ROGER BOHN

Kristen's Cookie Company (A2)

Start with the key questions posed in the "(A1)" case[1] and see how Production and Operations Management (POM) tools and vocabulary will help to answer them. For the initial analysis, assume all orders are for one dozen cookies (one tray).

First, how long will it take to fill a rush order, assuming that no other cookies are currently in process? To figure this out, you must calculate the amount of time it takes from the moment you begin to make a new batch of cookies with their custom-selected ingredients to the moment when the dozen cookies are packed into a box and payment is received from the customer. Looking at the process flow diagram (**Figure A**) and thinking about the production process will show you that this time, called the **throughput time,** is the sum of each of the times for each of the production steps. For an order of one dozen cookies, which can be made on one tray, the throughput time is 6 minutes for mixing, plus 2 minutes to spoon out the cookie dough, plus 10 minutes for loading and baking, plus 5 minutes for cooling, plus 2 minutes for packing, plus 1 minute for receiving payment, for a total of 26 minutes. (Notice the importance of your customized ingredients. A less-refined bakery could make cookies to inventory *before* orders were received, and get cookies to the customers even sooner.)

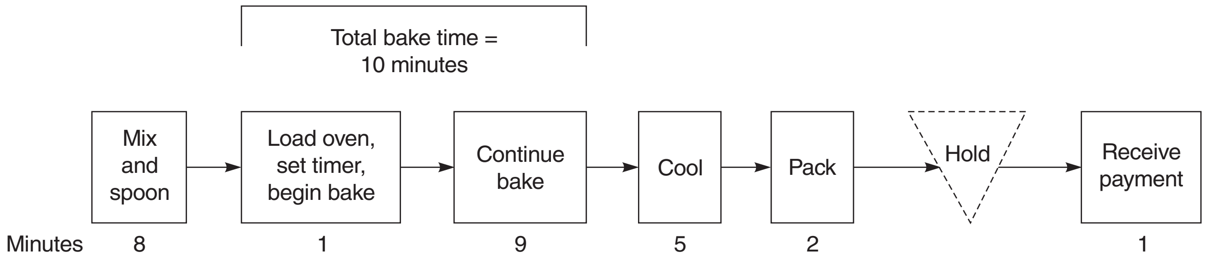
Illustration by Jane Simon

Second, how many orders can you fill in a night? (This information will help you set prices and guess whether you will cover your fixed overhead costs.) If it took 26 minutes to fill each order, that would mean that during the four-hour period of planned operation you could fill approximately nine orders. It will be hard to make money at that rate of production. However, the 26-minute throughput time is not the relevant number for calculating how many cookies you can make during a given interval. Instead, what you are looking for is the **capacity** of the process as a whole, which equals the capacity of the slowest stage. Therefore, look again at the process flow diagram to find the slowest stage.

[1] This case is designed to accompany "Kristen's Cookie Company (A1)," HBS No. 686-093.

Professor Roger Bohn prepared this case with the assistance of Research Associates K. Somers and G. Greenberg. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

Figure A Process Flow Diagram: One Order for One Dozen Identical Cookies



Consider only those orders for a dozen cookies. The individual operations' **cycle times** for orders of this size are 8 minutes for mixing and spooning the dough, 10 minutes for loading and baking, 5 minutes for cooling, 2 minutes for packing, and 1 minute for receiving payment. The slowest step is baking, which takes 10 minutes. (Because the oven holds only one tray at a time, you cannot schedule production so that the oven processes more than six trays in an hour.) *Therefore, the speed with which you can produce cookies is dependent upon the cycle time for baking, the bottleneck operation.* You can produce, at best, one tray of cookies every 10 minutes. When you are running flat out, one tray full of cookies will pop off the end of your production line every 10 minutes. This 10 minutes is therefore the cycle time for the whole system. The system cycle time is always the same as the cycle time for the **bottleneck** operation.

Your cookie-producing capacity is therefore one dozen cookies every 10 minutes or six dozen cookies per hour. (The capacity of a process is the inverse of its cycle time. Keep careful track of the units of measurement; in this example, everything is per dozen, not per cookie.) In a four-hour night, if you have enough orders to keep you busy, you can hope to produce 24 dozen cookies. However, some time will be needed for start-up and shutdown. The first dozen cannot start until 8 minutes after you open; the last dozen must come out of the oven eight minutes before you close. So if you must be open for precisely four hours, you can bake only 22 dozen. (In most processes, the usual concern is with the steady-state capacity, without worrying about start-up and shutdown. This is possible because in most factories work can be left partially completed overnight.)

Now, change the order size: How many cookies can you produce in a night if everybody orders two dozen cookies at a time? The mixing stage will take exactly 10 minutes *per order* (6 minutes for mixing plus 4 minutes for spooning out the two trays). The limiting factor is still the baking stage, with its cycle time of 10 minutes *per dozen*. Therefore our capacity, *in dozens*, does not depend on the order size. Another way of stating this is that the bottleneck operation (baking) is straight running time; there is no setup time. Thus, the bottleneck operation's capacity, in dozen cookies per hour, is independent of the order size. Later, we will look at how the bottleneck operation can shift away from the oven to the mixing stage. If this happens, the capacity of the whole system will depend on the size of the orders.

How much time are the two of you going to have to devote to these production steps? This is the **labor time**. The bottleneck operation is baking. Its capacity is much less than other operations; so, the other operations will have a lot of **idle time**. In fact, during each 10-minute cycle of the oven, your roommate only has 4 minutes to work and 6 minutes to study. You have either 8 minutes of work if it is the first tray of an order (6 minutes setup plus 2 minutes per tray) or only 2 minutes of work if you are on the second or third tray of a two-dozen or more cookie order. (A profile of expected order sizes would allow you to calculate your expected study time.) Of course, this assumes that you have enough orders to keep constantly busy. If your company has orders for fewer than 24 dozen cookies per night, you will have more idle time.

How much should you charge for your cookies? Business practice dictates that the proper price to charge depends on both the demand for your unique cookies and your production cost. You cannot address demand until you survey the market and the competition, but you can certainly figure out the production cost. The production cost is the cost of materials plus the cost of your labor time. Total labor time is the sum of the labor times in each of the process steps. Therefore, it is 7 minutes of setup labor (mixing and collecting payment) plus 5 minutes of run-time labor (two for spooning out the dough, one for loading, and two for packing) per dozen cookies in an order. Note that although cooling takes 5 minutes, it involves no labor. Thus, for a one-dozen cookie order, labor time is 12 minutes; for a two-dozen cookie order, labor time is 17 minutes. If you value your time at $.20 per minute, you should charge at least $2.40 plus material costs of $.70 or $3.10 for a one-dozen cookie order. You can charge $1.40 less (since the setup does not have to be repeated) for the second dozen of a two-dozen order.

Notice the importance of labor flexibility here. You and your roommate have 8 minutes of idle time during each 10-minute baking cycle of a one-dozen cookie order (10 minutes x 2 people - 12 minutes labor time). The amount rises to 23 minutes for a two-dozen order. The above cost calculations implicitly assume that this idle time can be put to another productive use—in this example, studying. If not, you have to pay for all the time (2 people x 10 minutes = 20 minutes for a one-dozen order) devoted to a baking cycle. If orders are received irregularly and there are gaps with no orders pending, idle time per unit of sales will be even higher.

A related problem that arises from worker inflexibility is that when there are no orders in hand, workers will be idle. One solution to both problems is to find a productive alternative for workers when they would otherwise be idle. In your situation, the alternative is studying. What is it in other fast-food restaurants?

Sequencing and Resource Conflicts

A Gantt chart helps to answer questions about timing and sequencing. Gantt charts show the time at which different activities are performed, as well as the sequence of activities—information that you cannot get from a process flow diagram. **Figure B** is a Gantt chart for one order of two dozen cookies. Each row represents a different activity. The last three rows show how different **resources** (you, your roommate, and the oven) are utilized. The chart as a whole illustrates how each tray moves through the process.

How long does it take to fill a two-tray order? The Gantt chart helps to answer this question. The first dozen goes in to bake at the end of 8 minutes. The second dozen will go into the bottleneck 10 minutes after the first dozen, so it will finish 10 minutes after the first dozen. In general, the throughput time for an n dozen cookie order = (throughput time for first dozen) + (n - 1) x (cycle time of bottleneck).

Number of Trays	Throughput Time	Labor Time[a]
1	26 min.	12 min.
2	36	17
3	46	22
4	56 min.	33 min.

[a]Assuming all cookies in the order have the same ingredients. Otherwise treat as separate orders. Setup time = 6 + I minutes; run time = 5 minutes per tray.

Orders for more than three dozen identical cookies require two mixing steps (because the bowl holds only enough for three dozen). Therefore, the fourth dozen will have 11 minutes of labor. However, you can start mixing the fourth dozen while the third is still in the oven, so throughput time increases by only 10 minutes.

The bottom row of the Gantt chart shows graphically that your oven will be very busy. (In general, if you have all the orders you can handle, the oven will be utilized all the time [except for start-up and shutdown]. This is what you would expect of the bottleneck operation.) It also shows that your roommate is not very busy. Can you run this operation by yourself?

Figure B Throughput Time for a Two-Tray Order

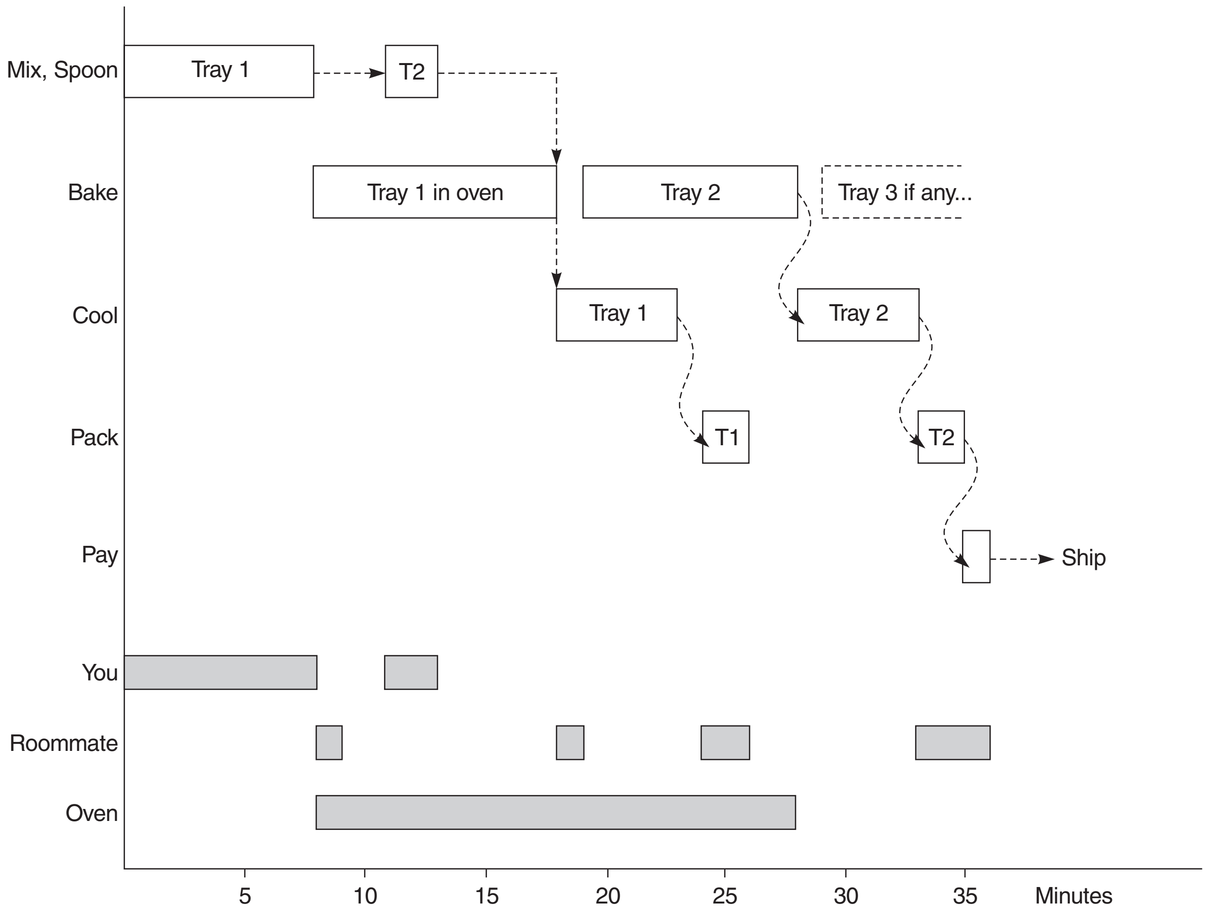


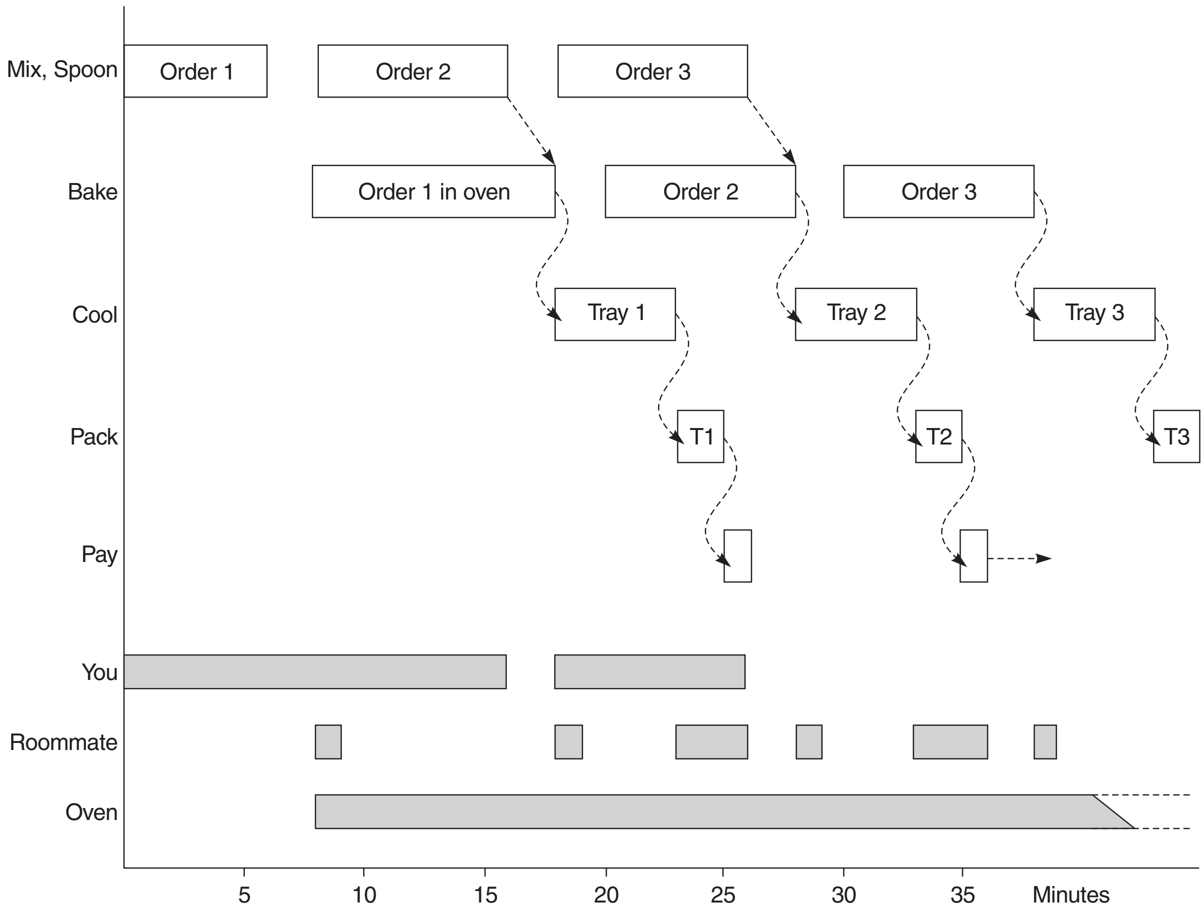
Figure B shows that you could do the order by yourself, because you and your roommate do not have to be busy at the same time. Even with successive orders back to back, you can do everything yourself.

With a succession of one-tray orders, however, you would run into trouble with only one person. **Figure C** shows consecutive orders for one dozen cookies. By the time you start working on the third order, you and your roommate must work simultaneously for part of the time.

You can get similar information from labortime calculations. With an order size of two dozen, 17 minutes of labor time are needed for every order (7 minutes setup and 5 minutes per tray). The cycle time per order is 20 minutes (2 x 10), so one person is adequate. With orders for one dozen, however, 12 minutes of labor time are needed per order. With one person, only 10 labor minutes are available during each 10-minute cycle.

Therefore, if you operate the company by yourself, you will be the bottleneck for orders of one dozen. Your capacity will fall from six to five dozen per hour, if all orders are for one dozen. From a business point of view, this might be worth doing if you were using outside workers. Your labor bill would be cut in half, and your capacity would fall by one-sixth or less.

Figure C Sequence of One-Tray Orders



This example shows that the bottleneck is not always the operation with the longest cycle time. The bottleneck can be the limiting resource; if so, the cycle time of the process is determined by that resource.

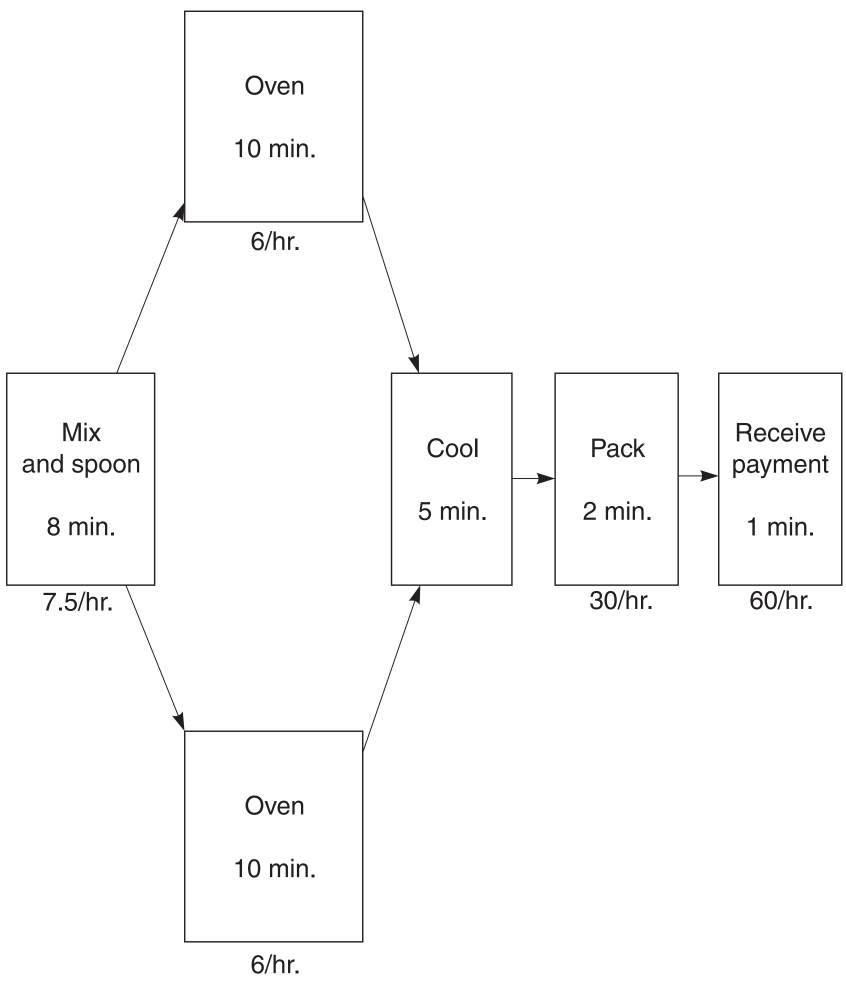
With both you and your roommate working, you will need only one food processor because baking is always the bottleneck. You may, however, need several trays. While one is in the oven, baked cookies can be removed on a second and raw cookies put on a third. Because trays are inexpensive, buy four or five to ensure that they are never a binding constraint. If you wanted to perform a precise analysis, you could add two resource rows to the Gantt chart—one for the food processor and one for the trays.

Improving the System

How can this system be improved? One goal would be to increase your total production capacity per night. This would allow you to better cover expenditures such as the fixed costs of going into business and of marketing. To do this you have to increase the cookie-making capacity. That means improving the bottleneck operation, which in this instance is the baking stage.

An obvious improvement is to provide two ovens, each capable of holding one tray. That will double the capacity of the bottleneck baking process from 6 dozen cookies per hour (60 minutes/hour - 10 minutes/dozen cookies) to 12 dozen cookies per hour. On your process flow diagram, you would draw the two baking machines in parallel, each with a cycle time of 10 minutes and a capacity of 6 dozen per hour (**Figure D**). The total capacity of different machines in parallel is the sum of the capacities of individual machines (6 dozen per hour plus 6 dozen per hour = 12 dozen per hour).

Figure D Capacity (trays per hour) for Each Production Stage (for order sizes of one dozen cookies in all orders)



Assume: One tray = one dozen.
No labor restraint (i.e., both you and your roommate are working).

If you increase the capacity of the bottleneck operation in this way, what happens to the capacity of the system as a whole? At best, you might expect it to double. However, it will not double in this example, because the bottleneck shifts to the mixing operation if the order size is one dozen cookies. Mixing still takes eight minutes per order, but you can start baking a new order every five minutes. So your new capacity is 7.5 dozen cookies per hour, if all order sizes are one dozen (7.5 = 60/8).

However, if your orders were for 3 dozen cookies at a time, then the capacity of the mixing stage would be 3 dozen cookies every 12 minutes (12 = 6 + 2 + 2 + 2) or 15 dozen per hour. Therefore, the baking stage with its capacity of 12 dozen cookies per hour would again be the bottleneck and would set the capacity for the system as a whole.

In this common situation the identity of the bottleneck, and thus the capacity of the system as a whole, depends on the exact composition of orders. Different orders create different demands on the resources of the system (people and equipment at different stages).

Once you have increased the capacity of the bottleneck to this level, further management analysis and judgment are required to determine which stage of the process to improve next. You, the manager, have to make some estimates both of future orders and of the importance to you of being able to fill big orders in contrast to small ones or simple orders in contrast to complex ones to determine where to put your next capital investment.

For example, after you acquire a second oven and if the majority of your orders turn out to be one-dozen batches, you might decide to premix in advance and refrigerate dough for some of the more popular cookies. This work-in-process inventory would eliminate the mixing step for those cookies and thus increase your capacity to 12 dozen per hour (the two ovens being the bottleneck again). An important factor, of course, would be the effect of refrigeration on the quality of your cookies and on your fresh-baked image.

Notice that it is worthless to improve the capacity of the packing operation. (Packing capacity is 30 dozen per hour.) A good rule of thumb is that it is useless to increase the capacity of an operation that is never a bottleneck. (It still might be worth making capital investments in packing if that would reduce the amount of labor time needed, reduce the throughput time, increase the yields, lead to a more attractive product, or some other effect.) This reason illustrates why it is so important to identify bottleneck operations before improving a process. All too often in practice, resources are spent on improving operations that are not bottlenecks, leading to essentially no improvement in system capacity.

A second improvement would be to reduce the required labor time so that you and your roommate can spend more time studying. For example, you could make a set of graduated measuring spoons that hold exactly the right amount of each ingredient. More likely, you could figure out clever ways of putting the cookie dough on the tray and packing the cookies into the box more quickly. Reducing throughput time might also be useful, even if it does nothing to improve capacity, because that would reduce the delivery time on rush orders. A hotter oven or an air conditioner above the cooling area might speed the baking and cooling steps, respectively. Obviously, you would need to experiment to test the effect of such changes.

Another improvement would be to **balance** the line better. At present, the process steps take very different times. This would be an important consideration if you could not use your workers' idle time.

Other improvements to the system are possible. The ones to pursue will depend on which aspects of your operation will have the biggest impact on your company's success.