A simulation analysis of part launching and order collection decision for a flexible manufacturing system

*Simulation Modelling Practice and Theory, 2016*

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1. Introduction
1. Introduction

Problem preview

FMS scheduling

- With simulation
- Focus on the 2 decision variables
  - Part launching rules
    - Selection of the parts to be loaded onto a pallet
  - Order collection
    - Among the parts in the output buffer of FMS, must be collected to form a completed order for shipment
    - Deciding the order of collecting the completed parts

Purpose

- Provide a simulation analysis by examining the above two decisions
- Decisions for make-to-order FMS
2. Literature review
2. Literature review

- **Literatures**
  - **Issues**: classified into eight scheduling problems
    - Sequencing of the parts to be loaded into the system
    - Part routing
    - Sequence the parts waiting in each machine to be processed
    - Sequence those parts that require transportation
    - Allocate material handling devices to fulfill the transportation requirements of the parts

  ![Order collection rule?](image)
3. Simulation model

1. Layout
2. Configuration
3. Job information
4. Material flow
3. Simulation model

- Layout of the FMS

- 4 Machines, 6 Parts
  - Each part type requires 4 to 6 operations
  - Machine selection by ARD rule
    - Shortest total time for travel, queueing and processing times
3. Simulation model

- Configuration
  - Each machine can carry out only one operation at a time
  - Part loading → proper fixture is available / On the loading station
    - With general pallet (total 15 pallets)
  - Operation preemption is not allowed
  - Processing times for each operation are deterministic
  - Machine may break down, MTBT : 34200 min, Mean repairing time : 18min
  - Dedicated fixtures → number of each fixture type is limited to 10
  - Local buffer capacity for each machine → limited to 5

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Distances between the facilities (unit: meter).</th>
</tr>
</thead>
<tbody>
<tr>
<td>To/From</td>
<td>L/UL</td>
</tr>
<tr>
<td>L/UL</td>
<td>—</td>
</tr>
<tr>
<td>MC1</td>
<td>41.85</td>
</tr>
<tr>
<td>MC2</td>
<td>36</td>
</tr>
<tr>
<td>MC3</td>
<td>18</td>
</tr>
<tr>
<td>MC4</td>
<td>12.15</td>
</tr>
<tr>
<td>WIP</td>
<td>9</td>
</tr>
</tbody>
</table>
3. Simulation model

- Job information

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Process plan for part types/processing times and required fixtures (unit: minutes).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part type</td>
<td>Operation</td>
</tr>
<tr>
<td>A</td>
<td>1 7 3 3 4 3</td>
</tr>
<tr>
<td>B</td>
<td>1 5 10 1 1</td>
</tr>
<tr>
<td>C</td>
<td>1 6 8 1</td>
</tr>
<tr>
<td>D</td>
<td>1 7 8 1</td>
</tr>
<tr>
<td>E</td>
<td>1 3 5 1</td>
</tr>
<tr>
<td>F</td>
<td>1 2 6 3</td>
</tr>
</tbody>
</table>

- Single Process plan
- Alternative machines
  - Based on Chan (2001) – 2 machines
- Refixturing if it required
3. Simulation model

- Material flows

- Loading $\rightarrow$ (AGV) $\rightarrow$ MC
- Operation $\rightarrow$ (AGV) $\rightarrow$ MC
  - Select the MC with ARD rule
    - Shortest total time
  - If the local buffer is full $\rightarrow$ send it to the central buffer
- AGV: select the closest one among the free AGVs
  - Among the requests from parts, dispatching with FCFS
4. Operational and control strategies in the FMS

1. Order collection
2. Part launching
3. Performance measure
4. Operational and control strategies in the FMS

- **Order collection rules**
  - **EDD**: Collect the completed parts for the order with the earliest due date
  - **CR**: Smallest CR value where \( CRI \) is defined as
    \[
    CR_i = \frac{(D_i - SCT)}{ETPT_i}
    \]
    \( ETPT_i \): estimated total processing time
    \( D_i \): Due date
    \( SCT \): Simulation clock time

- **MST**: Minimum Slack time defined as
  \[
  D_i - ETPT_i - SCT
  \]

- **Part launching rules (= input sequencing)**
  - **TEM**: Tardiness Estimation Method defined as
    \[
    ET_j = (SCT + ETM_j) - D
    \]
    Where, \( ETM_j = (Q_j - IQ_j) \times IC_j \)

**Definitions**
- \( IC_j \): Inter-completion time of the last two completed parts (for part type \( j \)).
- \( IQ_j \): The quantity of part type \( j \) that has been launched for production.
- \( Q_j \): The required quantity of part type \( j \).
- \( ETM_j \): The estimated total processing time for all the remaining quantity of part type \( j \).
4. Operational and control strategies in the FMS

- Part launching rules (Continued)
  - **LRPQ**
    - Largest Remaining Production Quantity
  - **LRPQ/TPQ**
    - Largest Ratio of (Remaining Production Quantity) over (Total Production Quantity)
  - **LTRW**
    - Longest Total Remaining Production work
  - **LRUW/TRPQ**
    - Smallest Ratio of (Unit Production Work) over (Total Remaining Production Quantity)
  - Random

- Performance measures
  - Mean tardiness
  - Maximum tardiness
  - Service rate
    - Ratio of the number of no-tardy orders to the total number of orders completed
  - Mean flow time
5. Experimental results
5. Experimental results

- Programed in C++
- After these 10,000 orders → warm up
- 5000 orders → computing the performance measure
- Due date: Arrival time + Allowance factor(K) * Estimated total processing time
  - Allowance factor
    - Tight orders ~ U(0.65, 1.45)
    - Loose orders ~ U(1.65, 2.45)

Table 5
Experiments in Phase I are conducted under the following conditions.

<table>
<thead>
<tr>
<th>System conditions</th>
<th>Order arrivals</th>
<th>Due date tightness (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Exp(800)</td>
<td>U(0.65, 1.45)</td>
</tr>
<tr>
<td>2</td>
<td>Exp(900)</td>
<td>U(0.65, 1.45)</td>
</tr>
<tr>
<td>3</td>
<td>Exp(800)</td>
<td>U(1.65, 2.45)</td>
</tr>
<tr>
<td>4</td>
<td>Exp(900)</td>
<td>U(1.65, 2.45)</td>
</tr>
</tbody>
</table>
5. Experimental results

- Results for part launching rules (with EDD rule for order collection)
  - Due-date based measure

- Service rate, mean flow time
  - Service rate: ratio of the number of no-tardy orders to the total number of orders completed
5. Experimental results

- Results for order collection rules (with TEM rule for part launching)
  - Under condition 1 (heaviest system loading condition)

- Mean Tardiness/Maximum tardiness
  - EDD outperformed others

- Service rate
  - CR is better than others

- Analysis
  - Some orders in CR have extremely high tardiness → increasing average
5. Experimental results

- Results for order collection
  - Comparing threshold values for pre-emption
    - If the threshold values is set 0.6
      - The collecting order can be pre-empted only when the completion percentage is less than 60%
  - Comparing threshold values under EDD, TEM rule combination

- Note: Different results of mean tardiness and service rate
6. Conclusions
6. Conclusions
Thank you

Any question?