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A NOTE ON MANAGING PROCESS FLOWS

This note focuses on the fundamentals of managing process flows. Recall that a process is any set of actions that converts a set of inputs into a set of outputs. For example the trade-to-settlement process at an investment bank converts trades initiated by traders on the trading floor into official trades. Processes at a hospital are intended to convert ailing patients into well patients. A process for transmitting information via an Internet-router system converts e-mail messages waiting to be delivered into delivered messages. At a supermarket, a cashier converts a line of customers waiting to pay into customers who have paid. A business unit uses a set of processes to convert raw materials and other inputs bought at cost dollars into products or services that bring in revenue dollars.

Often one can gain insight into a problem by examining it from different perspectives or through different lenses. The process viewpoint is one such perspective. Thinking of a set of activities as a process is very useful when the goal is to manage operational metrics such as capacity or responsiveness. Recall that the capacity of a process is the maximum rate at which it can process items, and that capacity is defined as the capacity of the slowest or the "bottleneck" stage. A related concept, responsiveness or throughput time, is a measure of how long an item takes to pass through a process. For example, how long does an insurance claim take to be processed, or a trade to be settled? Greater responsiveness results in better customer service and can result in lower costs as well. Thus, it directly impacts revenues by either increasing market share or allowing a firm to charge a premium for the better service provided.

Below we formalize four important metrics that are central to the management of process flows:

1. *Flow unit*[1]: Flow unit is a generic term used to describe whatever it is that is flowing through a process. For example, it could represent physical units such as cars that are assembled at an assembly plant or discrete jobs such as insurance claims that are processed at an insurance office, or legal cases that are processed at a court house. A flow

[1] We borrow this terminology from *Managing Business Process Flows* by R. Anupindi, S. Chopra, S. Deshmukh, J. Van Meighem, and E. Zemel, (Prentice Hall, 1999).

This technical note was prepared by Kamalini Ramdas, Associate Professor of Business Administration. It was written as a basis for class discussion rather than to illustrate effective or ineffective handling of an administrative situation.

unit could also represent an inherently continuous quantity, such as gallons of pulp processed at a paper mill. As another continuous example, a business converts cost dollars into revenue dollars, and the flow unit is simply dollars. Referring back to the examples introduced at the start of this note, what actually "flows" through a process could be physical units, people, jobs, messages, money, or anything else that gets processed.

Note that the units flowing through the process are transformed as a result of doing so. Thus, while it is relatively easy to visualize cars rolling off the end of a Toyota assembly line, further upstream the same cars are represented by various components and subassemblies, such as four tires, a set of seats, or an engine.

2. *Throughput rate*: The throughput rate is the rate at which flow units actually flow through a process. For example, **Figure 1** below shows the number of claims processed each day at an insurance company that has the capacity to process 40 claims per day, over a 30-day period.

Figure 1. Number of claims processed each day at an insurance company, over a 30-day period.

Day #	# Claims Processed	Day #	# Claims Processed	Day #	# Claims Processed
1	32	11	23	21	26
2	29	12	35	22	25
3	33	13	23	23	26
4	36	14	36	24	35
5	21	15	29	25	29
6	37	16	21	26	33
7	24	17	23	27	37
8	38	18	20	28	40
9	40	19	31	29	25
10	30	20	30	30	29

Clearly there is some variation in the throughput rate, with more claims being processed on some days than others. The average throughput rate is 29.9 claims per day. Note that throughput rate differs from capacity: The former refers to the rate at which flow units were *actually* processed, whereas the latter refers to the maximum rate at which flow units *can be* processed.

At an automobile factory, a measure of throughput rate is the rate at which cars roll off the assembly line. At a hospital, a measure of throughput rate is the number of patients released each day. If the flow unit is dollars, then the throughput rate is the sales rate.

3. *Throughput time*: Throughput time for a flow unit in a process is defined as the amount of time the flow unit spends in that process. For example, in the insurance claims processing example, the throughput time for a claim is the elapsed time from when that claim enters the claims process until it completes the process.

   It is important to note that the time spent by a flow unit in a process depends on how the boundaries of the process are defined. For example, if the claims process is defined as starting with registering of the claim and as ending with an employee mailing a letter to the claimant regarding the claim, the throughput time is the total time taken to complete these activities. But if the claims process is defined narrowly as the stage where an underwriter evaluates the claim, then throughput time is the much shorter time spent in this single stage.

   Throughput time typically fluctuates from one flow unit to the next. For example, a claim that arrives at a peak period would likely spend more time in the system than a claim that arrives during a slow period.

4 *Inventory*: Inventory is defined as the number of flow units that are within the boundaries of a process at any point in time. Like throughput time, inventory depends on how the process boundaries are defined.

   The inventory in a process will fluctuate over time. For example, if an unusually large number of claims are registered on a day when several employees are absent, the inventory may pile up. On another day when few claims are registered and everyone is present, the backlog of claims may go down.

Defining the Boundaries of the Process or "System"

As we have seen in the insurance claims processing example above, inventory and throughput time for the claims process both depend on how the boundaries of the process or system are defined. The same is true in any setting involving multiple activities. For example, a consulting company has a variety of activities going on within its offices. While the company as a whole can be viewed as converting client engagements into completed projects, a technician in the company's IT department may have a set of IT-related tasks such as setting up laptop computers for new hires, which she must process one by one.

When using a process approach, one needs to decide what activities to include in the process model or *system*. How the process boundaries are defined will depend on the management goal. In the consulting company example above, if the goal is to understand and manage the consulting company's portfolio of client engagements including the average completion time, one must include in the system all the activities that impact the overall time required to complete an engagement. If management is interested in evaluating the responsiveness of the IT department, however, the system would include steps within the IT department. Once the system boundaries are defined, one also needs to decide in what level of detail to examine the process that lies within the system. We will talk more about this point later.

A System in Equilibrium

A system is in equilibrium if the average number of flow units in the system stays the same over time. In contrast, a system is not in equilibrium if the average number of flow units in the system is increasing or decreasing or simply varying over time. To understand what it means for a system to be in equilibrium, it is useful to consider one that is not. Consider a hospital emergency room that can serve, on average, 100 patients per hour. If, on average, 120 patients an hour arrive at the emergency room, the average number of people waiting to be served will keep increasing over time, resulting in a system that is not in equilibrium.

For a system to be in equilibrium, the average rate at which flow units enter into the system must equal the average rate at which flow units leave the system. Notice that this average rate is in fact the throughput rate of the system. Thus, in the insurance claims processing example, for the claims process to be in equilibrium, claims must flow into and out of the system at a rate of 29.9 claims per day. By extension, for a system with multiple stages in sequence to be in equilibrium, the throughput rate at each stage must be the same. For example, the claims process at an insurance company typically involves a number of activities—registering the claim, underwriting, rating the policy, and writing the policy. Referring back to **Figure 1**, for the claims process to be in equilibrium, the average throughput rate through each stage in the process must equal 29.9 claims per day.

Figure 2. Average throughput rate at each stage in the claims process.

Stage	Average Throughput Rate
Registration	29.9 claims /day
Underwriting	29.9 claims /day
Rating	29.9 claims /day
Policy Writing	29.9 claims /day
System	29.9 claims /day

Little's Law

For a system in equilibrium, a fundamental law, proved by John D.C. Little[2], governs the relationship between the average rate of flow through a system (i.e., average throughput rate), the average amount of inventory in the system, and the average amount of time that a flow unit spends in the system (i.e. average throughput time).

[2] J. D. C. Little, "A Proof of the Queuing Formula $L = \lambda W$," *Operations Research* 9 (1961): 383–387.

For a system with defined boundaries that is in equilibrium, let

I = Average amount of inventory (i.e., the average number of flow units) within the system
R = Average throughput rate through the system
T = Average throughput time for flow units to pass through the system

Little's Law states that the relationship between I, R and T is given by $I = R \times T$.

In the insurance claims processing example, we know that R = 29.9 claims per day. If the average throughput time, T = 10 days, then the average inventory in the system, I = 299 claims. These claims would be distributed over the different stages of the system, either in process or waiting to be processed. Now imagine that the average throughput time T doubles to 20 days. If the throughput rate remains the same, this increase must be accompanied by a simultaneous doubling in inventory. Intuitively, keeping average throughput rate the same, longer waits go hand in hand with greater inventory (and vice versa).

Example: Average Duration of Consulting Engagements

A boutique consulting company completes on average 120 client engagements in a year. On average, the company has a portfolio of 20 active engagements underway. Given this information, what is the average duration of each client engagement the company undertakes?

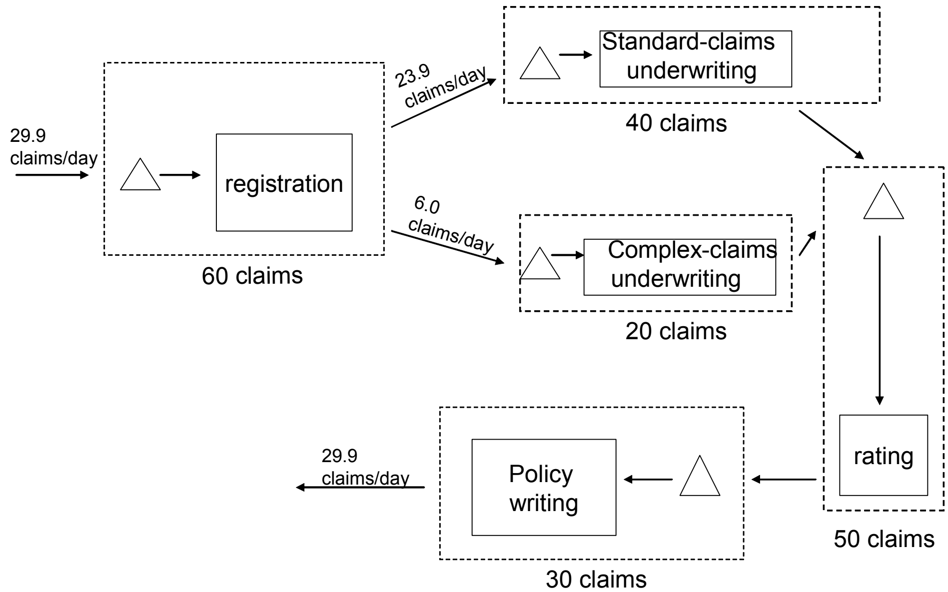
Here, R = 120 client engagements per year, and I = 20 client engagements. Therefore, by Little's Law, $T = I/R = 20/120 = 1/6$ years, or 2 months.

Example: Modifying the Insurance Claims Process to Improve Responsiveness

Consider the insurance claims processing example introduced earlier. Suppose that customers are unhappy with the average throughput time of 10 days. Management realizes that in order to maintain the current level of demand, the firm will need to improve responsiveness. The managing team is aware that 80% of the claims that are registered are fairly standard, while 20% require complex evaluation. In the current process both types of claims are routed through the same process, even though the standard claims are in fact more profitable.

Management decides to split the underwriting step into two distinct groups, one tailored to handle complex claims, and the other tailored to handle standard claims. In addition, the company hires a new underwriter to work on standard claims. As a part of the registration stage, claims are directed either to the complex-claims desk or the standard-claims desk for underwriting. Following underwriting, all stages remain unchanged. **Figure 3** shows the modified process.

Figure 3. The modified insurance claims process.



After trying out the new system for a few months, management finds that there are, on average, 60 claims at the registration step, either waiting or in process. Similarly, there are 20 claims at the complex-claims underwriting desk, 40 at the standard-claims underwriting desk, 50 claims at the rating desk, and 30 claims at the policy writing stage for a total of 200 claims in the system, either waiting or in process.

Have the operational changes instituted by management resulted in better service? First consider the entire system. If demand stays the same as before, then the flow rate into the system is 29.9 claims per day. Assuming the system is in equilibrium—and this is a reasonable assumption if inventory levels have stabilized, fluctuating around some average as opposed to showing an increasing or decreasing trend—the throughput rate R remains equal to 29.9 claims per day. Adding up the inventories at different stages, I = 200 claims. Using Little's Law, T = I/R = 200 claims/29.9 claims per day = 6.7 days. Clearly, overall responsiveness has improved relative to the original average throughput time of 10 days.

Let's now examine the process for the more profitable standard claims. Each of these claims flows through registration, the standard-claims underwriting desk, rating, and policy writing.

Now consider the registration stage as a system. Here, R = 29.9 claims per day as before, and I = 60 claims. Hence T = I/R = 2.0 days. Notice that at the registration stage, we treated the system as including claims that are waiting to be registered, as well as those that are being registered.

One could also separate the waiting claims and the in-process claims at the registration desk into two separate subsystems and apply Little's law to each subsystem, to determine the average wait time and average in-process time at registration. Of course, in order to do this, one would need to know the inventory in each subsystem. Also, conceptually the average *wait* time for a claim at the registration desk provides a lower bound for the *total* average time that a claim spends in the registration stage.

Next consider the standard-claims underwriting desk as a system. Here, R = 29.9×80% = 23.9 claims per day, and I = 40 claims. Hence, T = I/R = 1.7 days.

At the rating stage, claims from the two different upstream stages—the complex-claims underwriting desk and the standard-claims underwriting desk—merge into a single flow with a combined pool of inventory. Thus, the total inflow is the sum of the flows from these two desks, which equals the original input flow rate of R = 29.9 claims per day. Also, I = 50 claims. Hence, T = I/R = 50 claims /29.9 claims per day = 1.7 days. A similar calculation for the policy writing desks yields an average throughput time of 1.0 day. (You may want to do this calculation yourself to test your understanding of the concept.)

Thus, the total average throughput time for a standard claim is 2.0 + 1.7 + 1.7 + 1.0 = 6.4 days. A similar calculation shows that the total average throughput time for a complex claim is 2.0 + 3.3 + 1.7 + 1.0 = 8.0 days. Notice that the average throughput time for a claim picked at random is 20%×8.0 + 80%×6.4 = 6.7 days, which coincides with the answer we obtained by looking at the entire process as a system.

From the above analysis, we find that while the responsiveness of the claims process has improved for both types of claims, the more profitable standard claims now spend less time in the system than complex claims. Suppose that rather than demand staying the same, this improvement triggers greater demand from customers with standard claims. In this case the system will readjust itself again to reach a new equilibrium with higher inventory and longer throughput times.

Example: Cash Flow

The cost of goods sold at a plastics manufacturer is $12 billion per year, and the average dollar value of its inventory is $1 billion. How much time, on average, does material stay in inventory? Here R = $12 billion/year, and I = $1 billion. By Little's Law, T = I/R = 1/12 years or one month. Notice that in this example, the inventory turnover = COGS/(Average inventory) = 12 turns per year.

Summary

Taking a process viewpoint to analyze a set of activities offers a useful perspective if the goal is to manage operational metrics such as capacity, inventory, or responsiveness. In this note, we gained knowledge of what it means to take a process viewpoint. Doing so involves defining both the boundaries of the process, and the level of detail for analyzing the process. Both of these decisions are driven by what we aspire to gain from our analysis of the process.

We learned that for a process in equilibrium, a fundamental relationship called Little's Law governs the interaction among the average inventory in the system, the average throughput time for flow units, and the average throughput rate of the system.

Inventory, throughput time, and throughput rate of flow units are three crucial operational levers that can be managed to improve operational performance, and Little's Law helps us understand the links among these levers. Via examples, we gained intuition on these relationships.