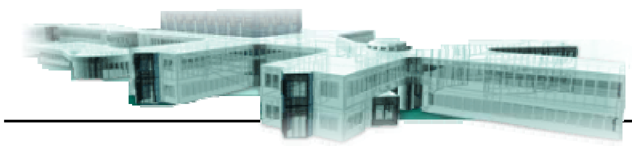
Analysis of decentral order-picking control concepts



Fraunhofer Institut Materialfluss und Logistik

International Conference on Dynamics in Logistics

Bremen, 30th August, 2007

Dr. Thorsten Schmidt

Introduction

- Motivation
- State of the art
- Modeling
- Comparison of strategies
- Conclusion and outlook

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Motivation

- Relation between theoretical breakeven performance and real productivity: Dependency on operating strategies
- Development trends
  - Self-controlled material flows
  - Internet of Things
- Importance of order-picking for the efficiency of logistic systems

State of the art

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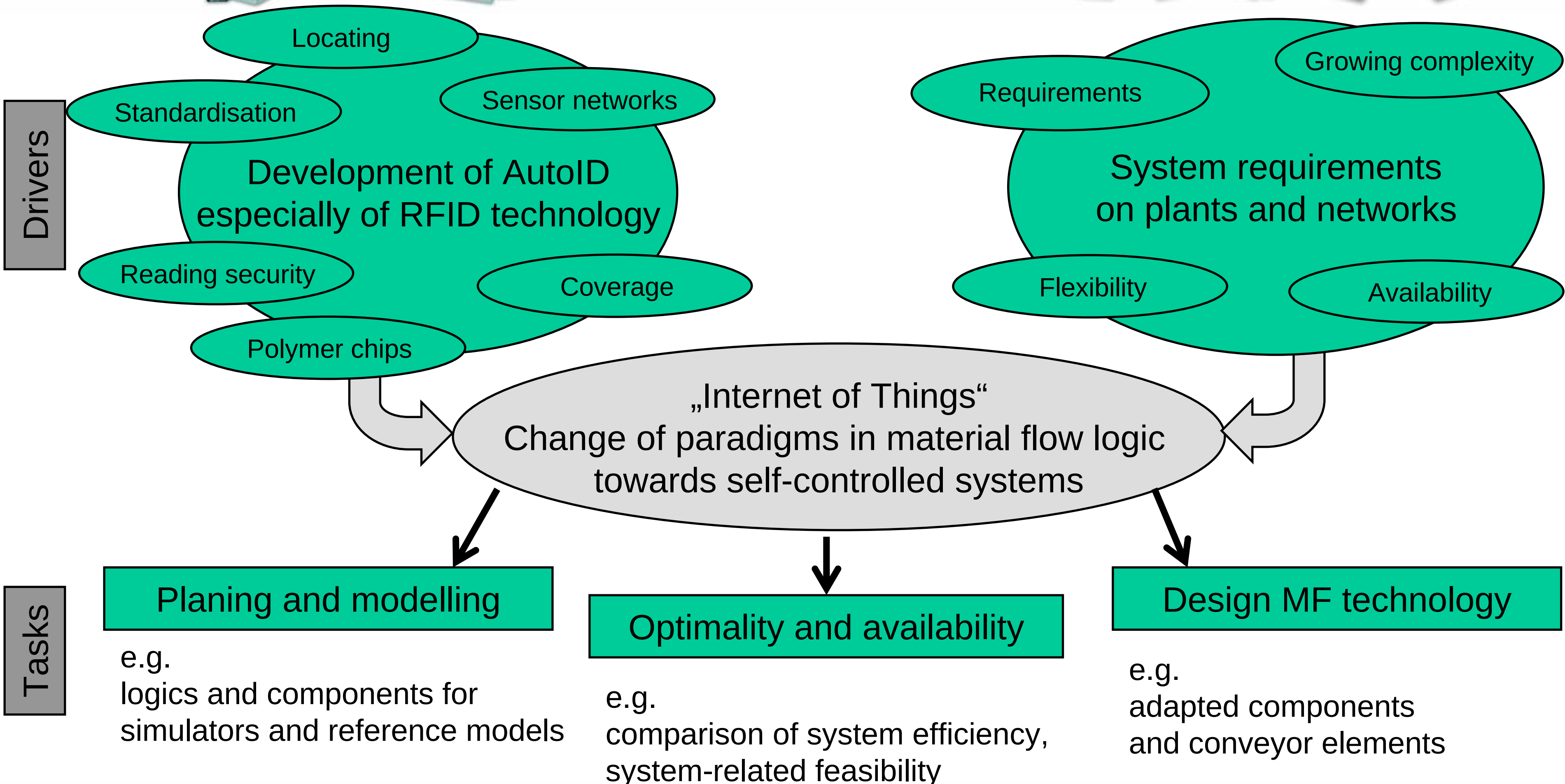
Self-controlled material flows and the „Internet of Things“



Basic problems regarding distributed controls

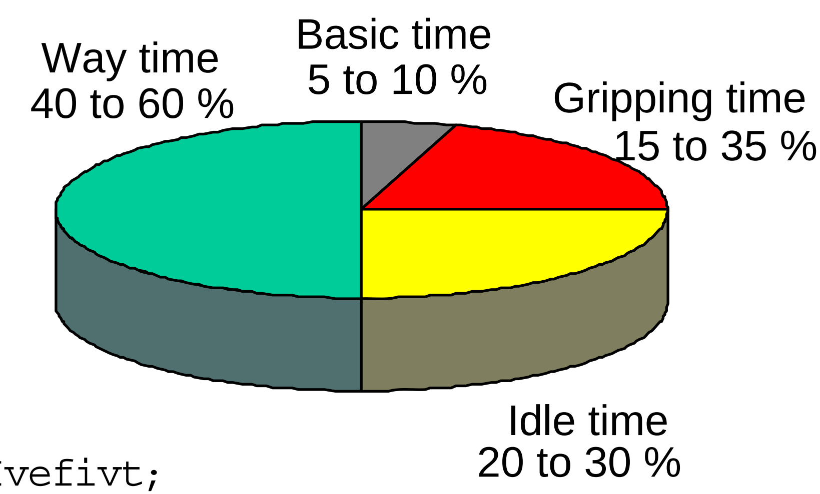
- Technology and form of the communication among decentral controls
- Reaction to failures
- Determination of the optimal operating point without knowledge of the general system status
- Definition of suitable strategies to optimize the system
- Handling of sequencing problems and priority rules

Initial situation Warehouse operation

- Increasing article range / higher shipping frequencies
- Cost driver order-picking
- Increasing performance of material handling systems

- Selection and planning are mostly based on rough empirical values; potentials are often not analyzed in detail in advance
- The control concept, strategies, etc. are often selected by the system provider
- Effectiveness and efficiency of process and operating strategies are largely unknown

- Order-picking is one of the main cost-drivers in distribution centers
- In classical, manual picking way and idle times account for the largest share
- Most rationalization attempts aim at optimizing these aspects



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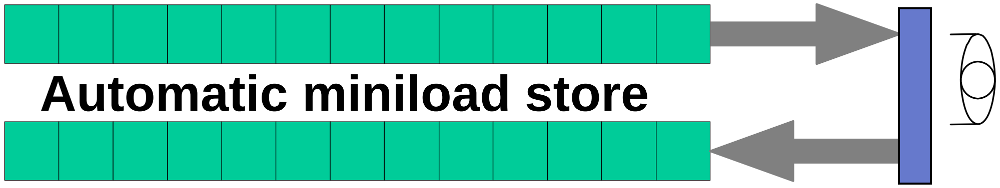
Storage technology in order-picking Goods-to-man



- Small number of order items at a relatively large article master (assortment)
- Typical picking performance: approx. 600 picks/h/person (goods-to-man, paperless, ergonomical arrangement)
- Warehouse performance: depending on operating method 100-600 bins per aisle/h

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Target criteria:
Optimization of goods-to-man systems

- Utilization of picking capacity (even utilization) and of the possible picking performance
- Minimum of order lead times
- Avoidance of over aging of orders
- Avoidance of deadlocks and utilization of the conveying capacity:
  - Minimum number of cycling bins
  - Control of receipts and issues
- Maximum utilization of warehouse capacity, minimum number of partial bins

Modelling

- Motivation
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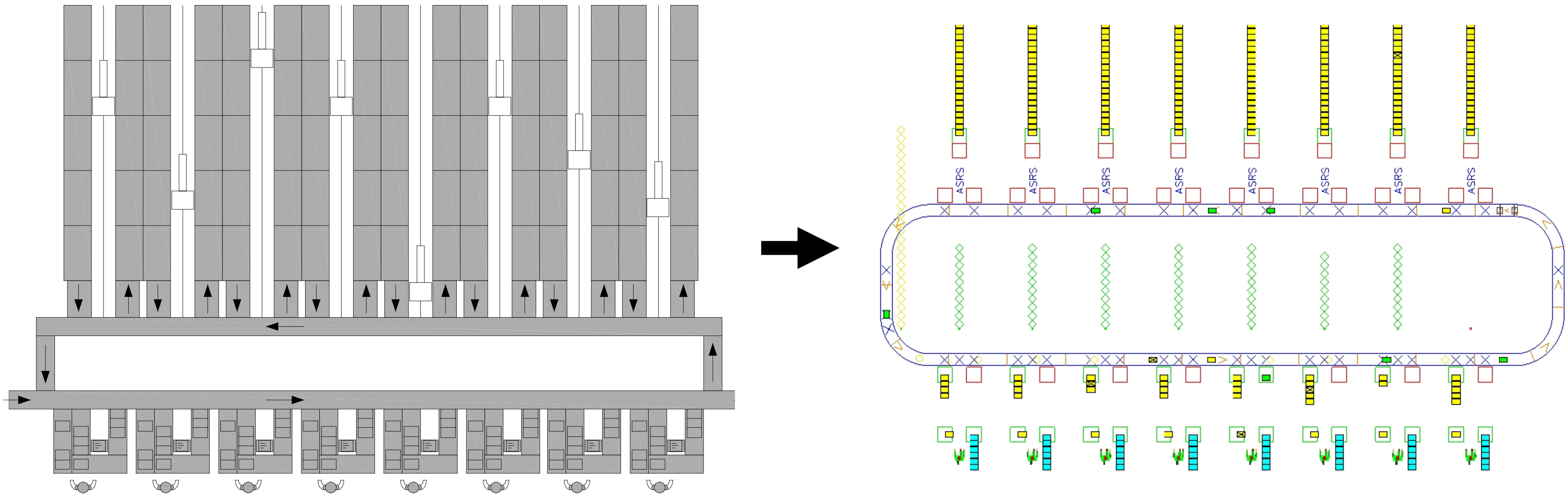
- **Modeling**
- Comparison of strategies
- Conclusion and outlook

Modelling

- Aims of the study:
  - Parallel order-picking as a special case of order-oriented picking with required temporal synchronization of article provision
  - Functionalities of central control logics compared to decentral logics
  - Possible optimization due to strategies and algorithms
  - Determination of reference efficiency factors
- Method
  - Detailed comparison of strategies
  - Consideration of stochastical interdependencies
  - Event-based simulation with AutoMod™

Modelling



- Automatic 8-aisle miniload store
- 8 picking stations with parallel handling of 1, 6 or 12 orders
- Conveyor loop with windows and a capacity of 25 bins at a speed of 1 m/s

System loads and parameters

Factor	*Chosen system load*
Size of assortment	500 / 2.000 / 10.000 articles
Order size	
- Order lines	Exponential distribution 1..20; $\mu = 5$
- Picks per line	Equal distribution 1..19; $\varnothing = 10$
Number of parallely handled orders	1 / 6 / 12
Capacity of article bins	100 parts / bin
ABC classification	20 % A-articles ~ 80 % order lines 10 % B-articles ~ 15 % order lines 70 % C-articles ~ 5 % order lines
Number of resulting order bins	Exponential distribution $\mu = 3$ bins/order max. 1 bin/order line
Picking performance	6 s/retrieval
Capacity of branch lines	Supply: 10 bins Disposal: 5 bins

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Comparison of strategies

- Motivation
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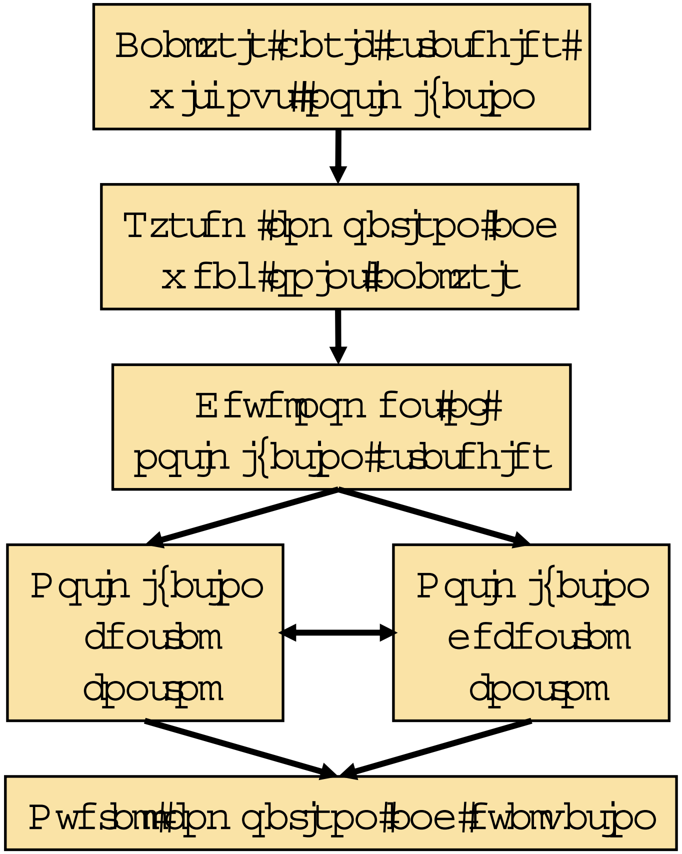
Frameconditions and strategies

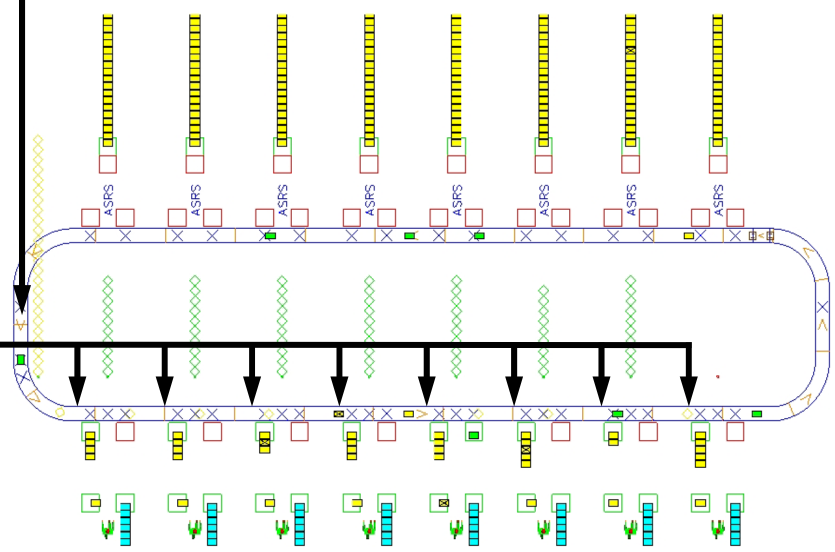
- Different optimization strategies and approaches
- Control logics call for different measures and procedures
- Comparison of central/decentral systems may be distorted because of the use of different strategies

➔ Step-by-step procedure

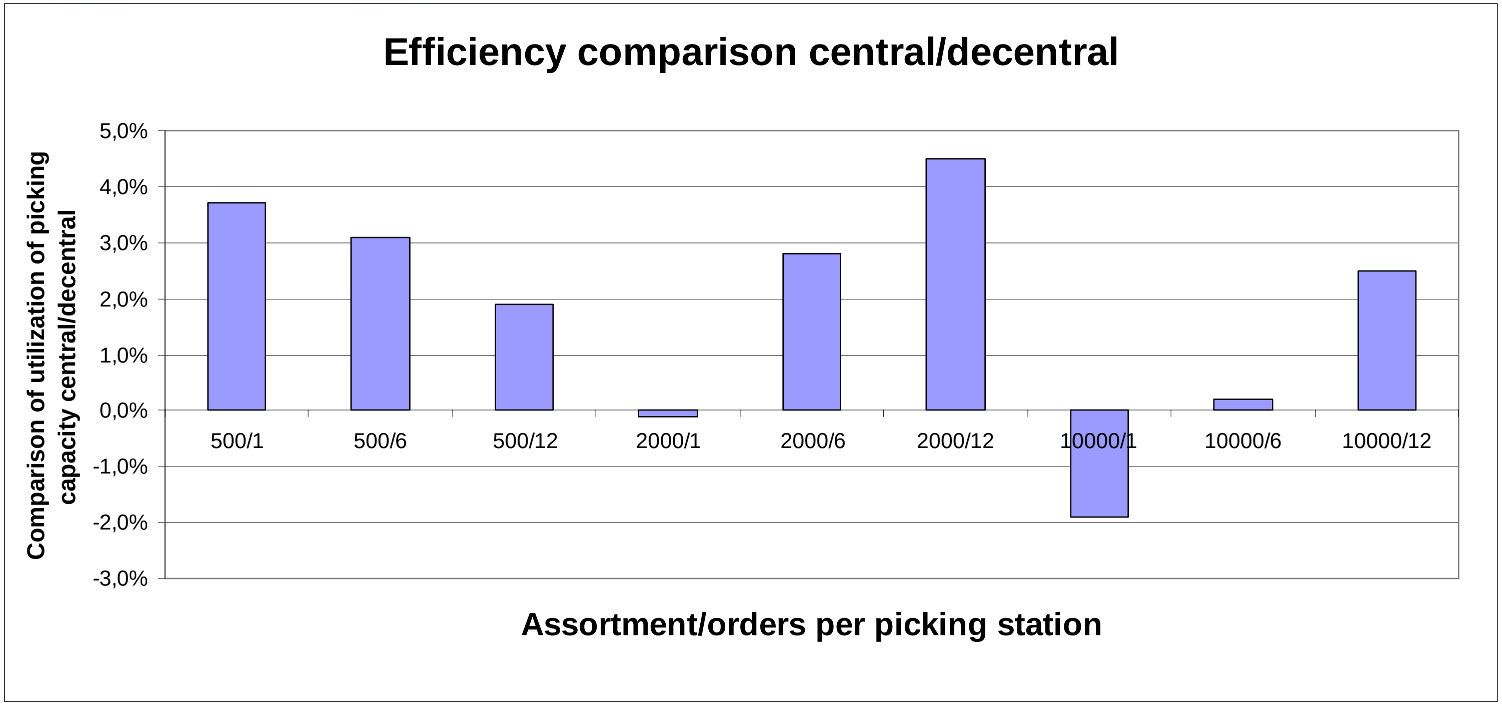


Basic strategies

- Central control:
  - Allocation at central scanner station
  - Request of system status at picking stations
  - Allocation acc. to „RemainingCap“ rule: Station with shortest queue
- Decentral control
  - Allocation in front of picking stations
  - Request of article demand *Y* and empty capacity *Q* on supply track: $Y \text{ A } 3 \wedge Q \geq 1$ = discharge

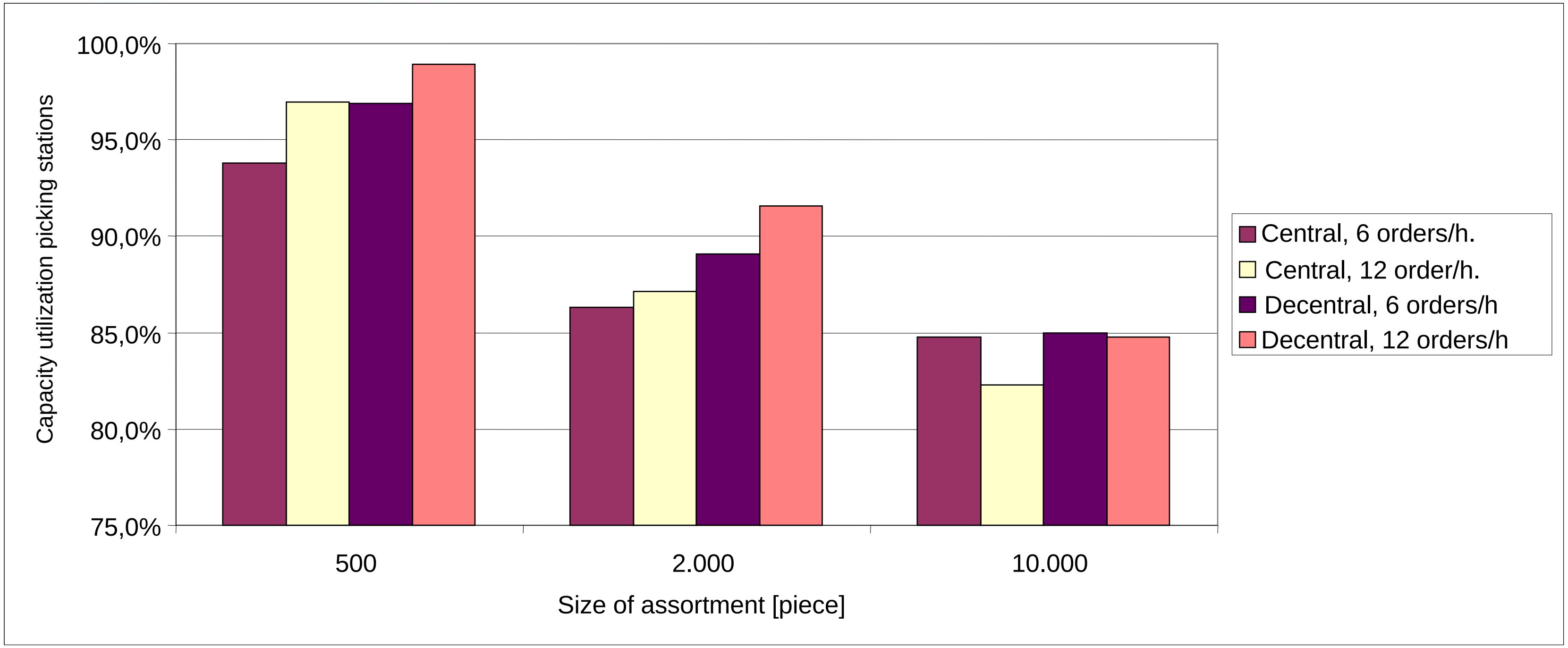


Comparison of the basic strategies



- Efficiency of both procedures comparable, decentral control slightly better (∅=+1.9%)
- No uniform tendency

Comparison of the basic strategies



- Performance decreases in line with size of assortment
- A large assortment requires more replenishments from the store and offers less access to movable stocks

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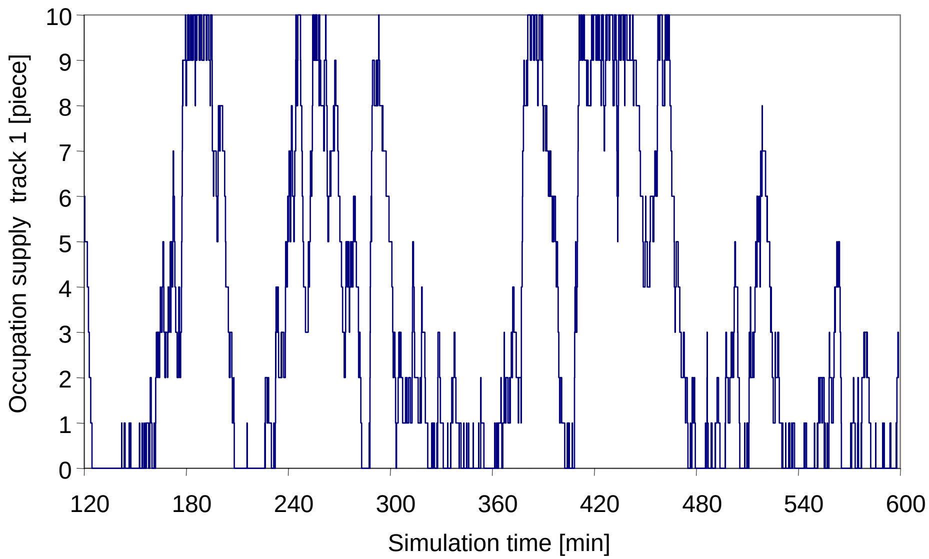
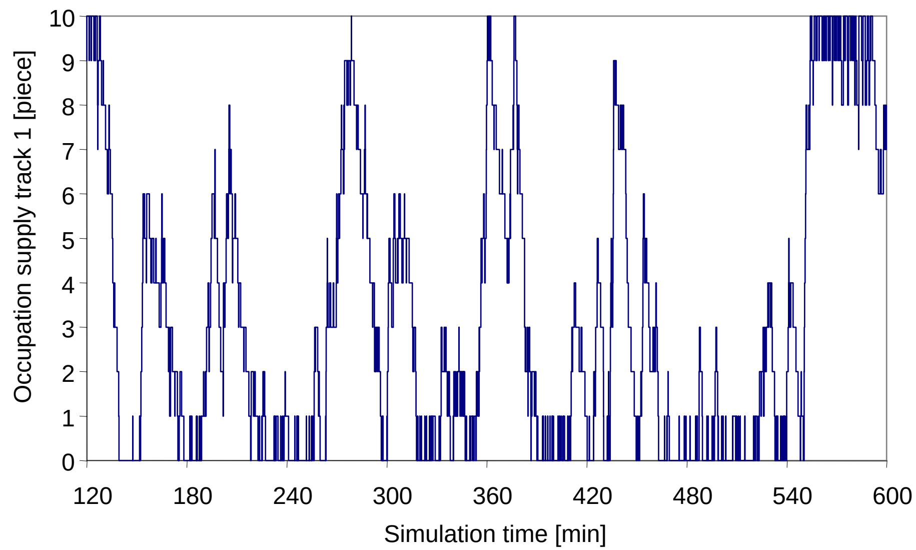
Comparison of the basic strategies
Utilization of the supply tracks





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- Fluctuating occupancy causes frequent flow breaks
- The weak point is the continuous supply of bins

Strategy optimization I

Target:
Even utilization of the loops and avoidance of overloads at single stations

- Central control:
  - Has already been realized with the „RemainingCap“ strategy
- Decentral control:
  - Immediate allocation reduces utilization along the picking stations and thus leads to an uneven load:
    - Bin quantity A is smaller or equal to the required quantity Y ($A \leq Y$)?
    - Buffer quantity Q is large than threshold Γ ($Q > \Gamma$ for Γ=1, 3, 5)?
    - Bin already recirculated R>1?
  - $Y > 0 \wedge Q \geq 1 \wedge (A \leq Y \vee R > 1) \vee Q > \Gamma$ = discharge

Strategy optimization II

Target:

Limitation of the sporadic, bunch-wise removal of bins at the start of a new order:

- Strategy: Limitation of the absolute number of bins which are started simultaneously; supply only after complete discharge
- Maximum bin quantity = 8 bins

- Decentral control:
  - No central bin tracking available ➔ quantity cannot be controlled
  - Time-based supervision: Definition of an intermediate arrival time t_A for the supply of bins from the store
  - The determination of the intermediate arrival time t_A is a critical process because of the longer reaction time and the possibly reduced utilization of the picking capacity

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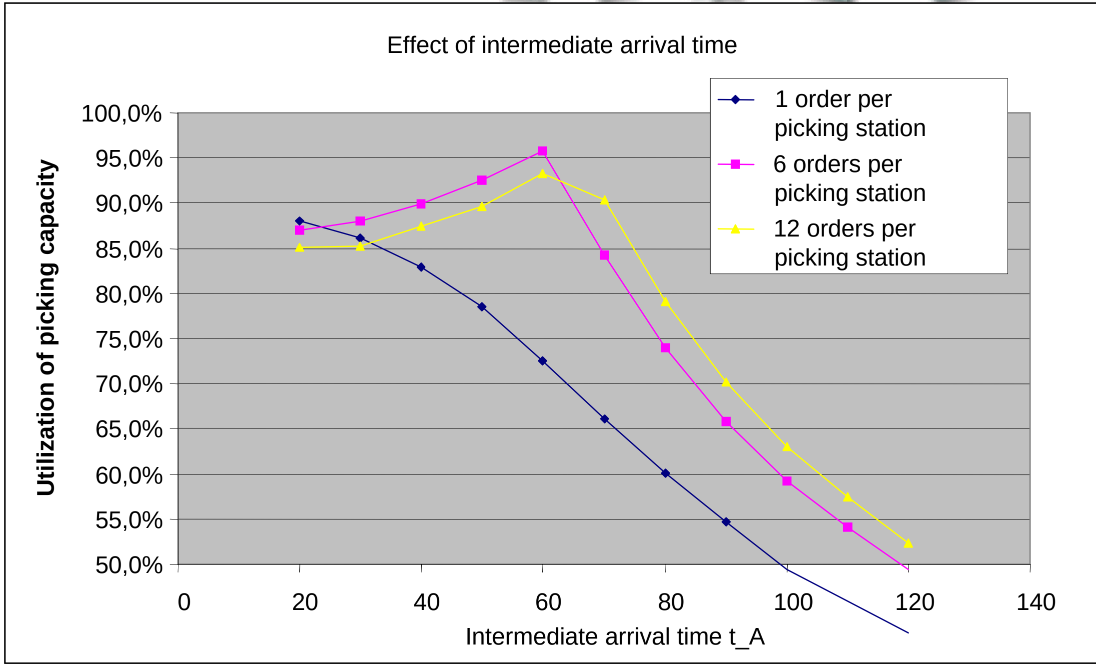
Strategy optimization III
Definition of intermediate arrival time

- Hypothesis:
  Ideal supply frequency corresponds to the average handling time at the picking station
- Reference model:
  Average gripping time = 6 s
  Average retrieval quantity = 10 pieces/order line
  ➔ t_A=60s



➔ Check by means of parameter variations

➔ Not profitable in case of serial handling (1 order/station)

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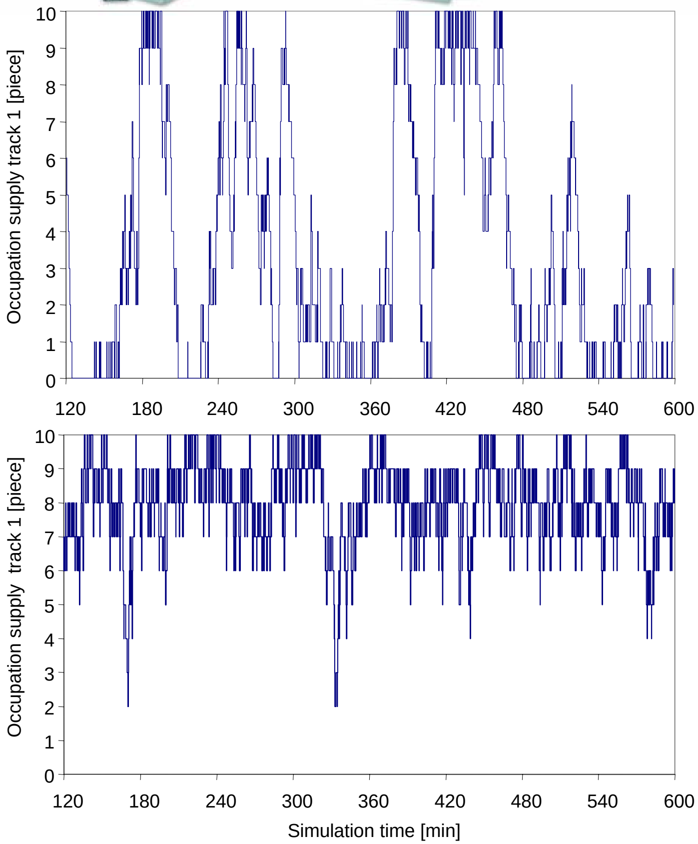
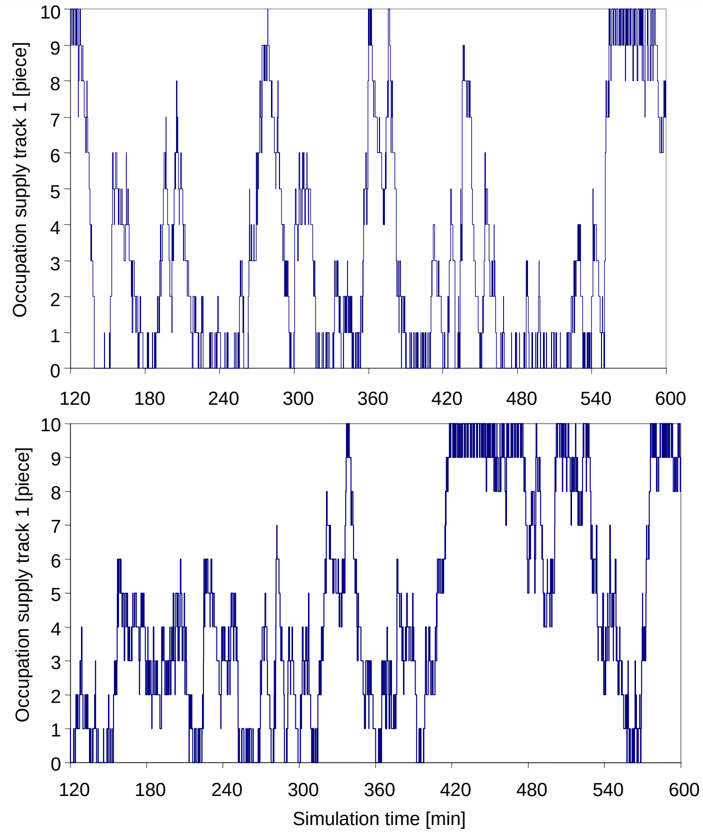
Optimization of the basic strategies: Utilization of the supply track

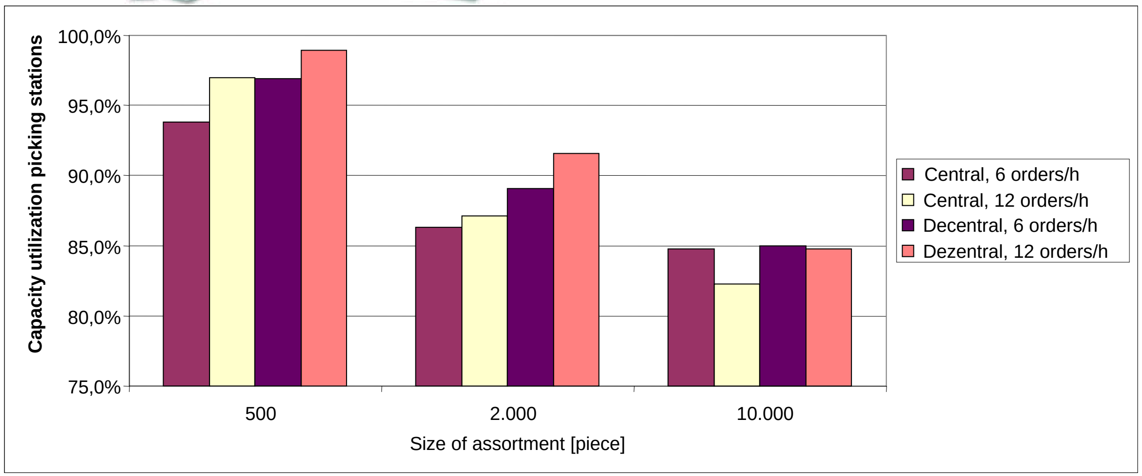


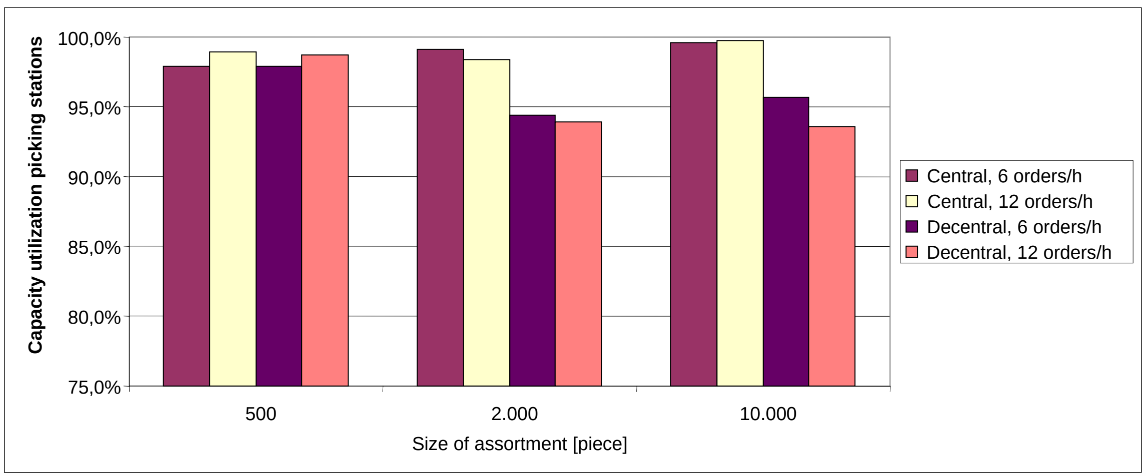
Central: Idle times
59.97 min → 0 min



Decentral: Idle times
159.81 min → 61.46 min

Comparison of the results





- Definite improvement with large assortments for central and decentral control
- Central control only slightly better (∅=+3,2%) because of quicker reaction at order setpoint tracing
- The discharging according to the target value Γ has no effect

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Conclusion and outlook

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Conclusion and outlook

- Generally, decentral controls are suitable to control complex warehouse and order-picking processes
- Established strategies of central controls can be transferred only to a limited extent
- They have to be optimized by carefully selecting suitable strategies
- Further analyses are required, e.g. for systems with routing tasks
- The linked communication between the units, e.g. via software agents, offers further potentials for optimization

Thank you very much for your attention!

Questions?