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Development of new warehousing systems and the use of modelling

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Embedded Systems Institute

falcon project

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Period: 2006/10 – 2011/09

20 FTE/year, 9 PhDs, 2 PostDocs

VanDerLande INDUSTRIES

TU/e technische universiteit eindhoven

TU Delft Delft University of Technology

University of Twente The Netherlands

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DEMCON advanced mechatronics

Goal

Architectures and methods that combine system and component choices for optimal system functionality, i.e. performance & reliability

Issues

- Mapping system onto components
- Consistency in system aspect choices
- Model based engineering
- Increased automation by robotics solutions

architectures: processes, layout, dynamical behaviour, self-optimising control

performance models

relate analysis, design, and implementation

robotic hands & visual guidance

Outline

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- System design & modeling
  - What, why, cost/benefit, lifecycle
- 3 Cases
  - Simple models, fast results
- Concluding remarks

Model-based design

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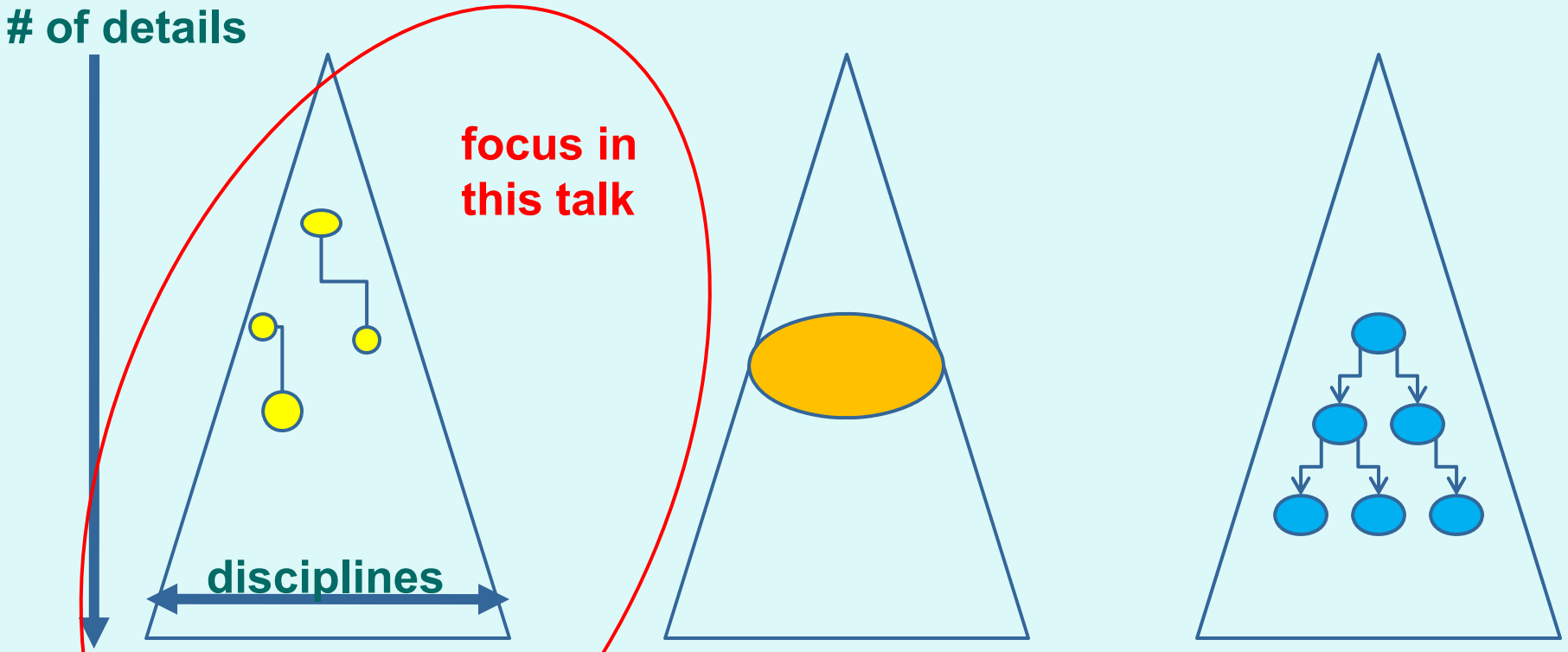
Three different ways of using models in system design



Supportive to critical decision making

Automatic design space exploration

Model-driven: generate design artifacts

What to model?

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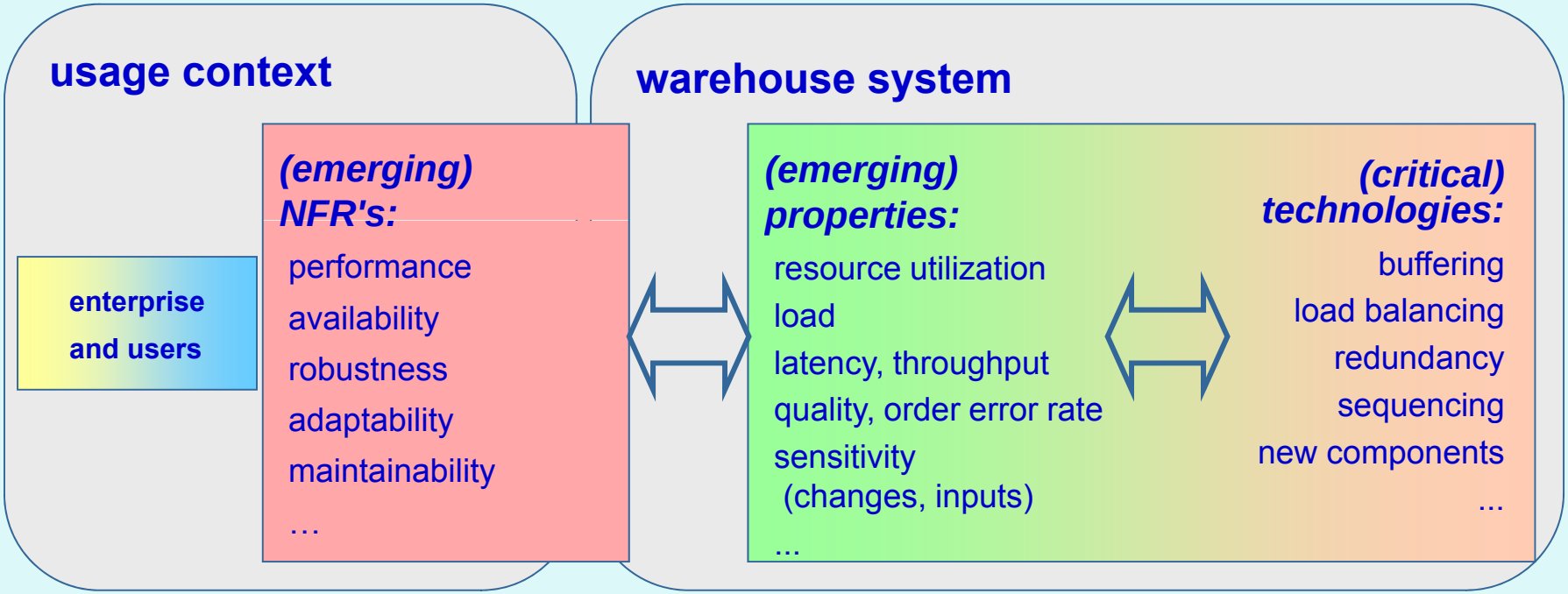

What & why to model?

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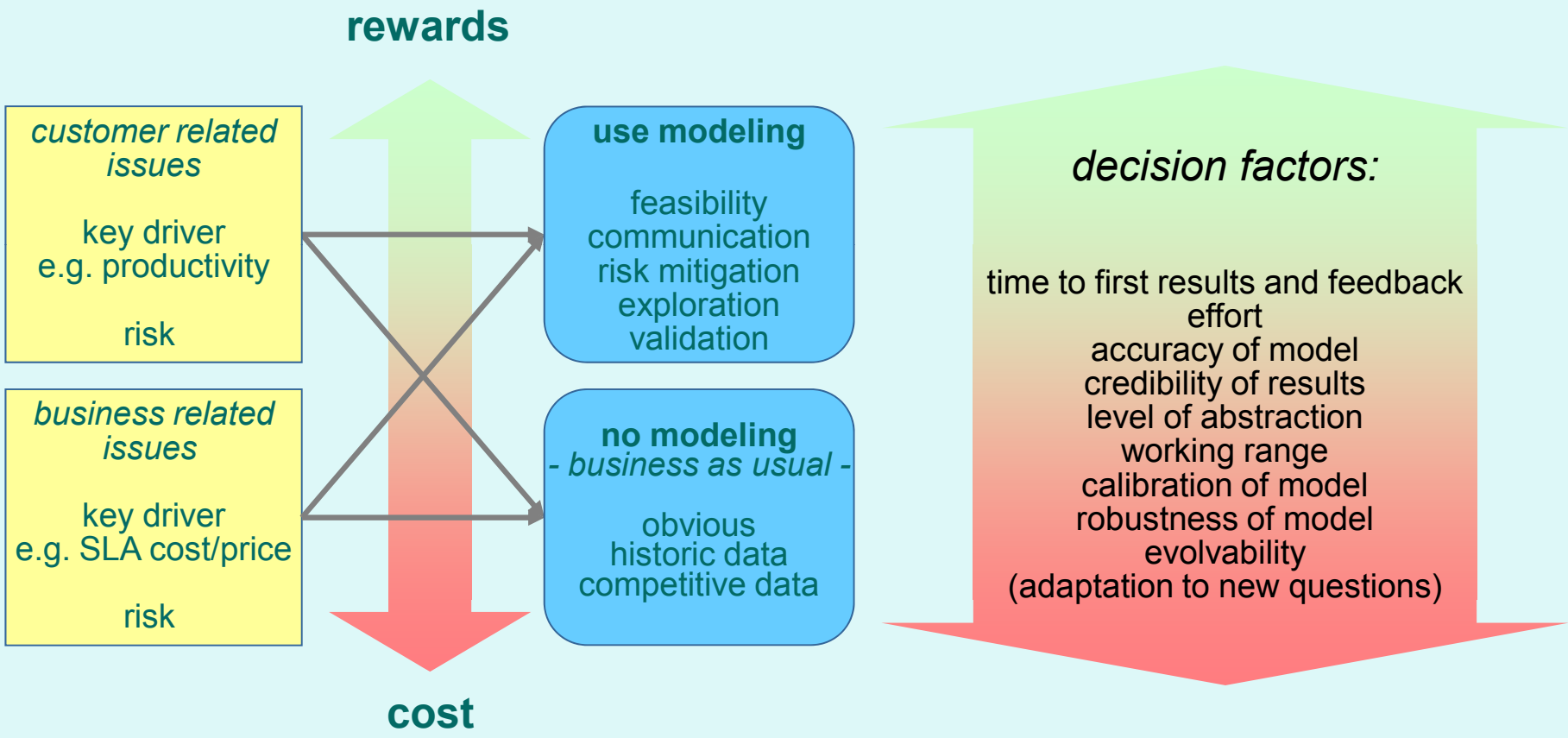

One aspect of model cost/benefit

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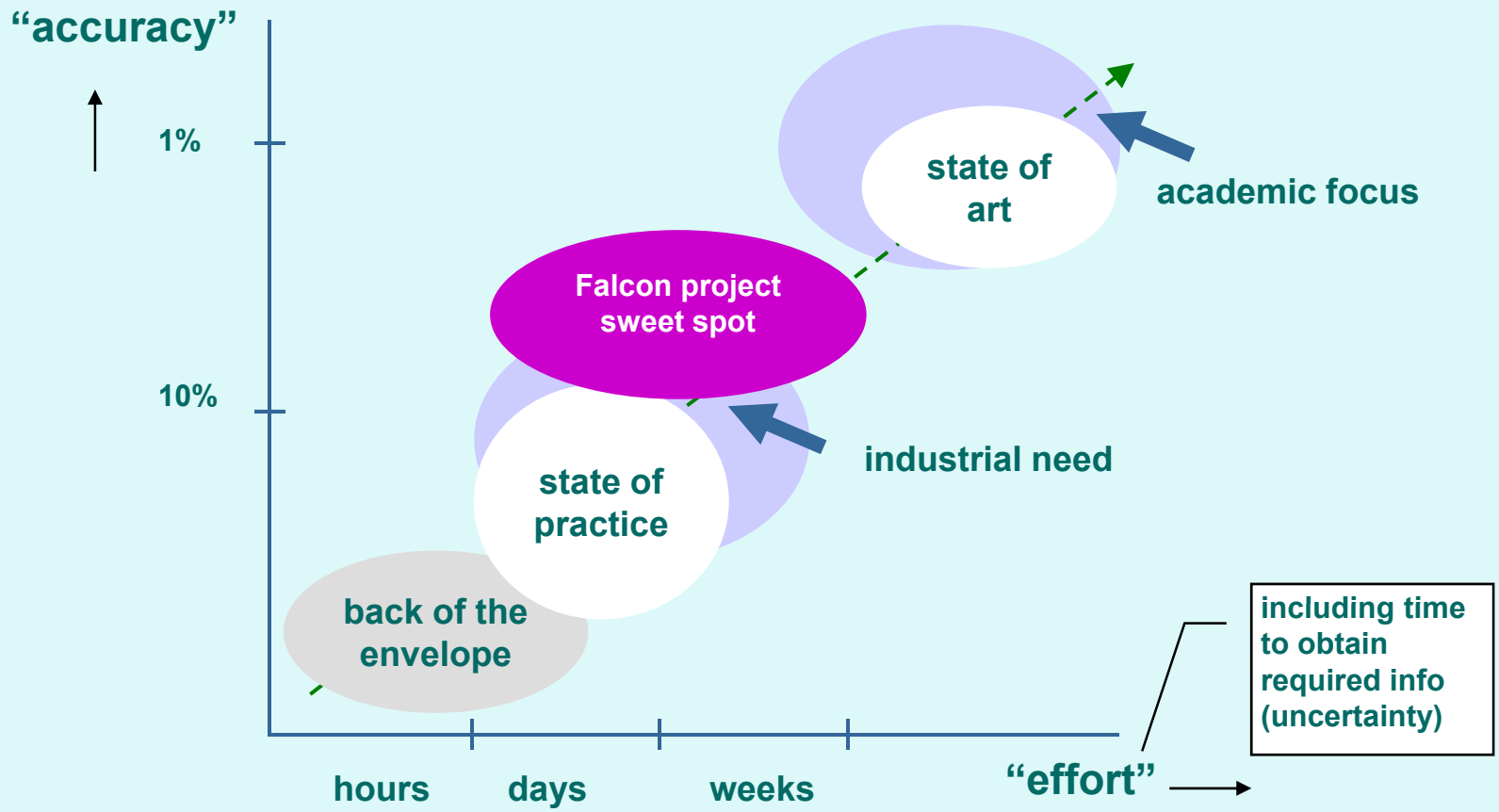

Purpose of Modeling

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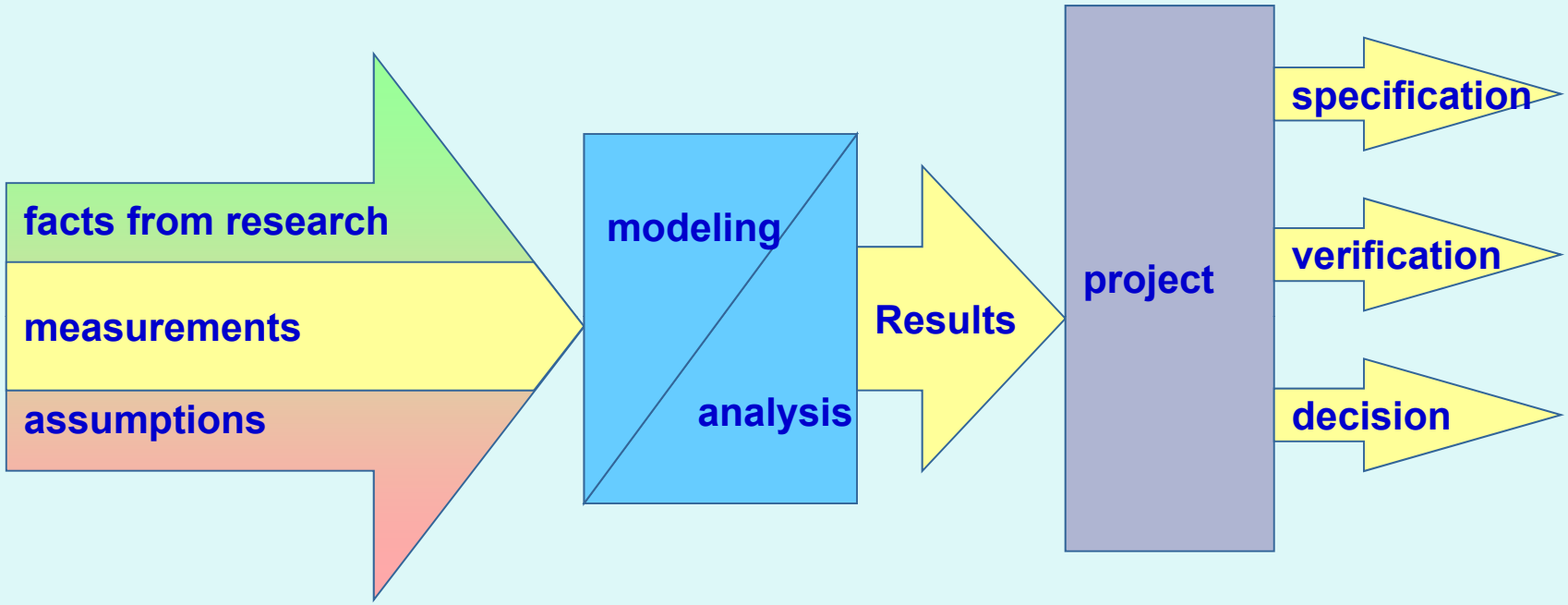

uncertainties
unknowns
errors

→

accuracy
working range
credibility

→

risk
customer satisfaction
time, cost, effort
profit margin

Model versus Reality

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Reality ≠ Model

"all models are wrong, some are useful"

George Box, statistician

Lifecycle of Models

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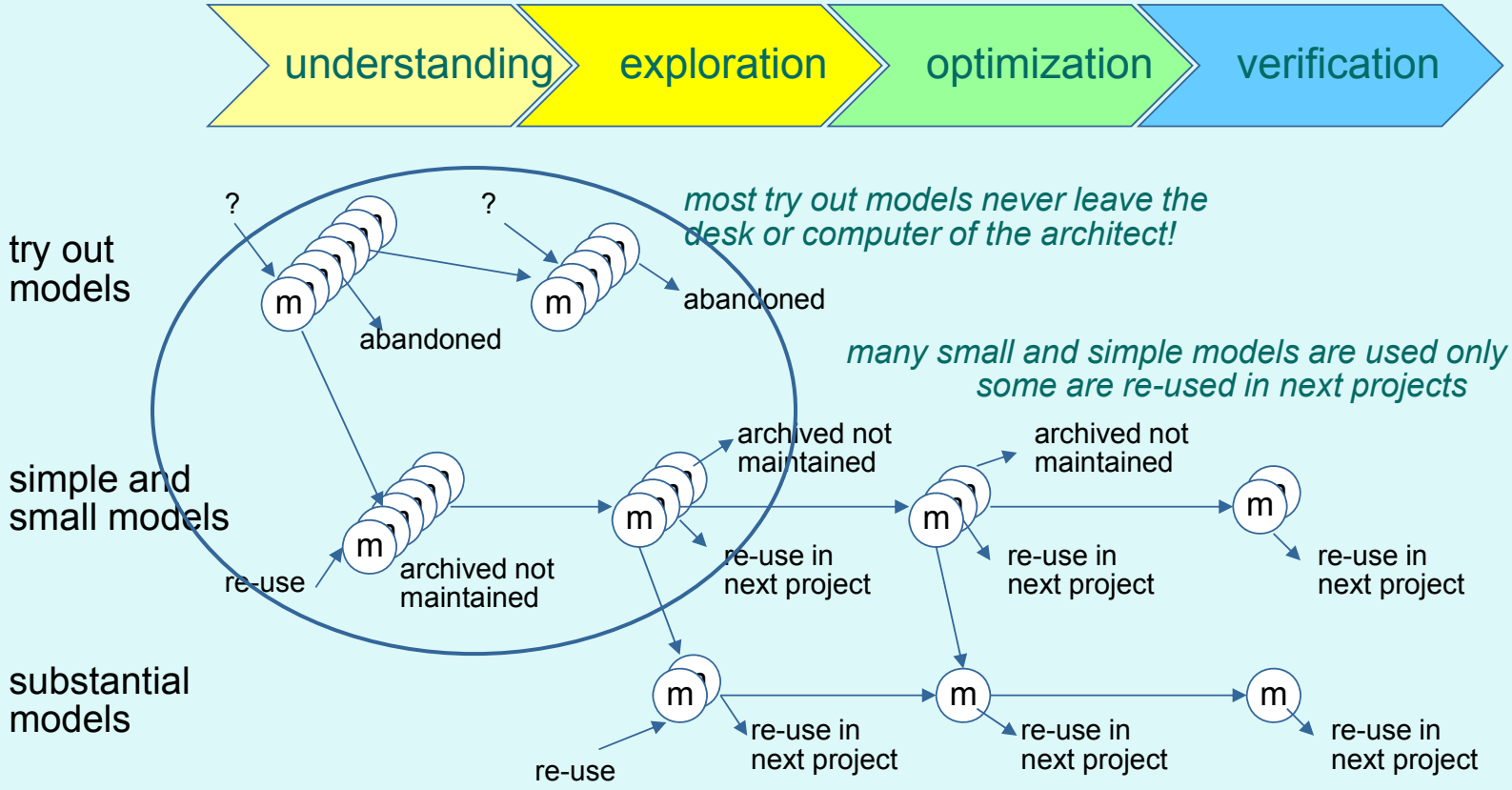

Cases for modeling in Vanderlande

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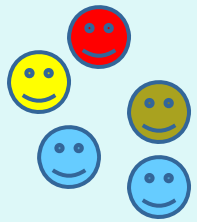
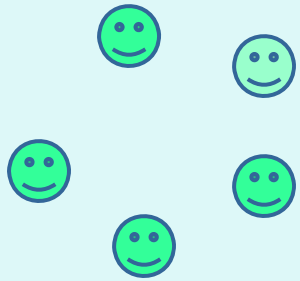
- **Support in a new product development team**
  - New variant of an automated retrieval system …
  - Early phase: understanding & exploration
  - Rapid changes of focus: balancing act
  - *Cases 1 & 2*



- **Support for sales engineering**
  - Middle phase: exploration & optimization
  - *Case 3*
  - *All modeling activities critically depend on set of people & their backgrounds*



Case 1: in-sequence item retrieval
context

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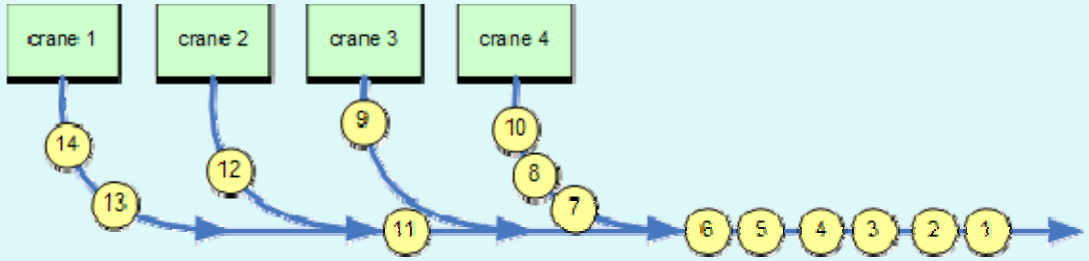
What is the effect on system performance?



Reality	Model
crane performance • dependent on route • dependent on items	**crane performance** • uniform probability distribution around average
items • have identities • have to be handled in sequence • number per job varies	**only consider sets of items** • "black box" sets • # of items sampled (from customer distribution) • "in sequence" is hidden in service
transport • causes different time-delays for different connections	**no transport model** • only interested in throughput
layout • widely different variants	**layout** • variants result in *n→1* mergers

Summary of results

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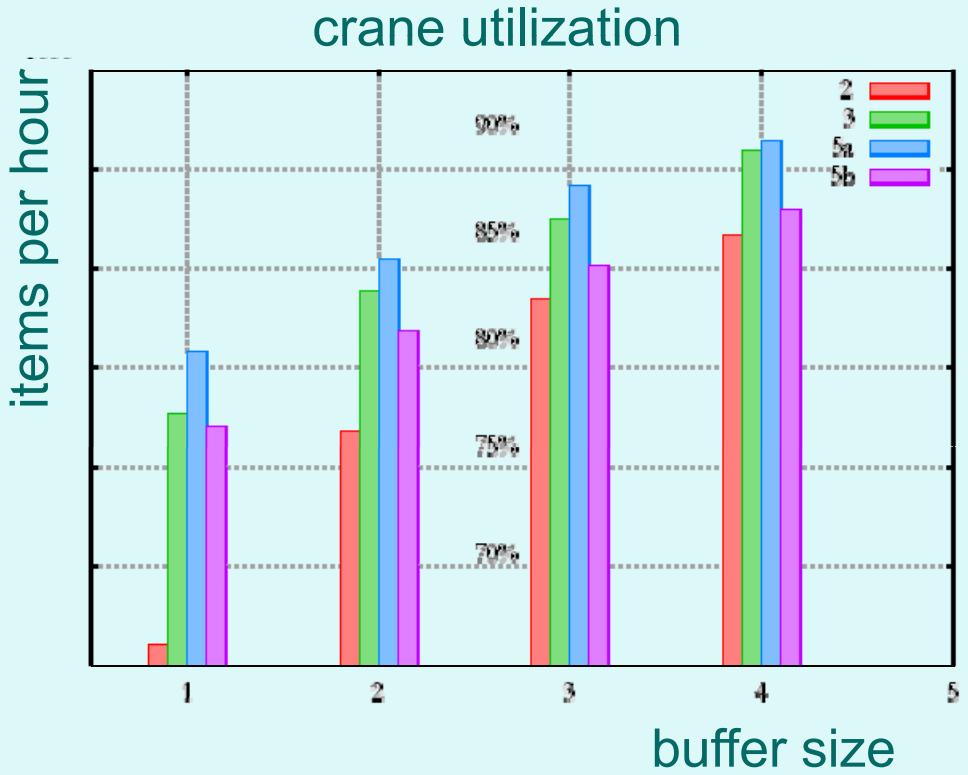
Result

- Model of different variants in 1 day
- First analyses of variants after 2 days

- Observations:
  - discussion about abstraction in buffer-size parameter
  - calibration of model was done w.r.t. other models
  - “we don’t want to know how you did it”



Case 1: in-sequence item retrieval

Model: simulated queuing network

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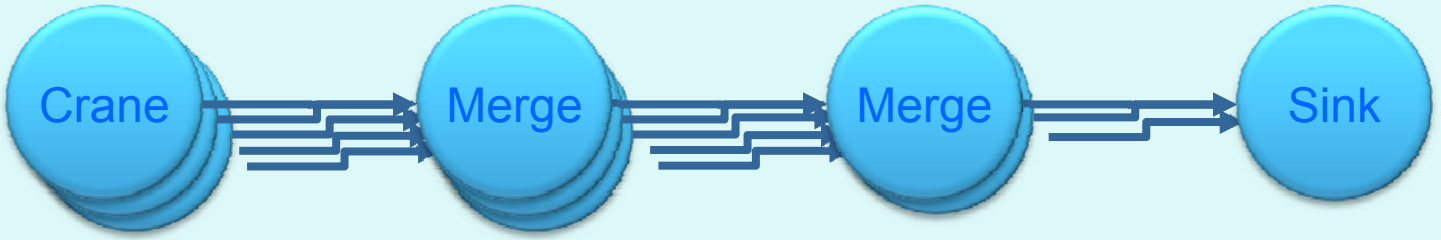


```
while there_is_work do
  p := new(set) setsize(size sample);
  delay EPT * p getsize();
  o!p
od.
```

```
par
  while true do
    [ buffer not full ] i?p;
    buffer put(p)
  od
and
  …
and
  while true do
    [ no buffer empty ] q = ∑ buffers get();
    delay EPT * q getsize();
    o!q
  od
rap.
```

```
while true do
  i?p;
  fileout logto(currentTime,p)
od.
```

Concluding remarks

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- **Simple simulation (just beyond the static calculus)**
  - Accuracy: mainly relative between different variants
  - Effort: very limited
- **Sufficient to give direction to further development**
  - Answer the relevant design question at that moment
  - Focus on that question only
- **Hurdles for transfer**
  - Specific model abstractions
  - Prerequisite knowledge of tools

Case 2: crane performance
context

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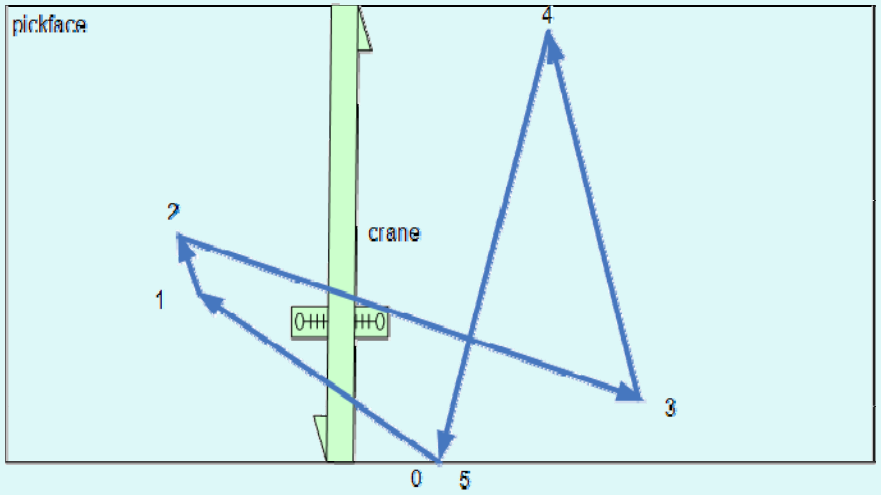
What is the effect of picking sequence on crane performance?



Reality	Model
crane performance, dependent on • route (how many items) • docking & undocking times • acceleration, velocity • loading & unloading times **layout** • height and width • discrete locations	**crane performance** • random route, path length calculation • first: constant velocity second: velocity & acceleration **layout** • height relative to width • continuous locations

Summary of results

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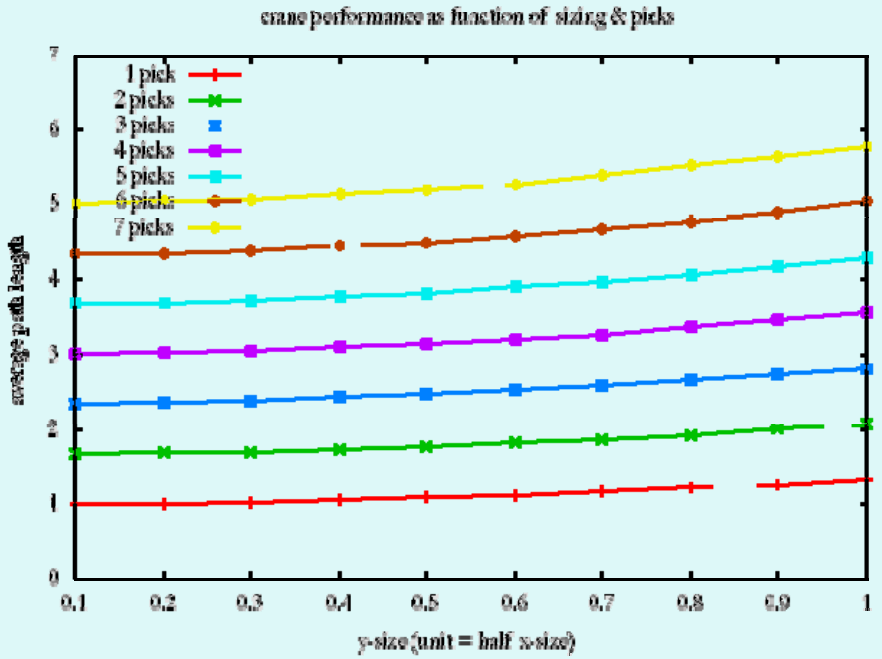
- Results:
  - First model after 2 hours
  - Second model after 1 day

- Observations:
  - Penalty on path length for low number of picks is very limited
  - Calibrated with Excel sheet with defined path calculation



Case 2: crane performance

Model: script involving rand()

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- Model in gawk
  (but anything will do)

```
BEGIN {
  ymax = 1
  x0 = 0
  y0 = 0
  steps = 6
  samples = 10000
}

function cycle(st) {
  x1,y1 = x0,y0
  t = 0
  for ( i=0 ; i<st ; i++ ) {
    if ( i<st-1 ) x2,y2 = 2*rand() – 1, ymax*rand()
      else x2,y2 = x0, y0
    t += max(abs(y2-y1),abs(x2-x1))
    x1,y1 = x2,y2
  }
  return t
}

END {
  srand()
  T = 0
  for ( n=0 ; n<samples ; n++ ) T += cycle(steps)
  printf("%f ",T/samples)
}
```

Concluding remarks

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- **Simple simulation (just beyond the static calculus)**
  - Accuracy: good?
  - Effort: very limited
- **Sufficient to address uncertainty**
  - Answer the relevant design question at that moment
  - Only answer that question
- **Hurdles for transfer**
  - Too much focus on reusability
  - Build it in Excel…

Case 3: compact pick system sizing
sketch of the system

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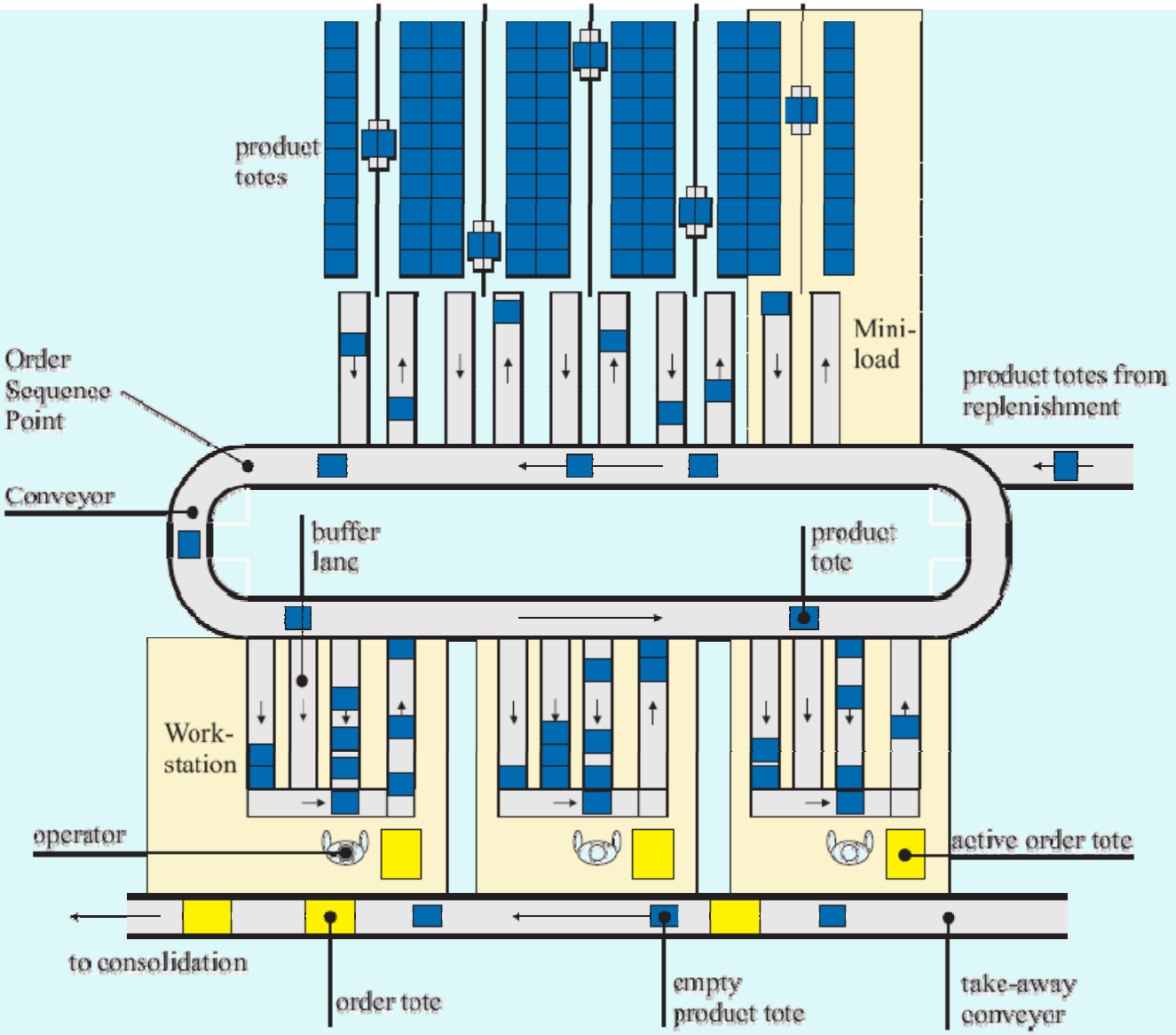

Case 3: compact pick system sizing

Context

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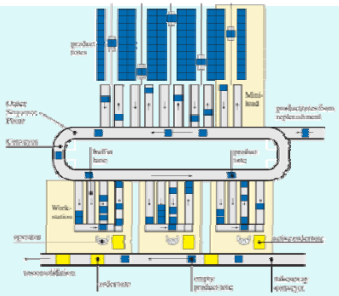
What is the effect of configuration on system performance, buffer utilization, and component utilization?



Reality	Model
ASRS • number, batching, performance statistics • dynamic stock **items** • number per job varies, distribution varies **Transport** • different time-delays for different connections • buffer function **workstation** • number, buffer spaces, performance statistics • # active orders, # open orders • type of buffer **control** • priority rules (job age, sequence, pipeline) • smart order planning	**ASRS** • performance with prob. distrib., batching • no stock allocation **items** • # per job sampled from customer distribution **transport** • Δt ~ connection index • parameterized buffer function **workstation** • performance with distribution, buffer size • # active orders, # open orders • FIFO versus random access **control** • priority rules as in real control • virtually no order planning

Approach

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- **Target group**
  - Sales engineers (quick answers to their questions)
  - System engineers (tool support to provide answers)
- **“Simulation-in-a-box” approach**
  - standard components
  - external input parameters
  - sampled order size distribution
  - self-monitored statistics (run-till-statistics-are-met)
  - retrospect visualization

Model Structure

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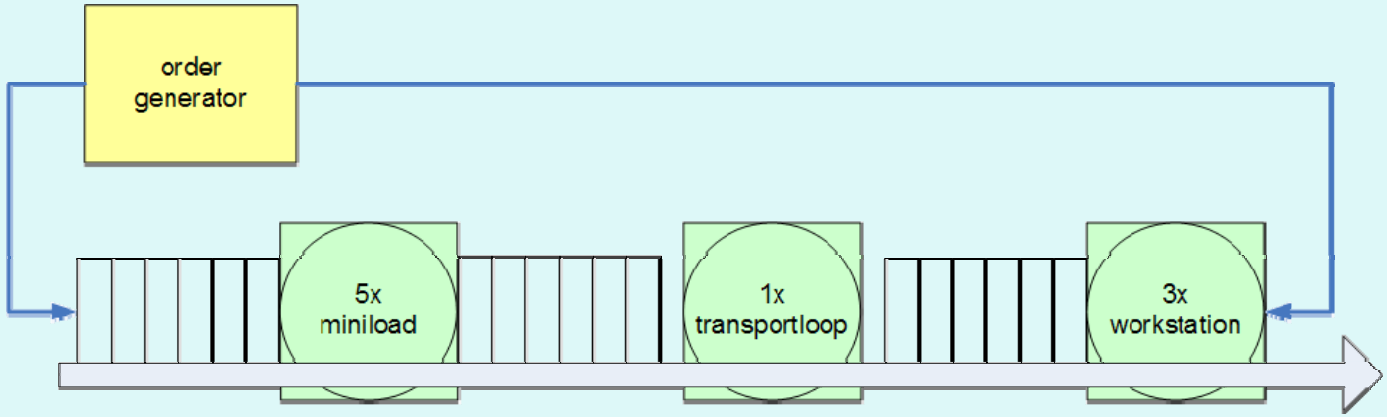
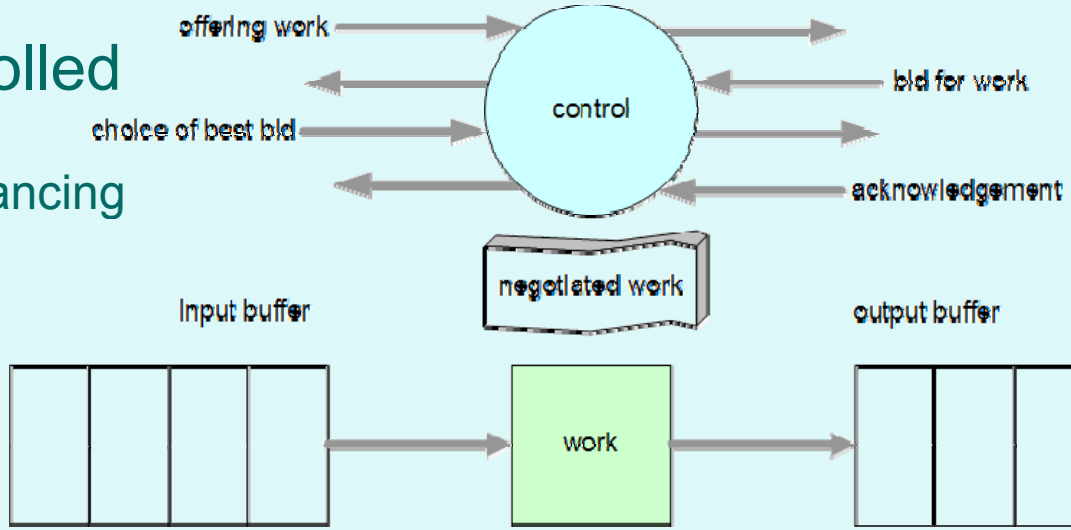
- Basic queuing network

  orders are stock as well as work to be done



- explicitly controlled

  negotiation in order to achieve load balancing



Model input parameters

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For each component: (they all are identical)

- component multiplicities
- input & output buffer sizes
- averages and spreads of triangularly distributed process times
- batch sizes
- type of input buffer (FIFO or SEQ)
- # open orders, # active orders
- process time dependency on connection
- availabilities & repair times
- priority rule (piece of code, not parameterized for now)

Example graphs

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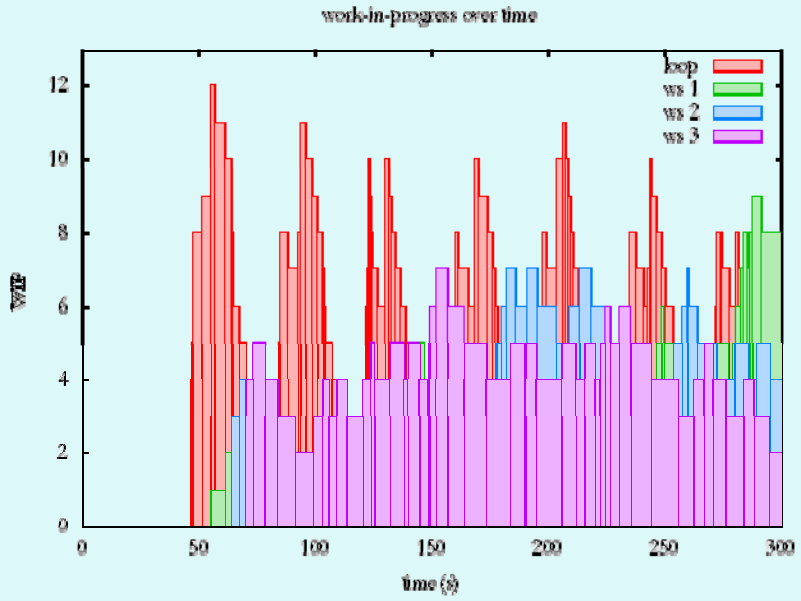
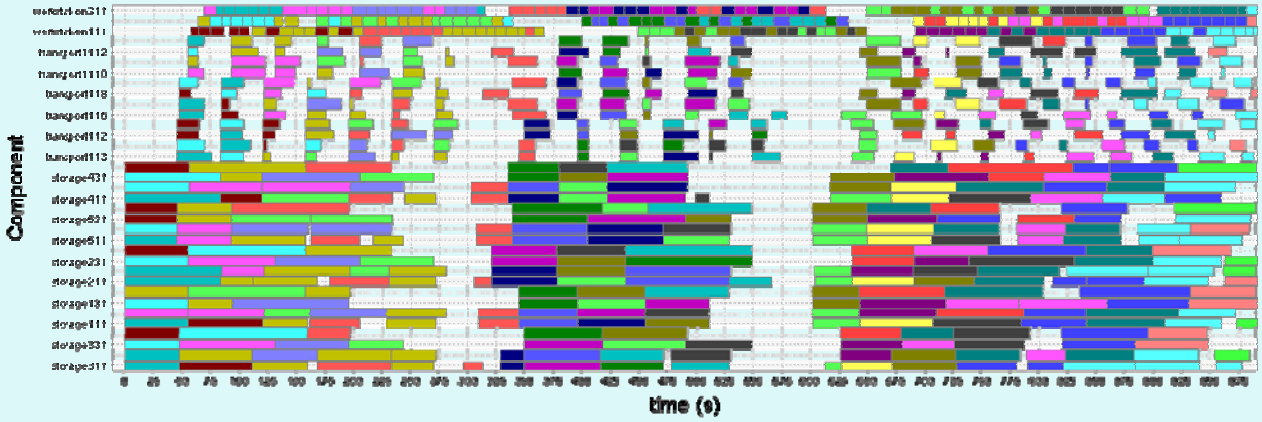
- Detailed log-files to study and validate system behavior over time



- Gantt charts representing tasks carried out by different system components



Results & concluding remarks

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- **Approximately 3 weeks of work**
  - Validation has to be completed
  - Easy-to-use front-end has to be connected
- **For sales engineers**
  - Averages, maxima of throughput, work-in-progress, flow-time
  - For every component separately
  - For nearly all occurring system variations
- **For system engineers**
  - Detailed analyses
- **Hurdles for transfer**
  - Prerequisite knowledge of tools

Concluding remarks

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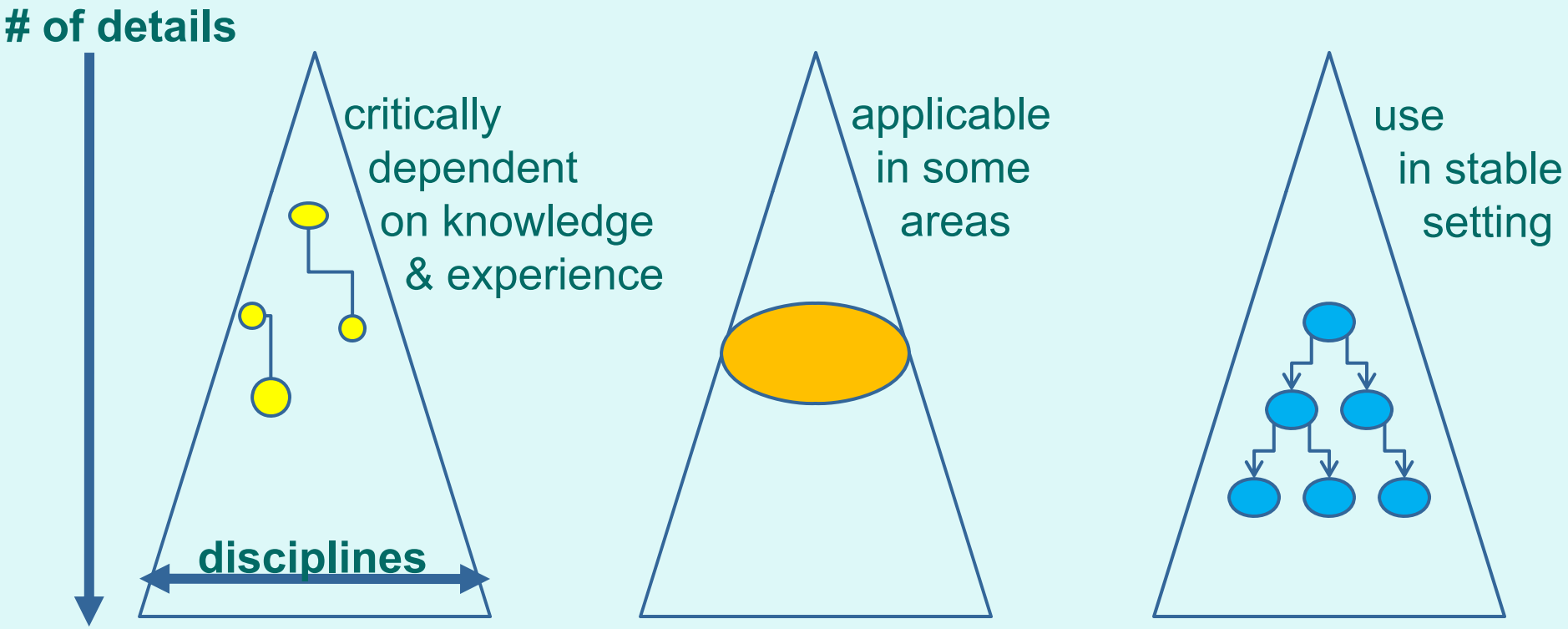
Three different ways of using models in system design



Supportive to critical decision making

Automatic design space exploration

Model-driven: generate design artifacts