Dynamic batching for order picking in warehouses
Jelmer van der Gaast, Bolor Jargalsaikhan, Kees Jan Roodbergen
University of Groningen

Introduction
- There is a need for more efficient ways to organize the order picking process as
  - the number of daily orders to be processed increase
  - the required lead time becomes shorter
- We propose/analyze
  - an analytical model for dynamic batching
  - the difference between static and dynamic batching

Dynamic batching
- Dynamic batching is characterized by combining product demand from multiple customer orders into one pick tour where new orders are continuously received.
- Updated picking instructions can be included in the current pick tours which allows pickers to be re-routed to pick for new orders even when they already started a pick tour.

Difference between static and dynamic batching

<table>
<thead>
<tr>
<th>Order Picker</th>
<th>Pick location</th>
<th>New pick location</th>
<th>Rerouting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Static batch picking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Dynamic batch picking</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure: The difference between static and dynamic batching. □ denotes a storage location, □ denotes a picking location for the current pick tour, and □ denotes a picking location for an incoming customer order that can be picked in the current pick tour in case of dynamic batching.

Flow diagram dynamic batching

- Walk Picker 1
  - Pick/Depot Picker 1
    - Calculate batches
      - Yes
        - New arrival
      - No
        - Available
          - Idle Picker 1
          - Pick lookup
            - None
            - Available

Model description
- At time t, a customer order i is either assigned to a current pick batch of an order picker (current batches) or to the backlog of orders for which an initial batching is made (future batches).
- The following model can be formulated

\[
\begin{align*}
\text{minimize} & \quad \frac{1}{M_t} \left( \sum_{j \in J} \sum_{r \in \Omega} c_{jr} \delta_{jk} + \sum_{r \in \Psi} \tilde{c}_r \delta_s \right) \\
\text{subject to} & \quad \sum_{j \in J} \sum_{r \in \Omega} a_{jr} \delta_k + \sum_{r \in \Psi} b_{r} \delta_s = 1 \quad i \in M_t, \\
& \quad \sum_{j \in J} \sum_{r \in \Omega} \theta_{jk} = 1 \quad j \in J, \\
& \quad \theta_{jk}, \delta_s \in \{0, 1\} \quad j \in J, r \in \Omega, r_s \in \Psi.
\end{align*}
\]

- \( \theta_{jk} = 1 \) if batch \( r_k \) is the current pick batch of picker \( j \).
- \( \delta_s = 1 \) if batch \( r_s \) is a selected future pick batch.
- \( a_{jk} = 1 \) if and only if order \( i \) is included in current batch \( r_k \) of picker \( j \).
- \( b_{r} = 1 \) if and only if order \( i \) is included in future batch \( r_s \).
- \( c_{jk}, \tilde{c}_r \) be the cost to pick the orders in batch \( r_k \) for order picker \( j \) or future batch \( r_s \).

Column generation algorithm
- In order to optimize the model we apply column generation.

Results – comparison static and dynamic batching

Conclusions and further research
- Dynamic batching leads to significant improvements in throughput and other statistics.
- Well suited for e-commerce companies that deliver same-day.
- Possible extensions
  - Robust route planning
  - Joint transportation planning

Mean total walking time (s)

Mean throughput time (s)

Order arrival rate (\%)