illustrates some of those concepts required to role American industry back to its leadership position.

The wheel has four concentric circles; each represents different aspects of the emerging production management theory. We briefly define each circle and then follow with a more detailed discussion. The **Hub** of the wheel is also the hub of all future systems; the **customer.** The **Delivery circle** (Circle 2): shows what the production system should deliver to the customer. The **Support circle** (Circle 3) indicates concepts needed to support what is delivered by the production system. The **Impact circle** (Circle 4) shows the consequence of those concepts on the whole organization

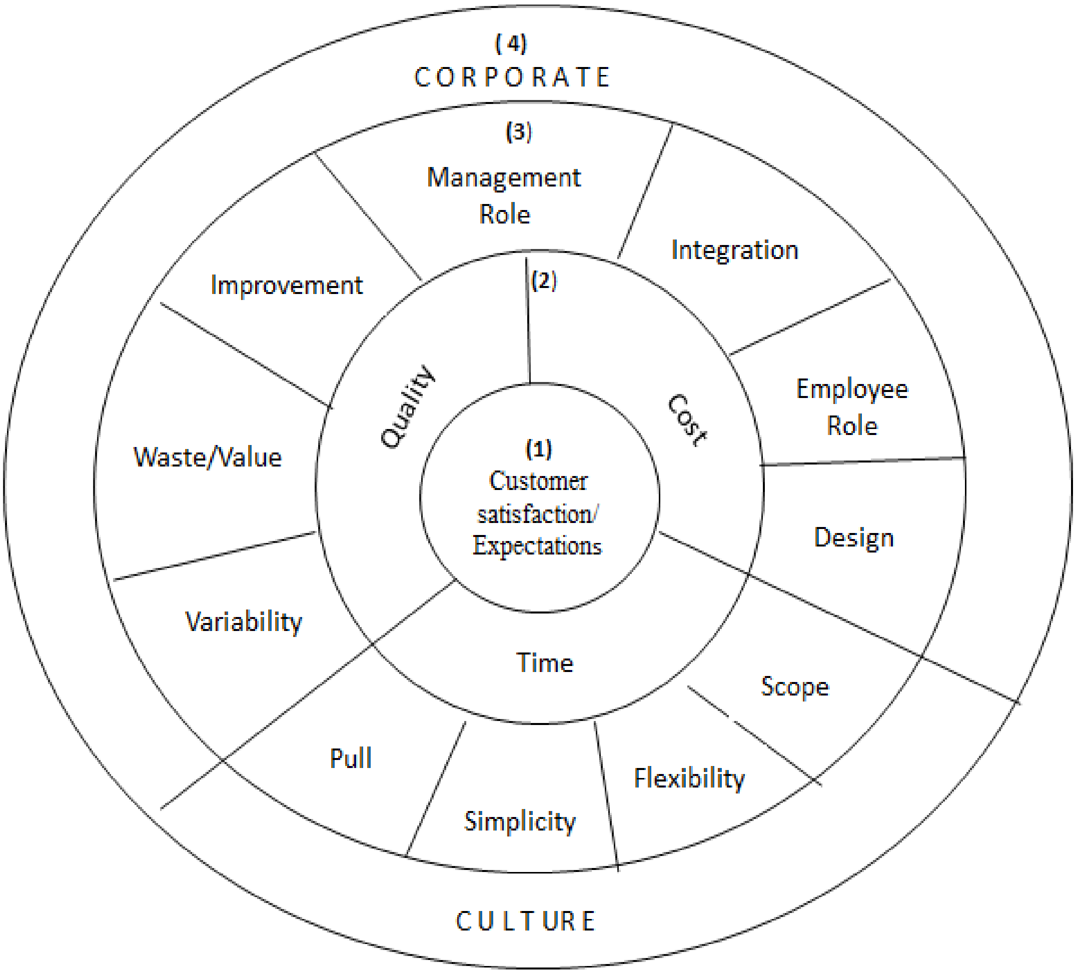


FIGURE 2-1 Wheel of competitiveness

3 THE HUB

It is no coincidence that the customer is the hub of the "new industrial world" concepts. The customer is the engine that drives competitiveness. This concept is not new, but the customer's importance, role, scope, and position have changed due to increasing customer sophistication. Education, technology, communication, and globalization are all elements that helped create the new customer.

Rather than operating to respond to and satisfy customer needs only, organizations must make an effort to achieve **customer satisfaction** as well. This term is simple linguistic one, but it is very complex industrial concept. Customer satisfaction is composed of many elements-needs, quality, cost, service, and more. Even the need satisfaction process of the past is totally different today. Emphasis is placed on satisfying the needs of the **individual** customer rather than those of the **average** customer. Constantly changing customer expectations ensure that satisfaction is dynamic and increasingly complex. Customers have changing requirements, and they expect flexible reactions, which can be achieved only if the organization gets close to the customer. The customer should be a part of the process rather than its terminal point. Securing a customer's allegiance has become more important than merely selling an item. Returning customers generate future sales.

The scope of the term "customer" has also changed dramatically. Traditionally the customer was regarded as the end user of the product. Today we have the " internal customer" whose needs must also be addressed. Thus, manufacturing is purchasing's customer, assembly is manufacturing's customer, or in a general way, any operation is a customer of the previous operation. Any organization's activities can be viewed as a chain of interconnected customers. Each customer is supplier of the next customer in the chain, and the whole production and business activity is governed by customer satisfaction.

If the customer is the engine driving the organization, expectation is the engine's fuel. Customer satisfaction with acceptable financial returns is the measure of business success.

4 THE DELIVERY CIRCLE

In order to achieve customer satisfaction and meet its expectation, the whole business has to rise to the challenge. Each segment must contribute its share, and the manufacturing system is no difficult. İts role is to deliver a product of superb quality at the required time while keeping the cost as low as possible at every point in the supplier-customer chain. Although each independent goal is achievable, combining the three into one unified goal makes a complex and difficult mission.

The proper sequence of these goals is the subject of ongoing debate. One proposition is

Quality ⟶ Time ⟶ Cost

This sequence may differ from one organization to another. We suggest arranging them in a circular fashion as shown in figure 2-2.

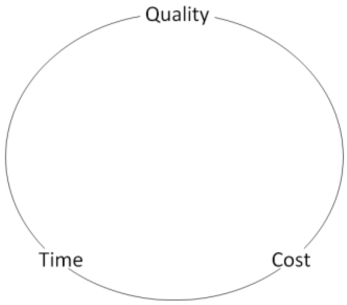


FIGURE 2-2 Delivery circle

4.1 Quality

Quality is a traditional concept whose scope has expanded and whose importance is enhanced in the modern production system. The common product-related definition of quality is **conformance to specifications**. But for the customer, quality is more complex issue including individual perceptions of value for money, expectation of performance, and appearance, pre-sale and after-sale service offered, and warranty.

The new approach to quality recognizes all facets. From the product point of view one way to measure quality is by the number of products in a manufacturing batch not conforming to specifications. , i.e., defective products. In the past a certain level of these measure was acceptable. Today we strive for perfection-allowing no defects at all. To put this change in perspective, not long ago three defective per 100 units was considered good quality. Today some industries especially electronics, consider more than one defective per one thousand units to be poor quality. This new attitude represents a big leap towards zero defect policy.

But quality includes more than product quality. All production, support (purchasing, accounting, etc.), engineering, research and development, and service activities need to be quality conscious. They must be aware of decisions affecting quality throughout the production chain, for both internal and external supplier and customer. Thus quality is an embracing concept, and each element in the production system services for perfection.

4.2 Time

Time has always been with us with multiple meanings. It has a “point” meaning (What’s the time now?), a “length” connotation (How much time does it take), and a “punctuality” interpretation (Be there on time!). In addition it sometimes has an “opportunity” flavor (The time was right.), not to mention less scientific and more qualitative meanings, such as good time, interesting time, etc. In production systems we view time as two different but related entities: time as a measurement of length and time as an indication of goal.

Delivery or lead time is the length of time needed to deliver a product from order until the receipt by the customer. Delivery date is a goal, representing either the date the product is needed or the date or the date promised for delivery. If we can shorten delivery time, we can promise sooner delivery dates. If the customer needs a shorter delivery date, we must find a way to shorten delivery time, keeping in mind that a shorter time may impact all components in the supplier-customer chain. Either we shorten raw material lead time, cut operation times, reduce setup or decrease time at some other point.

In today's market, the concept of time is associated with time reliability or consistency. It is not enough to shorten delivery time and deliver on time once. We have to be able to do it repeatedly.

4-3 Cost

Cost is a common term, but it has different meanings in different situations. Although the price of a product is a "cost" to the consumer, it is not the sum of the cost of all activities associated with generating the product. The price of the product should reflect profit the company intends to make above cost. Thus, cost and price are separate entities. For our purpose cost is defined as *one measure of resource use*, and it is expressed in the same units used in that business. Thus, cost is an internal measure, and, conceptually at least, we can control its components. The role cost plays has changed. Traditionally, cost has been the dominant measure of companies in running the production system, which is not surprising; a high proportion of the company's assets are tied up in manufacturing. The major responsibility of production management used to be **cost control**, that role is still exists, but another major responsibility, **cost reduction**, is gaining more and more importance.to achieve cost reduction we must identify causes of unnecessary cost such as excess inventory and eliminate them. The shift has been from **cost control** to **cause control**, in which cost is a convenient measurement used to track cost reduction.

Cost reduction is a key "delivery" in the modern industrial world. İn order to be competitive, cost can follow only one trend-down. The cost improvement required is in *orders of magnitudes*, not in small percentages. Cost, which was an input, has become an outcome of actions.

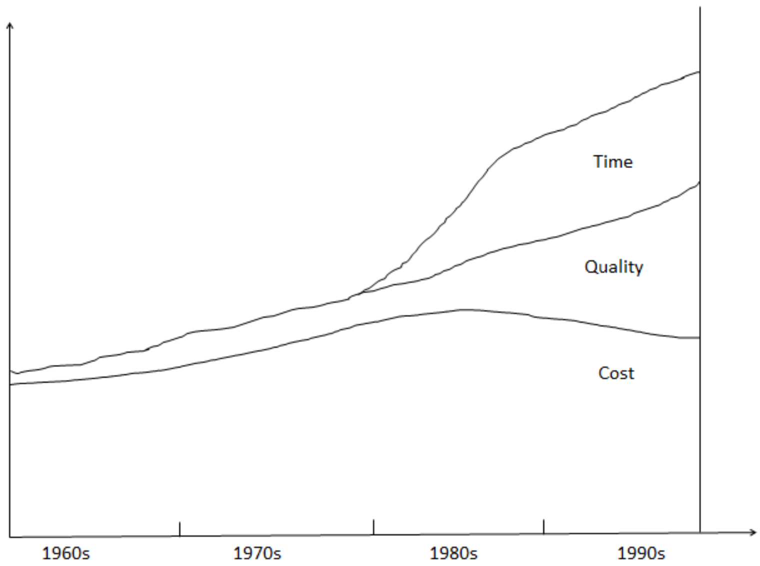
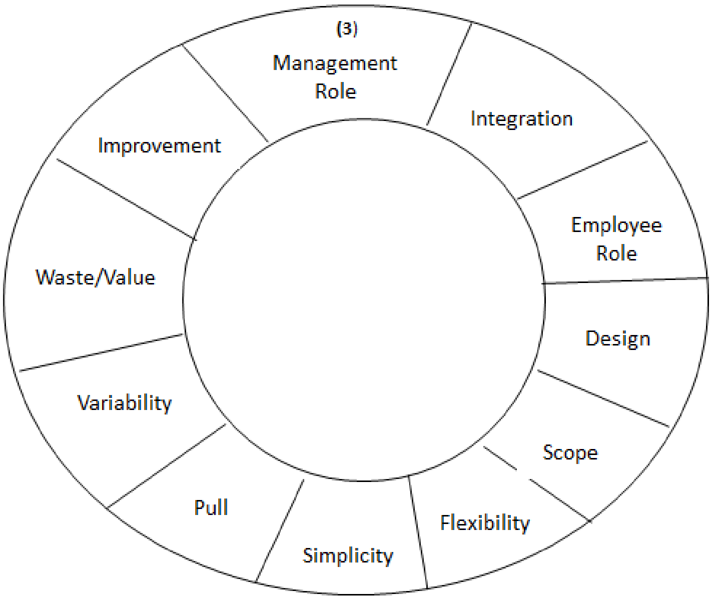


FIGURE 2-3 Evolution of cost, quality, and time

5 THE SUPPORT CIRCLE

We have stated the difficulty of combining the goals of the manufacturing system (quality, time, and cost) into one unified goal. Not surprisingly, many ways to achieve this larger goal have recently been suggested. Each of these suggestions, or combination of suggestions, represents a certain concept. List of the major concepts is shown in the support circle of figure 2-1. The location on the circle, the size of the segment, and its relation to the delivery circle are not significant. These concepts are discussed in a logical order.



5.1 Scope

The scope of a business has been redefined to include both the customer on one hand and the external supplier on the other hand, which represents a direct contrast to the past, when the customer was " out there" and the supplier was considered more an adversary than a partner. We have already identified the concepts of consumer becoming prosumer. The same relationship develops on the supply side; the supplier is brought in as a member of the team, with the intention of a long-term association. This policy greatly reduces the number of suppliers.

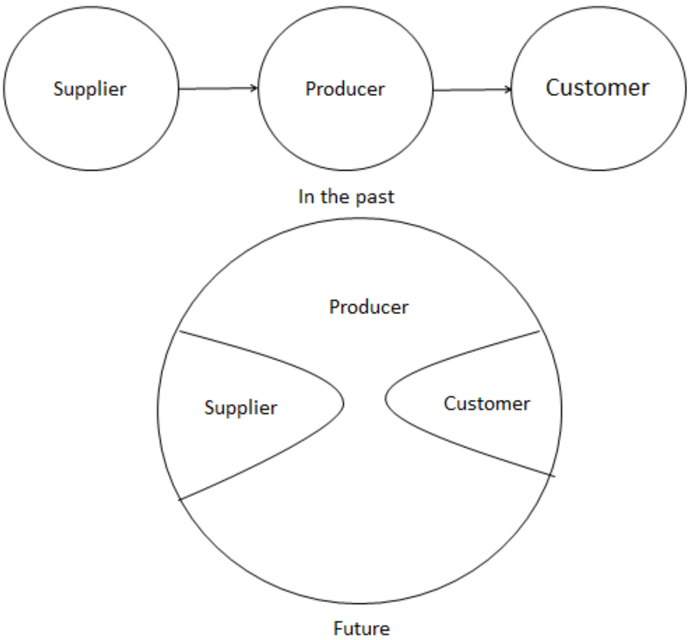


FIGURE 2-4 Supplier-producer-customer relationship

5.2 Integration

Integration is used in many contexts: technical, organizational, behavioral, and more. It may be used to discuss a concept or a technique; consequently, confusion results. We consider integration as the process of looking at a system rather than a component, or to phrase it differently, the process of seeking global. The process of seeking global optimization rather than local optimization. We use optimization not in its mathematical meaning but in the sense of obtaining good results. Both definitions imply recognizing the importance of interaction among components of the industrial organization.

Product design and process design were done separately in the past. What looked like a perfect product on paper turned out to be a nightmare in terms of the manufacturing process. Resulting in extremely high manufacturing costs. Today those two processes are integrated and the customer is also included. When designing the product, the designers consider manufacturing issues and check with the marketing people about possible changes in specifications. This integration of processes achieved the goals of reducing cost and time and increasing quality.

The concept of integration is often mistakenly associated with the advent of the computer. Integration, however, is a concept of its own, which can be applied without a computer, sometimes needing only simple communication among people. The role of the computer lies in increasing the speed, breadth, and depth of the information integration.

5.3 Flexibility

When discussing the hub, we mentioned that customers have changing requirements and expect flexible reactions. Those changing requirements include the fluctuations in demand, greater product variety, and new products. To stay competitive, production systems are designed to cater to a changing market. Flexibility requires the production system to be able to rapidly design a new product and introduce it to the market place, cater to changing patterns of product volume required, and cater to greater product mix. In each case the production system should be able to perform those tasks in the context of the unified goal of quality, time, and cost.

Implementing flexibility caused tremendous changes in the organization and on the production floor. Time needed to change a production facility from one product to another has been slashed from hours to minutes; time-to-market of a new product has been cut from years to months; and flexible production facilities can currently manufacture many different products.

Flexible manufacturing is replacing the mass production concept of the past. As much, it is a key concept in achieving competitiveness. Some companies make flexibility a major goal of their manufacturing strategy.

5.4 Design

Design has undergone a major turnaround. We accept the belief that the major portion of product cost and quality are determined in the design phase. If we are to give the customer more variety faster and at a low cost, it is impossible to use the same design approach as in the past. Design and product development are no longer isolated elements. Design now interacts with customers and manufacturing, tapping the expertise of other segments of the business. This integration, which fosters a team approach, helps achieve design for function (specifications), life (reliability), form (aesthetics), and effective manufacture. Although design has usually been a team effort, the composition of the team and its scope have changed.

5.5 Simplicity

At the beginning of the industrial age, simplicity was not a priority because things were simple by nature. In the new manufacturing environment we simplify for two important reasons.

- simple things are understood by more people
- simple situations enable us to use simpler solutions, which are less expensive, less time consuming, implemented faster, and have a low risk.

The new production environment is complex by nature. We have the technology, such as the computer and its derivatives, to deal with complex situations. It is tempting to rush into cutting edge technology to tackle the complex problem. Before complementing a complex solution to a complex problem, however, try to simplify the problem so that it becomes amenable to a less expensive solution. For example, in automation or computerization , a substantial share of the benefits (sometimes up to 80 percent) is achieved before automation was installed. İn some cases this level of benefits may be sufficient and will be more cost effective. The same rationale applies to simplifying other manufacturing aspects- product and process design, control, information, etc. Although this simplicity was necessary in the previous industrial era, the concept is even more important today. We should not be so quick to use “coping-with-complexity” advanced technology unless it becomes necessary.

5.6 Variability

Variability has been a problem since society moved from craftsmanship to the industrial era, everything varies- products, dimensions, manufacturing processes, delivery time, and quality levels. Variability, a universal enemy, is traditionally accepted as a fact of life. Now we try to eliminate it completely, reducing the need for a number of tools developed to control it. Note that this approach agrees with the concepts of simplicity and perfection introduced earlier.

Clearly, consistency of performance or reducing variability can reap great benefits. This idea was not ignored in the past; however, today we have the technology to implement this concept. For example, newer machine tools can have processes that have variability close to zero. These processes are referred to as deterministic manufacturing. In the case of hardware, low variability is a given technical characteristic of the machine. In other instances much efforts is needed to achieve it.

By applying one Japanese concept- Pokayoke- we can eliminate in our production system.

5.7 Pull

The production process is basically a flow process. First there is physical flow; the raw material, later the semi-finished product, moves from one machine workstation or assembly station to another. At each station some processing of the raw material is done, and the material moves to the next station in the manufacturing sequence. Other types of flows are nonphysical – the most important being information flow. İnformation flow can be either verbal, on paper, on a computer screen, or a combination of these.

Physical flow is the backbone of the system; without it there will be no output from the production system. Thus we want to maintain smooth flow of the product down the line with no delays. Note that a stop at a workstation of processing is not regarded as a delay, but it is part of the production process.

It is possible to compare the production flow to other types of flows, for example, flow in nature consider rivers, where the natural law of gravity dictates that the flow will be from high to low places. In contrast, production flows has man-made rules to govern it rather than natural laws. Traditionally the governing law was that of **push production: keep doing things regardless of what happens down the line-make to plan**. The information flows downstream, just as the physical flow, as shown in figure 2-5 (a). This rule worked well for production-driven systems in which we took the market (customer) for granted. Furthermore, upstream production was insensitive to what happened downstream.

Things changed for market-driven-systems with the customer as a “hub”. The governing law changed to the rule of **pull** or **pull production**. The essence of pull production is to **do things upstream only when requested from down stream**. The terminal point of the downstream is the customer. In a push production system, the physical and information flows are in the same direction. However in the pull system the physical and information flows are in the opposite direction, as shown in figure 2-5 (b). In pull production nothing in the supplier-customer chain starts unless there is a request (information) from the downstream activities. This concept applies not only to production floor activities and flows, but also to the external supplier and external customer as well.

The pull concept is not simple to implement. A great amount of preparation is required, and a number of techniques are needed for successful implementation. In the dynamic environment of market-driven systems, it is a potent concept.

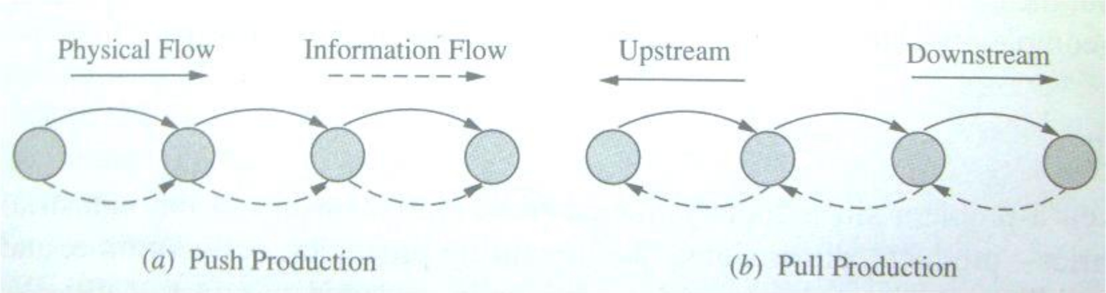


Figure 2.5. Push and pull production

5.8 Waste/Value

In our daily lives we often receive counsel not to “waste” assets such as out time or our money. Upon reflection we see that we are really being advised not to use an important resource (i.e., time or money) if no **value** is gained. Because the major mission of the manufacturing process is to increase value for the final customer, this simple principle becomes an important concept in production systems. The customer is willing to pay for value but not for waste.

In the context of manufacturing process, **waste** is defined as any resource extended over the amount required and valued by the customer. Although determining the minimum amount of resource required is not always easy, sometimes waste is obvious. The customer expects perfect quality in a product; we can achieve this quality by “doing it right the first time” (an important principle in itself) or by reworking the product until the desired quality level is achieved. From the customer’s viewpoint, value must be obtained “in one pass,” and additional rework and its resulting cost are waste. This example represents one measure of waste-in terms of cost. Reducing or eliminating waste amounts to reducing cost-a direct correlation to one of the major goals of the production system.

In general waste occurs in three forms: time, money, and effort. Time and effort may be expressed in a cost equivalent. Excess lead time and poor quality are waste, as are an over-engineered product design, excess inventory, and inflated overhead. Other activities whose contribution to the product value (and customer satisfaction) are questionable are also waste.

We classify production activities into two major categories: value-adding activities and cost-adding activities. **Value-adding activities** are those that by their nature are supposed to add value. Typically they are conversion activities where raw or purchased material are transformed from their received state into the final product. Here waste would be the use of excess resources. **Cost-adding activities** are those that enable a smoother operation or make life easier in the production system. They support a conversion process, and although they may be important and even necessary, add no value-for example, materials handling. A third type of hybrid activities falls somewhere in between value adding and cost adding-for example quality control.

Reducing waste should be approached differently for each of these activities. For value-adding activities, resource **optimization** is appropriate. For cost-adding activities, cost **elimination** is appropriate. Waste has always existed in production systems; its definition and recognition lead to devising ways to reduce it.

5.9 Improvement:

The concept of improvement has been used in production systems since the days of Taylor and the Gilbreths. Initially improvement was attempted at the job level, basically through motion study. As years went by, the concept of improvement expanded, and its scope included improvement in additional areas of manufacturing-processes, assembly, quality, time, and cost. The basis of the improvement approach included these three characteristics.

- A trade-off must be made; if you want better quality, you have to pay more for it.
- The outlook was local and not global; reduce the cost of an activity and not the total cost of the system.
- Typically, the improvement was of a project type to improve quality or reduce inventory.

Today's competitive market situation has made the improvement concept of improvement even more vital. To keep customers satisfies we must give them a good product now but also show that we are making efforts to give them a better product in the future. Thus, the "new" improvement process is based on the following two ideas:

- **Integrated improvement:** the improvement process is a multidimensional process. The goal of the production system has to be improved in all three dimensions: quality, time, and cost. We must provide better quality at low cost and reduced delivery time, which means we have to take a global rather than local approach to ensure that we improve the total system.
- **Continuous improvement:** improvement should be a continuous process; there is always room for future improvement. Our improvement leads to another, establishing a cyclical process.

This process is sometimes called *kaizen*, the Japanese term for continuous improvement. The Japanese emphasize that *kaizen*, practiced in Japan for years, is a process involving everyone, from management to the lowest paid employee. They also make the subtle distinction between kaizen and innovation. *Kaizen* signifies small improvements made in the status quo as a result of on-going efforts. İnnovation involves a drastic improvement in the status quo as a result of a large investment in new technology or equipment.

The biggest enemy of improvement is complacency. In Chapter 1 we saw the cost that American industry paid for being complacent. The concept of improvement is valid not only for more global, unified goals, but throughout the manufacturing system at all levels. Goal improvement can be achieved only through a series of mini-improvements, with constant adherence to the integration and continuity principles cited earlier.

5.10 Management Role:

Because the human element is the most important resource a company possesses, it should not be surprising that the last two concepts to be discussed involve people. At opposite ends of the spectrum are management and employees. *Management* has an expanded role in the new production system. It transforms the system from its current mode into a new operational ,ode represented by the concepts described thus far. The manager is basically overseeing a change process, introduction of which is difficult due to the people in the system. Change represents a challenge to the individual worker because skills may become obsolete, status may be downgraded, work environment or location may be changed,or, even worse, the job may be eliminated. The manager's role is to facilitate change positively in three ways.

- **Commitment**: management must first and foremost show a commitment to the new concepts, which may be a major break from the status quo.
- **Participation**: management should become a part of process and not stay above the process. Changes starts at the top, and management must undergo the elements of the change process throughout the organization.
- **Goals**: management should set extraordinary goals. Only then it is possible to obtain first rate results. İn quality, for example, the goal is perfection, without an "acceptable" level of defects.

Drastic changes usually are not introduced voluntarily. Often some severe external threat to survival makes change necessary

5.11 Employee role

Employees have always been part of the organization, but now they must become part of both the change process and mode of operation. In this context management has two goals for employees: involvement and development.

Employee involvement uses the creative energies of all employees to solve problems. It requires a high degree of commitment to the company by all employees. This improvement takes many shapes and forms, but the basic idea is that employees involved in the process more readily accept the outcome. In addition, the company makes use of a huge brain trust to generate a host of good ideas.

Many new production systems have new technologies embedded in them: new machines, processes, computers, and management technologies. Much preparation must be made within the organization for these new technologies. Employee development –upgrading the skills of the employees- is necessary for utilization of the new technologies. This system changes the traditional philosophy of employee control to a new concept of employee involvement and upgrade.

6 The impact circle

The concepts described in section 5 have tremendous impact on an industrial organization adopting all or part of them. The bottom line of this impact is represented by a major cultural change in the organization.

What is the organizational culture? Culture refers to the underlying values, beliefs, and principles that serve as a foundation for a management system. Also included are the set of management practices and behaviors that both exemplify and reinforce those basic principles. For example, IBM's organizational culture includes the following set of beliefs:

- Respect for the individual
- The best customer service in the world
- The pursuit of excellence

It is not difficult to observe the change in some components of organizational culture required by these concepts. The net result of this change is that the organizational culture changes from pursuit of **efficiency** to **effectiveness**, which has a broader scope.

Efficiency: a local measure of performance is defined as the ratio of output to input. The idea is to make things right.

Effectiveness, on the other hand, focuses on requirements of the total system, not subsets of it. The idea is to make the right things. Performance standards on the major parameters of the system are specified, and these become a framework within which efficiency measures still play a role.

Machine utilization: the percentage of the time a machine is operating and producing products is an efficiency measure. A machine with 30 percent efficiency seems to be doing a poor job, whereas a machine with 90 percent efficiency is producing almost all the time.

However, this analysis does not consider the effectiveness of the issue- in this case, whether the product is actually demanded by a customer. İf customers are only willing to buy 30 percent of the capacity of the machine, running it at 90 percent efficiency only creates products that will sit in inventory.

The transition from a culture of efficiency to a culture of efficiency to a culture of effectiveness is difficult. It usually takes several years to accomplish because the entire organization must be transformed. Adopting the concepts of the new industrial world is a commitment for the long haul; any quick fix or short cuts are doomed to fail.

7 PRODUCTION SYSTEM OBJECTIVE

The major objective of a production system is to make maximum contribution towards **continuously increasing** customer satisfaction. Other parts of the organization contribute their share as well, but the production system is the pivotal point of this effort. İt is the only place where ideas and material are transformed into a product delivered to the customer. Usually the objective of a system is defined as a prelude to the discussion. We waited until the reader is ready to appreciate this objective.

Derived from this major objective are the operational goals of the productions system: deliver a product of superb quality on time every time and at the lowest possible cost, or in short: quality, time, cost-combined. That is:

- Quality (improved)

- Time (on time all the time)
- Cost (simultaneously) decreased
- Combined

These are relatively simple goals to state but very difficult to achieve. An organization that can achieve them is on its way to becoming a World Class Manufacturer (WCM). Before discussing the world class manufacturing, we illustrate several aspects of integrated production and relate them to the concepts in the wheel.

8 FROM CONCEPT TO IMPLEMENTATION

So far, we have presented a host of concepts for market-driven production systems. You may ask, “does it really work that why in the real world, and if so, how? It sure does. And in this section we present some examples and show their relevance to the concepts in the wheel of competitiveness.

In this section we focus on integration, a significant new concept. We first discuss its implementation in a production environment; then we give three specific implementations of integrated production systems, cellular manufacturing systems, flexible manufacturing systems, and computer-integrated manufacturing; and we conclude the section by presenting three integration processes that can be used within the production environment.

8.1 Overview- Integrated Production Systems

In section 8.2, we discussed the general notion of integration. A legitimate question at this point may be “what is integrated manufacturing?” is it a new manufacturing technology, a new manufacturing technique, a new computer product, or a new way of life for the industrial organization? Probably, it is a little of each. The ultimate goal of integration is to enable the manufacturing organization to gain a competitive edge in the market.

To obtain further insight into integration, we borrow an example from a different domain- music. consider the case in which there is only one musician- a soloist. When playing, a soloist need only by concerned with the quality of his or her performance. The sense changes when we have a trio. Now every musician is a member of a team. If one ignores the others, we get noise rather than music. The music must be coordinated, or integrated, to be enjoyable.

At the trio level, the musiciancs manage to do the integration themselves. This integration is within the group. If two groups of musicians play together, then we must worry about integration between the groups. In a symphonic orchestra integration is much more complex. Not only should each group of instruments start and finish together, but the proper emphasis would be employed for each piece of music. The job is so complex that we need a conductor (equivalent to a manager) to coordinate the music. The coordinator uses music notes (algorithm) and a baton (decision-making tool) to run the orchestra. When is the music pleasant? When the integration works well and each musicians is in harmony with the team, and when each team is coordinated with the other teams.

In the real world, as in our music example, integration requires different approaches for different levels of the ensemble hierarchy. In the manufacturing environment, integration the activities of a number of machines in different from integration the activities of the whole enterprise. We briefly highlight three aspects of manufacturing systems integration: the integration niche, the integration essence, and the integration strategy, which are discussed in the next section.

8.2 Aspects of integrated Production Systems

8.2.1 Integration niche

The integration niche is the situation in which integration will have the greatest benefit. Market-driven environment require that manufacturers have the flexibility to accommodate the frequently changing product variety demanded by customers. Figure 2-6, a volume variety plot, helps explain the integration niche.

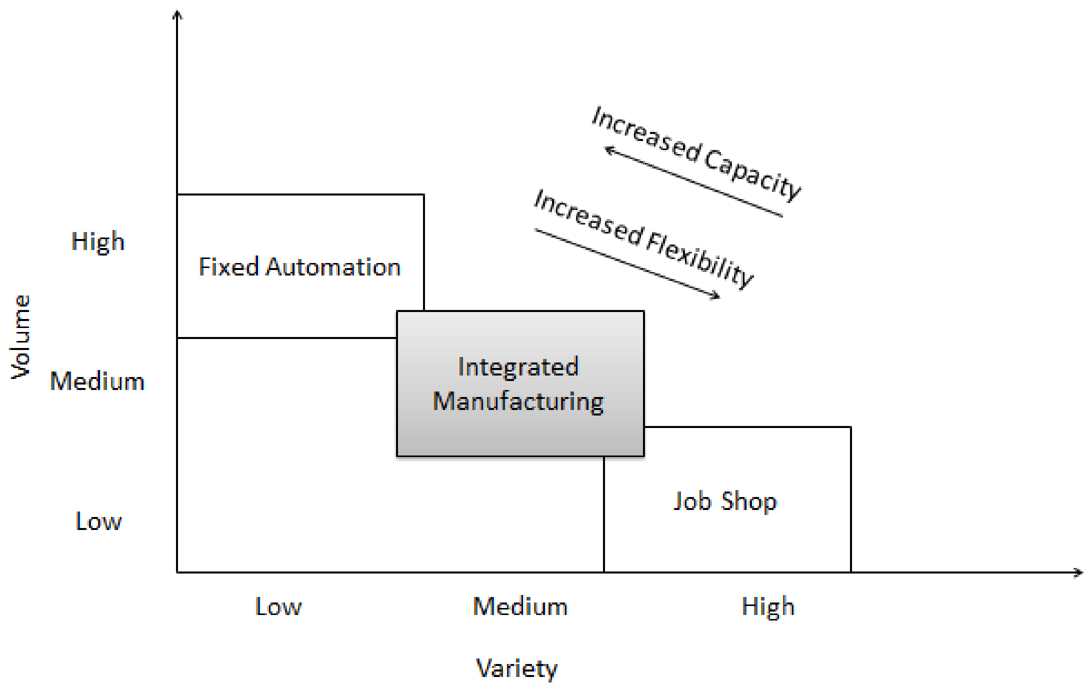


FIGURE 2-6 A volume variety plot

The best potential improvement from applying integrated manufacturing is in the medium-variety. Medium-volume zone where flexibility is required. The objective is to achieve economic production of a wide variety of parts, with many of the benefits previously associated only with mass production. The extreme regions are better served by other approaches-fixed automation for high-volume, low-variety zone and a job shop for the low-volume, high-variety zone. However, new technologies and management techniques (such as just-in-time) have also penetrated these areas.

8.2.2 INTEGRATION ESSENCE

At the system level, two important elements of integration are **physical integration** and **information integration**.

- **Physical integration** is achieved by property arranging the equipment on the production floor (layout) and the material handling equipment servicing it. The integration novelty is not in the layout /material handling arrangement but in the design, operation, and control concepts that govern it.
- **Information integration** is probably the most indicative single entity of integrated production systems. What truly indicates the system is not the closeness or remoteness

of its entities, but the information flow between them. This is true of all aspects of information: technical information, operational information, and managerial information. Thus, a free flow of information is *fundamental to the integration objective.*

8.2.3 Integration strategy:

Integration can be examined from two different perspectives: top down or bottom top. The two approaches are presented in figure 2-7. A top down perspective views the enterprise as a complete system. A bottom up perspective looks at the components and actions of the system.

Currently, there are three leading approaches to integrated production systems design-all focused on medium- variety and medium- volume production. They are as follows

- Cellular Manufacturing Systems (CMS)
- Flexible Manufacturing System (FMS)
- Computer Integrated Manufacturing (CIM)

8.3 Integrated Production System Design:

8.3.1 CELLULAR MANUFACTURING SYSTEMS (CMS)

In cellular manufacturing system terms production is organized around a manufacturing or assembly cell. What is a cell? A nımber of definitions exist, and we give two of them-one oriented more toward a manned cell, the other toward an unmanned cell.

A **manned cell** is dedicated to the manufacture or assembly of a family of parts that have similar processes. The operators in the cell are multi-functional, i.e., They can operate different kinds of machines. In an **unmanned cell**, the multi-functional worker is replaced by a robot (or other mechanical device) and a centralized cell controller.

The basis for cellular manufacturing is the process of grouping parts into families, which is known as group technology. **Group technology** is a manufacturing concept or philosophy in which similar parts are grouped together in order to take advantage of their similarity in design, process, scheduling, and facilities planning. Thus, similar parts are arranged into families that possess similar manufacturing or design characteristics, and the processing of each member of the family is similar. This arrangement makes it possible to achieve the economics of scale of mass production, both in terms of cost and quality. Therefore, group technology has become one of the cornerstones of integrated production systems.

A manned cell is usually organized in a U-shaped layout, in which multi-functional workers perform the required operations. The U shape decreases walking time for multi-functional workers, contributing to cell flexibility. Which can be further enhanced by reducing set-up times and employing pull control. An example of a manned cell for assessing flexible computer disk drivers is shown in figure 2-8. In manned cell, physical integration is achieved by the U-shaped layout, and information integration is achieved by the multi-functional worker. Production control does not necessarily have to be computerized.

In an unmanned cell physical integration is again achieved through the layout- either U-shaped or circular. Information integration is achieved by the cell controller, usually a computer that drives the controllers of the machines and other cell equipment. A production plan can be downloaded to the cell controller and then monitored by it.

A cluster of independent cells forms a cellular manufacturing system (CMS). However, this integration is only partial,i.e., integration within the cells, If the cells are linked together by some material flow device, full integration is achieved. This is call a linked cellular manufacturing system.

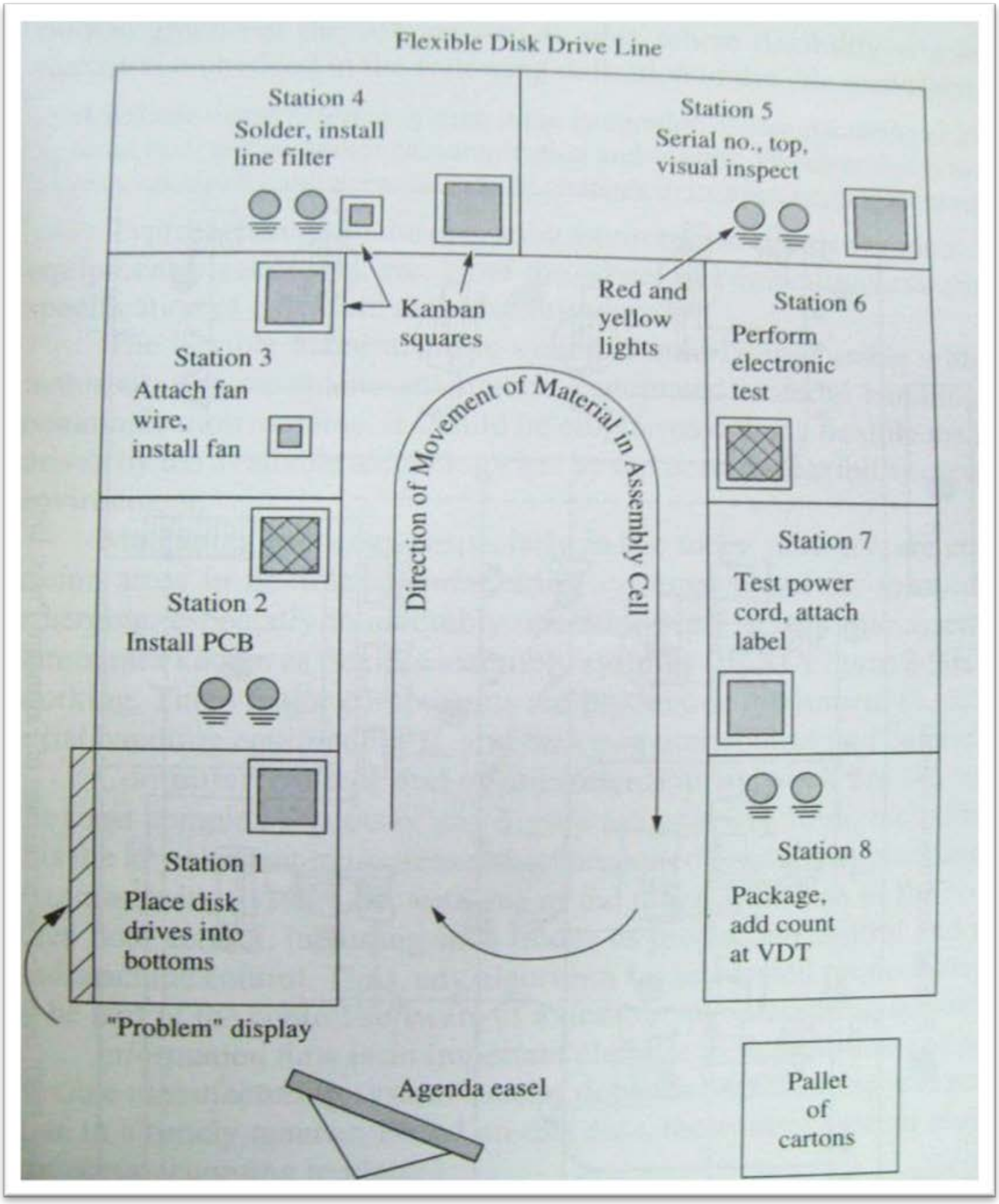


Figure 2-8 Manned assembly cell

8.3.2 FLEXIBLE MANUFACTURING SYSTEM (FMS).

A flexible manufacturing system is another important technology for production floor operation and control. It also covers the middle ground of the volume variety plot, where flexibility is a major requirement. This future is embedded in the following definition of flexible manufacturing system.

A flexible manufacturing system is the integration of manufacturing or assembly processes, material flow and computer communication and control. The objective is to let the production floor respond rapidly and economically to changes in its operating environment.

Typically changes in the operating environment concern product mix, production volume, equipment breakdowns, etc. Note the wheel of competitiveness concepts embedded in the specification of a flexible manufacturing system.

The flexible manufacturing system would be impossible without certain technologies maturing: programmable automation, automated material handling, computer control, and communication systems. It should be emphasized that a flexible manufacturing system is not driven by the available technology but by the need for flexibility created by the market-driven environment.

Machining processes, especially in the metal industry, are currently the largest application areas in flexible manufacturing systems. However, many different applications are emerging, especially in assembly operations (e.g. electronic assembly). These systems are sometimes known as flexible assembly systems (FAS). Figure 2-9 is a typical FMS for metal working. Three major components are production equipment (1, 2, and 7 in the figure), material handling equipment (3), and the computer control and communication network (12).

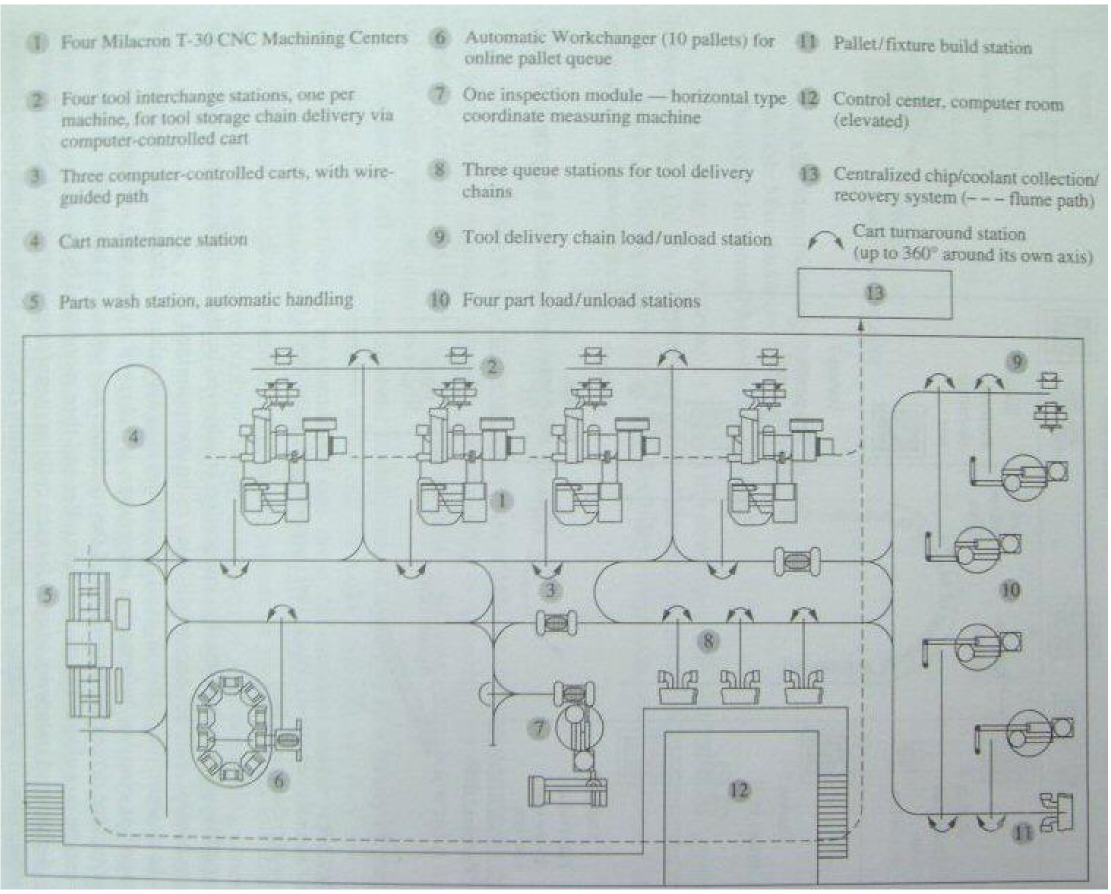


Figure 2-9 FMS at Milicron

Computer control and communication network are likely the most important and the most complex aspects of highly integrates systems, including and FMS: Furthermore, it is the key element in implementing integrated production planning control in a flexible manufacturing system, because one of the major functions of the computer control system is shop floor control, including such things as production control and scheduling, flow control and machine control. This any algorithm for integrated production planning and control has to be part of the control software of a flexible manufacturing system.

Information flow is an important element in the operation of an FMS. The success of a flexible manufacturing system usually depends on collecting and reacting to real-time status data in a timely manner. Based on this data, the control system must adjust when events do not occur according to plan.

8.3.3 COMPUTER INTEGRATED MANUFACTURING (CIM).

Computer integrated manufacturing is a third approach to medium-volume, medium-variety manufacturing. Computer integrated manufacturing has a broader scope than cellular manufacturing systems or flexible manufacturing systems. Not only is it computer-based, but it implies a high degree of integration between all parts of the production system. All functions of production are tied into one large computer database, and access to the data is provided to various departments (users) in the organization. Theoretically, materials come in one end of the plant, and finished products come out the other end, all at the push of a button. In readily, this objective has rarely been achieved.

So what is CIM? There is no standard definition. Some view computer integrated manufacturing as a technology, but others look upon it as a management philosophy that has the required technology to implement it. We therefore purpose the following definition:

Computer integrated manufacturing is a management philosophy that uses computers, communication and information technology to coordinate the business functions with product development, design and manufacturing. The objective is to obtain a better competitive position by achieving a high level of quality on time delivery and low cost.

It should be clear from this definition that the major integrating elements in computer integrated manufacturing are information and information technology. We want to carry the notion of computer integrated manufacturing one step further; it is a strategic goal that a firm strives to achieve over time. This definition is consistent with the wheel of competitiveness and the objectives of production systems we presented earlier.

There may be some confusion between flexible manufacturing systems and computer integrated manufacturing. One distinction is that FMS deals basically with the production floor, i.e., local integration, whereas CIM goes beyond the production floor toward global integration. Carrying this argument further, flexible manufacturing systems represent more of a bottom up approach to automation, but computer integrated manufacturing is top down.to phrase it differently, FMS creates islands of automation on the production floor, whereas CIM builds bridges between the islands to integrate them. In the long term, these two approaches will tend to merge. Flexible manufacturing systems will become just another aspect of a typical computer integrated manufacturing system. It will take some time before this happens on a wide scale, however. In order to get there, the system design must be part of a long-term automation strategy.

8.3.4. Benefits of Integrated Production Systems. Although achieved in different ways, certain benefits are common to the three types of integrated production systems. These benefits, corresponding to elements of the wheel of competitiveness, including quality, time, cost, integration, flexibility, and waste. A list is given in Table 2-1.
Numerous applications demonstrate the benefits of integrated production systems.

Table 2-1 Benefits of integrated production systems

Shorter lead (delivery) time,
Reliable delivery time,
Flexibility in production scheduling,
Reduced worker in process,
Reduced set up,
Reduced floor space requirements,
Better quality,
Consistent quality,
Improved management control.

8.4 Integration processes

Integration is a key element of market-driven production systems. The full benefit of integrated production system will not be obtained unless certain integration processes rake place. Some of these processes relate to designing the product and the system. But others relate to the operation of the system. We present an overview of three processes: teamwork, a part of the employee role in the wheel of competitiveness.

8.4.1 TEAMWORK. Machines do not run organizations, people do. People are the most important resource of an organization and in the final analysis make the difference. It is no wonder that the human element is the basis of many integration processes.

In our discussion of integrated production system design, we noted the need for two aspects of integration: physical and information. The same philosophy applies, in a sense, to involving people in the integration process, which is achieved by building multi-functional reams to achieve a certain objective. Team meetings provide the physical integration. Information integration results from each member sharing different disciplinary knowledge with the team.

One outcome of teamwork is the elimination of functional barriers within the organization, those "walls" between departments that impede integration. Furthermore, by involving people from different disciplines, the outcomes will be more acceptable to everyone. In addition, a broad brain trust is put to work, which can generate a wide range of good ideas.

Teamwork itself is not a new idea. The novelty lies in the fact that it has become a company-wide approach and part of the management process aimed at achieving integration. Teamwork is the basis for two major integration processes: concurrent engineering and total quality management. We discuss them in the following sections.

8.4.2 CONCURRENT ENGINEERING. Concurrent engineering, also known as simultaneous engineering or life cycle engineering, is best described the following definitions:

Concurring engineering is a systematic approach to the integrated, concurrent development of products and their related processes, including manufacture and support. This approach is intended to cause the developer from the outset, to consider all elements of product cycle, from conception through disposal, including quality, cost, schedule and user requirements.

Concurrent engineering substitutes the sequential procedure of product and process design with a parallel one; product and process design are considered together, with an extended scope, which eliminates the functional barrier between product design and product manufacturing.

The process of concurrent engineering is implemented by using a team approach; cross functional teams are formed that include representatives of design and manufacturing, marketing, quality, and sometimes finance. Each team is responsible for a product or family of products. Its mission is to shorten the time from product concept to market, often called the time-to-market. In doing so, a product design yielding low manufacturing cost and high quality is achieved.

Concurrent engineering organizes the team's work. It structures the flow of debate and decisions so that people whose decisions come later in the process are involved in the decisions made earlier. The level of involvement of team members during the concurrent engineering process is dynamic. Initially, marketing has heavier involvement. Then, when requirements are defined, the product design has heavy input, to be followed by the process designer. The important fact is that the process is integrated; each function is involved in every phase.

8.4.3 TOTAL QUALITY MANAGEMENT (TQM). Total quality management is a good example to demonstrate evolution of processes in market-driven systems. Some people feel TQM is a different approach to quality, but others view it as simply a new buzzword. So, what is it really? And what is its importance in the context of integrated production? These issues and others are discussed in this section.

TQM is an organization-wide quality focused culture. It is a journey to achieve excellence in all aspects of the organization's activity. It involves all members of the organization at all levels of operation.

Total quality management is a management philosophy rather than another quality technology. Its origin is attributed to Japanese industry, and it migrated to the west more than a decade ago. Ironically, in Japan, TQM emerged in the early 1950s from the quality philosophy of Dr. W. Edward Deming, a world famous American quality expert.

In the west, an evolutionary process led to TQM, the three major phases of which are statistical quality control, total quality control, and total quality management.

Statistical quality control is the use of statistical methods to control quality. It originated in the United States in the mid-1930s by Shewhart. These methods were extended over the years, and they are still a major part of any quality program. An important technique in this context is statistical process control (SPC), a statistical tool used to control the variability of process in order to achieve high product quality. Personal computers boosted statistical process control to widespread use on the production floor. Its organizational concept is that product quality is the responsibility of the quality control function. This philosophy is typical of the production-driven systems era.

Total quality control extends the organizational aspect of statistical quality control, but it does not change the basic tools. The total quality control philosophy recognizes that product quality is not just the responsibility of the quality control function. All parts of the organization, such as manufacturing, engineering, and marketing must share this responsibility too; this process is an example of organizational integration. In retrospect, this concept was part of the transition from production-driven systems in market-driven systems.

Total quality management can be regarded as a spin-off total quality control. It is a management philosophy with a set of tools to support it and is definitely a product of the market-driven system. Total quality management expands the scope of quality and the range of involvement in it. Quality no longer refers to just product quality; it is the quality of every activity in the organization, be it production or service. These activities include research and development, finance, maintenance, accounting, and sales. Furthermore, quality is the responsibility of every member of the organization, from the president to hourly employees.

9 WORLD CLASS MANUFACTURING (WCM)

The definition of **world class** is much discussed, as in the path to achieving it, and the term has recently become popular in the literature, mostly from Schoenberger's book, *World Class Manufacturing* (1996). Earlier, a common term**, manufacturing excellence**, was used. In both cases to goal is to achieve superior manufacturing capabilities. There is no standard definition of world class. However, the term represents the influence of the new market dynamics- the global market- and it nicely captures the breadth and essence of fundamental changes taking place in successful industrial enterprises. Some of the definitions that appear in the literature include only philosophies, but others include the philosophies and the means to achieve them. We present four definitions that appear in the literature and then propose our own.

Hayes et al. (1988) define world class manufacturing as follows:

- Become the best competitor; be better than almost every other company in your industry in at least one aspect of manufacturing.
- Be more profitable than competitors
- Hire and retain the best people
- Develop a top notch engineering staff
- Be able to respond quickly and decisively to changing market conditions
- Adopt a product and process engineering approach that maximizes the performance of both
- Continually improve

Huge (1988) describe a new philosophy of manufacturing excellence that is based on the two fundamental principles of continuous improvement and elimination of waste.

Schonenberger (1986) identifies the turning point to world class manufacturing as 1980, the year North American companies began overhauling their manufacturing apparatus. As the overriding goal he suggests "continual and rapid improvement" in quality, cost, lead time, and customer service.
The National Center for Manufacturing services (NCMS) Report (1988) presents eight areas of operating principles revolving around both customer and quality.

- Management approach
- Manufacturing strategy
- Quality and customer
- Manufacturing capabilities
- Performance measurement
- Organization
- Human assets
- Technology

Those areas are broken up into additional principles. The NCMS premise is that these principles, executed in concert, will increase the competitiveness of any manufacturer to that of a world class performer.

Obviously, these definitions are not contradictory, but rather complementary. Each emphasizes different aspects and provides a mix of concepts, principles, and tools.

Our definition of world class manufacturing is based on the objective of production systems defined in this chapter. *A world class manufacturing organization is one that subscribes to the objective of continuously increasing customer satisfaction; adopts the operational goals-quality, time, and cost-combined (QTCC); embraces the support concepts; and commits itself to the impact on the organization of the long-haul change process.* This definition is schematically represented in figure 2-10

There are two tendencies in the literature: one claims that all support concepts have to be adopted to succeed, but the other selects one or two "champions". We believe both approaches are wrong. Markets are different; organizations and cultures are different; so there is no one way to win this battle. Different situations, even in the same organization, may require a different mix of these concepts and their related tools. The **management art** of creating the proper mix will yield the best results. As Macbeth (1989) (used by permission of Springer-Verlag New York, Inc.) says.

One of the features of the Western business world is that we are too easily persuaded of the merits of a particular "solution," and as a result, assume nothing else remains to be done. In

this way companies move from one “panacea” to another as new “flavors of the month” are pushed by the latest “guru”
We cannot state too strongly that there is no “all in one” approach. A proper mix of these philosophies, concepts, and tools is determined by the particular situation.

Recently, two management philosophies elaborating on world class manufacturing have emerged; lean production and agile manufacturing. We discuss them next.

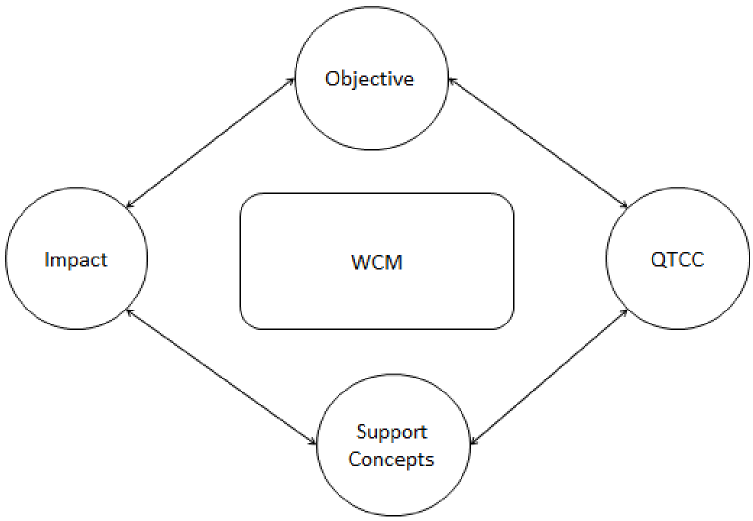


Figure 2-10 World class manufacturing

9.1 lean Production
Lean Production is a term coined by a research group at MIT. Their five-year-study on the future of automobile production examined 90 plants in 19 countries. It promotes elimination of inventory and other forms of waste, greater flexibility in production scheduling, shorter lead times, and advanced level of quality in both product and customer service. Lean production combines the advantages of craft and mass production without the high cost of the former or the rigidity of the latter. A cornerstone of lean production is the use of interdisciplinary teams at all levels of the organization.

Clearly, lean production employs many of the concepts and processes we described before. It is widely recognized that Japan was far ahead of the rest of the world in implementing lean production, which started in the 1950s at Toyota. It did not catch on in Western industry, however, until the 1980s.

The term was coined because it uses less of everything, compared to mass production –less human effort in the factory, less manufacturing space, and less engineering time to develop a new product.

Lean production differs from mass production in the number of ways, but the major difference is in the ultimate objectives. By implication, mass production set a limited goal- that of good enough. Operationally, there is an acceptable number of defects, an acceptable inventory level, and acceptable low product variety. The rationale was that to do better will be costly, and doing better was not required in the production-driven era.

Lean production sets its sights on performance, defining a path to production- zero defects, declining costs, higher flexibility, and more product variety. Thus lean production is a result of market-driven systems.

9.2 Agile Manufacturing

The concept of agile manufacturing started in a report titled " 21st Century Manufacturing Enterprise Strategy,"(Goldman et al, 1991). This study done by the Lacocca Institute at Lehigh University, involved more than 150 industry executives. The report describes how U.S.industrial competitiveness will –or might- evolve in the next 15 years. An organization called the Agile Manufacturing Enterprise Forum (AMEF) was formed to continue this work. The Lacocca Institute effort was, to a certain degree, inspired by the Japanese study manufacturing 21, which scripts scenarios for Japanese competitiveness in the twenty-first century.

The major thrust of agile manufacturing is an enterprise view, which, specifically, includes the following:

- Greater product customization –manufacturing to order but at a relatively low unit cost
- Rapid introduction of new or modified products, in some cases through quick formation of a temporary strategic partnership to take advantage of brief windows of opportunity in the marketplace, which is called a virtual enterprise or virtual organization
- Upgrade able products that are designed for disassembly, recyclability, and reconfigurability
- Interactive customer relationship
- Dynamic reconfiguration of product processes in order to accommodate swift changes in product design or entirely new products lines
- Commitment to environmentally benign operations and products

Examining these specifies, we see that agile manufacturing uses many of the concepts from the wheel of competitiveness.

On the production floor, reconfiguration is the main issue in agility. It is the ability to quickly gather necessary resources to meet a specific deadline, say a delivery date for a large order. Furthermore, the reconfiguration should be implemented at a reasonable cost.

The concept of agile manufacturing is still somewhat amorphous, and some of the support systems have yet to be developed. However, this approach appears to be the major thrust to create a vision to manufacturing enterprises in the next century.

9.3 Lean versus Agile

At first glance, agile manufacturing might seem to be another way to describe lean production. There are similarities, but there are also differences.

The major difference is that agile manufacturing takes an enterprise view, whereas lean production is typically concerned with the production floor. Further, lean production is regarded by some as an enhancement of mass production methods. Agility implies breaking from the mass production mold so that a wider variety of custom products can be made.

We believe that subtle differences between lean production and agile manufacturing are not that important. What really counts is that both are based on similar concepts-those outlined in the wheel of competitiveness. Furthermore, we view each as a milestone on a path to develop new production theories.

10 SUMMARY

American competitiveness declined in the mid-1960s. Since then, Japan has captured many markets in the United States and other countries because they could make products better, faster, and less cost. It took time to realize that different approaches are required to deal with this new industrial environment. In seeking new approaches we look at production in Japan and America.

American companies were initially surprised by the Japanese success. This surprise quickly turned to admiration and then to the realization that the Americans needed to regain a competitive advantage. Some U.S. companies attempted to imitate Japanese companies, while others tried new approaches. From trial and error, the best concepts from both Japanese and American production systems have emerged; some classical, some Japanese, and some new Americans.

Looking at the status of management theories today, we conclude that the classical theories do not cover all aspects of the new environment. Although concepts of future theory may not be certain, we list the major ones. We integrate these concepts in the “wheel of competitiveness.” We believe the concepts in the wheel of some of those required to return American industry to a leadership position.

The wheel has four concentric circles, each representing aspects of the emerging production management theory. These circles are hub, delivery, support, and impact. The hub of the wheel is customer. The delivery circle shows system shows system deliverables to the customer: quality, time, and cost. The support circle shows eleven concepts needed to support the production system deliverables. The impact circle addresses a change in the organizational culture.

The chapter includes a detailed discussion of each of the circles. Customer satisfaction, time, cost, and quality are defined. The concept of integration, flexibility, simplicity, pull, waste, improvement, and others are discussed. The impact of the organizational culture is reflected by the transition from a culture of efficiency to a culture of effectiveness. This transition takes years to accomplish; there is no quick fix.

In our definition, a production system’s objective is to make maximum contribution towards continuously increasing customer satisfaction, from which the operational goals, quality, time, and cost follow.

To further illustrate the concepts, we elaborate on integration, showing how it generating a new manufacturing environment- integrated production systems. We discuss three common implementations of integrated production- cellular, flexible, and computer integrated systems. While presenting these, we point out their use of the concepts presented in the wheel of competitiveness. We further elaborate on three processes-teamwork, total quality management, and concurrent engineering- that enhance integration.

Next we discuss the concept of world class manufacturing and give our definition. We stress the need to evaluate each situation independently; none of the concepts we discuss solve every problem. However, a proper mix of these concepts and common sense will provide a good start.

We conclude with a discussion of lean production and agile manufacturing. These two emerging management philosophies grew out of world class manufacturing and will likely impact the direction of production in the twenty-first century.