Variability

<Experimental result & analysis>

1. Report on the results from the experiment 1 and decide which machine is better.

   - Results from calculation

	t_e	c_e^2	σ_e^2	r_e	A
Hare X19	19.815	3.041	1194.135	0.050	0.757
Tortoise 2000	20	0.475	190	0.05	0.75

   - Results from simulation (Variability observation)

	Time Interval (0.5 hr)		**Time Interval (0.7 hr)**		**Time Interval (0.9 hr)**	
	Waiting time/U×t		**Waiting time/U×t**		**Waiting time/U×t**	
Process time	**Constant (15 min)**	**UNIF (5, 25)**	**Constant (15 min)**	**UNIF (5, 25)**	**Constant (15 min)**	**UNIF (5, 25)**
Hare X19	0.788	0.793	1.323	1.341	1.861	1.861
Tortoise 2000	0.301	0.313	0.477	0.473	0.624	0.630

2. Report on the results from the experiment 2 and decide which machine is better.

   - Results from calculation

구 분	t_e	c_e^2	σ_e^2	r_e	A
No setup M/C(M/C1)	1.2	0.044	0.063	0.833	0.757
Setup M/C(M/C2)	1.2	0.262	0.377	0.833	0.75

   - Results from simulation (Time interval change)

	Time Interval (1.2 hr)		**Time Interval (1.5 hr)**		**Time Interval (2 hr)**	
	Waiting time/U×t		**Waiting time/U×t**		**Waiting time/U×t**	
Process time	**Constant**	**Norm**	**Constant**	**Norm**	**Constant**	**Norm**
No setup M/C	0	0.007	0	0.004	0	0
Setup M/C	1.149	0.193	1.140	0.119	0.616	0.096

   - Results from simulation (Setup change, Variability observation, Time interval = 1.2 hr)

	(N_s: 10, t_s : 2 hr)		**(N_s: 5, t_s : 1 hr)**		**(N_s: 20, t_s: 4 hr)**	
	Waiting time/U×t		**Waiting time/U×t**		**Waiting time/U×t**	
Process time	**Constant**	**Norm**	**Constant**	**Norm**	**Constant**	**Norm**
No setup M/C	0	0.007	0	0.008	0	0.006
Setup M/C	1.149	0.193	0.229	0.107	2.008	0.137

<Discussion & conclusion>

(1) Discuss the effects of variability on the production system.

Variability in a production system refers to the randomness in fluctuations in areas such as process time, set-up time, and more.

1) Variability leads to reduced efficiency, as constant changes can result in longer cycle times and reduced throughput. Furthermore, to buffer against the uncertainties caused by variability, production systems tend to carry higher levels of work-in-process inventory. Increase WIP not only ties up capital but also increases storage costs, further worsening the overall productivity.
2) Variability also effects product quality. Inconsistent production can lead to fluctuations in product quality, resulting in higher failure rates and increased downtime. Additionally, randomness leads to unpredictable process times which causes schedule disruptions, making it hard to meet production deadlines and customer demand.

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(2) Consider the reason of using CV value instead of variance when measuring variability.

The coefficient of variation (CV), the standard deviation divided by the mean, is a measure of variability of a random variable.

1) Normalization can be a reason for why using CV is preferred when measuring variability. CV, divided by the mean, becomes dimensionless. Due to its dimensionless, it is convenient to compare across various contexts, different units or scales.
2) CV can facilitate relative comparisons. Unlike variance, which is affected by the scale of the data, CV can be compared between data with different units or means. This provides a more straightforward interpretation of relative variability.

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(3) Discuss why maximum utilization is not always the best.

Maximizing utilization can be defined as using resources to their fullest capacity.

1) A lack of flexibility is can be a drawback of maximum utilization. If a system is operating under maximum utilization, it is hard to handle unexpected variability or realistic randomness. or variability. This inflexibility can lead to increased defects and downtime, as there is no buffer time or inventory.
2) High utilization naturally leads to bottlenecks within the system, which also leads to longer lead times and a slower response to changes. This can hinder the system's ability to meet customer demand timely.
3) High utilization also results in great stress on both human and machine resources. Operating continuously at the full capacity rate burdens the machinery and employees, which leads to

higher maintenance costs and potential safety issues. Overly stressed resources can also result in compromising on quality of the products to keep up with high demand. This can lead to increased defect products and negatively impact customer satisfaction.

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(4) Can you say 'variability is always evil'?

The Variability Law states that increasing variability always degrades the performance of a production system.

1) Variability in process time. As randomness increases in process time, the system prepares for a wider range of possible outcomes, leading to inefficient production and delays. This pushes the best-case scenario toward the worst case.
2) Variability in demand. Fluctuation demand makes it hard to forecast future demands which leads to carrying more safety stock. This means there would be more inventory costs needed, or else there would be stockouts and low customer satisfaction.
3) Variability in cycle time. Inconsistent cycle time requires longer lead time to achieve the same rate of on-time delivery. Longer lead time leads to inefficiency in the production system.

These examples prove that variability worsens the overall performance of production system; thus, variability is always evil.

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(5) Discuss the possible variability inside and outside of the production system.

Inside the production system, process variability such as inconsistencies in processing times, cycle time, and setup times, acts as a disruption to the smooth flow of production. It leads to inefficiency as it requires more buffer and increased inventory costs. Variability can also take place in machine operation. Machine downtime due to random equipment failures can cause significant delays in the production process, leading increased operational costs. Lastly, there can be variability in the skills of workers. The differences of working pace, skills, or absenteeism among the workers can result in unstable production levels and product qualities.

Outside the production system, external factors of variability can be determined by the supply and demand. When the supply chain variability involves inconsistences in lead time or raw material availability, market demand variability is due to changes in customer demand, market conditions, and seasonal trends. In addition, regulatory variability which is driven by changes in regulations or environmental conditions can force changes unexpectedly in the production process, often leading to disruptions and increased costs.

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