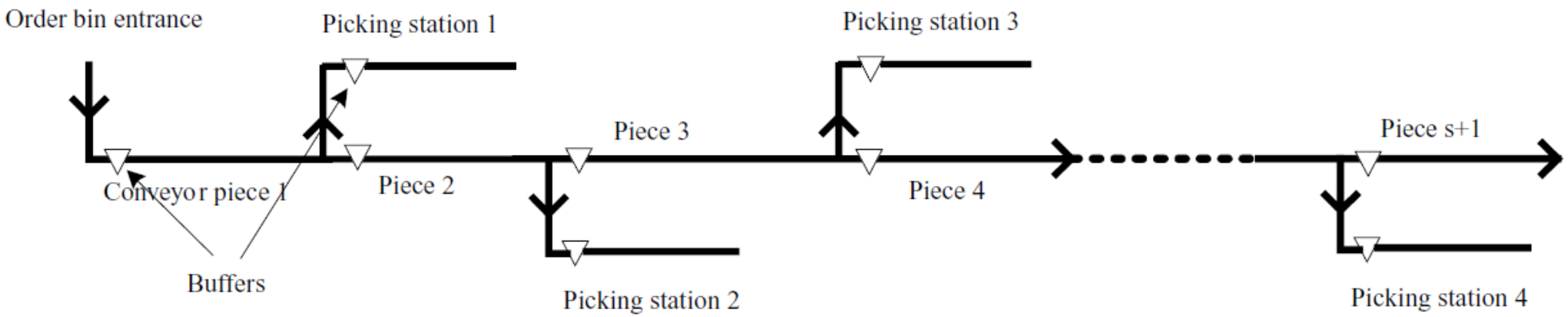
Developing order batching procedure in a pick-and-pass OPS with consideration for on-line order arrivals

Operations Analytics Laboratory
Department of Industrial Engineering
Pusan National University, Busan, SOUTH KOREA

Authors: **Henokh Yernias Fibrianto** and Soondo Hong

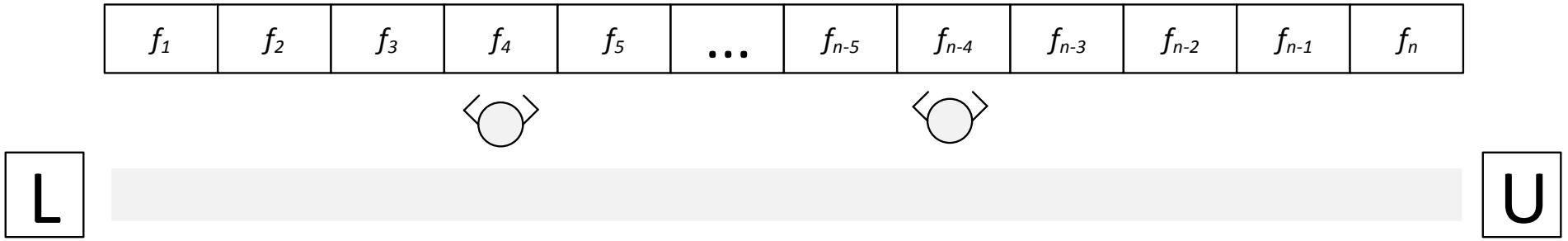
Pick-and-Pass OPS



- Common type of Pick-and-Pass OPS
  - Consists of several pick stations connected by a conveyor
  - Order is diverted into picking station if there is an item to be picked
  - Blocking can only occurs at picking station

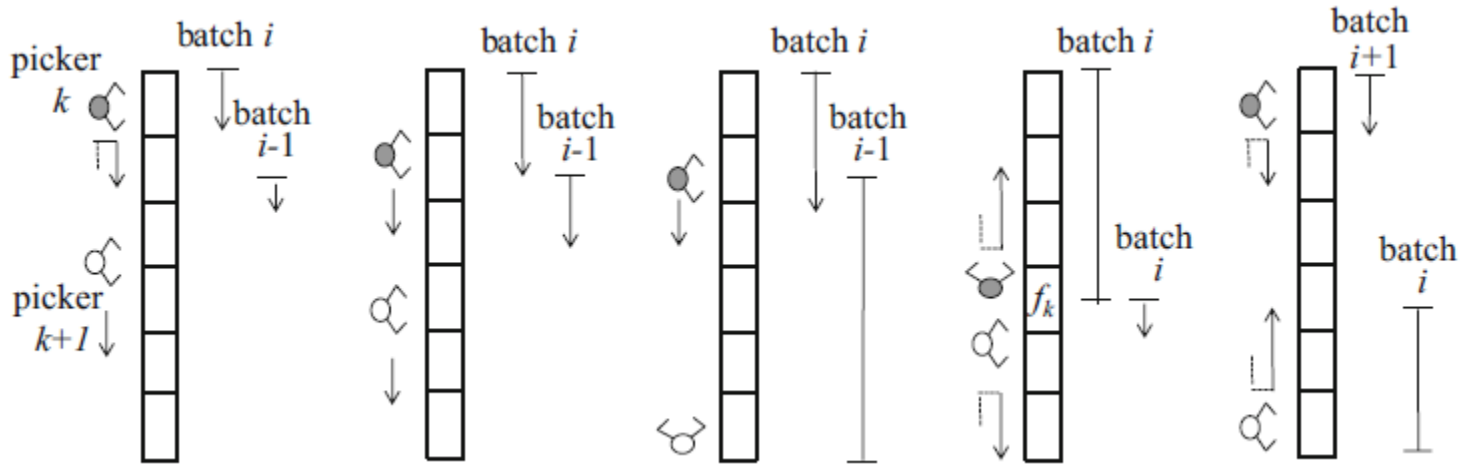
Yu, M. and De Koster, R., 2008. Performance approximation and design of pick-and-pass order picking systems. *IIE Transactions*, *40*(11), pp.1054-1069.

Pick-and-Pass OPS



- Pick-and-Pass OPS under Bucker Brigades principle
  - Consists of several pick faces connected by an aisle
  - Worker stop at a pick face if there is an item to be picked
  - Blocking may occurs in the aisle

Bucket Brigades OPS

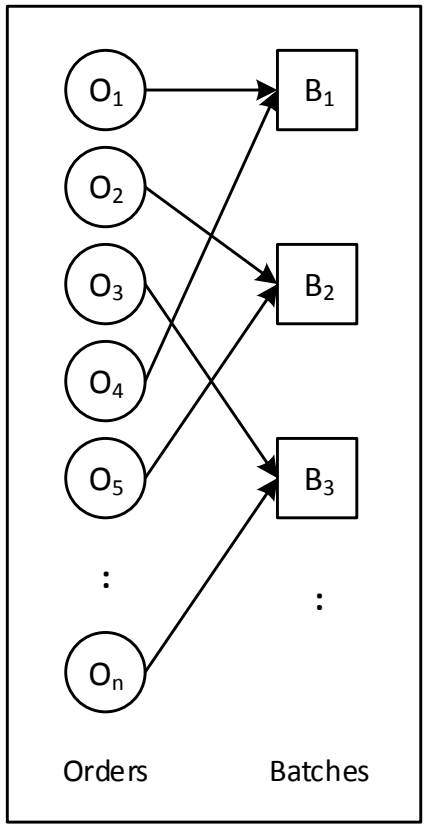


- "Pick forward until someone (downstream picker) takes over your work; then go back for more"[1].
- Congestion may occurs when downstream picker cannot takes over the work

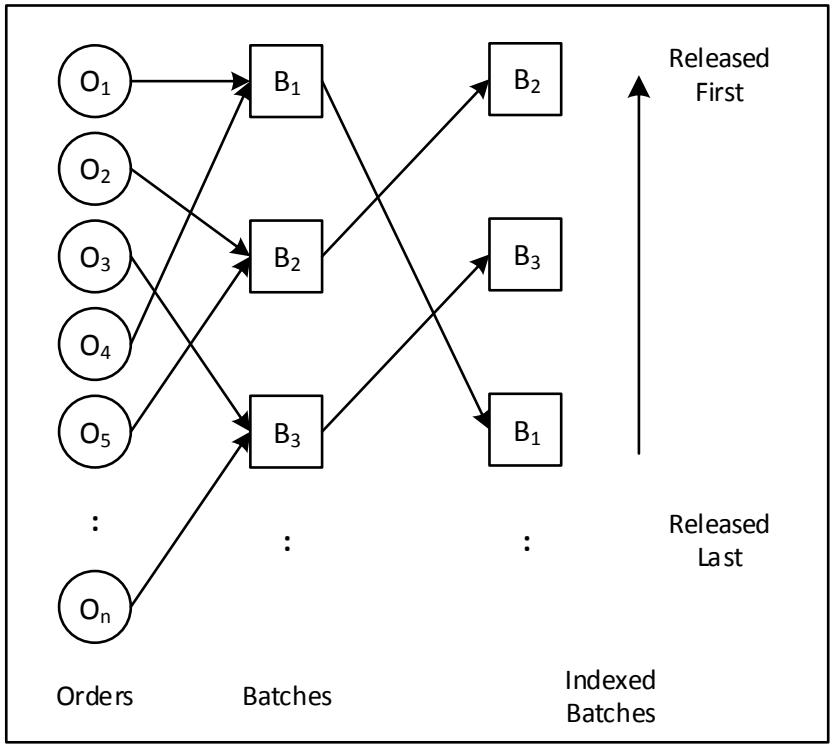
[1] Bartholdi, J.J. and Eisenstein, D.D., 1996. *A self-balancing order-picking system for a warehouse*. Technical Report, Dept. of Industrial Engineering, Georgia Institute of Technology, Atlanta, GA.

Bucket Brigades OPS

- Total completion time of an order consists of:
  - Total travel time
    - Order batching
  - Total picking time
  - Total delayed time caused by congestion
    - Picker arrangement
    - Indexed batching (order batching and sequencing)
      - Indexed Batching Model for Bucket Brigades (IBMB).



Indexed Batching Model for Bucket Brigades

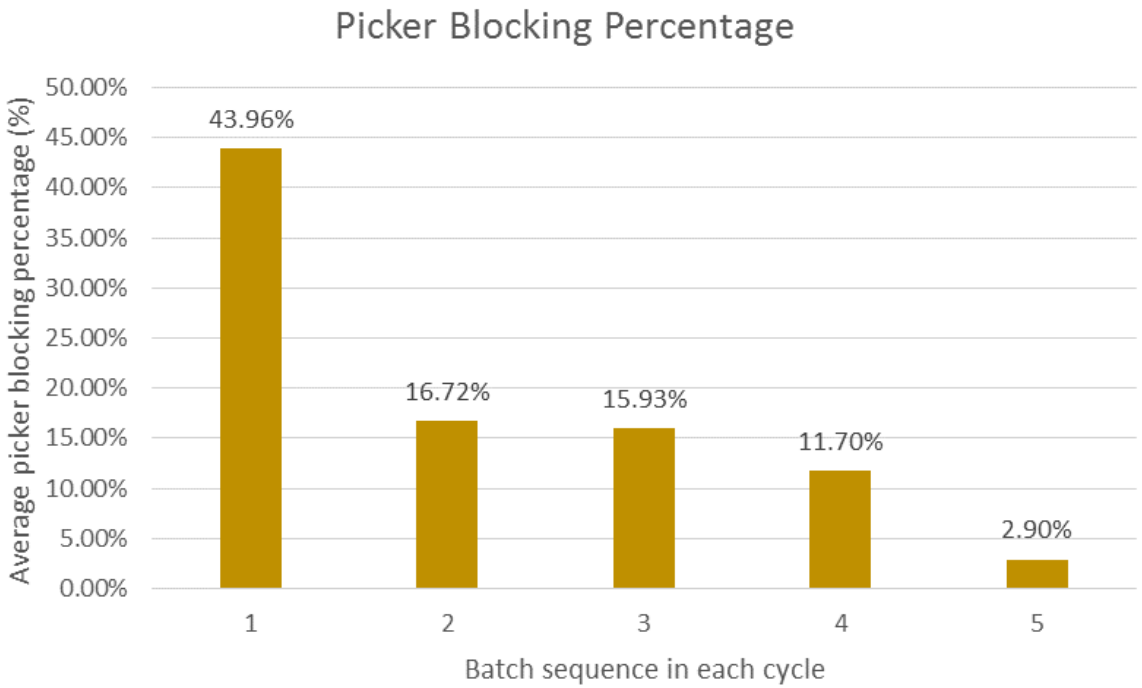


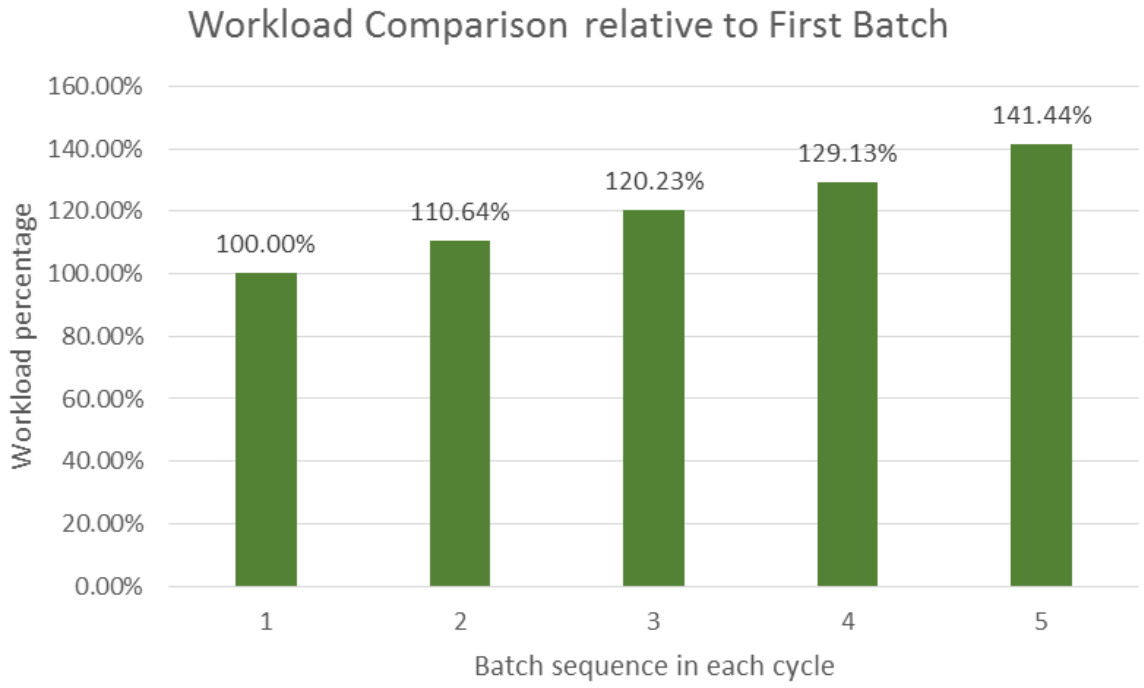
- Main Objective
  - Minimizing total completion time of all batches
- Constraints
  - Indexed batching constraints
  - Picker Blocking constraints
  - Release-time updating constraints

Indexed Batching Model for Bucket Brigades

- Practical Issues
  - Orders arrive almost continuously
  - Number of orders to be considered per IBMB cycle
    - Too small : poor quality
    - Too big : longer computational time
  - Continuity between IBMB cycle

Indexed Batching Model for Bucket Brigades



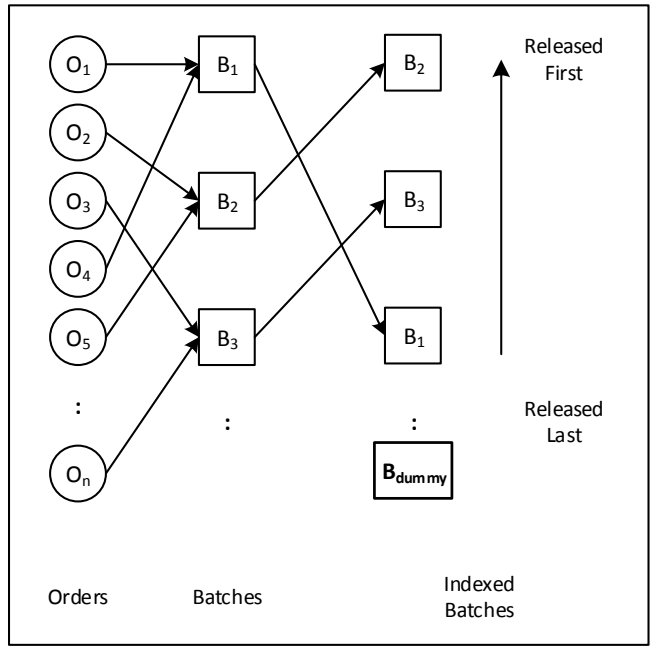


Analysis of batches in each cycle

- First batch in each cycle experiences severe delay
- Heavy workload concentrated at last batch in each cycle

IBMB considering Online Order Arrival

- Dummy Batch
  - Consists of no item to pick
    - $P_{dummy,f} = 0, \qquad \forall\, f \in Pickfaces$
  - Placed at the last sequence
    - Imitating the first batch at next cycle



IBMB considering Online Order Arrival (MIP Model)

- Objective Function

$$Minimize \quad \text{Total Travel time} + \text{Total Handoff Delay} + \text{Total Delayed time} + \text{Total Start time}$$

- Order Assignment and Capacity Constraint
  - All orders should be assigned only once
  - Total number of orders in each order should not exceed batch's capacity
- Pick Time Constraint

$$\text{Total pick time}_{batch,pickface} = \text{Pick time} \cdot \text{Total item to be picked}_{batch,pickface} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

$$\text{Cumulative Pick time}_{batch,pickface}$$

$$= \begin{cases} \text{Total Pick time}_{batch,pickface} & \{\text{first pickface}\} \\ \text{Cumulative Pick time}_{batch,previous\ pick\ face} + \text{Total Pick time}_{batch,pickface} & \{\text{otherwise}\} \end{cases} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

IBMB considering Online Order Arrival (MIP Model)

- Picker Blocking Constraint

$$\text{Delayed Time}_{batch,pickface} \geq \text{Leaving Time}_{previous\ batch,next\ pickface} - \text{Leaving Time}_{batch,pickface} - \text{Walk Time} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

$$\text{Cumulative Delayed time}_{batch,pickface}$$

$$= \begin{cases} \text{Delayed time}_{batch,pickface} & \{\text{first pickface}\} \\ \text{Cumulative Delayed time}_{batch,previous\ pick\ face} + \text{Delayed time}_{batch,pickface} & \{\text{otherwise}\} \end{cases} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

- Release-time Constraint

$$\text{Cumulative Walk time}_{batch,pickface}$$

$$= \begin{cases} \text{Start time}_{batch} & \{\text{batch} \leq \text{Total Picker, loading station}\} \\ \text{Leaving time}_{batch\ on\ previous\ time\ window} + \text{Total backwad time} + \text{Expected Handoff Delay} & \{\text{batch} > \text{Total picker, loading station}\} \\ \text{Cumulative Walk time}_{batch,previous\ pick\ face} + \text{Walk time} & \{\text{otherwise}\} \end{cases} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

IBMB considering Online Order Arrival (MIP Model)

- Start-time Constraint

$$\text{Start time}_{picker} = \begin{cases} 0 & \{\text{first picker}\} \\ \text{Time requred to hand over the first batch into } picker & \\ \quad +\text{Backward time from } picker & \{otherwise\} \\ \quad +\text{Expected Handoff delay} & \end{cases}$$

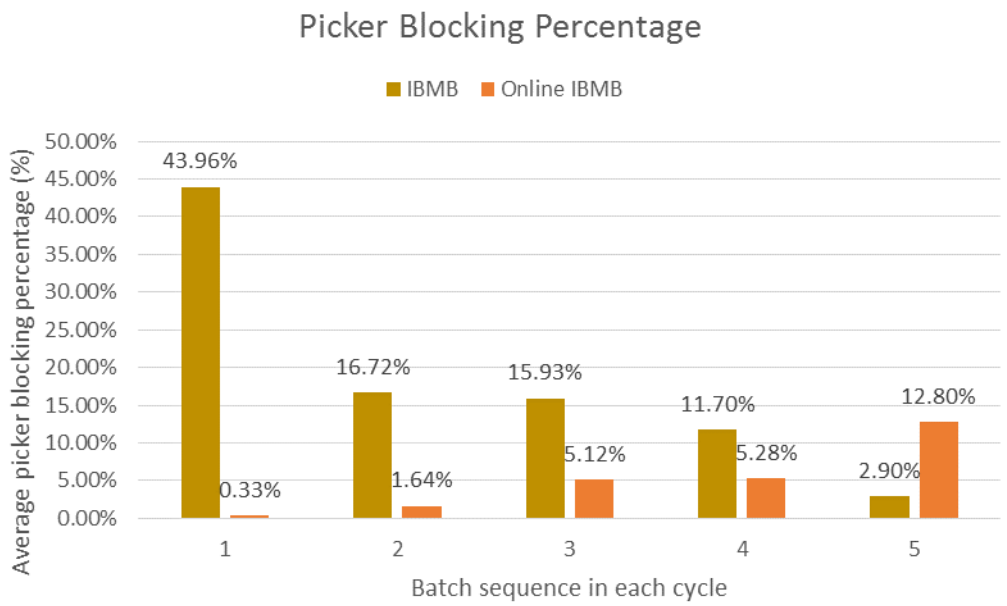
- Dummy Batch Constraint

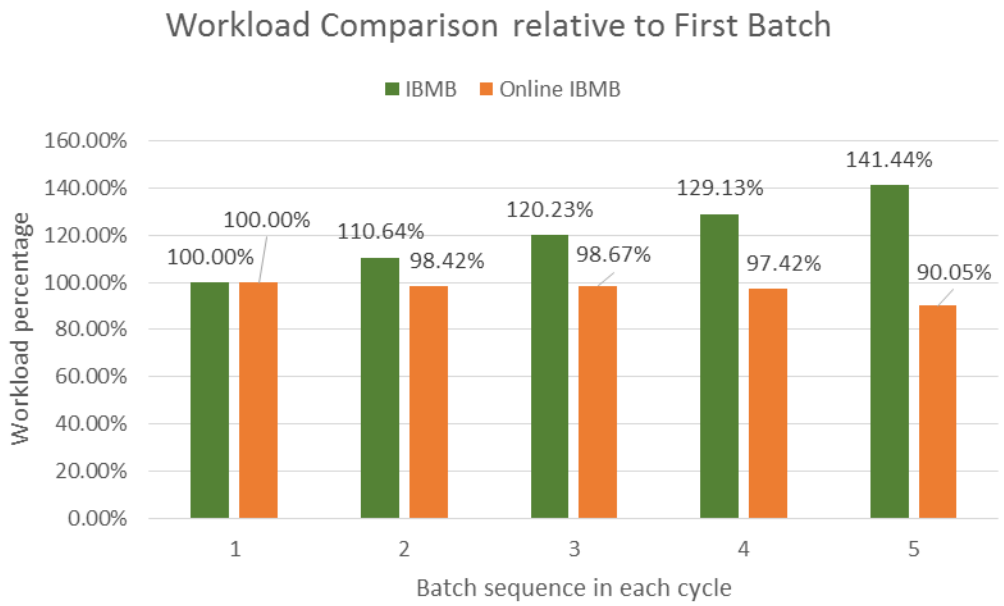
$$\text{Total item to be picked}_{dummy\ batch,pickface} = 0 \quad \forall \text{ pickfaces}$$

- Leaving time

$$\text{Leaving time}_{batch,pickface} \geq \begin{array}{l} \text{Cumulative Walk time}_{batch,pickface} \\ \quad +\text{Cumulative Pick time}_{batch,pickface} \\ \quad +\text{Cumulative Delayed time}_{batch,pickface} \end{array} \quad \forall \text{ Batchs}, \forall \text{ Pickfaces}$$

IBMB considering Online Order Arrival





IBMB considering Online Order Arrival

- Conclusion
  - Indexed order batching in pick-and-pass OPS under bucket brigades principle is able to minimize picker blocking
  - Analysis on blocking percentages for each batch shows that the last batch in each IBMB cycle has heavier workload among other batches
  - Consequently, the first batch in the next cycle experiences more blocking
  - By adding dummy batch at the end of each cycle, IBMB provide balanced workload among batches which also reduces the blocking percentages for the next batch in the following cycle
- Future Research
  - Similar control mechanism for other variant of pick-and-pass OPS can be formulated

THANK YOU

Henokh Yernias Fibrianto

Email : henokhyernias@pusan.ac.kr

Soondo Hong
Tel. : (+82) 51-510-2331
Email : soondo.hong@pusan.ac.kr

Operation Analytics Laboratory
Department of Industrial Engineering
Pusan National University, Busan, Korea

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