CHAPTER 1

MANUFACTURING

INTRODUCTION

It frequently surprises people when they learn that the world's leading manufacturing country is the United States of America. Why this may be so astonishing is the prevalence of "Made in China" labels found on so many consumer products, particularly clothing and electronics. In 2007, prior to the recession in the latter part of that decade, the value of goods produced by the United States reached over $1.8 trillion. (see http://unstats.un.org/unsd/snaama/cList.asp)—and, even more surprising, the amount produced in 2007 was nearly twice the value made two decades earlier. Today the United States is still a major producer, generating much of its prosperity from manufacturing. Nevertheless, there is no doubt that a large portion of our products come from overseas.

Part of the reason the United States continues to lead in the production of goods is the manufacturing methods or procedures

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that were developed during the twentieth century. These methods enabled companies to produce large amounts of affordable goods profitably. During the latter half of that century other nations adopted these methods and even made substantial improvements. Now many believe that manufacturing in the United States is too costly both in dollars and harm to the environment. This is not true. There are ways to make manufacturing sustainable and profitable while meeting environmental obligations and requirements.

MANUFACTURING SEQUENCE

To understand how this can be done let's begin by examining the *manufacturing sequence*. The production of a product begins after a raw material has been transformed into a manufacturing "stock." Think of "pig iron" as a raw material and 16-gauge cold-rolled steel as a manufacturing stock. Yes, an argument can be made that pig iron is a manufacturing stock after iron ore has gone through a smelting process. Regardless of where the starting point occurs there is a specific series of steps that occur in the manufacture of a product and its sale to a customer. Figure 1.1 illustrates these steps.

A simple example of this sequence is the manufacture of a molded plastic bowl that is actually a component that will be assembled with other parts to create a more complex product—an inexpensive food processor. The bowl is produced by a molding process using a stock of plastic pellets. The pellet stock is polystyrene, which is produced from an aromatic polymer that comes from a liquid hydrocarbon manufactured from the *raw material*, petroleum. The food processor is next distributed to a customer. After years of use the bowl cracks and the owner finds that it has a recycle number "6" discretely molded on the bottom of the bowl. The owner of the bowl deposits it in a recycling bin that ultimately allows it to be *recycled* into another stock. The manufacturing sequence in this instance is a closed loop, illustrating one of the several definitions for a *product life cycle*.

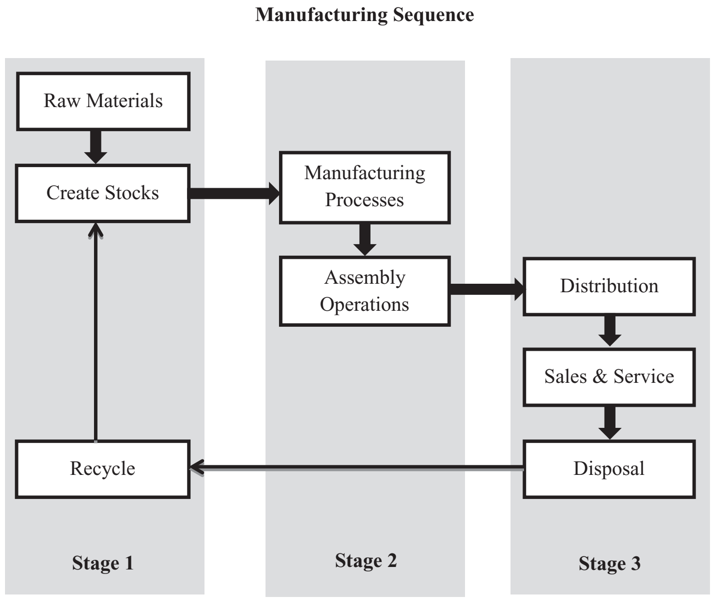

Figure 1.1. The general sequence of manufacturing.

PRODUCT LIFE CYCLES—THERE'S MORE THAN ONE

This concept of a product's life cycle based on the manufacturing sequence provides a useful perspective for developing a competitive and compliant facility. However, the term *product life cycle* is also used to name several other concepts. Probably the most well-known use refers to a marketing-oriented definition of the phases or stages a product passes through over its lifetime. Marketing people generally list five phases, beginning with "product development." The next phase is the product's "introduction into the marketplace," followed by a "sales growth" phase. The last two phases are "product maturity" and finally the product's "decline" in the marketplace. In this instance the life cycle traces the life span in terms of the product's sales volume in the marketplace.

A third form of analysis that shares the title "product life cycle" includes the term "management": *product lifecycle management*

(PLM), which involves managing the information acquired over a product's life so that a company understands how its products are designed, built, and serviced. The emphasis is primarily on the engineering and business aspects of producing the product.

The title of the fourth application, *product life cycle management* (PLCM), sounds identical to the previous one. The difference of course is *lifecycle* is now two words instead of one. PLCM has to do with the strategies a business uses to manage the life of a product in the marketplace. These strategies change based on the product's "marketing phase." Recall the five phases mentioned earlier.

There may well be other product life cycle methods or techniques in use. However, this sampling illustrates their basic objective—to enable a business to understand how a product is doing in the marketplace and what improvements or actions need to be taken to increase sales, performance, and/or safety. These techniques are used primarily for increasing a company's profitability. Our objective, however, is to improve both the company's profitably and its environmental performance.

To do this we'll go back to the general sequence of manufacturing. Recall the example involving the plastic bowl? The bowl started out as a raw material and moved through the manufacturing sequence until it was purchased and placed into use. When it cracked it was recycled. This sequence can be used as the basis for an analysis that examines how manufacturing impacts the environment: life cycle analysis (LCA).

LIFE CYCLE ANALYSIS

The origins of *life cycle analysis* probably came from the environmental impact studies and energy audits that were carried out in the late 1960s and early 1970s. These studies attempted to assess the resource costs and environmental implications of the industrial practices going on in the world at that time. Paper manufacturing, as well as its associated recycling processes, was one of several activities that received a great deal of attention in these early studies. The methods these studies used were unique at the time because they followed the entire sequence of business. As with the manufacturing sequence, these studies started with turning raw materials into usable stocks for production and followed the sequence through distribution, the customer's use, and finally the product's disposal or recycling. The analysis attempts to identify the environmental costs associated with a product by examining the all the resources and materials used along with the wastes released to the environment over a product's lifetime.

These studies have evolved into a defined protocol. The LCA has become a popular technique in building and construction projects. In fact its popularity has reached a level that there are several software products available to assist in the analysis. An example is the "Building Life-Cycle Cost" (BLCC) program developed by the National Institute of Standards and Technology (NIST). The U.S. Department of Energy's Federal Energy Management Program says that the BLCC enables architects and builders to evaluate alternatives to find the most cost-effective building designs in terms of energy use over the life of the project.

Along with LCA and BLCC there are a variety of other terms being used to describe this technique. The most familiar term is probably LCA, but there are others now in use such as *life cycle-inventory* (LCI) and *life cycle assessment* (also abbreviated LCA). Also, if you do an Internet search on LCA you will also find more terms such as cradle-to-grave analysis, eco-balancing, and material flow analysis. Regardless of the name, the primary aim of life cycle analysis is to identify the environmental impact of the materials and resources used in the manufacture and use of a product.

To be of value the analysis needs to identify and quantify the source and amount of waste generated over the entire manufacturing sequence. This is similar to a procedure that financial managers call *sources and uses*. Large publicly traded companies will include a "sources and uses of funds" statement in their annual reports. The resource in this case is money—where it is obtained, its source, and how it is used to carry out the activities of the business. Individuals and institutions that are contemplating lending money to a startup company look for a sources-and-uses worksheet because it is an excellent summary of the "startup's" financial plan. In a similar manner an LCA can be viewed as a sources-and-uses statement.

Most LCAs include a comprehensive listing of the inputs, the resources. The output defines how effective the facility is in converting these resources into products while minimizing waste. Inputs include all raw materials, stocks, and resources that are used for the creation of the product. Resources include energy demands (electricity, gas, oil, coal, etc.) and water. In some special instances land use might be included. While land is not considered a consumable in the creation of a stock or product, there could be a circumstance that would make the land unusable for a period of time. An example is strip mining.

Figure 1.2 shows an example of an LCA format. This format includes the most common steps in the manufacturing sequence plus extraction of raw materials and repair or service. The outputs of course include the product as well as everything else, which is defined as waste. The major waste categories are water and water effluents; airborne emissions; solid waste; and recyclables. An item that is often overlooked in the analysis of manufacturing waste is packaging. This is not the case in LCA. A major source of waste in the distribution step of an LCA is "single-use" packaging.

The LCA, like the manufacturing sequence, addresses material in the first two steps. On the left side of Figure 1.1 these steps are identified as Stage 1. In the first two steps of an LCA (extraction of raw materials; creation of the stock) the industry carries the name of the material being converted to a stock. As an example, when someone says "the steel industry" what comes to mind? In most cases an image of a steel mill will pop up in our mind's eye.

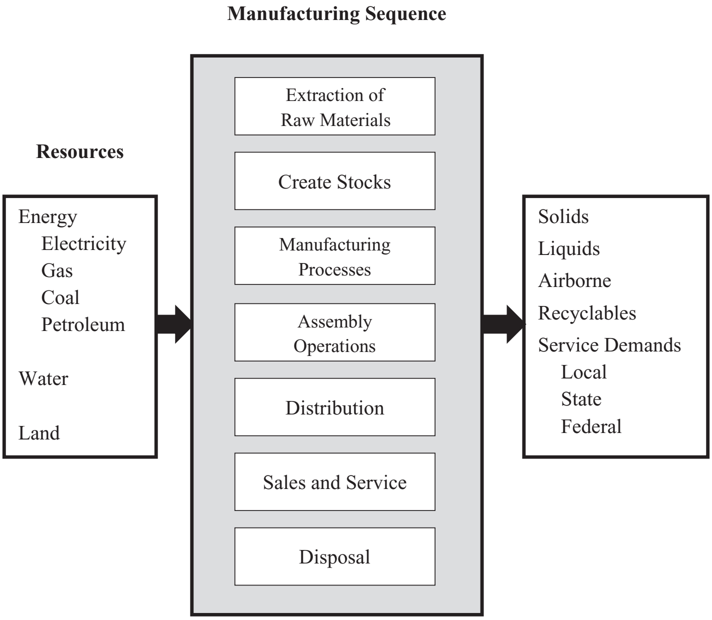

Figure 1.2. A life cycle analysis model.

However, when it becomes a coil of cold-rolled steel it is a stock that will be used to manufacture a product. So, beginning with the third step (Stage 2 in Fig. 1.1) of the LCA, the industry name changes from the material name to the product name. Steel would be replaced by a product name such as auto or appliance.

It is apparent that completing an LCA on just one group of materials or a single industry such as the appliance industry is a major undertaking involving hundreds of companies. However, it is the approach that the analysis uses that is valuable.

Measuring and quantifying the costs of all the materials and resources required to create a product is a basic part of manufacturing. Cost accountants have been allocating direct and indirect costs to specific products and work centers for more than a century. An example of a direct cost is the amount of a stock used to create a product. These direct costs and their proper allocation to a product are relatively easy to calculate. Indirect costs are more difficult to assign. They are expenditures that are not apparent by examining the bill for materials or the list of operations used to make the product. The classic example of an indirect cost is the person who sweeps the aisles when a shift is over. Accountants often handle these costs by allocating them as a percentage of floor space used in the plant to produce a specific product or by using some other proportionality. The task, which is also the problem, is developing a method that will account for all the stocks and resources and then accurately apportion them to the product.

A further complication when using LCA is its "comprehensive" approach. The point-of-view taken by an LCA is excellent. It is the environmental version of the sources-and-uses worksheet but it is applied on an industry scale—much too general for a company involved in just one step of the manufacturing sequence. The general approach of the LCA, however, would be useful for building a new plant. It is not difficult to list the activities at each of the seven steps of a manufacturing sequence for constructing a manufacturing plant. You can list the stocks and processes used to construct the building and the assembly operations to put in the electrical distribution system, the HVAC, the plumbing, and so on that are needed to complete the facility. Servicing the building and its final disposal can also be handled effectively. Therefore the LCA is an excellent technique for assisting management in costing and designing an environmentally effective manufacturing facility.

However the LCA doesn't adapt very well for a company that makes, for example, impeller blades for diesel fuel pumps and dishwashers. The overall approach of the LCA doesn't provide a means to identify or quantify the value of the alternatives available for improving profits and becoming environmentally compliant. The question then becomes how can the LCA concept be used? Chapter 2 introduces an alternative approach that carries with it the underlying notion of an LCA. It is founded on a detailed examination of the waste and resources required to process the materials to manufacture a product.

POTENTIAL FOR WASTE AND VALUE ADDED IN MANUFACTURING

Each of the seven major activities in the manufacturing sequence offers manufacturers opportunities for creating value and waste. Table 1.1 lists these opportunities along with their potential for creating waste. This potential will vary for each of the seven steps. For instance, an assembly operation may generate some waste but generally the environmental impact will be minimal. However, in some of the other steps the waste and environmental costs can be quite high. As an example for the extraction of raw materials a large part of all waste will be environmental costs.

The table's third column lists the *value-added potential* for each step in the manufacturing sequence. As is the case with waste, the potential to add value varies significantly depending on the step and certainly on the product being made. You'll notice that assembly operations have a low to moderate potential for waste and a moderate potential for adding value. Balancing the potential for waste against the potential for adding value has been a manufacturing tactic for years. Changes in technology and proprietary knowledge can also reorder the balance between value added and waste generated for a particular step.

TABLE 1.1. Potential for Creating Waste Compared with the Value-Added Potential for Each Step in the Generalized Manufacturing Sequence

Manufacturing Sequence	Potential for Creating Waste	Potential for Adding Value
Extraction of raw materials	High	Moderate
Create stocks	Moderate to high	Moderate
Manufacturing processes	Moderate to High	High
Assembly operations	Moderate	Low to moderate
Distribution	Low	Low
Sales and service	Low	Moderate
Disposal	High	Low

A company that limits itself to performing just one step in the sequence would in theory be simplifying its business by focusing on just that function. However, this limits the company to the amount of value added in that step. Alternatively a manufacturer could try to do all seven steps and earn all of the value-added potential from the raw material to the sale and disposal of the product. Of course all the potential for waste would be present too. Also, the company would have to develop the skill and expertise for all aspects of the manufacturing sequence. There is a company that became the classic example of this approach.

At the beginning of the twentieth century Ford Motor Company had success in producing a rugged and durable automobile. The car design was good but there were other autos being manufactured at the time that were just as good. Henry Ford, however, wanted to make large numbers of cars that were affordable. With this in mind he toured plants in other industries to understand how they made their product. It has been mentioned that he came up with the idea of a continuously moving production line after he had visited a meat packing plant. True or not, he eventually concluded that effective large-volume manufacturing has four principles:

- The product uses interchangeable parts; no custom fitting or modifications should be required.
- The product moves to each workstation at a predetermined rate; this was the introduction of continuous flow manufacturing.
- The work to manufacture the product should be broken into a sequence of simple easy-to-learn tasks.
- Reducing or eliminating waste of all kinds is an ongoing effort.

It took Ford five years to put these four principles into operation; that was in 1913 at his plant in Highland Park, Michigan. These changes created the first moving assembly line ever put into service for large-scale manufacturing. Very quickly the assembly line became the icon for Ford's system of production.

A year later the continuously moving assembly line had significantly increased production and labor productivity. However, Ford's monthly turnover of labor had reached 40 to 60 percent. The company realized that this was due largely to the tedium of assembly-line work and the frequent increases in the production quotas that were placed on the workers. Ford solved this turnover problem by paying his workers $5 a day when other manufacturers were paying about $2.50 per day. The increase in labor costs were offset by an increase in output (productivity) due to a more stable workforce. The improved productivity also provided a substantial increase in the company's profits. At the same time the company's profits were increasing, the price of the Model T continued to drop. The result was an increase in demand for the Model T. Before Ford stopped making the Model T in 1927 over 15 million of these cars had been sold.

VERTICALLY VERSUS HORIZONTALLY INTEGRATED MANUFACTURING

Certainly the manufacturing principles that Henry Ford and his team developed were important. But it shouldn't be overlooked that the company also had an intense commitment to lowering costs and capturing all the value-added opportunities available in making and selling automobiles. His company embodied most of the steps in the sequence of manufacturing, starting with mining the iron ore to create the steel stock that went into their cars. Ford's enormous industrial facility on the Rouge River in Dearborn, Michigan, took the iron ore off ships and just days later the ore was steel and iron in finished automobiles on the way to car dealers. The Ford Motor Company was an excellent example of a *vertically integrated manufacturer* and for its time a lean manufacturer. Recall Ford's fourth principle.

At the same time Ford was developing his system of manufacturing automobiles, most of the other car builders remained specialists, concentrating on some processing but primarily on assembly. These companies limited themselves to just one or two steps in the sequence of manufacturing. Therefore they could be described as being more nearly *horizontally integrated*. Usually a horizontally integrated manufacturer makes more than one product. The company can expand its production or sales by offering a wider range of products or models. If the company elects to purchase parts and limit its manufacturing operations to just assembly, then it becomes a *limited horizontally integrated* manufacturing company.

There is an interesting observation that can be made. Ford's innovations were primarily in the way cars were made—Ford developed manufacturing technology, not product technology. The change in product technology was modest during the period the Model T was in production, which started in October 1908 and continued until 1927 when its replacement, the Model A, was introduced. During this period Ford was able to master the complexity of the entire manufacturing sequence and capture most of the value-added opportunities.

So what is the downside for vertically integrated manufacturers? These companies are much more vulnerable when product technology is changing quickly. A horizontally integrated manufacturer can usually adopt new technology more quickly than a vertically integrated company. In part that's because the horizontally integrated manufacturer has a narrow focus, reducing the knowledge and skills that must be acquired. Similarly the amount of investment needed for new equipment and tooling is also less. The magnitude of change for the vertically integrated company can be enormous. They tend to "hang on" to processes and methods that are not competitive, thereby forcing them into a period of being unprofitable and relying on costly "stopgaps" to be environmentally compliant.

The personal computer (PC) industry provided a good example of the impact that fast-changing product technology can have on manufacturing. In the late 1970s several of the desktop PCs relied on an agglomeration of parts that included portable cassette-tape players for data storage. Assembly was very basic and similar to the methods used to produce a television set. In fact many of the popular desktop computers at the time were actually electronic kits that were assembled by hobbyists and technicians. The key component was the microprocessor, which was a single chip that replaced all the circuitry that formerly occupied large cabinets in mainframe computers.

By the mid-1980s there appeared to be an opportunity for a sophisticated vertically integrated computer manufacturer to enter the PC market. The PC market fueled by the popularity of word processing and spreadsheet programs was definitely in the sales growth phase. One such company that recognized this opportunity was IBM, which at the time spanned at least three of the seven steps in the manufacturing sequence of a PC.

However, the PC was being produced during a period of rapidly changing product technology. Most of the components used in a PC were produced by companies that specialized in just one step of the manufacturing sequence. When innovations in data storage occurred such as in "disk drives," the producers of PCs quickly adopted the new style "floppy disk" into their product. By the late 1980s the technical product life of PCs was measured in months, which meant the distribution step became critical in the sequence of manufacturing. Dell computers exploited this by selling directly to the PC user. During the early 1990s horizontally integrated companies became dominant as producers of PCs.

WASTE AND ITS UNEXPECTED SOURCES

Regardless of whether a manufacturer is involved in one or all of the steps in manufacturing, the fundamental strategy for a company should be to maximize value added by minimizing waste. Obviously during periods of rapid change in product technology a company might be wise to limit its manufacturing involvement to two steps, assembly and distribution. Products such as the tablet computer and the smart phone provide examples of how this strategy can work, especially while these products are in a growth phase in sales. However, product technology is normally an evolutionary process. It can creep up on companies particularly when their products are in a mature phase in sales. Too often companies feel that the most effective way to differentiate their product and maintain sales levels is through price, specifically price reduction. After the price is reduced the company then looks for ways to reduce its manufacturing costs so that it can remain or once again become profitable.

Too often organizations try to reduce cost by taking away value from the product. That is wrong. Reducing value by eliminating features, service life, or functionality is placing the burden of cost reduction on the customer when it should be the organization's responsibility. The focus of cost reduction must be on the elimination of waste. In later chapters specific methods for identifying opportunities for waste reduction are introduced. There are also some case studies to illustrate how some of these waste reduction methods are used by companies. However, before moving on to these topics the source and types of waste need to be defined.

The First Source of Waste

The first major source of waste originates in the way the company makes its products. Much waste is due to the product design and the manufacturing processes used in the plant. Certainly the type of materials a company uses, which is a function of the product design, will dictate the plant design and the processes. Each material and the associated manufacturing processes have their own set of waste parameters that defines the facility. But some of the waste occurs due to the organization of the facility and the operation norms that have been established. These are the fixed sources of waste that are seldom challenged. The following are examples of items that would contribute to this source of waste:

- *Resources*. The fuels needed to operate the processes, machines, and equipment used in the manufacturing sequence.

This would also include plant and office heating, lighting, and air conditioning.

- *Water*. This also includes the associated costs of sanitary and storm sewer services.
- *Supplies*. The secondary materials that are required to complete a manufacturing operation or process but do not become part of the product. An example might be cutting tool coolant/lubricant, towels, cleaners, copy paper, etcetera. These are waste materials that are "accepted" as being part of the manufacturing operation or process.
- *Wages Paid*. Payment to individuals and to contractors or suppliers who do not add value to the product. This is one of the most difficult categories to control.

It is unusual for manufacturers to think of the items in this list as waste. Often companies "see" these as givens, inherent and necessary to conducting their manufacturing operations and certainly not waste. Can this source of waste be eliminated? No, but there is waste that can be eliminated. Therefore the first step is to recognize that there is waste in this listing and then take the second step—determine the magnitude of the waste in these four categories.

Measuring resource costs and water use for specific manufacturing operations can be done with the help of technology in the form of *smart meters*. Devices of this type can provide the "where, when, and how much" for resources being consumed. These meters are often referred to as time-of-use meters. Currently the most widely used smart meter is for monitoring electrical consumption; however, similar devices exist for measuring natural gas and water use. In large installations these devices can be networked to provide for real time monitoring and control of consumption. There are several software programs available that can make it relatively easy to complete a detailed analysis for the dollar cost of resources per unit of production.

Supplies frequently receive a great deal of attention during recessions and business downturns. Often more attention than they warrant. This category needs to be judged using the *Pareto principle*. You may recall that this principle is based on the work of Italian economist Vilfredo Pareto, who observed at the beginning of the twentieth century that 20 percent of the people owned 80 percent of the wealth in Italy. He and others found that this distribution disparity occurs frequently. As an example the "eighty–twenty rule" as it is called may apply to customers: 80 percent of a company's sales go to 20 percent of its customers. So to put this principle into practice one needs to concentrate on the significant few—examine the major costs first and ignore the trivial many. The costs of supplies are often among the trivial many. However, before supplies can be dismissed they need to be assessed to make sure they are not one of the significant waste streams that demand immediate attention.

Identifying wages paid to people who do not add value to the product is a *can of worms.* The definition of the term "can of worms" describes the circumstances beautifully. It is a complex troublesome situation, a mess of entanglements arising when decisions or actions produce subsequent problems. This is why this source of waste is seldom addressed. Being identified as not adding value to your company or branded as a "source of waste" is definitely going to create a troublesome situation. Consequently this item has to be dealt with carefully.

To start we need to examine the definition of a value-added task. The strictest connotation states that a value-added task is an activity that changes or transforms a product or moves the product closer to the consumer. A more general definition recognizes indirect activities or tasks that add value to a product. Examples of these indirect tasks are found in purchasing, production planning, maintenance, billing, payroll preparation, and so forth. These are all support activities that don't touch the product. However, these activities must be carried out effectively for a manufacturing facility to perform efficiently. So the question arises: what is a non-value-added job? Some examples are "inspectors" trying to find defective parts or products, material handlers moving parts and products that can't be shipped, and managers meeting with employees trying to settle grievances. It can be argued that these three examples of non-value-added tasks just mentioned are necessary to be an effective manufacturer; however, they are definitely symptoms of a second source of waste.

The Second Source of Waste

The second source of waste comes directly from manufacturing operations. This source has received the most attention since factories were established to produce products. Over the past few decades the people involved in controlling this source of waste now include manufacturing operations and engineering; human resources; and training and development.

There are a lot of names and acronyms for programs, techniques, and tactics used to reduce waste in manufacturing. The concept of *lean manufacturing* has become the most comprehensive approach for waste reduction now being employed. In general a lean manufacturing program works to reduce eight types of waste:

A starting point for reducing waste is to conduct a "check-up" not unlike the way a physician conducts an annual physical. There are tests to be conducted and information to be gathered along with a physical examination. The manufacturing facility has to be examined in a similar manner. A helpful approach is to use a checklist for developing a diagnosis—an assessment of the problems from the eight sources of waste:

1. *Waste from Overproduction*. More products are produced than required by the customer. Often this is done to reduce idle time or to make up for anticipated defects or product losses; excess production also may result from incentive systems.
2. *Waste from Transportation*. There may be excessive movement of the product or its components during the production process. In practice this is moving work-in-process into and

out of temporary storage or moving work because of poor facility arrangement.

3. *Waste of Motion*. Waste of motion occurs when the operator has to look for tools or information, to make adjustments or repairs, to free jams, or to fill out incentive tickets or routing sheets.
4. *Waiting*. Time may be wasted, for example, waiting for setups to be completed, materials to arrive, or equipment to be repaired.
5. *Work-in-Process*. Work-in-process (WIP) includes all stocks, components, and subassemblies in the manufacturing system. The minimum level of WIP is the amount that is being processed (stocks and components that are in a value-added operation or process) at any point in time. Finished goods stored waiting to be invoiced are also counted as WIP.
7. *Defects*. This includes spoiled or rejected parts, subassemblies, finished goods, returns, warranty work, and product recalls.
8. *Scrap*. Material stocks are turned into scrap because of the product design or manufacturing process. Examples include paint overspray, punchings, trimmings, and end-of-reel fragments.

After looking over the types of waste you probably realized that many of the categories don't have any direct environmental impact. However, the indirect impact on the environment can be significant. For example, at a minimum a company that maintains large amounts of WIP needs more floor space, which means a larger building, which means more energy for heat and light. In a lean manufacturing environment a smaller building with lower energy and resource consumption would be just as productive. The excess WIP is a primary source of waste and the associated resource requirements are a secondary waste. In nearly every category of waste it is possible to identify a secondary cost to the environment.

If the waste happens to be in a form that is regulated either directly or indirectly, it will generate additional costs or limitations on a manufacturer. Of course it is essential that companies comply with these government regulations. However, compliance doesn't mean carrying on as before by paying fees and installing abatement equipment. It is essential that manufacturers make choices when they design their product, plan their manufacturing buildings, staff the facility, and select production processes and equipment that will avoid or minimize the cost of the regulated waste.

The Third Source of Waste

The third major source of waste is the materials and activities that are part of the value-added operations and processes used to manufacture the product. To minimize this source of waste requires the designers of the product and the manufacturing engineers and technicians to optimize the materials and processes needed to produce a product. What does optimizing mean? It means selecting materials and processes that minimize waste while providing a product that meets its intended function safely, reliably, and at a value that matches or exceeds its cost to the customer while being profitable for the manufacturer. The phrase "being profitable for the manufacturer" implies being environmentally compliant.

This source of waste is controlled by three groups of people. The first group specifies the product's characteristics and function. The second group uses this specification to design the product and works with the third group to specify how it will be manufactured. These three groups (functions) of people involved in this activity are the following: marketing; product design and engineering; and manufacturing engineering and operations. They are the ones who will select the materials and processes used to manufacture the product.

A basic precept in design states that the selection of a material defines the manufacturing processes that will convert the material stocks into a product. Therefore for a new product the reduction of waste and emissions begins with material selection. Of course someone will be quick to point out that there are several manufacturing processes that can perform a specific operation for a given material. For example, suppose the product design requires that a metal plate must be cut in half. The basic process is called *separating*. There are several ways to carry out this process but we'll consider just three ways; sawing, shearing, and flame cutting. Of these three, shearing would probably result in virtually no material waste, minimal energy use, and no primary emissions.

The methodology for controlling this source of waste uses an approach involving a matrix that considers material classes associated with basic processes. Chapter 2 introduces this approach and provides a tool to evaluate alternatives in materials and processes to identify a design that can be both profitable and environmentally compliant.

A NEW PRODUCT—FIRST PHASE FOR WASTE REDUCTION

Once the costs are obtained the next challenge is to identify alternatives that can reduce these expenses and put the operations into compliance for the least cost. This raises the question, who will do this? We have talked briefly about this in the preceding section on sources of waste. So the answer to this question is; well it depends on whether it is a new product or an existing product—it's a two-stage progression. For a new product the first phase of waste reduction involves marketing, product engineering, and manufacturing engineering to make these decisions. Figure 1.3 shows the groups involved and the inputs guiding their decision making. These inputs, some might call them constraints, form the criteria that shape the design.

How well each group responds to these inputs in defining the product, materials, and processes will determine the potential for waste and its associated costs. Consequently it is critical that they

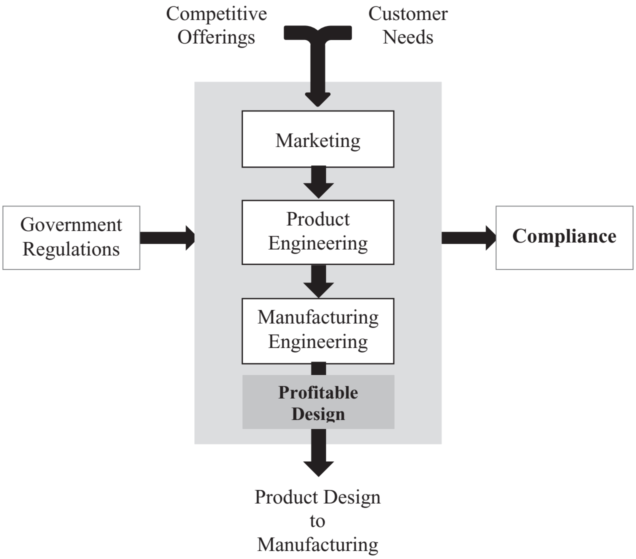

Figure 1.3. The functions and inputs responsible for the design and production of a profitable and compliant product.

recognize the sources of waste and examine alternative designs that meet the customer's requirements. The objective is to create a design that can be produced profitably and be environmentally compliant. Figure 1.3 depicts a linear sequence, which probably never happens. Actually it should never happen. Manufacturing should be consulted and involved in the design of the product just as product design should be involved in marketing—and, marketing should have input in design and manufacturing. This caveat needs to be kept in mind throughout this discussion.

One more comment should be made. A manufacturer that has a product design function (note that many manufacturers do not design the products they make) has to maintain an engineering database that reflects the current state-of-the-art in materials and process technology. The point being that government regulations are continually impacting material stocks and the way they can be processed or used. For example, lead-based paints are no longer included in the engineering database for a furniture manufacturer.

It should be stressed that manufacturing engineering has the responsibility to be aware of the good manufacturing practices that pertain to their industry. Relying only on the processes currently in place will not allow an organization to become or even maintain a competitive and environmentally compliant position in today's marketplace.

One of the best sources for learning about good manufacturing practices is through industry associations and professional organizations. The Society of Manufacturing Engineers (SME) is a professional organization whose goal is to aid manufacturing engineering professionals in staying up-to-date on leading trends and technologies in manufacturing. The American Composites Manufacturers Association (ACMA) is an example of an industry association. This association has over the years carried out practical research on environmentally compliant manufacturing processes and offers education on good manufacturing practices for the composites industry.

Often professional and industry associations provide certification programs for their members, such as the ACMA certification program for composite technicians. The training focuses on the fundamental technologies used in the industry such as open molding (used to make boats and truck bodies), polymer casting, and compression molding. This type of education is one way to develop a foundation for establishing and maintaining profitable and environmentally compliant manufacturing processes.

EXISTING PRODUCTS—SECOND PHASE FOR WASTE REDUCTION

However, the situation changes for plants manufacturing established products using existing processes. The strategy that must be developed in these circumstances will have the same goals—being profitable and in compliance with environmental regulations—but the organizational functions taking the lead in developing this strategy will change from design engineering to production

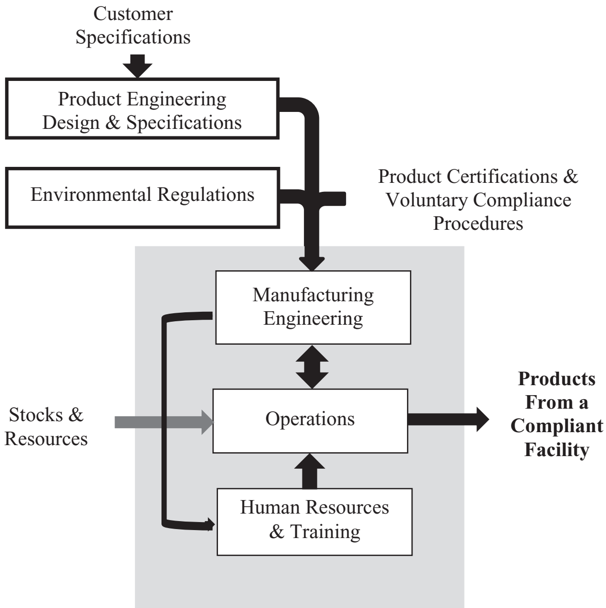

Figure 1.4. The groups involved in reducing waste in an established product design.

and manufacturing engineering and from marketing to human resources and training. Figure 1.4 shows the groups responsible for this stage of manufacturing—producing an established design profitably and in compliance.

These are the people that will take on the responsibility for reducing waste and ensuring that the manufacturing facility is in compliance. If you think about it, this second phase of waste reduction seems to capture more attention because more often product designs tend to be taken as a given. This is true in part because underwriter certifications, life testing, and other forms of product performance qualifications make it more difficult to obtain significant changes in an existing product design. However, there is more latitude in changing processes and operations than there is in changing a stock. But these changes should be done in coordination with the product design group. Nonetheless there are plenty of opportunities for waste reduction at this second stage.

The point is the strategy for environmental compliance should not be limited to abatement, permitting, and lawful waste disposal.

REGENERATION

A factory can be like a basement, garage, or an attic—a place that collects "stuff," stuff that has no immediate use and gets overlooked in day-to-day business. Besides being a symbol for waste, all those bits and pieces get in the way as unneeded fat in a manufacturing operation. Getting rid of marginal or out-of-date equipment and processes gets a manufacturing facility ready to change, adapt, and re-create itself. This also applies to the organization and staffing of the manufacturing facility.

Organizational fat can be detected by observing how an organization handles problems. When a major problem arises does management handle it by creating a new department or group to deal with it? If this is management's approach it makes the problem an ongoing fixed cost causing the organization to swell in size with these specialty groups. Problem solving is a basic function of line management not specialty staffs. Management must clear away its organizational structure as it should clear away out-of-date equipment and stocks.

Ideally a plant should be operated in the same way as a convention center or theater for the performing arts. That means it is set up for the event that is currently running but can be quickly changed over to handle a new event that's totally different. Each event will (it must) use profitable and environmentally compliant manufacturing processes. Unfortunately most plants are fixed hard-wired facilities. These facilities have so much inertia that it is nearly impossible to make meaningful improvements quickly or efficiently.

One of the first objections from managers when asked why they are not adopting a more effective method for producing their product is cost. They explain the "price tag" for new equipment and processes makes it prohibitive and they can't afford or don't have the money to invest. This argument misses the point. First of all buying new equipment and trying to squeeze it into some corner of a packed manufacturing floor is not the solution.

The first step is not buying new equipment but getting rid of the waste in the system. Remember the three sources of waste? A comprehensive waste reduction program makes money that later on can be used to update processes or purchase new equipment and locate it where it should be, not where it can be squeezed in. One starting point for regeneration is adopting the concepts and techniques that are known as lean manufacturing. Each of the three sources of waste provides a starting point and the reasons for adopting the values of lean manufacturing.

LIFE CYCLE OF THE MANUFACTURING FACILITY

Life cycle is actually another term for a life span. If you drive around the outskirts of any large city in the Midwest or Northeast one can see the sad sight of huge crumbling factories. But it's not limited to just these areas of the country; during every economic downturn there are factory buildings old and new that go vacant. It is part of the life cycle of manufacturing. Unless an organization is committed to regeneration it will cease to exist. Buildings like people have a finite working life. Companies and organizations are no different unless they become adept at regenerating themselves.

One plant manager explained that a company should never own a building because it is a constraint to its ability to regenerate itself. An apt analogy was the experience of a couple that owned a house that they had lived in for 20 years. An excellent business opportunity became available for them in a town 45 miles away. They took advantage of the opportunity but decided to commute each day instead of moving to the new location. So putting social and family ties aside, the transportation costs and the time spent commuting to avoid relocating became waste caused by the inertia of property ownership.

The unwillingness to be open to regeneration also applies to the people who work in manufacturing plants. Job skills have a finite life too. During most of the twentieth century people with good work habits could find work in factories that paid enough to make unskilled or semiskilled factory work a career. In the twenty-first century that's less likely. A partial explanation is the technological improvements in manufacturing, like the technical revolution that occurred in agriculture a century ago, means there are fewer unskilled and semiskilled factory jobs even though factory output has grown tremendously. Furthermore today's manufacturing jobs require more skills and versatility.

Manufacturers should tailor work so employees have a path to follow that enables them to progress in the organization. This progression is part of the regeneration process. An organization that allows its workforce to "stay put" in one job is committing itself to a finite life cycle. The art and science of current manufacturing has by design created "jobs" that can be mastered in a matter of months if not weeks. After that period of learning the person's job skills too often remain fixed. Persons in these jobs can and do expect increases in pay based on "time on the job." You can probably deduce that in a company like this their wage costs grow not because of innovation or productivity improvements but because of their employee's time in service. Unless the organization can develop a strategy for renewal it will find itself unable to compete against younger companies or companies that are able regenerate themselves.

An example of a company that was faced with this problem of workforce regeneration developed an innovative solution. This company services tooling for the automobile and appliance industry. They repair dies and make replacement punches that fit in the die-sets. These punches create the hole, square, or in some cases the oblong shapes in the metal part that is being stamped out by the die-set. Typically a skilled machinist, a toolmaker, does the work and makes the punches for the die. When the company receives a die-set from a customer they would remove the punches, sharpen the die, make any needed repairs, and replace the punches.

Over the years the company developed an outstanding reputation for their work and meeting tight schedules. However, the company was losing some of its skilled toolmakers through retirement and was even being pressed by competition overseas.

Finding replacements meant trying to hire skilled toolmakers away from other companies. Increasing the pay rate over the standards for the area would only make for more competitive problems. So the company decided on a different course of action. They would make their existing skilled toolmakers mentors and problem solvers. The replacements would be new graduates who had specialized in machinist programs in area community colleges.

One of the many advantages in hiring these graduates was their knowledge of technologies that were not currently being used in the company. These men and women became the initiators that started a regeneration process within the company. The company provided these graduates with good starting pay and a good deal of responsibility for their own projects. With the help and backup from the senior toolmakers these young machinists gained excellent experience in tool and die work. A further benefit, which seemed at first to be a problem, was that these individuals were being lured away by other companies after three or four years on the job. The benefit of course was new graduates came into the company with new enthusiasm and the wage structure remained stable and was not inflated by "length of service" raises. Becoming a "machinist" at this company was a "stepping stone" not a career. If you wanted to remain at this company and have a career you needed to work to become a "senior toolmaker."

CREATING A CLASSIFICATION SYSTEM FOR A COMPLIANT AND PROFITABLE MANUFACTURING SYSTEM

In the next chapter the discussion introduces a systematic approach for evaluating and selecting the materials and processes to satisfy the inputs to the three functions shown in Figure 1.3. The approach will enable engineers, technologists, and managers to systematically analyze the materials and processes used to find opportunities to reduce waste.

To use this approach effectively you'll need to gain an understanding of the scope of the environmental regulations. Therefore in Chapter 3 there is an overview of the federal regulations that govern the creation, handling, and disposal of specific wastes.

In some states and localities there are more stringent regulations and requirements. These state regulations are too region specific and complex to be handled here. Nevertheless the limits and prohibitions that federal regulations establish will serve to expand the definition of waste. Also, the federal regulations do provide a framework that can help you understand the approach used by individual states and localities. It is particularly important to factor in the impact that these regulations will have at the design stage when material stocks and processes are being evaluated and compared.

In either event, designing from new or manufacturing an existing product, the material and process classification system is a basis for creating a strategy for being a profitable and compliant manufacturer. Once the materials and processes are established there are a multitude of tools that will be needed to implement a strategy to become a cost-effective "green" manufacturing facility. Many of these tools are introduced in the case studies in Chapter 4. The introduction to these tools or methods and techniques then continues in Chapter 5.

Overall the sequence of chapters as presented follows a path that can be used to establish and implement an effective strategy. However, as with most endeavors in manufacturing this will be an ongoing activity—once again think about Ford's fourth principle. To be successful the strategy developed should be a means to create a way of thinking, behaving, and evaluating. The tools and methods are activities. The outcomes for the strategy being followed should be profitability, compliance, and the ability to regenerate the manufacturing facility.

SUMMARY

Nearly a hundred years ago Henry Ford and key members of his company started work on a new design. It was not a car but a manufacturing system. The impact it had on the country and the company was revolutionary. It made his company profitable and his company's product affordable for nearly every working family in the country. Ford's manufacturing system became a pathfinder for industry in the United States. The vertically integrated manufacturing system he created enabled his company to capture nearly all the valued-added opportunities in the sequence of manufacturing. This strategy worked well as technology evolved during the first half of the twentieth century. Today product technology is changing much more rapidly. The vertically integrated manufacturing operation has a difficult time in regenerating itself so that it can adopt new know-how quickly and profitably.

Today manufacturing is facing the same challenges that Ford faced—making products that are affordable and profitable. However, part of this affordability involves reducing the environmental costs of production. Companies today can gauge these costs by tracing their effectiveness in transforming materials and resources into finished goods.

As the twentieth century manufacturers realized, each step in the manufacturing sequence provides an opportunity to profit in proportion to the amount of value added at each step. However, each step carries costs that include the environmental impact of processes and operations. The strategies that can be employed to control these costs may be as simple as cost avoidance. Companies can choose to limit their involvement to just one or two steps of the manufacturing sequence. The most extreme and simplistic strategy would be for a "manufacturer" to design a product and have others produce it. The manufacturer, in name only, would be involved in just one step of the manufacturing sequence, the product's distribution. The most complex strategy would be Henry Ford's approach in creating a manufacturing operation that spans nearly the entire manufacturing sequence.

The life cycle analysis (LCA) that came into use nearly 40 years ago is an ideal technique for cataloging and assessing the transformation of resources into products and the environmental impact. This analysis involves all three stages of the manufacturing sequence.

- Stage 1, creating the manufacturing stock
- Stage 2, product manufacture
- Stage 3, distribution sales & service and disposal.

However, any one company that would attempt to span the entire manufacturing sequence would require a great deal of technical and management skill to effectively control all the costs, which includes environmental compliance. This can be done. In fact being "Green" can be the basis of a strategy for improving a company's profitability. Both green manufacturing and lean manufacturing share a common goal, to get rid of waste. Waste includes everything that does not add value to the product in the hands of the buyer. Eliminating waste is the foundation for creating a profitable manufacturing operation.

There are two groups of people directly responsible for eliminating or minimizing waste. The first group is involved when the product is being designed and all options are available to create a "green and lean" product design. The second group takes over this responsibility when the facility is producing an established design. There the options to change material stocks and processes are limited. Nonetheless there are still opportunities to reduce waste.

Many of these opportunities arise if the company is able to regenerate, adopt change, and renew itself. Companies that are rigidly structured both organizationally and physically limit or impede their ability to sustain themselves. This resistance or inability to regenerate creates waste, which means it can be measured as a cost. Consequently an organization needs to adopt a systematic approach for identifying and quantifying the cost of waste as a basis for designing a production system that is compliant and profitable.

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