3 Economic and performance analysis of dual-bay Vertical Lift Modules

Fabio Sgarbossa, Martina Calzavara and Alessandro Persona
University of Padova

1. Small Objects Order Picking Solutions

- Higher throughput (dual tray)
- Picking errors reduction
- Ergonomics improvement
- Safe products storage

2. Objective of the Research

In this paper, dual-bay VLMs, compared to a carton racks warehouse, have been analysed from an economic point of view.

Some mathematical formulations have been developed, to estimate the total annual cost and the respective applicability limits of both systems, according to their productivity.

Moreover, some useful guidelines for practitioners are derived.

3. Compared Warehousing Solutions

- Carton racks warehouse (W)
  - Picker to parts solution
  - Picker travels within the aisles (travel time lower than case-pick-from-pallet warehouse)

- Dual-bay Vertical Lift Module (V)
  - Parts to picker solution
  - In a dual-bay system, picker works in parallel with the crane, standing in the picking bay

The total annual cost \( T_{C_{W}} \) or \( T_{C_{V}} \) includes a fixed cost term (space & equipment) and a variable one (operators).

4. Cost Models

\[
TC_{W} = C_{op} \cdot k_{W}^V \cdot \frac{V}{SL_{W}} \cdot h_{y} + C_{sp} \cdot \frac{Q}{Q_{V}} \cdot h_{y}
\]

\[
TC_{V} = N_{V} \cdot \left( C_{op} \cdot k_{V}^V \cdot \frac{V}{SL_{V}} + C_{sp} \cdot \frac{Q_{V}}{Q_{V}} \right) \cdot h_{y}
\]

\( N_{V} \) - number of VLMs to install to perform the picking of \( Q \) items and to stock the total storage volume \( V \)

5. Economic & Performance Comparison

\[
R_{TC} = \frac{T_{C_{V}}}{T_{C_{W}}} < 1 \Rightarrow \frac{Q_{V}}{Q_{W}} > \frac{Q_{W}}{Q_{V}}
\]

\[
R_{Q} = \frac{Q_{V}}{Q_{W}} = \frac{V_{W}}{V_{V}} \cdot \frac{k_{V}}{k_{W}}
\]

Trend of \( Q_{V}/Q_{W} \) and VLM applicability region for \( c_{1}^V = 24,000 \) €/year, \( k_{V} = 3,600 \) h/year, \( k_{W} = 1.5 \) and (a) \( C_{op} = 80 \) €/m² or (b) \( C_{op} = 120 \) €/m², while (c) has \( c_{1}^V = 18,000 \) €/year and \( C_{op} = 80 \) €/m²

\[
R_{TC} = \frac{T_{C_{V}}}{T_{C_{W}}} < 1 \Rightarrow R_{Q} > R_{Q_{c}}
\]

\[
R_{Q_{c}} = 1 + \frac{V_{W}}{V_{V}} \cdot \frac{k_{V}}{k_{W}} \cdot \frac{C_{op}}{C_{sp} + h_{y}}
\]

Trend of \( R_{Q} \) varying \( V_{V} \) for \( c_{1}^V = 24,000 \) €/year, \( k_{V} = 3,600 \) h/year and (a) \( C_{op} = 80 \) €/m² or (b) \( C_{op} = 120 \) €/m² and for (c) \( c_{1}^V = 18,000 \) €/year, \( k_{V} = 3,600 \) h/year, \( C_{op} = 80 \) €/m²

6. Conclusions and Future Research

Conclusions on \( Q'/Q'' \) and \( R_{Q}^c \):
- they are not very sensible to the total volume of the stocked items \( V \)
- they depend on the annual floor space cost per square meter and on the annual cost of the VLM
- Generally, the required throughput \( Q \) and the number of working hours per year \( k_{y} \) can affect the applicability of the VLM

Modelling of the Refilling activity:
- since it is different for the two systems and it has an impact on the storage allocation, on the travelled distances and, then, on the overall time
- Extension of the comparison to other systems:
  - Development of a complete tool for their evaluation and comparison. This could help the choice of their most proper application in real warehouse picking contexts