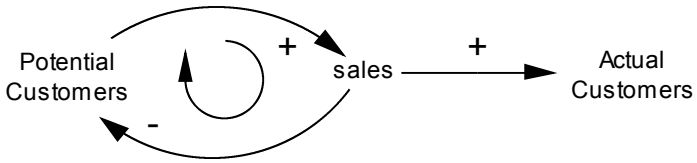
CHAPTER 2

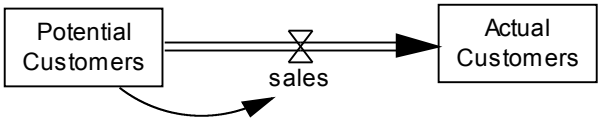
A Modeling Approach

The issues we will address to improve our understanding of how business processes work are illustrated by the causal loop diagram in Figure 2.1a. This models a simple advertising situation for a durable good. There is a pool of Potential Customers who are turned into Actual Customers by sales. Potential Customers and sales are connected in a negative feedback loop with the goal of driving Potential Customers to zero. If we visualize a typical mass advertising situation, we would expect that the greater the number of Potential Customers, the greater the sales, and this is shown in Figure 2.1a by the positive arrow between Potential Customers and sales. Similarly, greater sales lead to fewer Potential Customers (since the Potential Customers are converted into Actual Customers by sales), and hence there is a negative arrow from sales to Potential Customers. Since there are a odd number of negative links in the feedback loop between Potential Customers and sales, this is a negative feedback loop.

We obtain from this diagram the (not very profound) insight that eventually sales must go to zero when the number of Potential Customers reaches zero. However, this insight by itself is not particularly useful for business management purposes because there is no information about the *rate* at which Potential Customers will go to zero. It can make a big difference for managing the production and sales of this product if it will sell well for ten months or ten years before we run out of Potential Customers! For a simple situation like this, we could use a spreadsheet to develop a quantitative model to investigate the rate at which Potential Customers will go to zero, but as the complexity of the situation increases, this becomes more difficult. In the remainder of this chapter, we develop a systematic approach to investigating questions of this type which can be applied to both simple and complex business processes.



a. Causal loop diagram



b. Stock and flow diagram

Figure 2.1 *Advertising example*

2.1 Stock and Flow Diagrams

Figure 2.1b illustrates a graphical notation that provides some structure for thinking about the rate at which Potential Customers goes to zero. This notation consists of three different types of elements: stocks, flows, and information. As we will see below, it is a remarkable fact that the three elements in this diagram provide a general way of graphically representing *any* business process. Furthermore, this graphical notation can be used as a basis for developing a quantitative model which can be used to study the characteristics of the process.

This type of diagram is called a *stock and flow* diagram. As with a causal loop diagram, the stock and flow diagram shows relationships among *variables* which have the potential to change over time. In the Figure 2.1b stock and flow diagram, the variables are Potential Customers, sales, and Actual Customers. Unlike a causal loop diagram, a stock and flow diagram distinguishes between different types of variables. Figure 2.1b shows two different types of variables, which are distinguished by different graphical symbols. The variables Potential Customers and Actual Customers are shown inside rectangles, and this type of variable is called a *stock*, *level*, or *accumulation*. The variable sales is shown next to a bow tie or butterfly valve symbol, and this type of variable is called a *flow*, or *rate*.

To understand and construct stock and flow diagrams, it is necessary to understand the difference between stocks and flows. However, before considering this in more detail, it is useful to discuss what we are attempting to do with this approach to modeling business processes.

2.2 Generality of the Approach

I noted above that the stock and flow notation illustrated in Figure 2.1b provides a general way to graphically characterize any business process. This may seem ambitious: *any* process! In particular, if you have previously worked with computer simulation packages for, to take a specific example, manufacturing processes, you know that they generally contain many more elements than the two shown here. For example, a manufacturing simulation package might contain specific symbols and characterizations for a variety of different milling machines or other manufacturing equipment.

This type of detailed information is important for studying the specific detailed operation of a particular manufacturing process. We will not be providing such details here because they are specific to particular equipment (which will probably soon be obsolete). Instead, we are considering the characteristics that are generally shared by *all* business processes and the components which make up these processes. It is a remarkable fact that all such processes can be characterized in terms of variables of two types, stocks (levels, accumulations) and flows (rates).

The conclusion in the previous paragraph is supported by over a century of theoretical and practical work. Forrester (1961) first systematically applied these ideas to business process analysis almost forty years ago, and extensive practical applications have shown that this way of considering business processes provides significant insights based on solid theory. As the old saying goes, there is nothing more practical than a good theory, and the theory presented here can be turned in practice, yielding competitive advantage.

2.3 Stocks and Flows

The graphical notation in Figure 2.1b hints at the differences between stocks and flows. The rectangular boxes around the variables Potential Customers and Actual Customers look like containers of some sort, or perhaps even bathtubs. The double-line arrow pointing from Potential Customers toward Actual Customers looks like a pipe, and the butterfly valve in the middle of this pipe looks like a valve controlling the flow through the pipe. Thus, the graphical notation hints at the idea that there is a flow from Potential Customers toward Actual Customers, with the rate of the flow controlled by the sales valve. And, in fact, this is the key idea behind the difference between a stock and a flow: A stock is an accumulation of something, and a flow is the movement or flow of the something from one stock to another.

A primary interest of business managers is changes in variables like Actual Customers over time. If nothing changes, then anybody can manage just do what has always been done. Some of the greatest management challenges come from change. If sales start to decline, or even increase, you should investigate why this change has occurred and how to address it. One of the key differences

between managers who are successful and those who are not is their ability to address changes before it is too late.

We will focus on investigating these changes, and in particular learning how the elements and structure of a business process can bring about such changes. Because of this focus on the elements which make up a process (which are often referred to as the *components* of a *system*) and how the performance of the process changes over time, the ideas we are studying are often referred to as *system dynamics*.

Distinguishing between stocks and flows is sometimes difficult, and we will provide numerous examples below. As a starting point, you can think of stocks as representing physical entities which can accumulate and move around. However, in this age of computers, what used to be concrete physical entities have often become abstract. For example, money is often an important stock in many business processes. However, money is more often than not entries in a computer system, rather than physical dollar bills. In the pre-computer days, refunds in a department store might require the transfer of currency through a pneumatic tube; now they probably mean a computer credit to a MasterCard account. Nonetheless, the money is still a stock, and the transfer operation for the money is a flow.

Another way to distinguish stocks and flows is to ask what would happen if we could freeze time and observe the process. If we would still see a nonzero value for a quantity, then that quantity is a stock, but if the quantity could not be measured, then it is a flow. (That is, flows only occur over a period of time, and, at any particular instant, nothing moves.) For readers with an engineering systems analysis background, we use the term stock for what is called a *state variable* is engineering systems analysis.

Types of Stocks and Flows

Most business activities include one or more of the following five types of stocks: materials, personnel, capital equipment, orders, and money. The most visible signs of the operation of a process are often movements of these five types of stocks, and these are defined as follows:

Materials. This includes all stocks and flows of physical goods which are part of a production and distribution process, whether raw materials, in-process inventories, or finished products.

Personnel. This generally refers to actual people, as opposed, for example, to hours of labor.

Capital equipment. This includes such things as factory space, tools, and other equipment necessary for the production of goods and provision of services.

Orders. This includes such things as orders for goods, requisitions for new employees, and contracts for new space or capital equipment. Orders are typically the result of some management decision which has been made, but not yet converted into the desired result.

Money. This is used in the cash sense. That is, a flow of money is the actual transmittal of payments between different stocks of money.

The first three items above (materials, personnel, and capital equipment) are conceptually relatively straightforward because there is usually a physical entity corresponding to these. The last two items above (orders and money) are somewhat more subtle in this age of computers. Whether something is really money or just information about a monetary entry somewhere in a computer database may not be immediately obvious.

2.4 Information

The last element in the Figure 2.1b stock and flow diagram is the information link shown by the curved arrow from Potential Customers to sales. This arrow means that in some way information about the value of Potential Customers influences the value of sales. Furthermore, and equally important, the fact that there is no information arrow from Actual Customers to sales means that information about the value of Actual Customers does not influence the value of sales.

The creation, control, and distribution of information is a central activity of business management. The heart of the ongoing changes in business management is in changing the way that information is used. Perhaps nowhere is the impact of the computer on management potentially more significant. In a traditional hierarchical business organization, it can be argued that the primary role of much of middle management is to pass information up the hierarchy and orders down. This structure was required in pre-computer days by the magnitude of the communications problem in a large organization. With the current widespread availability of inexpensive computer-based analysis and communications systems, this large, expensive, and slow system for transmitting information is no longer adequate to retain competitive advantage. Business organizations are substantially changing the way they handle information, and thus the set of information links is a central component in most models of business processes oriented toward improving these processes.

The information links in a business process can be difficult to adequately model because of the abstract nature of these links. Materials, personnel, capital equipment, orders, and money usually have a physical representation. Furthermore, these quantities are conserved, and thus they can only flow to one place at a time. Information, on the other hand, can simultaneously flow to many places, and, particularly in computer-intensive environments, it can do this rapidly and with considerable distortion.

Practical experience is showing that modifying the information links in a business process can have profound impacts on the performance of the process. Furthermore, these impacts are often non-intuitive and can be dangerous. Some companies have discovered, for example, that computer-based information systems have not only not improved their performance, but in fact have degraded it. Doing large-scale experimentation by making *ad hoc* changes to a crucial aspect of an organization like the information links can be dangerous. The tools we discuss below provide a way to investigate the implications of such changes before they are implemented.

No one today would construct and fly an airplane without first carefully analyzing its potential performance with computer-based models. However, we routinely make major changes to our business organizations without such prior modeling. We seem to think that we can intuitively predict the performance of a changed organization, even though this organization is likely to be much more complex than an airplane. No one would take a ride on an airplane whose characteristics under all sorts of extreme conditions had not previously been analyzed carefully. Yet we routinely make significant changes to the structure of a business process and then take a ride in the resulting organization without this testing. The methods presented below aid in doing some testing before implementing changes to business processes.

2.5 Reference

J. W. Forrester, *Industrial Dynamics*, The MIT Press, Cambridge, Massachusetts, 1961.