Basic Factory Dynamics (1)

<Experiment result & analysis>

- Find r_b, T_0, W_0 of the current line.

r_b = 0.33 jobs/minute

r_b is the bottleneck rate which the rate of the process center that has the least long-term capacity.

	Station 1	Station 2	Station 3	Station 4
r_b	0.33	0.4	0.33	0.4

The slowest workstations, 'Station 1' and 'Station 3' has a bottleneck rate of 0.33.

T_0 = 58 minutes

T_0 is the raw process time which is the sum of the long-term average process times of each workstation in the line.

$T_0 = 15 + 30 + 3 + 10 = 58$

W_0 = 19.33 jobs

W_0 is the critical WIP in which the WIP level for which a line having parameters r_b and T_0 with no variability in process time achieves maximum throughput with minimum cycle time.

$W_0 = r_b * T_0 = 0.33 * 58 = 19.33$

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- Verify the Little's Law by performing the simulation and recording the CT and WIP while changing the production rate (TH) of the current line.

The Little's Law shows the fundamental relation between WIP, CT, and TH over the long-term as $WIP = TH \times CT$.

[TH] The production rate can be changed by adjusting the time between arrivals. It is observable that as the time between arrivals increases, the throughput decreases.

[CT] The workstations' machines and its processing time remains the same which leads to equal cycle time of 58 minutes, despite of the change in throughput rate.

[WIP] Through the performed stimulation, the WIP is obtained.

It is observable that the Little's Law stands, as $WIP = TH \times CT$ is kept throughout the process. The results of various simulations are listed in the table below.

Time Between Arrivals	TH (j/min)	CT (min)	WIP (jobs)
3 minutes	0.333	58	19.333
5 minutes	0.2	58	11.6
8 minutes	0.125	58	7.25
10 minutes	0.1	58	5.8
15 minutes	0.067	58	3.866

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- When adding a new machine, calculate the maximum production rate (TH_{max}) and think of a method to verify it and confirm it using the simulation.

TH	Add to Station 1	Add to Station 2	Add to Station 3	Add to Station 4
Calculation	0.33	0.33	0.33	0.33
Simulation	0.2	0.2	0.2	0.2

[Calculation Process]

1) Let's add the new machine to Station 1. Originally, Station 1's production rate was 0.33. By adding a new machine, the production rate of Station 1 would be higher than 0.33 or at least the same as 0.33. Yet, in either case, as Station 3's production rate stays 0.33, TH_{max} stays 0.33.
2) Let's add the new machine to Station 3. Adding a new machine would improve Station 3's production rate, being higher than 0.33. However, Station 1's production rate remains 0.33 which means that TH_{max} also remains 0.33.
3) Let's add the new machine to Station 2. Similar to the cases above, adding a new machine and increasing its capacity would lead to Station 2's production rate being same or higher than its original rate which is 0.4. In this case also, since Station 1 and Station 3's production rate stays 0.33, TH_{max} remains 0.33. The analogy stays the same for the case in which the new machine is added to Station 4 - TH_{max} remains 0.33.

Through calculation, it is observable that, whichever station the new machine is added, the maximum production rate is fixed to 0.33.

[Simulation Process] Using Arena Simulation, it is obtained that the maximum production rate stays 0.2 through all four cases.

The difference between the results obtained by calculation and simulation comes from the difference in time between arrivals. Through the calculation process, it was assumed that the time between job arrivals do not exist. Whereas, in the simulation process, the time between job arrivals is set to 5 minutes which leads to limiting the production rate to 0.2. That is why although the bottleneck rate is 0.33 throughout the workstations, the maximum production rate is fixed as 0.2.

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< Discussion & conclusion>

(1) If TH is close to r_b, using Little's Law, identify the relationship between a) WIP and Cycle time of the production line, b) final product inventory and production time, and c) vehicles at the tollgate and their average queue time.

a) WIP is the average number of items in the production system, and Cycle Time is the average amount of time items stay in the system. If the throughput is close to the bottleneck rate, it means that the production system is operating close to its maximum capacity. According to Little's Law, if the throughput remains constant as the WIP increases, the Cycle Time should also increase proportionally. Conversely, reducing Cycle Time requires reducing WIP under the assumption that the throughput remains unchanged.

b) End product inventory can be viewed as a type of WIP, where it is the average number of finished products in the inventory, and production time is the average amount of time in the inventory before the product is sold or delivered. If throughput is close to bottleneck rate, maintaining a high level of finished product inventory means longer production time. To reduce production time, we need to reduce inventory levels, assuming that throughput is close to bottleneck rate.

c) The number of vehicles at the toll gate and the number of vehicles waiting to pass at the average queue time toll gate corresponds to WIP, and the average queue time corresponds to CT. If the throughput of the toll gate is close to the maximum speed at which the toll gate can handle the vehicle (bottleneck rate), Little's law states that increasing the number of vehicles at the toll gate leads to longer average queue times. If the goal is to reduce queue times, you need to add more toll gates, increase processing speed (throughput) or manage vehicle arrival rates, which may require automating charge collection.

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(2) Production line A has a high WIP and a long cycle time. Production line B has a low WIP and a short cycle time. Is it possible for production line A and production line B to have the same output (TH)? If you were to choose one production line, which one would you choose and why? (Regardless of the experiment result).

It is possible for Production Line A with a high WIP and long cycle time and Production Line B with a low WIP and short cycle time to have the same output. Throughput is a measure of the number of units processed over a given period and does not directly account for the amount of WIP or the cycle time. A line with high WIP and long cycle times can still achieve the same throughput as one with low WIP and short cycle times if it processes larger batches or if the lead time allows for the completion of an equivalent number of units within the same time frame.

If I had to choose one production line, I would choose Production Line B, which has a low WIP and a short cycle time, for several reasons:

First, a system's agility and responsiveness are critical allows it to respond quickly to changes in demand or required production. This is particularly useful in markets where customer preferences are rapidly changing. In addition, production B lines can significantly increase customer satisfaction by speeding up order fulfillment with shorter cycle times.

Furthermore, lower WIPs reduce the amount of capital tied to inventory in the process, which not only reduces storage and processing costs but also mitigates risks associated with unsold or old inventory, allowing cash flow to be managed more efficiently.

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(3) Discuss the area where Little’s Law can be applied besides the production system.

In healthcare, especially within hospitals and clinics, Little's Law is critical for effective resource management and patient care optimization. For example, in emergency departments that typically experience variable and unpredictable demand, the law can be applied to predict the average number of patients waiting for treatment. Healthcare administrators can analyze patients' arrival rates and average length of stay to estimate the level of manpower required and optimize scheduling to minimize latency. By ensuring that the system can accommodate incoming patient flows without excessive delay, healthcare providers can improve patient satisfaction and outcomes, reduce stress on healthcare staff, and increase the overall efficiency of patient care delivery.

In traffic and traffic engineering, Little's Law provides valuable insights into traffic flow and congestion management. It can be used to determine the average number of vehicles in a section of a road by evaluating the percentage of vehicles entering and the average amount of time that vehicles pass through. On highways, for example, it helps to construct entrance ramp metering ratios to regulate the flow of vehicles that merge into traffic, ensuring that roads operate within capacity.

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