HARVARD BUSINESS SCHOOL

CASES

MBA核心课案例教学推荐教材

Technology and Operations Management (Reprint)

技术与运营管理

（英文版）

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出版说明

随着MBA教育逐渐走向成熟，人们对于案例教学已不再陌生，很多院校，特别是首批MBA试点院校已经比较普遍地采用案例教学这种模式。案例教学、案例编写也成为全国MBA教学指导委员会十分重视并大力推广的重要工作。为满足教学需要，中国人民大学出版社与哈佛商学院出版公司达成了引进出版哈佛商学院案例的协议，围绕MBA教学选择了十门课程，包括：战略管理，人力资源管理，营销管理，公司财务管理，领导学，组织行为学，供应链管理，技术与运营管理，财务报告与控制，企业、政府与国际经济，中文版和英文版同时推出。先由哈佛大学教授从其数千个案例中进行选择、推荐，再由中国教授从推荐的案例目录中遴选，在翻译的过程中又作了进一步的调整，最终确定了目前的案例。

多年来，中国人民大学出版社一直在不懈地打造经管类图书的品牌，特别是，作为高等教育教材出版的市场领先者，我们一直希望能为中国的管理教学和实践提供更多、更好的产品。随着中国MBA市场规模的扩大，学生人数的增加、素质的提高，教师队伍的成熟，我们发现，案例教学教材的数量不足及质量不高成了一个比较大的问题，基于大量的市场调研，哈佛商学院的案例便成了我们针对MBA教学引进案例的首选。毕竟，哈佛大学是最早开始MBA教育的，其MBA学位计划有近一百年的历史。哈佛案例每年能销600万份，其案例教学法也在逐渐为世界上各大学校所熟悉和借鉴。作为一家以为高等教育服务为己任的大学出版社，我们深感哈佛案例的引进对于我国工商管理教育理论和实践的提升具有十分重要的意义，事实上，我们在2002年曾引进出版了一套哈佛商学案例，分商务基础系列和实务系列，共21种，在当时引起了很大的反响，只是囿于条件，案例没能根据课程设置选取，不便于教师在教学中使用，基于此，便有了我们这套针对MBA核心课程的案例。

在运作这套案例的过程中，我们广泛听取了老师们的意见和建议，我们发现，单是引进一些案例并出版不能满足教学的实际需要，对于很多老师来说，如何讲授哈佛案例才是一个难点。同时，我们在前期调研和筹备工作中也深感案例的推广不再局限于传统意义上的图书推广工作，它已超出了传统单纯出版图书的概念，变成了一种教学理念和教学方法的推广，它需要我们提供更多、更长期的后续服务，并改变传统的出版模式。

就在我们策划出版这套案例书之际，哈佛商学院酝酿已久的PCMPCL (Program on

Case Method and Participant-Centered Learning）培训计划正式启动。为配合 PCMPCL 项目，哈佛商学院出版公司邀请包括中国大陆、香港、台湾等地区和新加坡在内的 16 所大学的商学院选派一些教授到哈佛商学院参加哈佛案例教学的培训。首次培训定于 2005 年 8 月，同年 12 月还将在中国举办第二期有关案例教学与写作的培训。

同时，为帮助广大教师更好地使用哈佛案例，中国人民大学出版社还将配套引进案例的教师用书、教学录像等辅助资料（出于授权限制，仅向使用本案例教学的教师提供）。在案例出版后，我们还将提供教学支持，帮助中国教师更好、更便利地使用案例。

运作案例出版的过程是艰苦的，但结果是美好的、令人难忘的。在和哈佛商学院出版公司的合作中，我们一次又一次地听到他们虔诚地谈及他们的使命：改善管理实践。在案例出版的过程中，很多人做了辛苦的工作，我们感谢哈佛商学院高级副院长、贝克基金教授史蒂文·C·惠尔赖特（Steve C. Wheelwright）先生，他为我们的案例出版写了序，他在这套案例书 10 门课的选择中起了决定性的作用，没有他的努力，这套书的出版是不可能的。感谢 John Quelch、Michael Tushman、Debora Spar、Pankaj Ghemawat、David Hawkins 以及 David Upton 等教授，他们在我们初选案例的过程中给予了建议和指导；感谢哈佛商学院和哈佛商学院出版公司的下列人员，他们为案例的挑选做了许多工作：Paul Andrews、Tim Cannon、Tad Dearden、Mike Derocco、Pat Hathaway、Amy Iakovou 和 Carol Sweet；感谢哈佛商学院出版公司国际部总经理陈欣章先生，他促成了案例最终出版协议的签订和执行，并完成了整个过程中的协调工作。最后，也要感谢所有参加案例中文版翻译的教授，他们都有自己繁重的教学任务，在出版时间紧迫的情况下，各位教授都保质、按时地完成了翻译工作。

我们希望这套案例书的出版以及后续的培训工作能影响几百、几千乃至上万个 MBA；我们希望他们能用一种新的视角，适应国际化的大趋势，理解现代企业的管理方法，理性地接受信用经商的理念，推动中国经济的更大发展；我们希望能通过我们的出版物来引导中国的管理实践。如能做到此，那么其间的各种辛苦努力也就值得了。

感谢您选用或关注我们的这套案例书，对您的任何反馈我们都十分珍视。我们的联系方式：010-62510566 转 551 或 541；E-mail: rdcbsjg@crup.com.cn 或登录：http://www.rdjg.com.cn。

中国人民大学出版社
2005 年 7 月

序

“培养世界上有影响力的领导人”是哈佛商学院的使命。1908年，哈佛商学院正式成立。为实现这一使命，哈佛商学院通过实施各种项目，影响众多不同的人。哈佛商学院最出名的可能是其MBA项目，但同时我们也通过开展高级管理人员培训项目（Executive Education Program）（包括AMP项目以及其他逾100个为职业经理人开设的各种培训项目）和通过哈佛商学院出版公司的出版物追求我们的使命。我们的出版物包括《哈佛商业评论》、哈佛商学院图书、网络课程，以及哈佛商学院案例研究。

为杰出院校提供建议也是我们使命的一个重要方面。在过去的60年里，哈佛商学院为世界上许多院校不仅提供了教学案例，还通过各种项目帮助他们及其教师提升了自己的案例教学能力。包括：国际教师项目（ITP）、以参与者为中心的教学法培训项目（CPCL）、案例教学与以参与者为中心的教学法培训项目（PCMPCL）。其中，PCMPCL项目发起于2005年8月，其目的在于帮助中国大陆、香港、台湾等地区和新加坡的主要商学院提升其在MBA项目、高级管理人员培训项目以及以管理实践为导向的研究中，熟练运用案例教学和启发式教学的能力。

通过多年的实践，哈佛商学院发现案例教学的应用通常需要经历三个阶段。第一阶段，案例在管理学课堂上是作为概念或原理的例子、说明来使用的。第二阶段，将案例研究作为主要的学习方法，依靠案例讨论。第三阶段，教授开始把他们在案例研究和课程发展上取得的成果大量应用于教学，以便更好地理解和传授如何做决定。

为实践我们的使命，哈佛商学院和哈佛商学院出版公司很高兴与中国人民大学出版社携手帮助中国商学院及其教授实现从第二阶段向第三阶段的跨越。我们的努力包括：为来自中国大陆、香港、台湾等地区和新加坡的教授提供为期10天的PCMPCL培训；出版一套根据MBA核心课编辑的案例书（分中文版和英文版）；组织一系列后续服务的案例教学和案例写作的培训班；建立一个服务于中国教师的案例服务中心。

我们这样做的目的有两个，并且这两个方面都与哈佛商学院的使命紧密相连。一

个目的是通过帮助全球教育机构——正如我们在中国发现的那些机构一样——发展他们自身的、着眼于管理实践的案例教学能力，从而促进全球管理教育水平的提高。另一个目的是帮助这些机构培养一些能够在他们的学校中起到带头作用的教师，使他们能够写出新的、能够与世界分享的案例研究和教学资料。这种既符合国际标准，又与中国具体管理实践相关的案例研究正是中国管理教育机构所急需的。

我们很高兴中国人民大学出版社和中国许多优秀的商学院加入我们的队伍。我们希望哈佛案例书在中国的出版能对中国的教育机构、教师及其培养的未来职业经理人有所帮助，帮助他们实现在全球经济中扮演重要角色的梦想。

史蒂文·C·惠尔赖特（Steven C. Wheelwright）

哈佛商学院高级副院长，贝克基金教授

2005 年 6 月

PREFACE

The mission of the Harvard Business School (HBS) is "to educate leaders who will make a difference in the world." Founded in 1908, when Harvard University was already more than 250 years old,HBS achieves this mission by reaching a wide range of audiences through a variety of programs. While HBS is perhaps best known for its MBA Program, it also pursues this mission through its Executive Education Programs (including the Advanced Management Program as well as over 100 additional programs for practicing managers)and through the publishing activities of Harvard Business School Publishing (HBSP) which include Harvard Business Review, HBS Press (books), E–Learning products, and HBS Case Studies.

Providing guidance for leading academic institutions continues to be an important aspect of the HBS Mission.Over the past 60 years,HBS has not only made its case studies available throughout the world, but has assisted other Universities and their faculties in developing their ability to teach by the case method.This has included the offering of such courses as The International Teachers Program (ITP), Colloquium on Participant Centered Learning (CPCL) and the Program on Case Method and Participant Centered Learning(PCMPCL). The PCMPCL Program initiated in August of 2005 is aimed at helping leading Business Schools in Greater China and Singapore to develop excellence in the use of the case method and participant centered learning in both MBA and Executive Programs, as well as in practitioner–oriented research.

HBS has discovered over the years that adoption of the case method often proceeds through three stages. The first stage is where cases are used as examples and illustrations of principles and concepts being taught in a Management Course. The second stage is where cases become a primary means of learning, with a majority of the class sessions in a program relying on field–based cases. The third stage is then where the faculty begin doing significant amounts of their case –based research and curriculum development to better understand and teach about decision making.

Consistent with our mission, we at HBS and at HBS Publishing are pleased to offer—in conjunction with our partner, China Renmin University Press—a comprehensive approach to Chinese Business Schools and their faculty, that is focused on helping them progress through the second stage of participant-centered learning and into that third stage. This overall effort consists of offering the 10-day PCMPCL Course to teams of business school faculty from Greater China and Singapore, providing a series of case books (through China Renmin University Press) tailored to the Ministry of Education's MBA curriculum recommendations, offering a set of follow-up case teaching and case writing seminars in China, and establishing an academic support center to assist faculty with their unique course and case requirements.

Our purposes in doing this are two-fold, but both are directly tied to the HBS Mission. One purpose is to facilitate better management education throughout the global economy by assisting leading educational institutions—such as those found in China—in developing their capabilities in practitioner focused, case based teaching. The other purpose is to help the leadership at such institutions to develop a critical mass of faculty who can lead the efforts of their own institutions in creating additional case-based teaching and research materials that can be shared with other parts of the world. Such China-specific management materials of a world class caliber are anxiously needed by academics elsewhere in the world.

We are pleased that China Renmin University Press and so many leading Chinese Management Schools would join with us in pursuit of these purposes. We anticipate that this series of case books will be a significant contributor to the pursuit of the important role that Chinese Educational Institutions, their faculty, and the practitioners they serve will have in the global economy.

Steven C. Wheelwright
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Senior Associate Dean, Publication Activities
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Harvard University
Boston, Ma 02163
June 2005

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Process Fundamentals

Imagine that upon graduation you take a job managing a large bakery supplying supermarket chains with products ranging from breads to pies. Your mission is to improve the profitability of the operation. How will you start? Well, first, you will have to develop a good understanding of the current operation, the activities that take place to transform flour, water, yeast, and other ingredients into baked goods, and the effort involved in each activity—such as the labor, materials, and equipment required at each step. You will also need to understand the different products the bakery offers, and the reason that customers buy them from you and not your competitors. Do you have lower prices, faster delivery, higher quality, or a better product line that allows your customers to buy all their bakery needs from one source? Only after understanding the physical process itself, how it links to the performance of the bakery, and the level of performance required by customers, can you begin to look for opportunities to improve the bakery's profitability.

The goal of this overview is to provide tools that can help you understand operations, not just for a bakery, of course, but any type of operation. These tools are important not only for improving operations, but also for the daily management of an operation, or for the design of a new operation.

This overview begins by discussing the activities that take place in a "process". Analytical tools such as the process flow diagram are provided to help you walk into a new operation, such as your bakery, and understand how each of the process steps fits together. You'll be introduced to the types of management choices for designing, operating, and improving processes. Next, measures of the performance of a process and basic process analysis, the method used to determine what and how much a process is capable of producing, are introduced. You'll see how different types of processes can be used to make the same product, and how managers choose which process to use. Finally, the note focuses briefly on the complexity stemming from uncertainty and variability in the process, factors that make managing operations particularly difficult.

Elements of a Process

Throughout this course you will hear the terms "process," "operation," and "operating system." These will be used to mean any part of an organization that takes inputs and transforms them into outputs of greater value to the organization than the original inputs. In most situations we will focus on a subset of the entire organization—a single process that transforms a set of inputs into useful outputs. When talking about a set of processes, and in some cases the entire organization involved in transforming inputs into outputs, we will use the somewhat broader terms "operation" or "operating system."

Research Associate James Leonard and Professor Ann E. Gray prepared this note as the basis for class discussion. It is a rewritten version of an earlier note by Professor Paul W. Marshall, "A Note on Process Analysis," HBS No. 675-038.

Consider some examples of processes. An automobile assembly plant takes raw materials in the form of parts, components, and subassemblies. These materials, along with labor, capital, and energy, are transformed into automobiles. The transformation process is an assembly process and the output is an automobile. A restaurant takes inputs in the form of unprocessed or semiprocessed agricultural products. To these, labor (a cook and a server, for example), capital equipment (such as refrigerators and stoves), and energy (usually gas and/or electricity) are added, and the output is a meal.

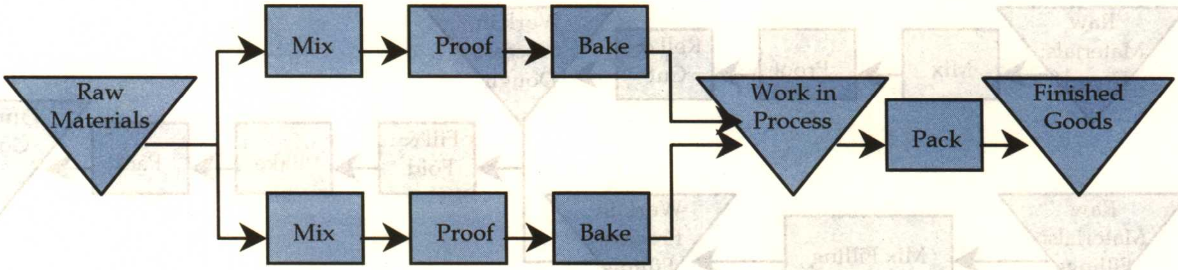
Both of the processes mentioned above have physical products as an output. However, the output of some operating systems is a service. Consider an airline. The inputs are capital equipment in the form of airplanes and ground equipment; labor in the form of flight crews, ground crews, and maintenance crews; and energy in the form of fuel and electricity. These are transformed into a service, namely, a means of transportation between widely separated points. Processes with a service output also include those found in a hospital, or in an insurance company. In a hospital, capital, labor, and energy are applied to another input, patients, in order to transform them into healthier or more comfortable people.

More formally, *a process is a collection of tasks, connected by flows of goods and information, that transforms various inputs into more valuable outputs.* People, machines, and procedures are generally involved in the transformation. In order to understand a process it is useful to have a simple method of describing the process and some standard definitions for its components. A convenient way to describe an operating system is a *process flow diagram.*

Returning to our bakery example, let's assume there are two distinct production lines in the bakery for making bread. Flour, yeast, and water enter at the left and are converted into loaves of bread through mixing, proofing (letting the dough rise), baking, and packaging. This is a bit of a simplification, but we'll use it for illustration. There are two mixers, two proofers, and two ovens organized so that the ingredients mixed on the first mixer are automatically fed into the first proofer, and then sent to the first oven. All of the baked loaves of bread are packaged on the same packaging line. **Figure 1** shows the process flow diagram for the bakery.

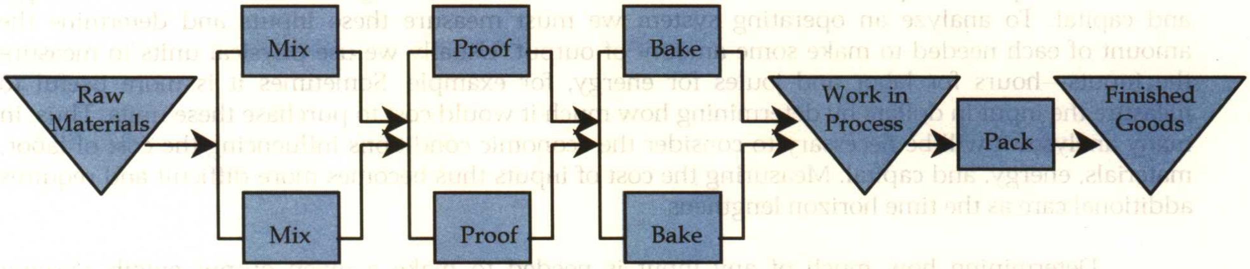
Tasks in this process are shown as small rectangles, flows as arrows, and the storage of goods as inverted triangles. We see two identical *parallel lines* for mixing, proofing, and baking. Within each line, the tasks of mixing, proofing, and baking are defined as being in a *series* relationship, because one step cannot start until the previous one is complete. The maximum capacity of the two parallel lines would be found by adding the capacity of each line. Work-in-Process Inventory (WIP) is shown before packaging because, at times, the bakery may produce different types of bread at the same time, one on each line, yet only one type can be packaged at a time. If there were parallel packaging lines, there may not be the need for holding WIP between baking and packaging except, perhaps, to allow the bread time to cool. Once packaged, the bread moves into Finished Goods Inventory, and from there is transported to grocery store customers.

Figure 1 Process Flow Diagram for Bread-Making with Two Parallel Baking Lines



If the mixers, proofers, and ovens were not set up as two distinct lines, and the product could flow from *each* mixer to *either* proofer, and then to *either* oven, we would draw the process as in **Figure 2**. In this case, it is the individual *tasks* that operate in parallel, instead of two distinct parallel lines. (The distinction between these configurations will become important when performing a more detailed process analysis to determine the *capacity* of the system.)

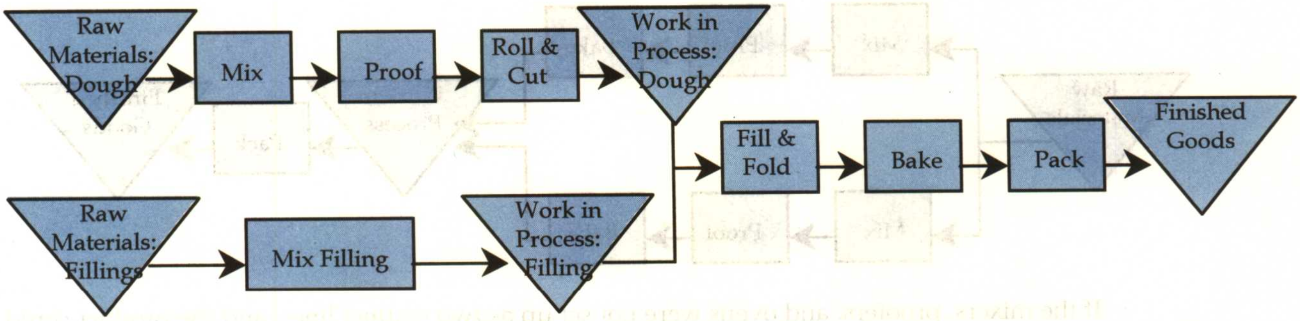
Figure 2 Process Flow Diagram for Bread-Making with Two Mixers, Proofers, and Ovens



We may also want to show on a process flow diagram tasks that are performed in parallel but which must *both* be completed before the process can continue. For example, our bakery makes filled croissants in addition to breads. For these, the mixing, proofing, rolling, and cutting of the pastry take place in parallel with the mixing of the filling as shown in **Figure 3**. All these tasks must be completed before the croissants can be filled and baked. Proofing the dough takes longer than any of the other pastry-making steps. Proofing also takes longer than mixing the filling. This means that the rate at which filling and folding takes place is limited by the rate at which the *dough*, not the filling, is ready. And the rate at which the dough is ready is limited by the rate at which proofing takes place. It is the rate of the proofing step, the longest task, that defines how much bread can be made per hour.

Note that the nature of the parallel activities for making croissants is different from that of the two bread lines working in parallel as in **Figure 1**. To determine the capacity of the bread-making operation up until the dough is baked, we *add* the capacity of each of the parallel bread lines. To determine the capacity of croissant-making, however, we would take the *minimum* of the capacity of the two different parallel processes, in this case, the capacity of pastry making. This is because the output of the two lines must be *combined* to make the final product. We will revisit this issue in Section 1.2, when we do a formal capacity analysis.

Figure 3 Process Flow Diagram for Croissant-Making



Once a process has been described using a process flow diagram, its components must be analyzed in order to draw some conclusions about its *performance* as a whole. In the following sections we will discuss each component of the process—the inputs, outputs, tasks, flows, and storage of goods—and begin to develop measurement and analysis methods along the way.

Inputs

The inputs to a process can be divided into at least four categories: labor, materials, energy, and capital. To analyze an operating system we must measure these inputs and determine the amount of each needed to make some amount of output. Usually we use physical units to measure the inputs—hours for labor and joules for energy, for example. Sometimes it is more useful to measure the input in dollars by determining how much it would cost to purchase these units. Thus, in many analyses it will be necessary to consider the economic conditions influencing the cost of labor, materials, energy, and capital. Measuring the cost of inputs thus becomes more difficult and requires additional care as the time horizon lengthens.

Determining how much of any input is needed to make a given output entails varying degrees of difficulty. Some inputs (e.g., labor and materials) are fully consumed to produce an output and thus are easy to assign to that unit of output. For example, it is easy to measure how much energy the oven uses to bake a batch of bread. Other inputs, however, are utilized in the production of an output, but are not fully consumed—the oven itself, for instance. The capital input is often the most difficult of the four categories to assign to a specific output because it is almost impossible to measure how much capital is consumed at any point in time. Generally accepted accounting rules are often used to allocate fixed costs, such as capital, to each unit of output.

Outputs

The output of a process is either a good or a service. The process flow diagram in **Figure 1** shows that the product is stored in Finished Goods Inventory (FGI) before leaving the system. In some organizations the finished goods inventory is kept apart from the operating system producing the good and is managed separately. Sometimes, the finished goods inventory does not exist at all: the process produces the output directly for distribution. In fact, this is an important characteristic of most processes providing services. It is often not easy (or possible) to store it for later distribution.

Although it is a simple matter to count the number of loaves of bread produced by the bakery, or to count the number of patients served by a hospital, it may not be simple to place a value on this output. The question of valuing the outputs can be approached from an economic point of view if a market will place a value on the output through the pricing mechanism. So, if we know the revenue that can be obtained from selling the good or service, that should serve as a measure of its value. For this reason, we must have a good understanding of the economic environment within which the process exists. Thus, "What are the market conditions?" and "What is the competition doing?" are important questions to address when analyzing a process.

For a new product, or one that has some improved characteristics, however, the question of what price *will be* paid for the output is difficult to answer unless some other information is known about the output. Here, we will consider three output characteristics: the *cost* of providing the output, the *quality* of the output, and the *timeliness* of the output. Often none of these measures is easily obtained, but they can serve as a checklist in our analysis of operating systems. If we are going to consider making a new type of bread, or increasing the quality of the bread, we may not know the price we can get for it. However, we do know that to value the new product, it is important to take into account the new product's characteristics, market conditions (is there an oversupply of specialty or high-end breads?), and the competitive situation (should we match the price of a competitor's similar product?).

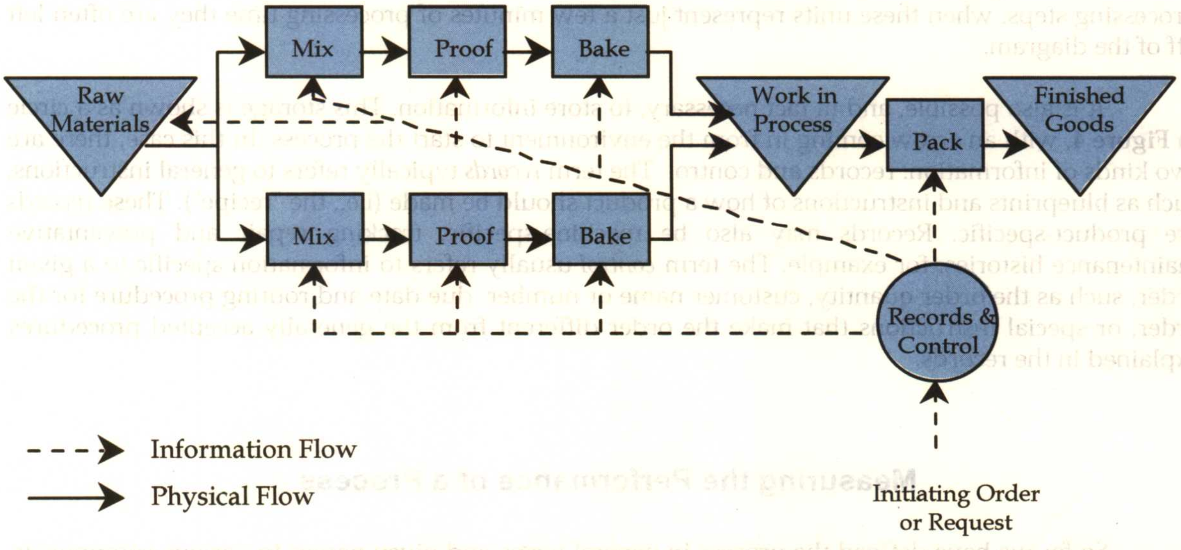
Tasks, Flows, and Storage

So far we have discussed what goes into and what comes out of a process. We must also understand what goes on inside a process. The specifics of every process are different, but there are three general categories for all activities within the process: tasks, flows, and storage.

A task typically involves the addition of some input that makes the product or service more nearly like the desired output. Some examples of tasks are (1) operating a drill press to change a piece of metal; (2) inspecting a part to make sure it meets some standard; (3) flying an airplane; and (4) anesthetizing a patient before an operation. A task quite often takes the form of added labor and capital; in processes with some form of automation, capital and/or material may be substituted for labor in a task.

There are two types of flows to be considered in each process: the flow of goods and the flow of information. **Figure 4** depicts a process flow diagram with the flow of information shown explicitly—the flow of physical goods is indicated by solid lines and the information flow by broken lines.

Figure 4 Information and Physical Process Flow Diagram for the Bread-Making Process



Information flows in the bread-making process depicted in **Figure 4** are quite simple; they take the form of recipes and production orders. The list of ingredients and quantities for the type of bread that will be made next must go the operators or material handlers in charge of getting the raw material ingredients to each mixer. Information on mixing times and methods must go to the operators of the mixers, and baking temperatures and times must go to operators of the ovens. We will also have to inform packaging of what types and quantities of breads will be arriving to the packaging area so that they can set up their equipment with the correct bags.

In some types of operations, the information flows take place with the physical flows, often in the form of a routing slip attached to a single product or a batch of products. The analogy here would be the entire recipe and the production order moving with the bread. The oven operator, for instance, would receive baking instructions with the proofed dough as it arrives at the oven. If the operator could not or would not need to adjust the oven in advance, not providing this information in advance would not cause any production delay and would simplify the information flows. Other information that might be included on the routing slip includes the packaging lines that the loaves should be sent to (if there are multiple packaging lines), the appropriate bags to use for packaging, the supermarket name and location, the delivery date and time, and possibly even the truck into which the finished product should be loaded.

When the information does not physically move through the process with the goods, the worker may need to go to a central location to obtain the information before performing the task, or the worker may have the necessary information at the workstation or in his or her head. In analyzing a process it is often important to consider the information flows in addition to the physical flow of goods or services.

Storage (the holding of inventory) is the last of the three activities within a process we will define. Storage occurs when no task is being performed and the good or service is not being transported. In **Figures 1 - 4** we have shown the storage of goods as inverted triangles. While the bakery is operating, there will usually be work-in-process inside the mixers, proofers, and ovens, at the packaging machines, as well as some work-in-process inventory between each step, and raw materials and finished goods inventory in the warehouse. If there is no storage between two connected tasks there must be a planned continuous flow between these tasks to allow the receiving task to operate continuously. **Figures 1** and **2** show only one work-in-process storage, whereas **Figure 3** shows two. In many processes that are considered continuous, there are at least a few units of work-in-process inventory on a rack or chute waiting to be fed into a machine. Although technically these units are in storage and could be depicted on the process flow diagram as inverted triangles between processing steps, when these units represent just a few minutes of processing time they are often left off of the diagram.

It is also possible, and in fact necessary, to store information. This storage is shown as a circle in **Figure 4**, with an arrow coming in from the environment to start the process. In this case, there are two kinds of information: records and control. The term *records* typically refers to general instructions, such as blueprints and instructions of how a product should be made (i.e., the "recipe"). These records are product-specific. Records may also be machine-specific, tracking repair and preventative maintenance histories, for example. The term *control* usually refers to information specific to a given order, such as the order quantity, customer name or number, due date and routing procedure for the order, or special instructions that make the order different from the generally accepted procedures explained in the records.

Measuring the Performance of a Process

So far we have defined the process in general terms and given names to various components of the process, namely the *inputs*, the *outputs*, and the *tasks*, *flows*, and *storage* within the process. We have also noted that the process does not exist in isolation. Economic conditions influence the values of inputs and outputs, and the state of technology influences the nature of the tasks and flows. Using these concepts as a base, we can now explore some process characteristics, concentrating on four: *capacity*, *efficiency*, *flexibility*, and *quality*.

Capacity

Capacity is the maximum rate of output from the process and is measured in units of output per unit of time: a steel mill, for instance, can produce some number of tons of steel per year, or an insurance office can process some number of claims per hour. *Capacity is easy to define and hard to measure.* It is often possible to determine the *theoretical capacity* of a process—the most output it could generate under ideal conditions over some period of time. For planning purposes and management decisions, however, it is more useful to know the *effective capacity* of a process. And to measure effective capacity, we must know a great deal about the process, carefully analyzing the particular situation at hand.

Managers often believe that the capacity of a process is an absolute fixed quantity. This is rarely true. The capacity of a process can change for many reasons, and we will encounter several cases where this is a key factor. The steel mill, for instance, may be designed for some ideal capacity, but its effective capacity may be different due to a variety of internal and external factors, and management decisions. The nature and availability of the raw materials being utilized, the mix of products being produced, the quantity and nature of the labor input, and the number of shifts of operation will all impact the effective capacity. The yield of the process is also important. In most instances, the rate of *good* units produced is the relevant capacity measure.

Efficiency

Efficiency is a measure that relates the amount or value of the output of the process to the amount or value of the input. "Efficiency" is widely used to measure physical processes. Every engine has an efficiency, expressed as a ratio of output energy to input energy. So, an engine with 75% efficiency can deliver 75% of the input energy as useful output energy. The energy efficiency of physical systems cannot exceed 100%; the useful output energy is always less than the energy input. This is not generally true of economic processes, however. For example, if the process is going to generate sufficient resources to support its own continued operation, the *value* of the output should exceed the value of the input. If we measure the value of output by the revenues it will bring in the market, and if we measure the value of inputs by their costs, the measure of efficiency is profit, i.e., revenue minus cost. Thus, the profit is the value of output minus the value of input. Profit, however, is a very simplistic definition of efficiency; measuring efficiency is generally much more complex.

In some cases, the price received for the product is not a good representation of the economic value of the output. In certain markets, for example, it may be possible initially for a company to sell a product of low quality at a standard price. Over time, however, the company's reputation may be hurt by doing this, and *all* of the company's products, not just the low quality product, might become less desired by the market. The long-term loss in revenue should have been considered when establishing the cost and quality level of the original product. When determining the efficiency of a process as measured by profitability, it is important to look at long-run profits, not just the profit generated from any short-run action.

Utilization is another common measure. Utilization is the ratio of the input the process actually used in creating the output to the amount of that input available for use. In a labor-intensive process, for instance, direct labor utilization is often an efficiency measure. If, say, 100 workers are employed in a given process, and during an eight-hour shift 700 hours of labor were consumed in the actual manufacture of product, then the direct labor utilization during that shift was 87.5% ([700 hours/(100 X 8 hours)] = 0.875). In a similar way, to measure capital efficiency, companies often pay a