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Production Processes

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1 Introduction

Manufacturing and service delivery processes typically consist of a complex organization of technology, people and practices. Developed and operated effectively, they can provide a firm with significant competitive advantage; if poorly conceived and mismanaged, they can saddle a firm with inefficiencies and performance problems that are difficult to overcome. This note provides an overview of production processes.

First, we discuss why it is important to view production activities as a process - an integrated whole consisting of inputs, outputs, resources and activities - and examine some generic stages in a typical manufacturing and service process. We then examine their basic characteristics and performance measures.

2 The process view of production and service delivery

In this note, and throughout the course, we will view production and service delivery not as a collection of isolated activities, but as a *process*; that is, as a *system* of interrelated components that must be understood and managed as a single entity.

The implications of this point of view are subtle but significant: As a unified system, processes have their own characteristics, such as capacity, efficiency, speed, flexibility, consistency, etc., that can be quite independent of the product or service they produce and often depends in complex ways on the interactions between all the various components of the process. As a single system, the process itself must be designed, developed and improved over time to achieve the mix of characteristics necessary to support the business objectives of the firm. Processes also have their own *process technology* distinct from the *product technology* of the product or service they produce. Finally, the activities of a production or service process span many functions of an organization – purchasing, manufacturing, human resources, finance, sales, marketing – and thus adopting a process view implies taking a point of view that spans traditional functional boundaries.

3 Production and service delivery processes

Production and service delivery processes are diverse, but at their heart contain four basic elements:

- *Inputs* - Inputs are either consumed or transformed by a process. Automakers require sheet steel, airlines require fuel, hospitals need medical supplies and energy, schools need students, news services need content (wire stories, photos, video), etc.
- *Outputs* - Outputs are the end product of the process (or service performed by the process). The completed car, the transported passenger, the cured patient, the educated student, the completed news story, etc.
- *Resources* - Resources are the means by which inputs are converted into outputs. Resources include assets such as land, facilities, equipment, and also people, technology and knowledge. The auto plant, the airport gates, the specialized knowledge of a physician, the classrooms, the network of local reporters, etc.
- *Activities* - Activities involve a specific use of resources to help convert inputs into outputs. Bolting a bumper onto a car, loading an airplane with passengers, performing an operation, teaching a class, dispatching a reporter to cover an election, etc.

While all this may seem painfully obvious, it is often clarifying to explicitly identify these four basic elements when analyzing a firm's operations. Ask yourself: What exactly are the inputs to the process? What are the outputs? What resources does the firm use or have available to it? Which activities does it perform - or not perform? At its core, operations management is about managing these four components of production and service delivery - identifying the outputs that are required to be competitive, sourcing and efficiently utilizing inputs, assembling the right mix of resource and then defining, organizing and managing the activities required to make the process operate efficiently and effectively.

While there is almost a limitless variety of types of production and service processes, most follow a few generic stages. We first examine the basic stages of a manufacturing process and then examine service delivery processes.

3.1 Typical stages of a manufacturing process

Manufacturing, at its most basic level, involves transforming raw materials and/or components (inputs) into products (outputs) that provide value to a firm's customers. This transformation usually involves five major stages: procurement, fabrication, assembly, test and distribution. We discuss each of these in turn.

Procurement

Procurement is the act of acquiring the basic inputs required to manufacture a product. Procurement activities may involve securing mineral rights and leases for natural resources, purchasing components and raw materials, developing supplier networks, overseeing the component design activities of one's suppliers, certifying supplier quality, coordinating inbound logistics, etc. In some industries such as oil and gas, coal and forest products, procurement is the central operations activity; in others, e.g. semiconductor manufacturing, it is much less important. As we shall see later in the course, however, clever management of the procurement function is increasingly being viewed as an important means to achieving operational advantages.

Fabrication

Fabrication refers to the basic processes used to form parts, components and materials required in later stages of production. Fabrication processes are usually among the first steps required in making a product. Examples of fabrication processes include molding plastic parts from resins, stamping automobile body panels from sheet metal, die casting aluminum valve covers, weaving and dyeing fabric, extruding molten steel into bars or rods, etc. We will see specific examples of fabrication processes in many of the cases we look at throughout the course.

Again, the degree to which a firm engages in fabrication varies widely. For some firms, such as an automotive parts supplier, it may be the primary activity. Other firms do no fabricating of parts at all. For example, a company like Dell Computer makes a point of doing little more than designing and assembling. We will examine reasons for each approach to fabrication later on in the course.

Assembly

Assembly is the process of putting together components to produce more complex intermediate components (called *subassemblies*) or to produce the final product (called a *final assembly*). In assembly, parts are snapped, bolted, welded, glued, etc. together to produce the required subassembly or product. As distinguished from fabrication, an assembly process usually does not alter the form of incoming parts.

The classic example of an assembly process is an automotive assembly line, in which body panels are spot welded together to form a shell, the shell is painted and dried, major subassemblies, such as the engine, transmission, suspension system and steering column are bolted to the shell, wiring harnesses, windows and seats are installed, etc., the final result being a finished automobile ready for distribution to dealer lots. Indeed, many automobile plants do very little "manufacturing" – in the sense of fabricating parts – at all, and serve merely as points where components are consolidated and combined to form a finished automobile. Other examples of assembly processes include sewing garments, assembling televisions and the final stage of assembling hamburgers at a fast food restaurant.

Test

Testing of some sort is usually part of any manufacturing process. Sometimes only testing of the final product is performed. More often, testing is performed at a variety of stages within both fabrication and assembly. In some industries, testing is a significant and time consuming part of the entire production process. For example, complex semiconductors, such as microprocessors, require extensive tests of their basic functionality, which are time consuming owing to the tremendous complexity of these devices. Military electronic parts often require a "burn in" period at high temperatures and/or extreme voltages, to eliminate parts that are subject to early failures (*infant mortality*). By law, pharmaceutical companies must test and certify each batch (*lot*) of drugs produced, which again can consume significant amounts of time.

Packaging and distribution

Packaging involves placing products into boxes, bottles, cans, pallets [1] or other containers for delivery to customers. In some operations, such as the production of household cleaners, cosmetics and many food products, packaging is a critical part of the process. For example, in a mineral water or soft drink bottling operation packaging is the core production activity. In other cases, e.g. automobile production, it may be a relatively minor activity, involving only a few simple steps to ready a product for shipment.

Distribution – the shipment of final products to a firm's customers – is usually the final stage of a manufacturing process. Distribution is often a complex process in itself, involving processing customer orders, managing distribution centers, controlling inventories, picking and assembling orders for shipment, selecting shipment modes, routing and scheduling trucks, and increasingly due to "green" laws, handling return flow of product and packaging waste.

Some firms choose to outsource many of these distribution activities, either by selling only to large wholesalers or by subcontracting distribution to a third party. However, for many firms it is a vital activity. For example, for grocery store chains and many other retailing businesses it is a central activity. Indeed, operationally retailing is essentially a business of procurement and distribution.

[1] A *pallet* is a standardized, square wood platform on which products, boxes, drums, etc. are stacked for shipping. The cargo is usually wrapped with steel bands or plastic (*shrink wrap*), to secure it to the platform. Pallets allow fork-lift trucks and other material handling equipment to easily lift and move products in and out of warehouses, trucks, etc.

Again, we will discuss the variety of issues that arise in managing the distribution function in some detail later on in the course.

3.2 Service delivery processes

Services too are provided through a production process. For example, when your car has trouble starting you may take it to an auto repair shop, where the problem will be diagnosed, a repair estimate will be made, and you will decide whether to proceed with the repair. If you proceed, parts will be ordered, the repair performed and finally the car will be returned to you. While the stages of a service process tend to be more diverse than those of a manufacturing process, there are some generic features worth pointing out.

The most important feature of service operations is that the output – or service offering – and the delivery process that provides it are often indistinguishable – in a sense, the service *is* the process.

Consider the automobile repair example above. What, exactly, is the service offering? Essentially, it is the process we described above: visiting the shop, getting an estimate, waiting for the repair and taking delivery. The entire sequence – the service experience – really defines a firm's service offering. Similarly, consider a trip on a commercial airline. The service is the entire transportation experience: arriving at the gate, checking in baggage, boarding the aircraft, in-flight service and meals, connecting through a hub, retrieving your bags. Again, the service offering is really the process of transporting you from one location to another. What distinguishes one airline's service from another is not so much the transportation part (moving you from A to B), but all the design choices and execution surrounding your experience from the time you make a reservation to the time you pick up your bag upon arrival. Contrast this with the case of a clothing manufacturer, where you as a customer experience only the result of the production process (the finished garment and its various characteristics) and not the process of making the garment itself.

The consequences of this difference are significant. It means that in service operations, managers have to pay attention to attributes such as the cleanliness of facilities, the perceived order and efficiency of the process, the courteousness and appearance of employees, etc. that would be relatively unimportant in a manufacturing process. As a result, careful attention to details in the design and management of the production process can be even more critical in service businesses.

Of course there may be other activities that take place behind the scenes in order to provide a service. The parts of a service delivery process that customer's experience directly are often referred to as *front office* operations, while those that are largely hidden from customers are referred to as *back office* operations. It is in a firm's front office operations that the differences between manufacturing and service processes are most acute; back office operations are, to a large extent, more like the operations of a manufacturing firm.

4 Process characteristics

What characteristics of a particular process are important to a firm? In this section, we define five important characteristics: efficiency, capacity, quality, throughput time and flexibility. Specific techniques for measuring these quantities are discussed later.

4.1 Efficiency

Efficiency, in the simplest terms, is a measure of how much input is required to generate a unit of output - the input/output ratio. If one measures inputs in monetary terms, for example by converting the labor, material, energy, etc. to their monetary equivalent, then efficiency is a measure of the cost of producing a unit of output.

For obvious reasons, efficiency is an important characteristic of a production process. Unfortunately, efficiency can be somewhat difficult to measure. Why? First, a good measure depends on a proper allocation of costs to the various activities of a firm. In this course, we will primarily be concerned with identifying which costs are *fixed*, i.e. they do not increase with the output volume, and those that are *variable*, i.e. they increase with the level of output. This separation helps identify the *marginal cost* of an activity, which is important information for making good economic decisions. Such cost allocation is the domain of managerial accounting, and in this course we will depend on your knowledge of this discipline in making proper assessments of costs.

A second difficulty in measuring efficiency is that different firms (or different operating units of a single firm) may use different mixes of inputs and resources to produce the same output. For example, some firms may use lots of equipment and minimal labor, while others may use less equipment but more labor. To talk only of a single ratio (labor-hrs./output or machine-hrs./output) in such cases can be misleading, since a firm (or operating unit) may be economizing on the use of one resource but wasteful in its use of other resources. Converting everything to monetary units might appear to solve the problem, but such an accounting measure of efficiency risks obscuring the true *technical efficiency* of the process. For example, a producer in a low-cost labor market may look "efficient" in accounting terms (e.g. have low cost) compared to a producer in a high-labor-cost market, when in fact they may be using much more labor per unit of output.

Both cost and technical efficiency are important. Technical efficiency matters because it shows which methods and processes make the best use of inputs and resources - regardless of their cost. Understanding it helps pinpoint the best organization of production, best work methods and technologies, etc. But even the most efficient use of an input or resource may result in an unprofitable business if its cost is too high. Conversely, a technically inefficient process may be profitable provided its input and resource costs are low enough. Thus, one needs to keep an eye on both technical efficiency and cost.

4.2 Capacity

Capacity is a measure of the maximum output a process is capable of sustaining. It is usually expressed as a rate, such as the number of parts per hour a machine can produce, the number of kilowatts per hour an electric plant can provide, or the number of passengers per trip that a plane can transport.

The capacity of a process is important for a variety of reasons. First, insufficient capacity can limit the total demand that a firm is able to satisfy, resulting in lost sales if demand is high. On the other hand, excess capacity, that is capacity that exceeds the current demand rate, is wasteful because it often means a firm is incurring extra costs for idle equipment, building space, labor, etc. that are not needed for its current level of output. The output expressed as a fraction of capacity defines the *utilization* of a process. (Often expressed as a percentage.) Utilization is a carefully watched measure in most operations.

Generally, firm's like to maintain high utilization to spread fixed costs over the largest number of units possible; however, high utilization can degrade other measures of operating performance such as product availability and delivery time. Managing capacity and these various performance trade-offs is one of the key responsibilities of operations managers.

Again, however, capacity is often not an easy quantity to measure, since it can depend on the mix of products or services that a process produces. We discuss capacity measurement in more detail later in the course.

4.3 Quality

Another important characteristic of a production process is the *quality* of its output. Poor quality can significantly affect production costs, due to scrap, rework and warranty costs. It also affects both the price customers are willing to pay for a firm's output and their long-term loyalty. As we will see later in the course, quality refers to a broad range of characteristics that are often difficult to precisely define, measure and control.

A basic definition of quality, and one that will suffice for now, is that it is a measure of *conformance* with a product's design standards. Taking this viewpoint, one is often interested in the fraction or percentage of defective parts or products (those that do not meet the design standards) as a measure of the output quality of a process. The fraction of output that is acceptable is referred to as the *yield* of a process. In a service operation, one may define service standards and hence measure the quality of a service delivery process in terms of the fraction of customers who are served within these standards.

4.4 Throughput time

An important characteristic of almost and manufacturing and service process is the time it takes to provide a product or service. Most customers value speedy service and fast delivery times - and many are willing to pay a premium to firms that provide speed. Indeed, entire industries, such as fast food and overnight package delivery, have evolved precisely to meet consumers' desires for the speedy provision of goods and services.

Throughput time is defined as the elapsed time experienced by a order, product or customer between entering and exiting a given process (or part of a process). Think of throughput time as being measured by spray-painting a widget red, putting it in the process and measuring the elapsed time until the red widget appears as output. For example, the order throughput time of an on-line retailer is the elapsed time you experience between submitting an order on the web site and receipt of the goods at your home. The manufacturing throughput time of an auto plant is the time it takes for a car to work its way - start to end - through the plant. Transportation throughput time is the time it takes to move something from location A to location B, etc.

Throughput time is important at intermediate stages of production as well. We will see later in the course that shortening supplier throughput times can significantly reduce the operating costs of a manufacturer. Thus, speedy suppliers are able to charge a premium, even though their throughput times may have a negligible effect on the throughput time experienced by the final consumer.

4.5 Flexibility

Flexibility is a characteristic that is sometimes difficult to define precisely, but is nevertheless critical to understand and manage. Roughly speaking, a process is said to be flexible if its operating cost and performance is not adversely affected by *changes* in the outputs it produces.

The two main dimensions to flexibility are *volume* flexibility and *product mix* flexibility. Volume flexibility refers to the ability of a process to change its output rate without having significant negative effects on other characteristics such as efficiency, quality, throughput time, etc. The more volume flexibility a process has, the easier it is to match short-term, erratic changes in demand. Volume flexibility is especially valuable in businesses that have volatile and uncertain demand (e.g. fashion apparel) or strongly seasonal demand (e.g. agricultural chemicals).

Volume flexibility implies roughly constant average unit costs of production (no economies or diseconomies of scale), so that cost and profit per unit remain the same regardless of the level of output. But it further implies that other performance measures - such as quality and throughput time - remain the same at different levels of output as well. Often, a volume-flexible process will not be the most cost-effective one at any given volume, but may still be preferred because volumes change frequently. For example, a process based on manual labor may be more expensive at high volumes than an automated process. However, when sales volumes drop, the labor force can be reduced proportionately while it is often difficult to reverse a big investment in automation.

Product mix flexibility refers to the ability to switch production among a range of products or services – again without detrimental impact on operating costs and performance. A process with high product mix flexibility makes it possible to offer a wide range of product types and to customize products or service offerings to satisfy small market niches. Product mix flexibility also allows a firm to introduce new products more easily and to quickly adapt to changes in consumer preference.

Mix flexibility implies unit costs that are largely independent of the which product variant is produced. Again, a mix-flexible process may not be the most cost-effective one for producing any one product variant. For example, a computer can be produced at lower cost if a fixed number of memory chips are installed on the mother board. Adding connectors and making the memory modular – so that different amounts can be installed on the same board – increases cost but allows the computer to be configured with different amounts of memory. Such *modular* design is typically more costly for a given product configuration, but allows a firm to produce many variations of the product and change variations without adversely affecting either the cost, quality or timeliness of the process. Services too can be modularized, for example banks can often configure different account features for different customers within a common information and reporting system.

4.6 The interrelationship of process characteristics

If all these five characteristics were independent, then managing production processes would be considerably simplified; one would simply choose to make a process as good as possible along each dimension, i.e. make a cost efficient, high quality, fast and flexible process of unlimited capacity. In practice, of course, this is not possible. Indeed, there are often very clear – and sometimes not so clear – tradeoffs that must be made among the various attributes of a production process.

For example, we already mentioned that a process with extra capacity is often not very cost efficient because it incurs many unnecessary fixed costs. We shall see shortly that a heavily utilized process typically has longer throughput times owing to the effects of congestion, so that throughput time and utilization are often at odds. Similarly, as mentioned, a flexible process that can produce a wide variety of products is often less cost effective than a process that is specialized to one product only. Finally, achieving high quality may mean sacrificing some cost efficiency and/or flexibility, though a more contemporary view suggests that improving quality often decrease costs owing to savings in scrap, rework, warranty costs, lost capacity, etc.

Understanding the interrelationships among these various process characteristics and developing and managing a process to deliver an effective mix of characteristics for the particular competitive environment in which a firm operates is a major management challenge. Further, new production technologies and methods continually redefine the “efficient frontier” of these various trade-offs, meaning that firms are increasingly able to achieve world-class performance on several dimensions simultaneously. As a result, these trade-offs have to be actively managed, keeping a keen eye on new technologies and management trends both inside and outside one’s own industry.