In this session we’ll discuss process flow analysis. The main concept in process flow analysis is the Little’s Law. Perhaps no other formula in business school has an impact as high as the Little’s Law. When we look at the process, we see 5 elements, inputs, outputs, resources, information structure, and the network of activities and buffers. Flow units in terms of inputs come into the network of activities and buffers. They benefit from human and capital resources and information structure and become outputs. In this network, we have activities; rectangles and buffers; triangles. Activities are value added. Buffers are non value added. We say enterprises compete with each other in a four-dimensional space of time, cost, quality, and variety. Among them it is believed that in today’s competition time plays the most important role, and it is believed that it has profound impact on the other three dimensions. For example, if flow time is short, then flow units spend less time in manufacturing and service settings. They have less time to absorb overhead costs and when the flow time is low, that means normal value added part of the process is small. When flow time is short quality is high because one of the basics of flow time production is if quality is low you should stop the process. When you stop the process flow, time is not low. And if nothing flows, so flow time cannot be short, when flow time is low, as we will later see based on the Little’s Law, inventory is low. When inventory is low, that means you don’t have too much flow units in the processes; therefore, if customers change their preferences and if new technology comes into the market, you can quickly and easily switch to new products because you don’t have too much work in process. So we understand enterprises compete with each other in 4-dimensional space, and in that 4-dimensional space time plays the most important role, and time can have profound impact on the other three dimensions. According to the Little’s Law, time is connected to flow rate and inventory. Flow time is the time required by a flow unit to move through all the processes from entry point to the exit point. Flow time is not the same for all flow units. Why? Because first you may have different flow units. Patient who go to a physician office are entirely different flow units. One may stay with the physician for 2 minutes, the other may stay for 20 minutes. Second, even if two flow units are exactly the same, they may have different flow times, because we are not living in a deterministic world. Things are probabilistic. Even if you are doing two exactly identical tasks, one may take 10 minutes, the other may take 11 minutes. So we will not talk about flow time of a specific flow unit, but we talk about average flow time of all flow units.

Then we have flow rate, the number of flow units passing a specific point, entrance point, exit point, any intermediate point per unit of time. Flow rate also is not constant. It changes over time. During an hour sometimes we may have one customer per minute coming into a grocery store. Sometimes we may have 2 customers per minute. Sometimes we may have no customer per minute. And one other reason is seasonology. For example, more customers per hour come to a grocery store in the morning and in the afternoon compared to the other times. Regarding the flow rate, also we don’t talk about flow rate in each specific time unit, but we talk about average flow rate per time unit, which is constant in a stable process. And we refer to average flow rate as throughput. And then we have inventory. When we go to a car assembly plant, we see a lot of work in process over there that is inventory. When we go to a physician’s office we see patients in the waiting room. That is inventory. The number of flow units in an assembly plant may vary from one day to the next. The number of patients waiting in the waiting room for the physician may vary from one day to another day or from one hour to another hour. We talk about the average inventory. We look at all days and all hours averaged, and that would be the average inventory. We talk about average inventory, average flow rate, which is throughput, and average flow time. According to the Little’s Law, there is a relationship between average flow time, average flow rate, which is throughput, and average inventory. When we look at CSUN, when we go through the records at CSUN, we realize on average there are 36,000 students. That’s average inventory. We may go through records and find out on average each year 7,500 students graduate from CSUN. That’s our throughput. Then we may go and ask a student, how long did it take you to graduate? One student may say it took me 4 years. Another one may say it took me 5 and a half. We ask all those 7,500 students, add both times up and divide it by 7,500, and that would be the average flow time. However, according to the Little’s Law, there is another way to find out the average of how long it takes a CSUN student to graduate using the throughput and the average inventory. The ultimate strategy of all for profit enterprises is to have good financial performance. The essence of this strategy is to maximize net present value. In order to have good financial performance, we need to satisfy our customers. We cannot have good financial performance in the long-run if we don’t satisfy our customers. Customers define the expectation in a 4-dimensional space of time, cost, quality, and variety. We promise them a customer value proposition to satisfy what they expect to have in this 4-dimensional space. In order to deliver that customer value proposition, we need to develop appropriate process competencies. Process competencies in the final analysis are translated into a 4-dimensional space of time, for time, cost for cost, quality for quality, and flexibility for variety. To improve financial performances we need to satisfy our customers. To satisfy our customers, we need to propose them something which is consistent with the product attribute that they have defined in that 4-dimensional space. In order to be able to deliver that customer value proposition, we need to develop process competencies in 4-dimensional space of time, cost, quality, and flexibility. And the essence of these process competencies in the final analysis can be translated into the essence of process flow, which is the average inventory, throughput, and flow time. We are trying to prepare the stage for the Little’s Law. And the Little’s Law does not talk about this minute, next minute, this hour, next hour. It will talk about average per minute, average per hour and so forth. In a simple process, inflow rate is equal to outflow rate, what comes in goes out. 60 customers per hour come in, 60 per hour go out. In one hour maybe 58 come in and 54 go out. In another hour maybe 58 come in and 62 go out because there are some inventory from the previous hour. However, we don’t talk about hour 1, hour 2, hour 3. We talk about the average. Average inflow rate is equal to average outflow rate. We refer to average flow rate as throughput. Ideally, throughput, which we show by R, should be equal to customer demand. We produce that much which is required by the market, nothing less, nothing more. That is the idea of the situation.

Look at an airport security check point. The book talks about Vancouver Airport. If you assume that the process is stable, then throughput is constant throughout the day. Suppose average flow rate is 600 passengers per hour, and because we assume it is uniform we distributed so that would be 10 passengers per minute. The scanners at security check point can handle 12 passengers per minute. Can we have 9 instead of 12? I don’t think so, because if 10 passengers per minute come in, then we can handle 9 passengers per minute, after a while we have many passengers waiting in the line. You cannot say that after 8 hours you will stay for 2 more hours and handle the remaining passengers because in that case for 8 hours you have 10 per minute but for 2 hours you have 0 per minute. Your average flow rate would be 8 per minute for 10 hours, and here you have 9 passengers per minute for 10 hours and your capacity is more than the demand you can handle. Capacity cannot be less than demand. Can we have 20 capacity and still have waiting line? So 10 passengers per minute come in. We have capacity of 20 passengers per minute. Can we still have waiting line? The answer as you will see in the waiting line analysis is yes. Why? Because there is variability. It is not the case that in each minute exactly 10 passengers come in. In some minutes there might be 0 passengers and in some minutes there might be 40 passengers. While capacity is much greater than the demand, still we may experience waiting line. We will discuss it later, but for the time being we are only concerned with averages, average flow time, average inventory, which is the number of people waiting in the line, and average flow rate, which is throughput.

Average outflow capacity, which is process capacity, must be greater than average inflow rate, which is throughput. Why the average inventory is not 50. Here is the Little’s Law. Flowing units come into the system at rate of R per time unit; R units per hour, R units per day, R units per minute, and they leave the system at the same rate. Throughput is R units per unit of time; R units per hour, R units per minute, R units per day, R units per week. A flow unit at its entrance point into the system observes I flow units waiting there. While the flow unit is waiting, the waiting flow units leave the system one by one. When this flow unit reaches the point to leave the system, it looks over its shoulder and again there are I flow units. Wait. It will take this flow unit key units of time to go through the process yielding T units of time. Other flow units have come into the system at rate of R. How many flow units have been accumulated inside the system during that time period? I. In the time period of T, flow units have come in at the rate of R and I units have been accumulated. R times T is equal to I. An alternatively, to explain the Little’s Law is units coming to the system and leave the system at rate of R. On average, at any second, there are I units within the system. So I units are there. They are served at rate of R. How long does it take them to be served? T units of time. T times R is equal to I. Throughput times flow time is equal to inventory.

In a security check point in Vancouver Airport on average there are 17 and a half passengers waiting in the line. 17 and a half on average means sometimes there are 18, sometimes there are 19, sometimes there are 17. When we add all these numbers and weighted average them the average is 17.5. For example, if you have one person in a waiting line 50 percent of the time and there is no one in the waiting line for 50 percent of time, then on average we have .5 percent waiting in the line. The hour rate of the security check point is 600 passengers per hour. On average, 10 passengers per minute. On average how long does it take a passenger to pass through the security check point? R times T is equal to I. 10 passengers per minute times T is equal to 17.5. T is equal to 1.75. 1.75 what? Throughput is 10 passengers per minute. 1.75 minutes.

In this example we have a garage door production plant. On average, there are equivalent to 2,000 garage doors inside the plant. They are at different stages of production. On average, everything over there is equivalent to 2,000 completed garage doors. Our production rate is 1,000 garage doors per week. Total cost of production of each garage door is $3,300. Suppose we pay for everything when the flow unit enters into the system and collect what we have paid when the garage leaves the system. Now I want to translate throughput and inventory into dollars and find on average how long does it take from the time when I put a dollar into the system until the time I get that dollar back. What is the flow time of the dollar inside my system? I have equivalent of 2,000 garage doors in inventory. Each one costs me $3,300, so on average I have $6,600,000 in inventory. Each week I produce 1,000 garage doors. Cost of goods sold is $3,300, therefore, my throughput rate is $3,300,000 per week. I implement the Little’s Law. I is $6,600,000. R is $3,300,000. Therefore, the average flow time of $1 is 2 weeks. Throughput is explained in terms of weeks.

These are my last attempts to try to make the Little’s Law clear and also make it clear the difference between throughput and inventory. Suppose we have an insurance claim. Everyday 80 applications come on his desk, and because we are in a city state, we are in a stable process. 80 will go out. On average there are 20 applications waiting on his desk. What is the flow time? How long does it take an application to come here and go out? 80 is R. 20 is I. R times T is equal to I. R is 80. T we don’t know. I is 20. T is 20 divided by 80, which is equal to ¼ of a day, because 80 is per day. So T is ¼ a day, or if a day is 8 hours, it is 2 hours. In an earlier example I said let’s assume CSUN has 36,000 students, and I said let’s suppose each year we accept 7,500 new students. How long does it take an average CSUN student to get graduated? Each year 7,500 come in and 7,500 go out. R is equal to 7,500 per year. The number of students who are still students at CSUN is 36,000. That is I. R 7,500 times T is equal to I 36,000. T is equal to 4.8 years. Based on this example, cash transactions in Europe is around 300 billion Euros per year. Each person or each entity when they take cash, they keep it for an average of 2 months. How many coins do we need? This is R. This is T in terms of months. R and T must be of the same nature, 300 per year divided by 12, that would be 25 billion per month. R times T is equal to I. 25 per month multiplied by 2 months is equal to 50 billion, and that is equal to I, the volume of coins we needed. So I have 300 per year. I could have translated 2 months in 2 years. 2 months is 2 divided by 12 or 1/6 years. R times T is equal to I. 300 times 1/6 is equal to 50 equal to I. So it doesn’t matter if I translate time in terms of R into T or T into R, but they should be stated in terms of unique time limit.

Here Taco Bell service 1,500 customers in 15 hours. So that is 1,500 divided by 15 which is 100 per hour. That is R. On average there are 75 customers in the restaurant. I is 75. How long does an average customer spend at Taco Bell? R times T is equal to I. 100 times T is equal to 75. T is equal to .75 hours or 45 minutes. And what is the average customer turnover? Turnover is defined as R divided by I. R is 100 per hour. I is 75, therefore, customer turnover per hour is 1.33. If you want per day it is 1,500 divided by 75, and that would be 20. Turnover means how many times do we replenish inventory? In each hour our seats are empty and filled 1.33 times. In one day 20 times. See if you can solve this problem. Stop the recording and solve the problem.

R equal to 10,000 per year. The average processing time is 3 weeks. T equals 3 weeks. What is the average number of claims in process? What is I? 10,000 come in. They are going through the process and 10,000 go out, but on average there are I units over there. It takes a flow unit to go from here to there 3 weeks. I should state R and T in the same time unit. R is 10,000 per year and year is 50 weeks. 10,000 divided by 50 is equal to 200. 200 per week. Here I have 200 per week, and here I have 200. R times T is equal to I. 200 times 3 is equal to I. On average 600 claims are waiting there.

Solve this problem quickly. (Material flow). R equal to 5,000 per week. I is equal to 2,500. R times T is equal to I. 5,000 times T is equal to 2,500. T is equal to .5 weeks. $300 million sales. So we send $300 million statement to our customers. This is our accounts receivable. We send statement to our customers. They send cash to us. On average we have 45 million accounts receivable. Sales is 300 million. We sent 300 million statements, and we collect $300 million. How long does did take from the time that we send the statement until we get the cash? R times T is equal to I. 300 million per year times T is equal to 45; therefore, T is equal to 45 divided by 300. .15 year or if I multiply by 12, 1.8 month.

A steel plant processes $400 million in material, $200 million in labor cost, $600 million cost of goods sold. 600 comes in, 600 goes out. Average inventory 100. What is the flow time for a dollar from the start of the process until that dollar leaves the process? Flow unit is a dollar cost. Process is steel manufacturing, average inventory is 100. Throughput is 600. Flow time is R times T equal to I, 600T equal to 100. T is equal to 1/6 year, and that is 2 months.

In this example a manager states that their inventory turns three times a year. Inventory turn is defined as throughput divided by average inventory. If throughput is per year, inventory turn is per year. If throughput is per month, inventory turn is per month. If throughput is per day, inventory turn is per day. But look at T. R times T is equal to I; therefore, T is equal to I divided by R. I divided by R, R divided by I. Inventory turn is equal to 1/T. For example, if T is 3 months, inventory turn is 1/3 per month. If I want to change it into year that would be 1/3 times 12. That would be 4. The take away of this discussion is inventory turn is equal to R divided by I, which is equal to 1 divided by T. R divided by I is equal to 3, which is equal to 1/T, and therefore 3T is equal to 1, and therefore T is equal to 1/3 years. And 1/3 years is 4 months. At the same time she claims that whatever company gets it is processed in 6 weeks. 6 weeks is about 1.5 months, and this one says it is about 4 months.

Contradiction, these two statements are not consistent. Out of 3 operational measures of performance, inventory, throughput, and flow time, we need only 2 of them. As soon as we have 2 of them we can compute the third one. Do we collect data regarding R and T or R and I or I and T. If I have R and T, I can compute I. If I have R and I, I can compute, T. If I have I and T, I can compute R. Collecting data regarding which way is cheaper, and I want to collect data regarding T, then for each patient who comes to the physician office, we should put on tag on him. When did you come in? And I should put a tag on him when he leaves, then I subtract those two numbers and find the time that flow unit has spent in the system. Then I should compute it for all flow units and average it, and that would be the flow time. For each CSUN graduate I should find out when he or she came to CSUN and find out when he or she graduated, subtract those two numbers from each other, average it for all CSUN graduates, and that is the flow. Expensive job. I don’t want to do that.

What about R? Is it expensive to collect data regarding R? No. All companies already have information regarding R. Every hour, every day, every week, they write down how many units have they have produced, so I really don’t need any additional time and effort and budget to collect data regarding R.

What about I? It is not as cheap as R, but at the same time it is not as expensive as T. Companies have inventory systems. When I look in the system I can find out how much inventory is there. All of the companies also have 1 or 2 or 3 times physical inventory check. They go and count the inventory they have to find out the difference between physical inventory and what they have in computer. That data is also there. Out of 3 operational measures of performance, I collect data regarding T and I and use that to compute T. I ask CSUN how many students are there? 36,000. On average how many graduate per year? 7,500. T is equal to 36,000 divided by 7,500. As we discussed earlier 4.8 years. So we have R times T is equal to I. We always want to reduce T. That is our main objective. One way to reduce T for a given R is to reduce I. Another way to reduce T for a given I is to increase R.