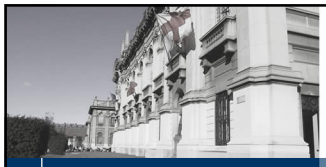

POLITECNICO DI MILANO





Order Picking System design: Insights from Italian research

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Agenda

- Observatory on material handling
- Order Picking System (OPS) design: research questions
- OPS design: Identification of key drivers
- Framework for “Pick-and-sort” system design

Observatory on material handling

- Permanent Observatory on Material Handling Systems since 2003 at Politecnico di Milano, Department of Management, Economics and Industrial Engineering.
- First MH observatory in Italy, aiming to investigate the current diffusion of automated systems for storage, retrieval and picking activities within Italian warehouses, as well as contribute to the diffusion of 'logistics education' among academics and practitioners
- The Observatory is funded by a number of material handling providers (e.g. Dematic, TGW, Incas group)

Observatory on material handling

- Each year a specific topic is tackled, and a number of publications are produced (i.e. reports, publications in journals, presentations in international/practitioners conferences)
- The studies undertaken so far have focussed on:
  - "Analysis of the implementation level of AS/RS"

    (reference: M. Melacini, G. Marchet, F. Dallari, S. Perotti, "Automation in Warehousing: when is it worth it?", Logistics Solutions, Vol 19, No 3, 2006)
  - " Analysis of the implementation of OPSs"

    (reference: M. Melacini, G. Marchet, F. Dallari, "Design of order picking system". Int J Adv Manuf Technol 42,(1-2):1-12, 2009)
  - "An exploration of automation in retail distribution centres"

    (reference: Dallari F., Marchet G., Melacini M., Perotti S., " New developments in retail logistics: an italian perspective" ,5th International Logistics and Supply Chain Congress, 8th November- 9th November 2007, Istambul, Turkey)
  - "An exploration of automation in the diary industry" (no references in English language)
  - " Analysis of pick-and-pass systems"

    (reference: G. Marchet, M. Melacini, S. Perotti, "Performance assessment of pick and pass systems: a case study", 14th Annual Logistics Research Network Conference (LRN), pp 916-919, Cardiff, UK, 9-11 September 2009)
  - "Analysis of pick-and-sort systems"

    (reference: G. Marchet, M. Melacini, M. Mizzi, Assessment of overlapping in sortation systems", 14th Annual Logistics Research Network Conference (LRN), pp 399-405, Cardiff, UK, 9-11 September 2009

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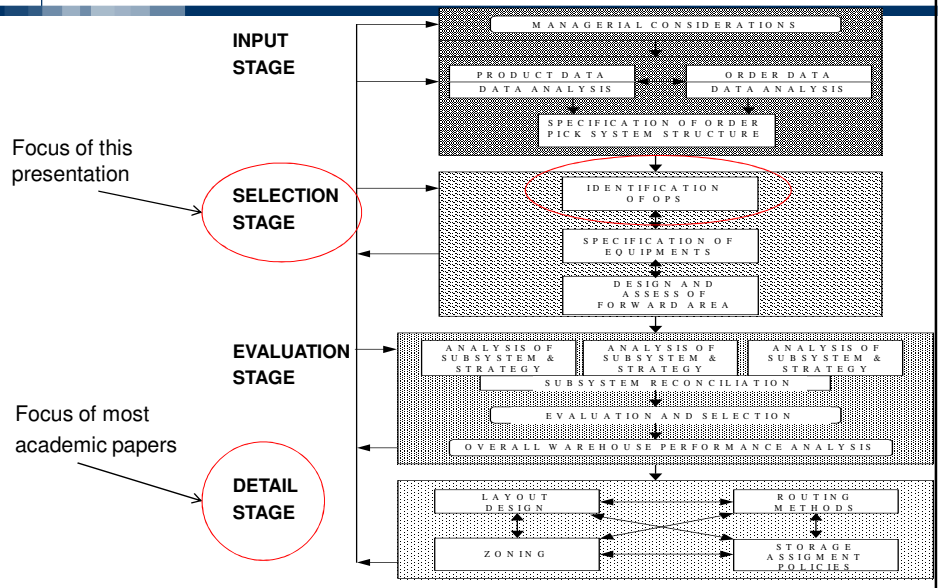
A Framework for OPS design



(derived from: Marchet *et al.*, “Design of order picking system”. Int J Adv Manuf Technol 2009)

Research question

- The increase in the number of available solutions brings greater complexity to the design process and makes it increasingly difficult for the designer to answer the question, “Which picking system best meets a given set of objectives?”
- During the selection phase in picking system design the designer need a quick estimate of the cost and performances of one OPS in comparison with the others
- Once the suitability of the solution has been assessed, it will be possible to develop the operational functions further

Need to develop frameworks or models to support warehouses designer in the selection stage

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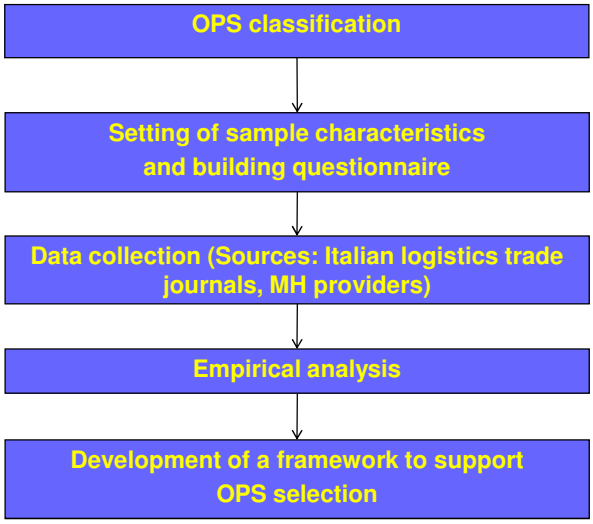
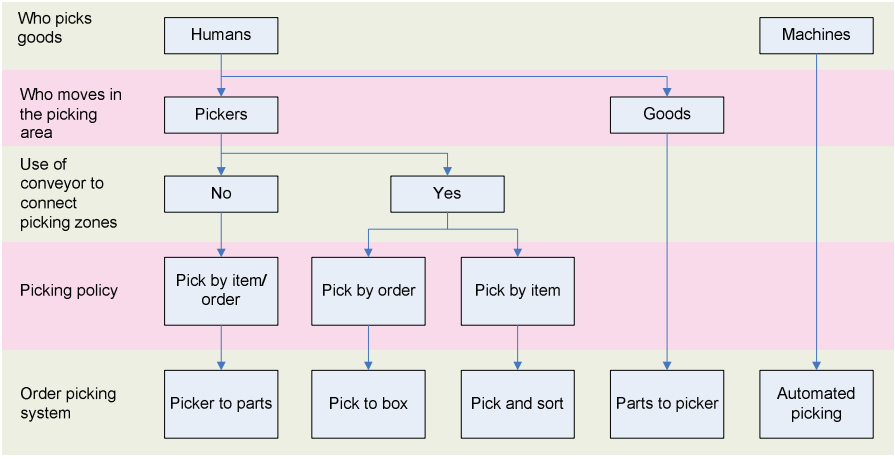
Research methodology



OPS classification



(derived from: De Koster, 2003)

The “completely automated picking” system has not been considered, since it is employed in very limited contexts

Sample characteristics

Warehouses of companies with revenues higher than 10 mln €. Companies belong to several industry sectors ranging from FMCG, consumer electronics, textile&apparel, mechanical, pharma/cosmetics

Some information has been collected elated to:

COMPANY: company name, revenues, industry sector

WAREHOUSE: location, type of unit load handled, type of building (new building, etc.), size, number of shifts, picking systems in use (not considering automatic picking)

DESIGN PARAMETERS: response time (hours, days, …), picking accuracy, number of SKUs, ABC classification, activity information, picking complexity (number of order lines), product requirements (FIFO policy, chilled goods, inflammable goods, etc.), unit load to be picked (item, carton, etc.)

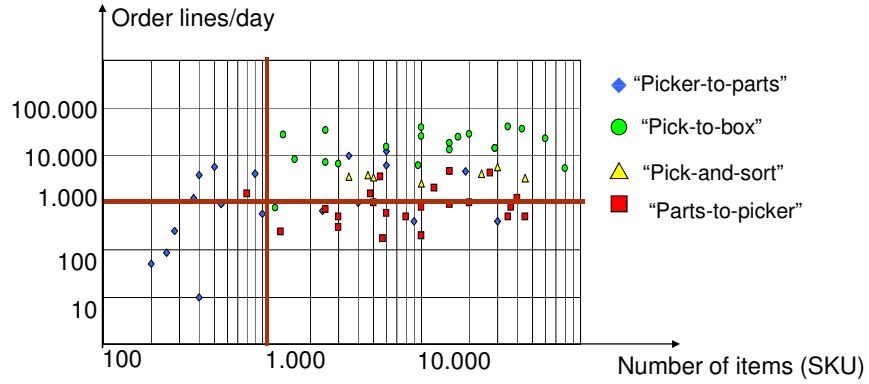
Empirical analysis

- Analysis has been developed with two detail levels to assess the relationship among OPSs and the aforementioned dimensions, considering:
  - The whole sample of cases (aggregated analysis)
  - A subset of cases according to customer order size (segmented analysis)
- We analysed the relationship between the four OPSs and the material handling requirements
- Statistical data analysis has been performed to study the relationship, according to two different approaches:
  - By studying the characteristics of the population, having inference on the examined sample, supposing an unknown variance
  - By assessing the use of one of the examined OPS through the Logit model, that is the computation of the probability of choosing one of the OPS (binary variable *Y=1*) when changing material handling requirements

$$Prob(Y = 1|X) = \frac{e^{X'\beta}}{1 + e^{X'\beta}}$$

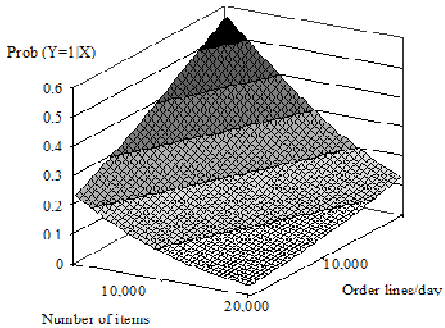
Empirical analysis – aggregate analysis

- Results of aggregate analysis (sample size: 68 warehouses), on a scatter diagram, with logarithmic scale for both dimensions:

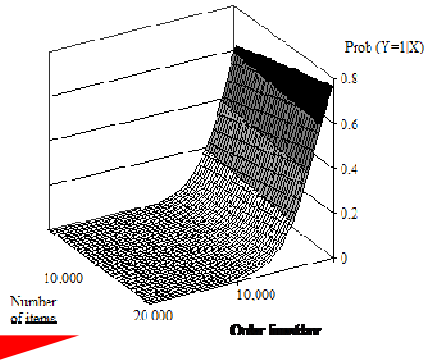


Empirical analysis – aggregate analysis – logit analysis

Probability to use "Picker-to-parts"

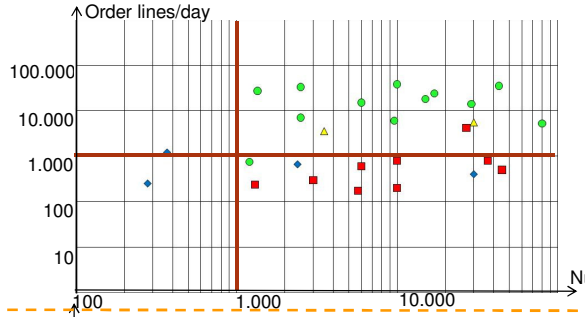


Probability to use "Parts-to-picker"

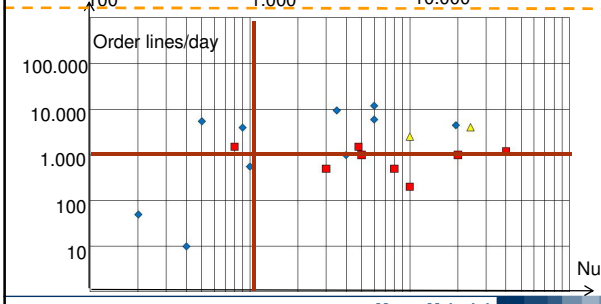


- The probability to use "Picker-to-parts" is very high when number of items is lower than 1,000, although it is employed also when the number of items is higher than 1,000
- With high significance (*p*-value equal to 0.000014) we can state that "Parts-to-picker" is used when the number of items is higher than 1,000. At the same time this OPS does not fit when the number of order lines picked per day increases

Empirical analysis – Segmentation analysis



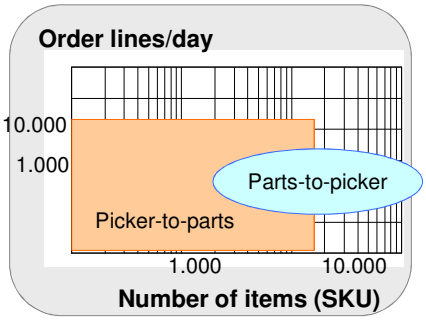
Order size:
lower than 0.5 m³
(sample: 27 warehouses)



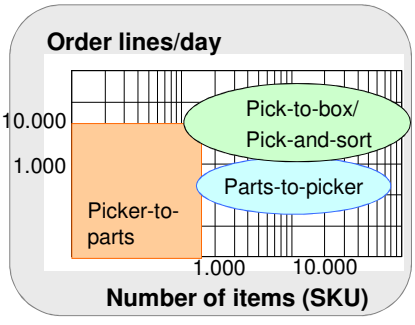
Order size:
greater than 0.5 m³
(sample: 21 warehouses)

Framework to support OPS selection

Order size >= 0,5 m³



Order size < 0,5 m³



Framework to support OPS selection

- The framework has been built based on the observation of systems in place
- Evidence emerged from the study seems reasonable from the design viewpoint
- It is not certain that the systems in place selected by companies are the most suitable (design parameters change over time, design errors, etc.)

- The aim of further research is to evaluate effectiveness of OPS selection
- This analysis could be performed according to DEA (Data Envelopment Analysis) approach

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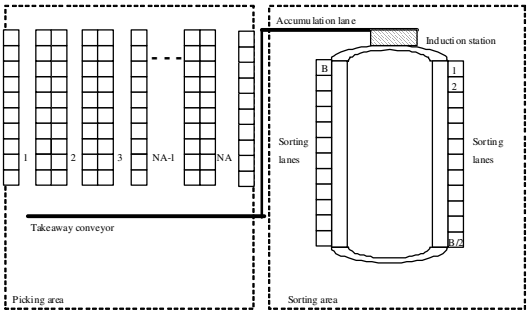
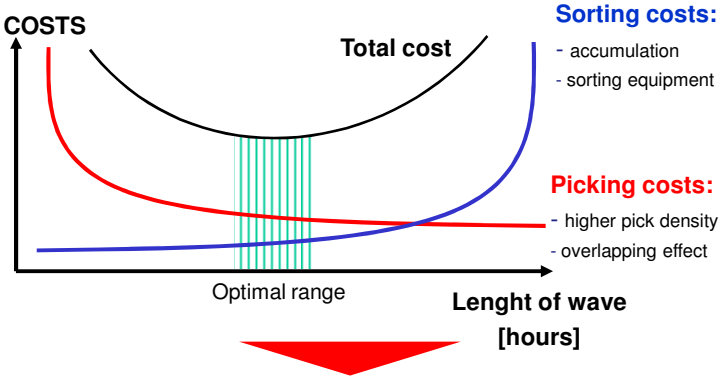
Pick-and-sort

- In pick-and-sort systems pickers retrieve the quantity of each single item resulting from the batching of multiple orders (wave) and place these onto a takeaway conveyor connecting the picking area to the sorting system
- The organisation of the pick-and-sort system is based on the separation of the daily picking activities into picking waves, where the wave length is defined as the period of time in which a group of orders is processed in one area of the OPS (i.e. picking area) before proceeding to the next area (i.e. sorting system)



Pick-and-sort: the wave length effect

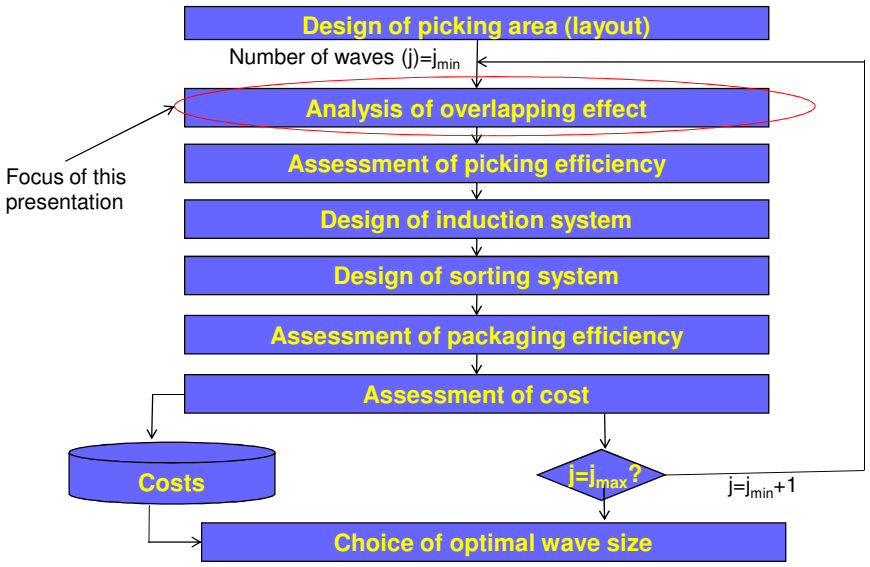
- The wave length has an effect on both picking efficiency and sorting costs



There is little research on pick-and-sort systems, and the question of the optimal number of waves has not been extensively considered.

Above all, there is no model to estimate the picking rate in function of the wave length

Framework for Pick-and-sort design



Overlapping effect

- Under the following assumptions:
  - No optimisation criteria in the construction of a batch
  - Demand for each item is indipendent from each other
  - Small order size (with respect to the number of SKUs S in the picking area)
- Taking LW_{max} as the maximum number of order lines picked per picking wave (equal to the sum of the order lines of the orders processed in the wave), the expected number of items to be picked per wave (LW) has the form:

$$LW = \sum_{i=1}^{S} \left[1 - (1 - \frac{1}{S})^{LW_{\max}} \right]$$

Where $(1-\frac{1}{S})^{LW_{\max}}$ indicates the probability that LW_{max} independent items are not in a specific wave

Overlapping effect-validation

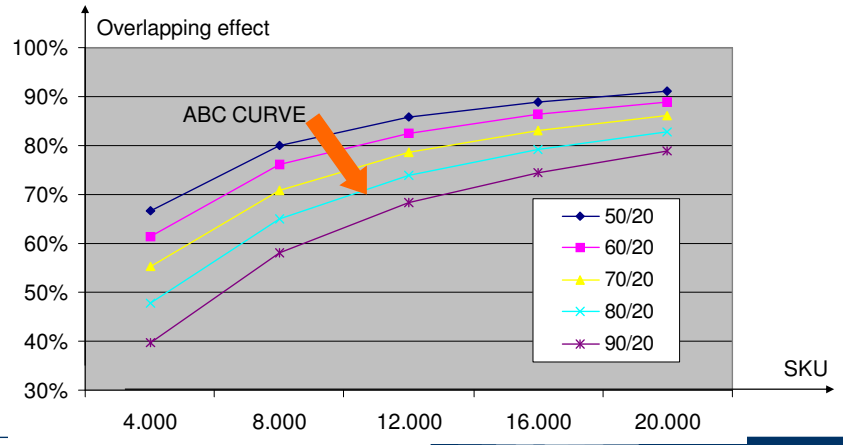
- Hypothesis:
  - ABC curve of 80/20 (i.e. the 80% of order lines associated to the 20% of SKUs (ranked by descending popularity);
  - The number of items: 8,000
  - Number of orders per day: 2,000
  - Number of order lines (OL) in an order as 10
  - Number of simulation run: 30

Number of waves	Simulation experiments: Number of order lines per wave: Mean	Simulation experiments: Number of order lines per wave: Std. Dev.	Confidence interval width (%) (0.01 significance level)	Number of order lines per wave (analytical model)	Difference between analytical and simulation results (%)
12	1,231.4	10.19	0.38%	1,230	-0.12%
10	1,393.5	12.09	0.37%	1,399	0.39%
8	1,623.3	13.82	0.34%	1,623	-0.02%
6	1,933.3	14.64	0.29%	1,931	-0.12%

The proposed analytical model gives a low margin of error

Overlapping effect-results

- We studied the overlapping effect (ratio between LW and LW_{max}) varying context conditions:
  - Number of items (SKU)
  - ABC curve (%order lines associated to % of number of items)



Conclusions

- We are completing the model for the estimate of the picking rate when varying the picking wave
- Further developments on the topic of pick-and.sort system design may go towards modelling of the costs and activities of the sorter, in order to evaluate the efficiency of this solution (Please see for instance the impact of the final packaging activity)
- Innovation level (and also automation level) by MH providers is increasing. Therefore, for the near future it will be more and more important to support designers in the choice of the most suitable systems …

… so let's get to work!!