Batching

< Experimental result & analysis >

1. Report on the results from the simulation, and explain.

	Batch size (1)		Batch size (5)		Batch size (10)	
	Waiting time/U×t		Waiting time/U×t		Waiting time/U×t	
Processing time	Expo (15)	Expo (20)	Expo (15)	Expo (20)	Expo (15)	Expo (20)
Move Batching	0	0	0.014	0.002	0.021	0.004
Process Batching	0	0	0.032	0.009	0.096	0.054

[Observations]

- Batch Size 1: For both Expo (15) and Expo (20) processing times, there is zero variability. This suggests that when items are processed on an individual level, there is no additional variability introduced.
- Batch Size 5: It is observable that variability increases with batch size. Move Batching generally results in lower variability compared to process batching. Processing times of Expo (20) result in lower variability compared to processing times of Expo (15).
- Batch Size 10: Patterns are similar to batch size 5. Move batching shows lower variability compared to process batching. Variability increases more significantly with larger batch sizes and slower processing times.

[Overall]

- As batch size increases, the variability also increases. Larger batches introduce more variability because simultaneous movement in larger groups of products can lead to greater fluctuations in the time items spend in the system.
- The impact on variability is more pronounced in process batching compared to move batching. It can be estimated that process batching requires the entire batch to be completed before moving to the next stage, increasing the potential for variability. Whereas, move batching allows items to be processed right away when the batch is ready, which can reduce the waiting time and the following variability.
- Faster processing times lead to lower variability compared to slower processing times because faster processing can reduce the time items spend in the system, leading to less variability.

< Discussion & conclusion >

(1) Discuss the effects of batch size on the production system.

Batch size refers to the quantity of items that are produced or processed at the same time and is a factor that influences various aspects of a production system.

[Waiting Time]

- Items with small batch sizes are processed and moved more frequently, leading to shorter waiting times. It is because the system can respond quickly to unexpected fluctuations because fewer items are held up in each batch. It is also observable in the simulation above, smaller batch sizes have zero waiting time, indicating immediate processing without delays.
- Items with large batch sizes are titled to wait until the entire batch is processed before moving to the next stage, which naturally increases waiting time. The simulation proves that the increase in batch size leads to the increase in waiting time, especially in process batching scenarios.

[Flexibility]

- Small batch sizes lead to greater flexibility as the system can quickly adapt to changes in operation schedules, and it is easier to implement just-in-time and lean manufacturing principles.
- Large batch sizes lead to reduced flexibility as the system is programmed to processing larger quantities before any changes can be made. This makes it difficult to respond quickly to changes in unexpected fluctuations.

[Inventory Levels]

- Small batch sizes reduce the need for large storage spaces as items are processed continuously. Such lower inventory levels minimize holding costs and excess supply.
- Large batch sizes, on the other hand, leads to higher inventory levels, because items would accumulate while waiting for the entire batch to be processed. This leads to increased inventory requirements and inventory holding costs.

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(2) Discuss the reason simulation results of move batching and process batching are different.

[Definition]

Move batching is a strategy for grouping items into batches for the purpose of moving between different stages of the production process. The focus is on the transportation of a group of items from one stage to another, not processing them together. Process batching, on the other hand, involves grouping items into batches specifically for the processing step. In this strategy, an entire batch is processed together at a single processing stage and is proceeded to the next stage together.

[Mechanism]
The main goal of move batching is to optimize the transportation process which is why items are collected into batches and moved as a unit to the next stage. Once the batch is moved, items can be processed individually. However, the objective of process batching is to optimize the processing itself. So, items are processed as a single batch in which the entire batch must be completed before moving to the next stage and items finished processing should wait until the entire batch is ready for processing.

[Waiting Time]
Waiting times are mostly lower for move batching strategies because items are moved as soon as a batch is ready and can be processed at the next stage instantly. As move batching has its focus on transportation, there is less waiting time. This results in smoother flow and reduced bottlenecks in the production system. Yet, process batching has significantly higher waiting times, since the entire batch must be processed together. Items must wait until the whole batch is complete before processing can start. This creates bottlenecks at processing stages and increased overall waiting time.

[Flexibility]
Move batching offers greater flexibility to changes in demand, production schedules because it allows quicker adjustments, and items are processed more frequently. Contrastly, process batching is inherently less flexible due to its constraint in completing entire batches. It is slower in adapting to changes because the system must wait for batch completion before making any adjustments.

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(3) Why does move batching in a big production line have the long batch waiting time with high utilization than with low utilization?

[Queue Lengths]
In high utilization production lines, resources are constantly in use, resulting in longer queues for each stage, causing longer waiting time before moving to the next stage. High demand for resources creates bottlenecks, causing system-wise delays. Conversely, in a low utilization scenarios, queues at each stage are shorter because resources are not fully occupied and items can be processed more quickly. As batches spend less time in queues, it results in reduced waiting times which leads to a smoother flow through the production line.

[Resource Saturation]
In a high utilization scenario, resources such as machinery operating close to full capacity, leaving little to no idle time. This means that any delay can produce a significant backlog, making the system less flexible and more congested because there is no buffer capacity to absorb any fluctuations. Conversely, when there is low utilization, resources have more idle time and can handle fluctuations in demand or processing times more easily. This allows the system to absorb delays without increased in waiting time, as resources are not fully occupied.

[Batch Synchronization]
In a high-utilization operation, coordinating the movement of batches is made more complex because multiple batches compete for the same resources. Synchronizing the availability of resources for moving batches to the next stage is difficult when resources are fully occupied. It is because any delay in one part of the system amplifies delay time in other parts; thus, increasing overall waiting time. On the other hand, in a low-utilization operation, synchronization is easier as resources are more available. Batches can be moved faster and with less waiting, thereby resulting in reduced overall delays.

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(4) Explain the effects of batch size on the production system when processing time is fixed at EXPO(30) for the process batching model.

[Throughput]
The fixed processing time of Expo(30) allows the system to handle more batches at a given time period with smaller batch sizes because each batch is smaller and has faster processing speed on average. Frequent completion of smaller batches allows for higher throughput, as it keeps production lines moving efficiently. On the other hand, throughput can be negatively affected by larger batch sizes, as it takes more processing time due to longer cumulative processing times predicted by the exponential distribution. Less frequent batch completion can slow the production line, potentially reducing overall throughput.

[Resource Utilization]
Since items are processed continuously to avoid long idle times, resource utilization is more balanced with smaller batch sizes and fixed processing times at expo (30). Yet, increased setups and transitions between small batches can lead to inefficiencies. In contrast, resources could be used more frequently during the processing of large batches, leading to higher utilization. However, this can also result in high utilization periods followed by idle times while waiting for the next large batch to be ready,

reflecting the variability and unpredictability associated with the exponential processing time distribution.

[Waiting Time]

Due to the fixed processing time, which follows an exponential distribution with a smaller batch size and an average of 30, each batch spends less time processing, resulting in lower queue. Items within a batch are processed faster, reducing waiting time before proceeding. Conversely, the larger the batch size, the longer the latency for all items within the batch, as they have to process the entire batch together. The amount of time that waits for a batch to be fully processed increases, resulting in higher overall latency. Also, handling large batches makes the total processing time more likely to fluctuate, resulting in higher variability in latency.

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