UNIVERSITY OF TWENTE.

SERVICE TOOLS: WHY BOTHER?

Optimization of stock levels for service tool inventory

SECOND ISRAELI-DUTCH WORKSHOP ON QUEUEING THEORY

SEPTEMBER 29 - OCTOBER 1, 2010

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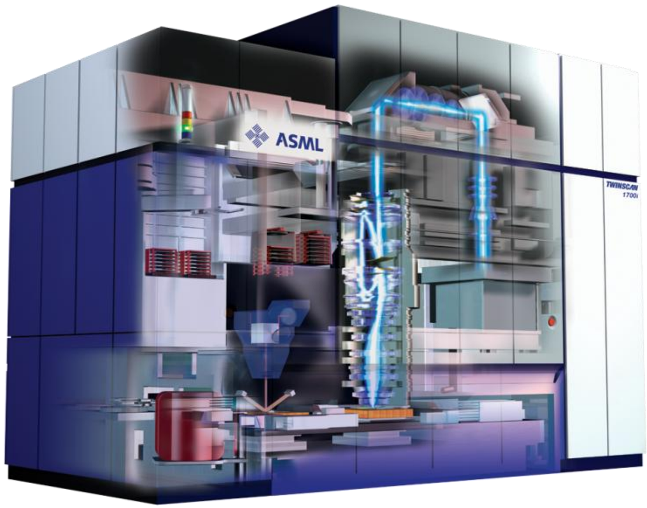
INTRODUCTION

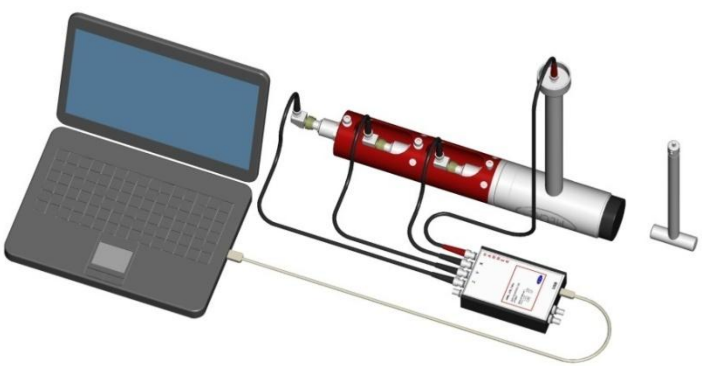
- ASML: High tech company produces technical machines
- Responsible for machine uptime
- To ensure uptime:
  - preventive maintenance
  - corrective maintenance
- Needed for maintenance:
  - service engineers
  - spare parts
  - service tools



INTRODUCTION – SERVICE TOOLS

- Tools used for, among others, the repair, cleaning and/or calibration of machines
- Expensive
- Low demand rates
- Many different tools

- So, no screw drivers…



INTRODUCTION - DIFFERENCES PARTS AND TOOLS

- Main differences with spare parts:
  - Tools are usually demanded in sets
    - Coupling in demands
  - Spare parts are consumed, while tools are only used
    - After usage returned to stock point together
    - Coupling in returns

- Now the question is:
  - Do we need to develop new heuristics for the stock planning of service tools? Or can we (continue to) use available heuristics for spare parts?

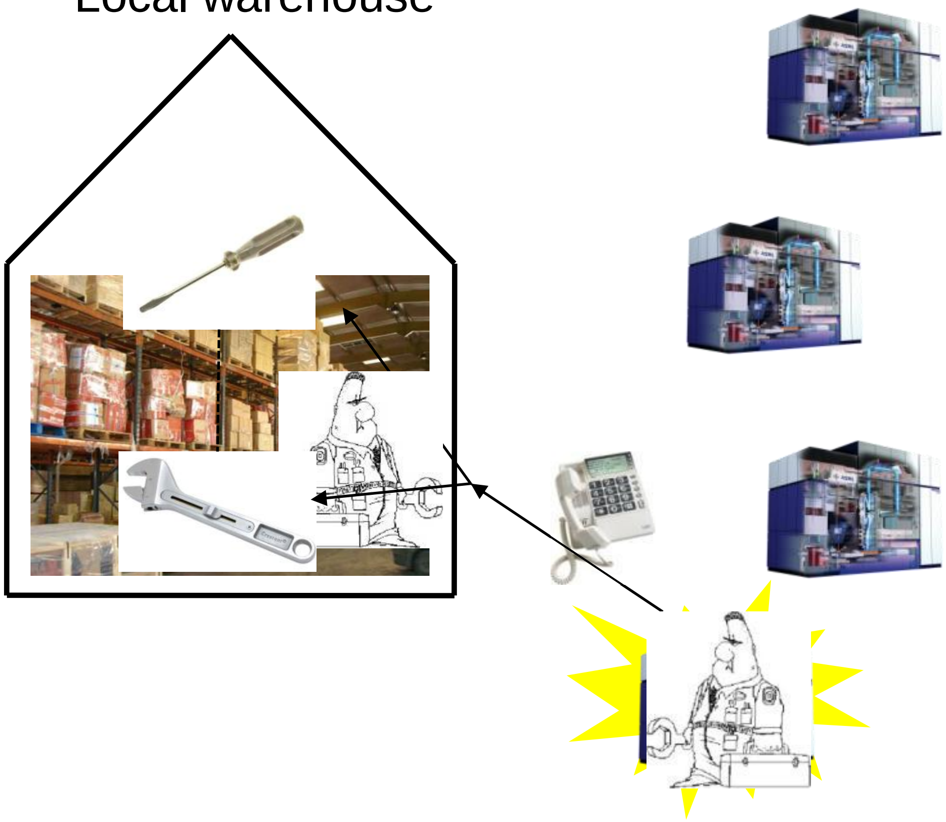
INTRODUCTION – MAIN QUESTION

Service tools: why bother?

INTRODUCTION – SITUATION

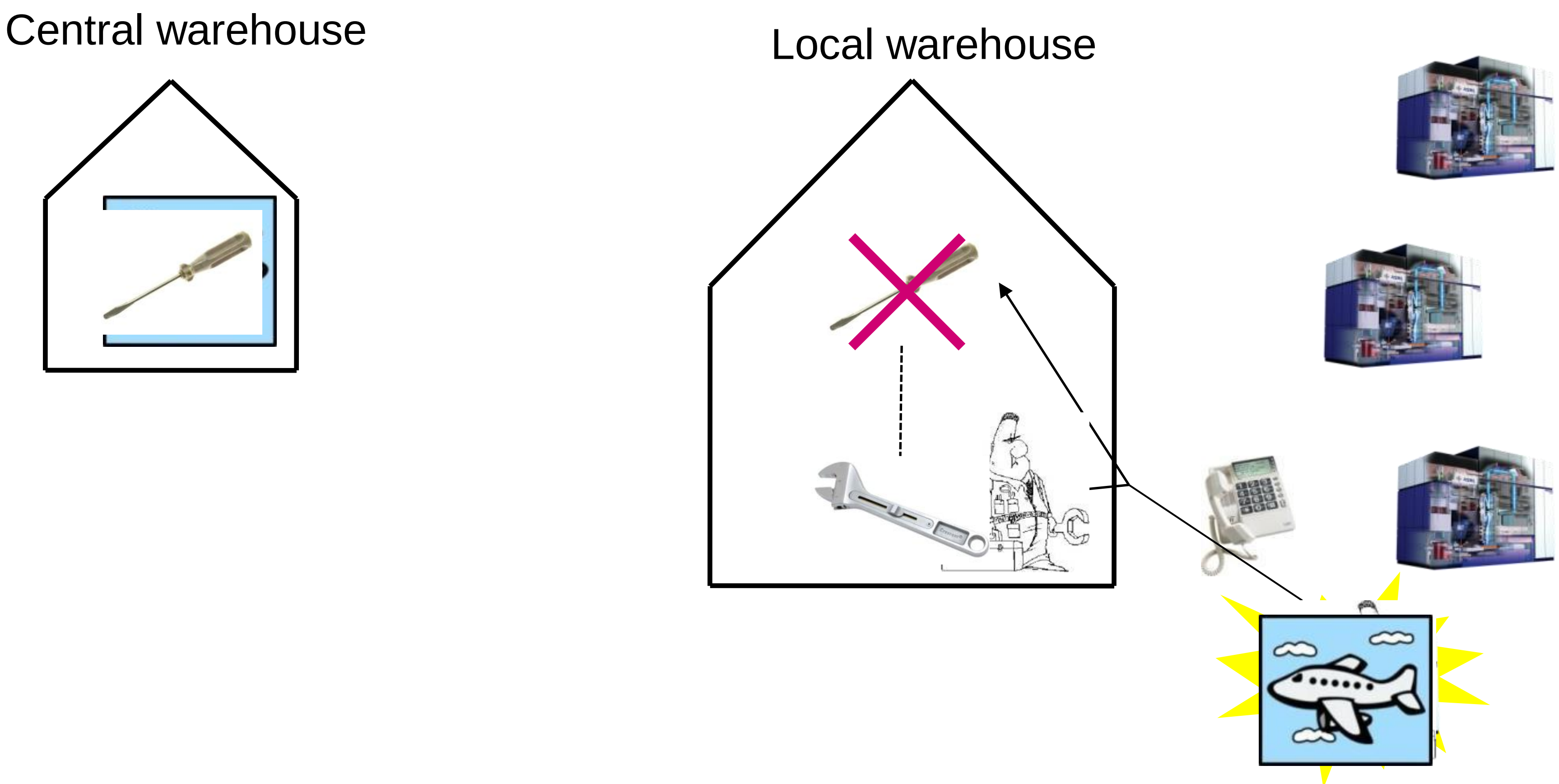
Central warehouse

Local warehouse



INTRODUCTION – SITUATION

MACHINE BREAKDOWN, TOOL NEEDED ... EMERGENCY SUPPLY



INTRODUCTION – GOAL STUDY

- Objective ASML:
- Min Inventory holding costs
- s.t. Service level ≥ Target service level

- Goal of research:
  - Develop an efficient heuristic to determine near-optimal stock levels for service tools for this optimization problem
  - Compare heuristic with known heuristic for the planning of spare parts

OUTLINE

- Introduction
- Literature
- Model
- Approach
- Results
- Conclusions & Implications
- Ongoing research

LITERATURE

- Spare parts:
    - Kennedy et al., 2002, Sherbrooke, 2004, and Muckstadt, 2005
    - No coupling in demands
- Repair kit problem:
    - Single period problem
        - Brumelle and Granot (1993), Mamer and Smith (1982, 1985), Mamer and Shogan (1987), Teunter (2006)

LITERATURE

- Kit management problem:
  - Slightly different model, but analysis differs considerably
    - Güllü and Köksalan (2008)
- Assemble-to-order:
  - Mostly backordering
  - Lost sales: no coupled returns
    - Song and Zipkin (2003) (overview), Song, Xu, Liu (1999), Iravani, Luangkesorn and Simchi-Levi (2003), Dayanik, Song and Xu (2003)

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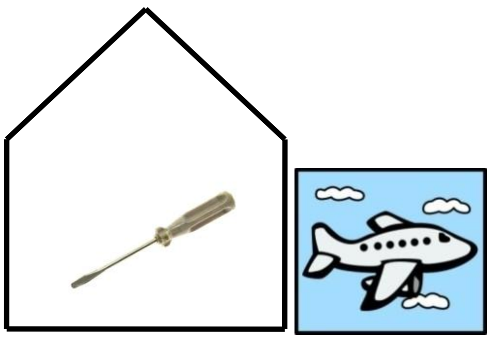
MODEL

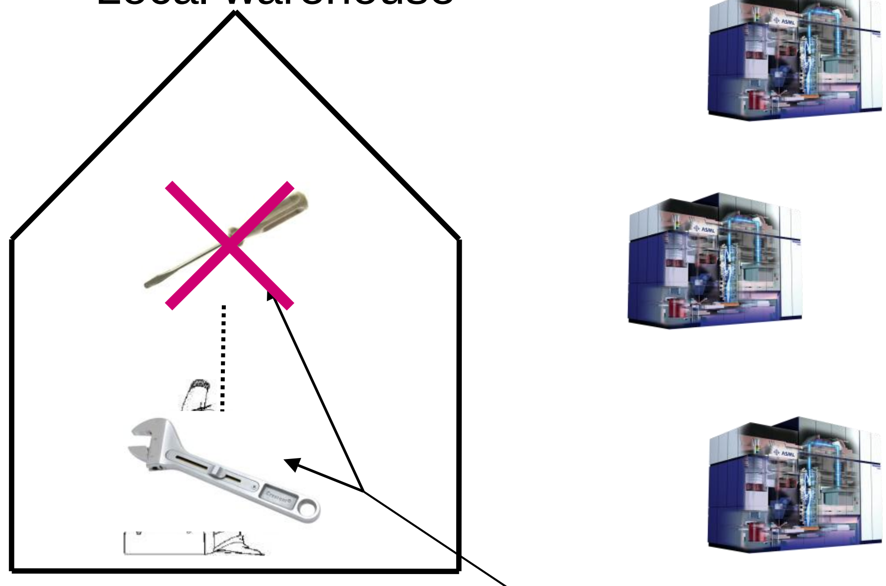
Central warehouse

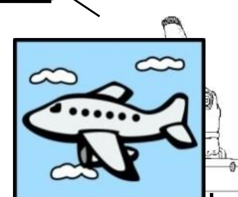


Available tools to customer, rest of demand satisfied via emergency shipment:
- **lost sale** for warehouse under consideration
- **partial order service**

Equal exponential return times
- coupled returns

Base stock policy per tool





oisson process for
ets of tools:
coupled demands

Single location, multiple service tools

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APPROACH

- Developed 3 heuristics
- Compared costs with a lower bound
- Validated whether solutions meet the target

HEURISTICS

- 3 Heuristics developed:
  - All use a greedy algorithm
  - Different evaluation methods

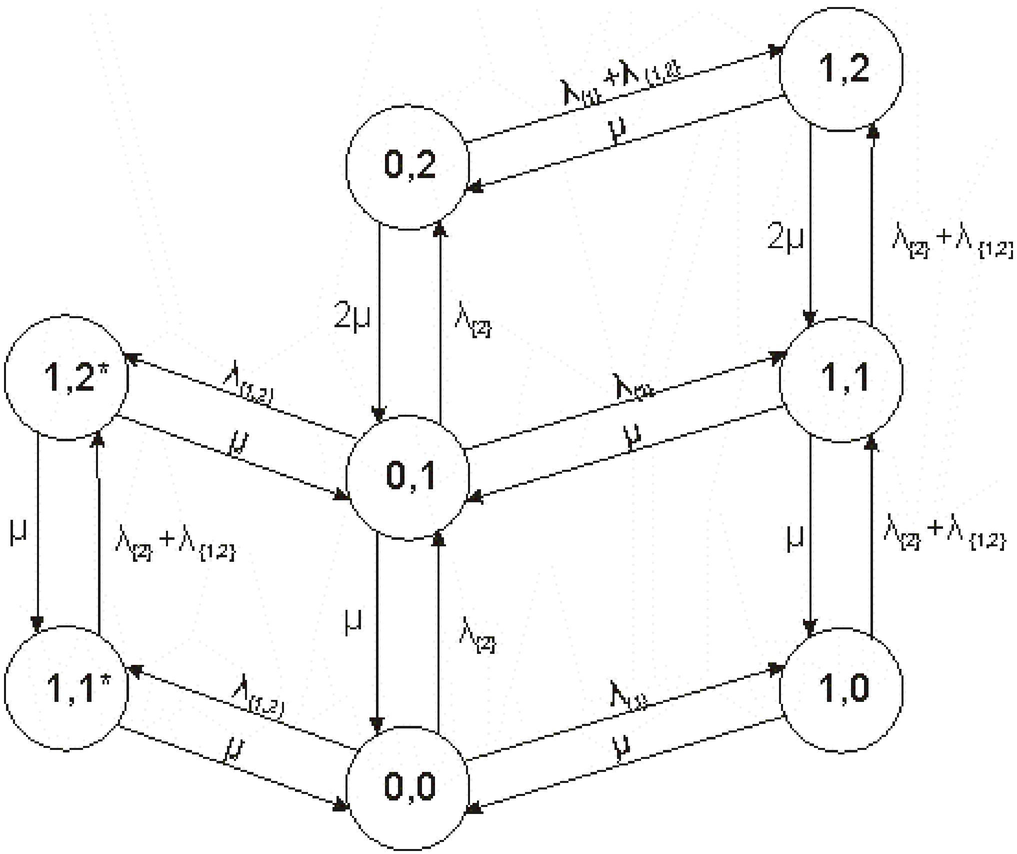
		Coupled demands	
		Included	Excluded
Coupled returns	Included	Heuristic 1	
	Excluded	Heuristic 3	Heuristic 2

HEURISTIC 1

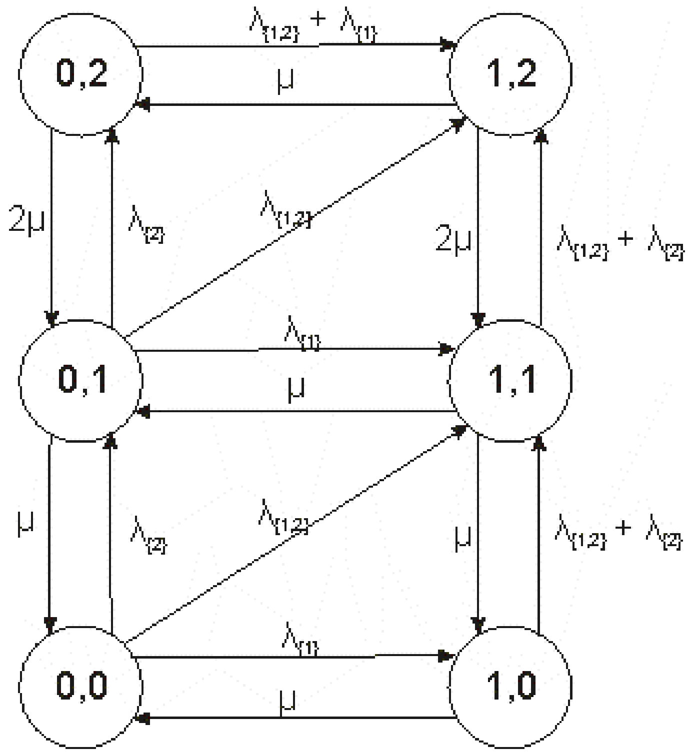
- Vliegen and van Houtum (2009)
- Exact evaluation: very time consuming
- 3 approximate evaluation methods
  1. Overestimates the service level
  2. Underestimates the service level
  3. Weighted average of (1) and (2)
     - Leads to efficient and accurate results

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

HEURISTIC 1 (2)



Original model



Lower bound

HEURISTIC 2

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

- Model currently used for spare parts
- Two main assumptions:
  - No coupling in demands
  - No coupling in returns
- The demand for sets of tools is decoupled into demands for each separate tool $\beta^2 = \sum_{i\in I} \frac{\tilde{\lambda}_i}{\tilde{\lambda}} \tilde{\beta}_i$
- Where
  - β^2 is the aggregate order fill rate approximated by method 2
  - $\tilde{\lambda}_i$ is the aggregate demand rate for item *i*
  - $\tilde{\lambda} = \sum_{i\in I} \tilde{\lambda}_i$ is the total demand rate
  - $\tilde{\beta}_i$ is the fill rate for item *i* (using Erlang loss formula)

HEURISTIC 3

- Similar to Schaefer (1983)
- Two main assumptions:
  - No coupling in returns
  - On hand stock levels are independent

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

$$\beta_k^3 = \prod_{i \in I_k} \tilde{\beta}_i$$

- Where
  - β_k^3 is the order fill rate for demand stream *k* approximated by evaluation method 3
  - I_k is the set of tools demanded by demand stream *k*
  - $\tilde{\beta}_i$ is the fill rate for item *i* (using Erlang loss formula)

APPROACH

- Developed 3 heuristics
- Compared costs with a lower bound
- Validated whether solutions meet the target

LOWER BOUND - STEPS

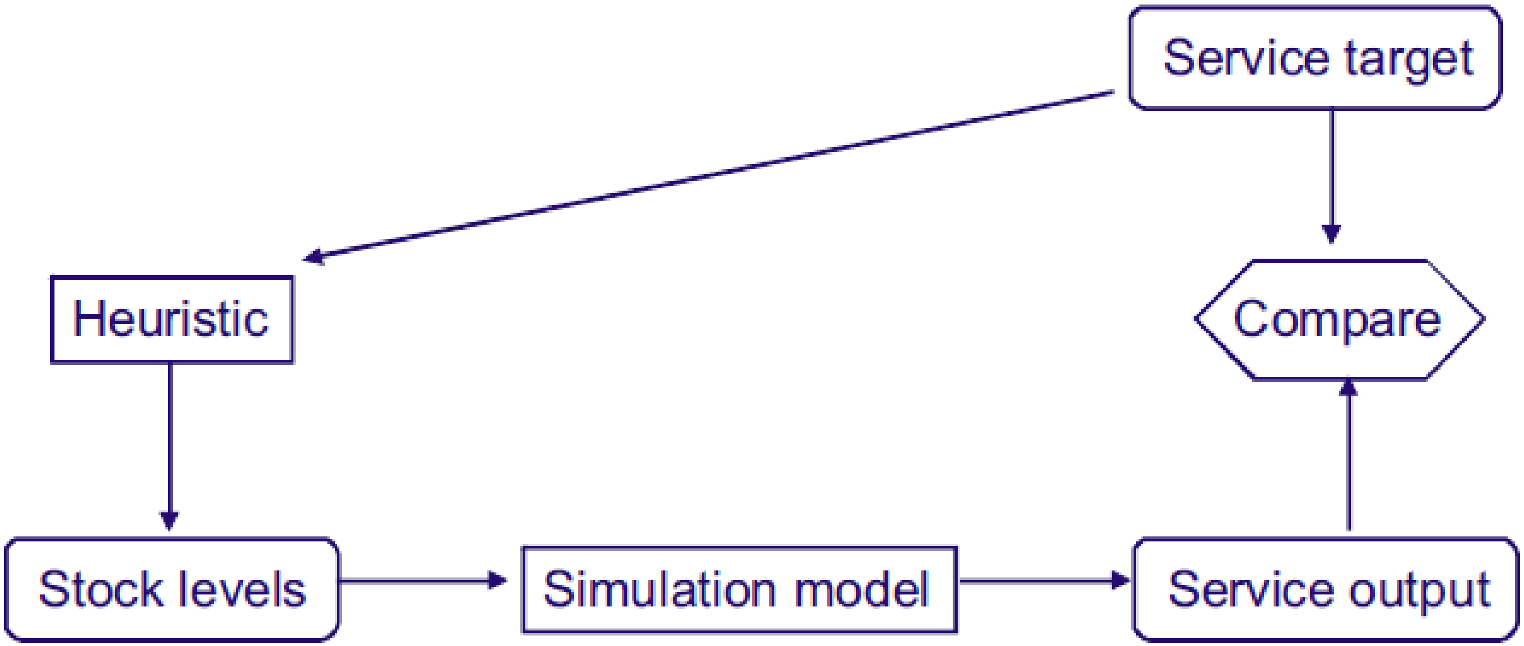
1. Using Lagrangian relaxation (Fisher, 1981);
2. Splitting the problem in smaller subproblems (similar as done in Kranenburg and van Houtum (2007));
3. Using bounds on the service level (Busic, Vliegen, Scheller-Wolf, 2009);
4. Using smart enumeration.

APPROACH

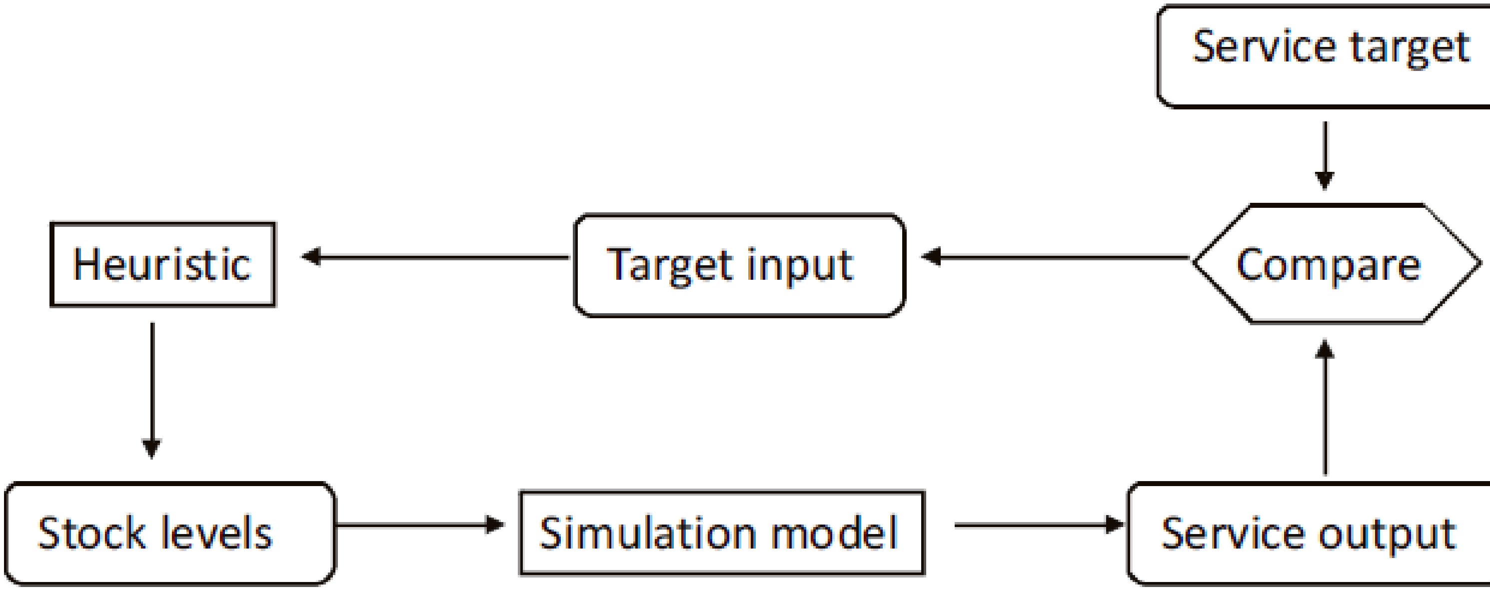
- Developed 3 heuristics
- Compared costs with a lower bound
- Validated whether solutions meet the target

- Simulation tool:
  - Establish solution’s fill rate
  - Tune solutions

VALIDATION – ESTABLISH FILL RATE



VALIDATION – TUNE SOLUTION



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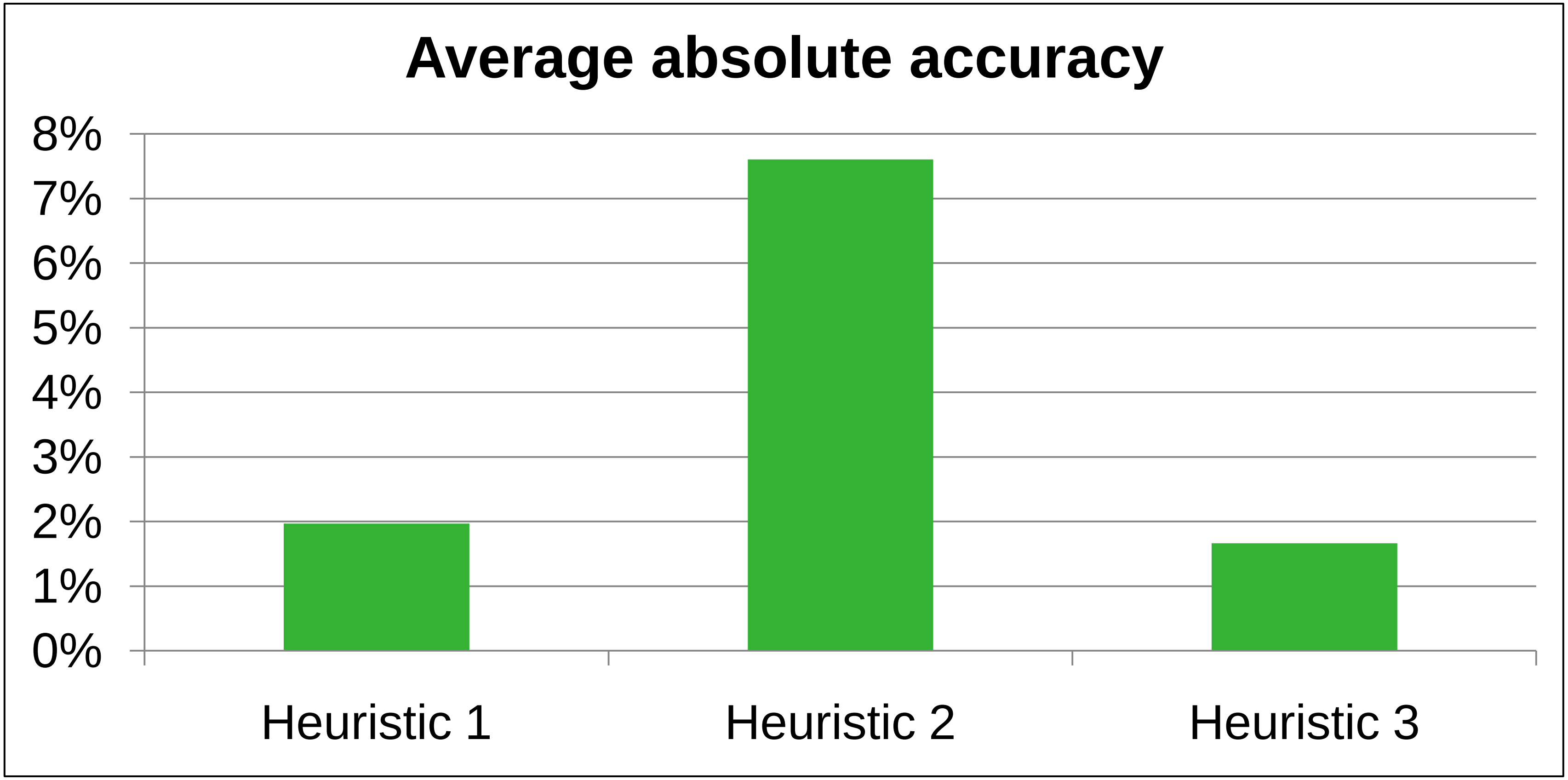
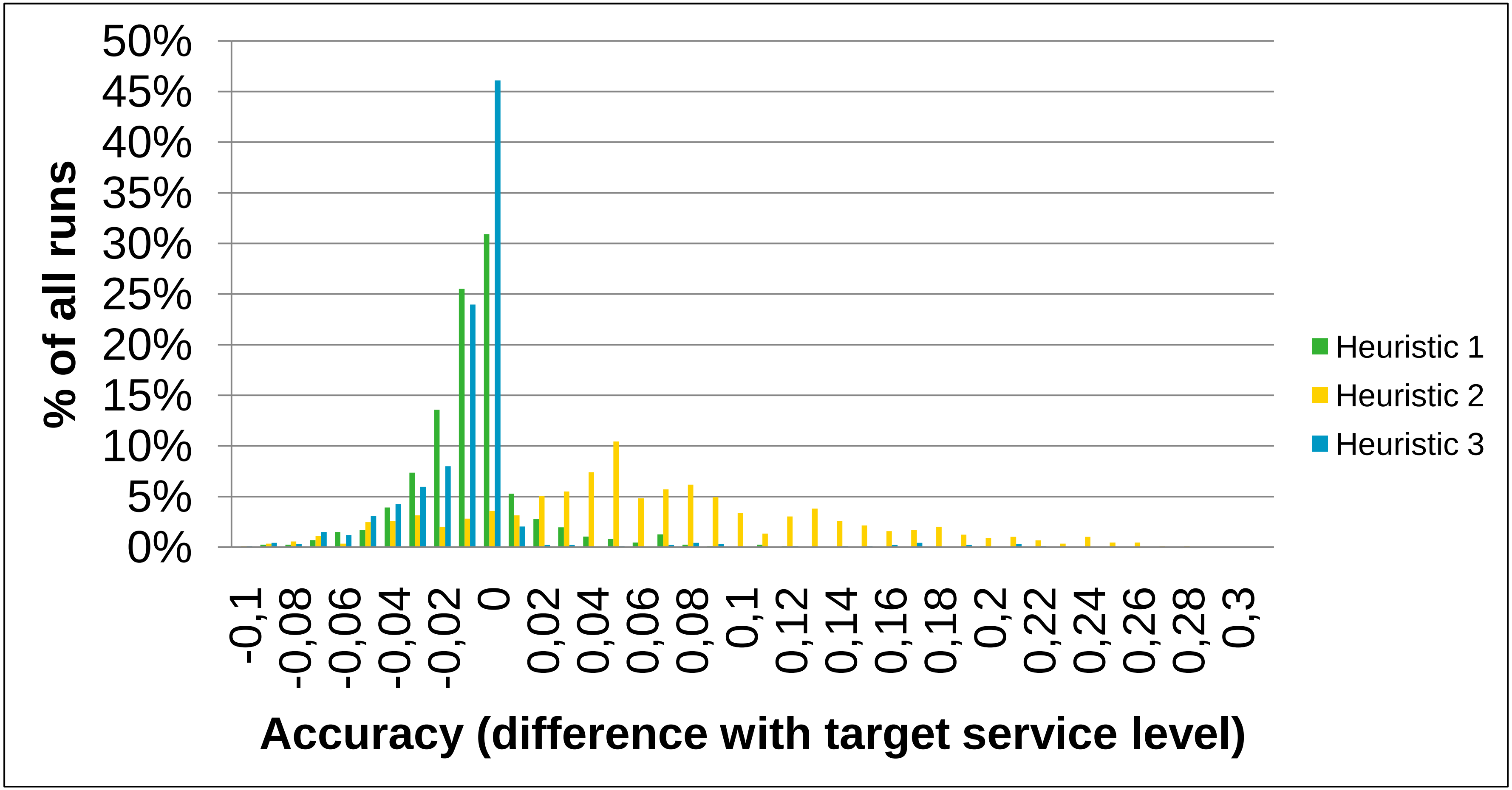
RESULTS

- Test bed:
  - 972 instances:
    - Amount of demand streams
    - Demand rate
    - Size of demand streams
    - Service level
    - Division of demand over demand streams with different sizes
    - Relation between tool demand and price

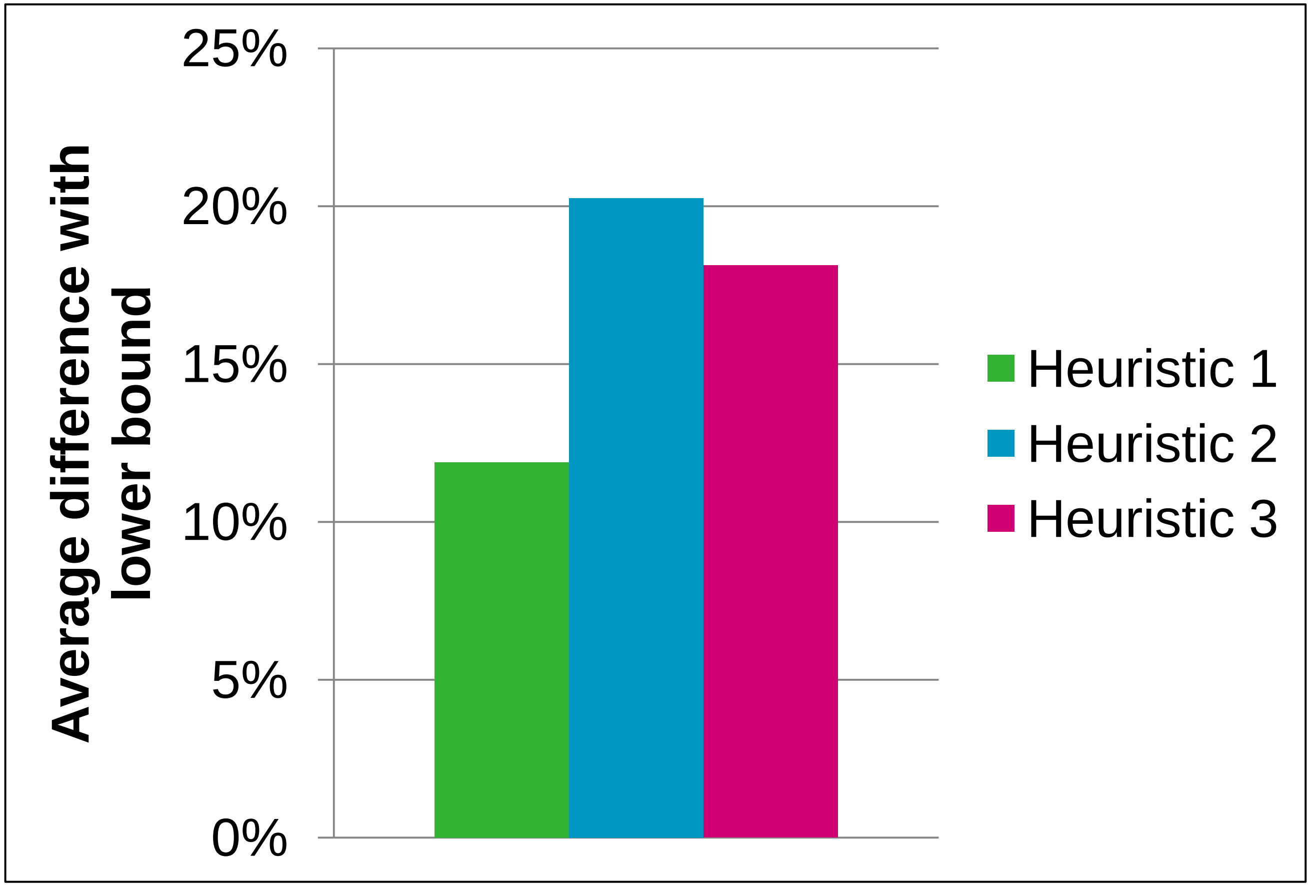
RESULTS - ACCURACY



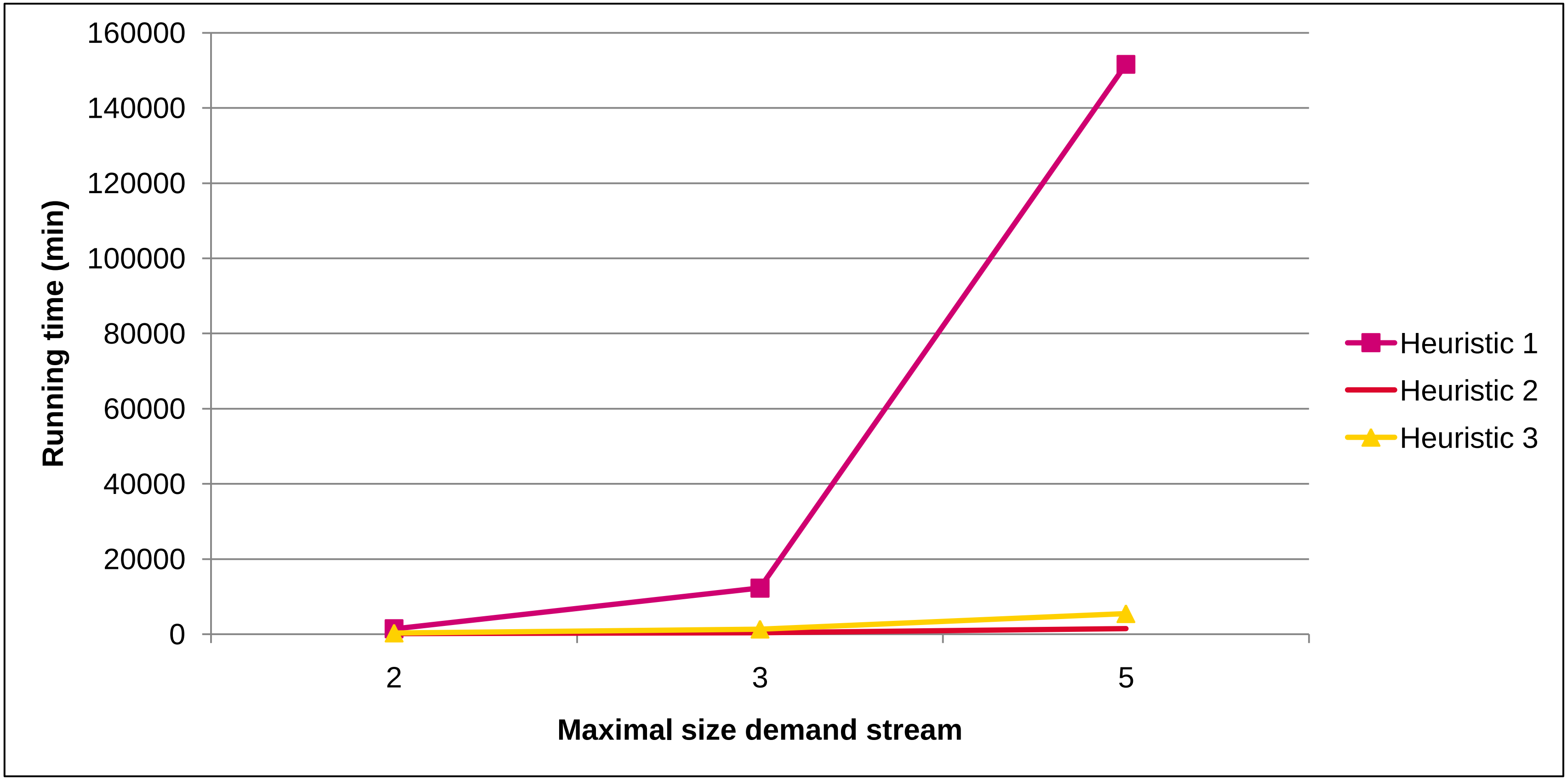
RESULTS – VARIABILITY OF ACCURACY



RESULTS – COST EFFICIENCY



RESULTS – RUNNING TIME



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CONCLUSIONS – HEURISTIC 1

- Most detailed
  - Leads to lowest costs
  - But very high running times
  - Cannot be used in practice

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

CONCLUSIONS - HEURISTIC 2

- Very fast (seconds)
- Very inaccurate & accuracy variable
- Highest costs (7% higher)

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

- So, spare parts models are not appropriate to be used for the stock planning of service tools

CONCLUSIONS – HEURISTIC 3

- Takes into account coupling in demands, but not in returns
- Very accurate
- Higher costs than Heuristic 1 (5% higher)

→ Use Heuristic 3

		Coupled demands	
		Y	N
Coupled returns	Y		
	N		

IMPLICATIONS

- ASML has started collecting data on:
  - What sets are demanded
  - Demand rates for these sets

- A business case is being carried out to see the implications for the whole network

- A case study is done to see the performance of Heuristic 1 and 3 in a multi-location setting

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ONGOING RESEARCH

- This study:
  - Improving lower bound/Decreasing gap with solutions
    - Larger subsets
    - More items
  - Include heuristic based on total order service
  - Include transportation costs

- Further:
  - Substitution of tools by so-called tool kits
  - Interaction with spare parts and service engineers

SUMMARY

- Planning the stock levels of service tools with the spare part model leads to more costly solutions that are very inaccurate
- Taking into account all special characteristics of service tools leads to the cheapest solutions, but to very high running times
- By taking into account only coupling in demand, the accuracy of the heuristics becomes very good, and the costs are only slightly higher than when all details are taken into account