Bucket Brigading

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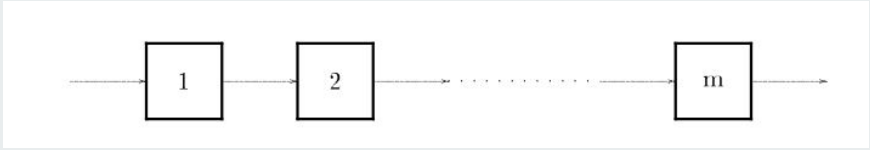
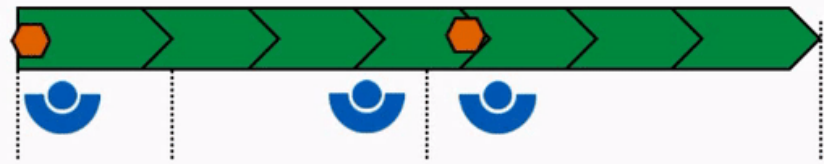
What is Bucket Brigading?

- Single line of workstations
- Each station operated by one or zero workers at any point
- Worker must go in order to their workstations
- Must wait for theirs to be free, cannot seek other work



Benefits to Bucket Brigading

- Workers carry items, so no need for mechanical delivery systems
- Takes advantage of simple behaviors that are easy to implement
- Work material is taken as needed to prevent overflow
- Implementation usually results in an increased production rate
- The increased production rate is achieved without causing congestion



https://www.allaboutlean.com/bucket-brigade-1/bucket-brigade-overall-loop/

Optimal Production

- The maximum number of products produced at a time:
  - Cannot exceed the number of workers (n)
  - Cannot exceed the slowest product/time of all machines ($1/p_{max}$)
- Having any more workers than $1/p_{max}$ is inefficient
- The production efficiency will always converge on the fastest speed ($\min\{n, 1/p_{max}\}$)
- As such, the ordering of machines has no effect on the overall production efficiency

Proof of Convergence

- Assume workers are indistinguishable
  - Treat the machines as a circular queue for workers to move around
- The slowest machines have a speed of $1/p_{max}$
- Queues may start existing on some of the faster machines, but they will disappear
  - As the slowest machine process, they output at a rate of p_{max}
  - Since the next machine outputs equal to or faster than p_{max}, they will exhaust queues and start also outputting at p_{max}
  - The same follows going all the way around, until all fast machines have exhausted their queues
- For queues on the slower machines, it depends

Proof of Convergence

Three separate scenarios:

- If $n < 1/p_{max}$, then the rate of workers entering the slowest machines will always be less than the rate of workers exiting. The slowest machines will exhaust any queues, and the rate of production will be n
- If $n > 1/p_{max}$, then there will permanently be a queue of workers at the slowest machines, and the rate of production will be $1/p_{max}$
- If $n = 1/p_{max}$, then the production rate follows perfectly the first scenario, while also matching the speed of the slowest machines

Potential Waste

- Waste refers to time added to work when introducing bucket sizes larger than one
- Most often this results in time lost, as a worker has to spend time loading and unloading a buffer of items
- In few instances, having size greater than one will increase production rate, but the batch size should aim to remain small.
- Formula represented as: m(tg + ta + tp + tr)
  - Time to get batch
  - Align items
  - Put items
  - Time to recover/move from output to input buffer

Potential Waste Diagram

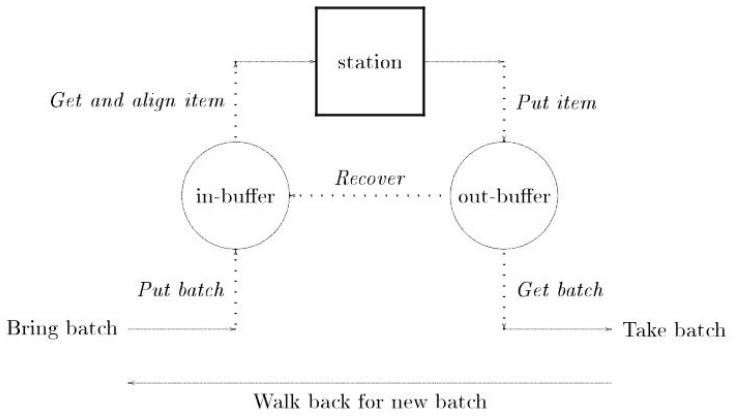


Figure 2: Potential waste in worker movement during production by bucket brigade. The dotted lines indicate additional waste incurred when batch size Q is larger than 1.

Setting up Bucket Brigades

1. Setup workers so that number of workers $n < 1/p(max)$
2. U shaped lines are favored to decrease travel time between stations
3. Favor smaller teams, larger teams tend to form groups themselves which reduces production rate
4. If task time differences between jobs become large, larger buckets may be more beneficial than typical size one buckets.
5. Once a line has been planned, it can by copied and setup several times in a facility to archive desired production.

Evaluation

- Ideas presented are clear and concise
- Backed up with mathematical proofs
- Does give real-life example, but could have used more to bolster the idea
- Follow up paper has hundreds of papers referencing it
- Gives good guide on how to emulate this behavior

References

https://www2.isye.gatech.edu/~jjb/bucket-brigades/papers/tss.pdf

https://www.allaboutlean.com/bucket-brigade-1/bucket-brigade-overall-loop/ By Christoph Roser at AllAboutLean.com under the free CC-BY-SA 4.0 license.