TECHNISCHE UNIVERSITÄT DRESDEN

Dresden University of Technology
Department of Computer Science
Chair for Modeling and Simulation

M&S Modellierung und Simulation

Benefits and Drawbacks of Simple Models for Complex Production Systems

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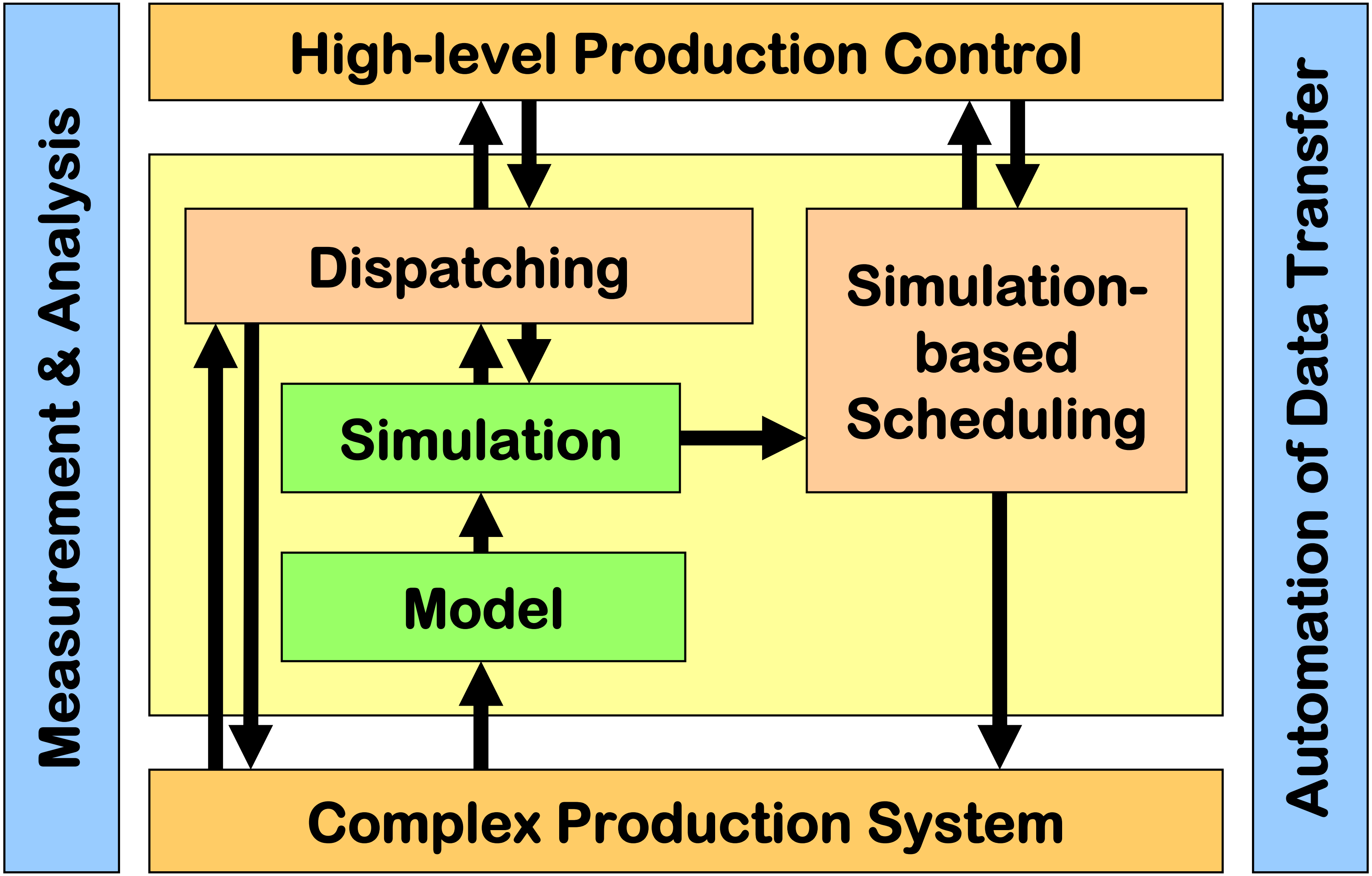
Dresden University of Technology

- ▷ Dresden located in the state Saxony, often called “Silicon Saxony” (factories from Infineon, Qimonda, AMD, and ZMD; lots of suppliers)
- ▷ Largest German University of Technology
- ▷ Focus on Computer Science, Electrical Engineering, and Mechanical Engineering
- ▷ About 35,000 students, 3,000+ students in Computer Science, 600+ beginners in winter semester 2006/2007
- ▷ Faculty of Computer Science consists of 28 chairs
- ▷ Institute of Applied Computer Science has 5 chairs, dealing with different aspects of factory planning, control, and automation

Research Overview



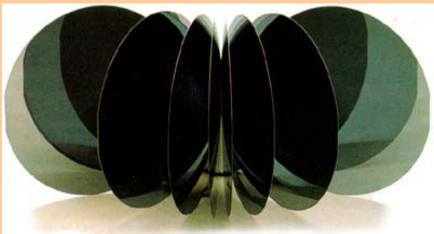
Cooperations

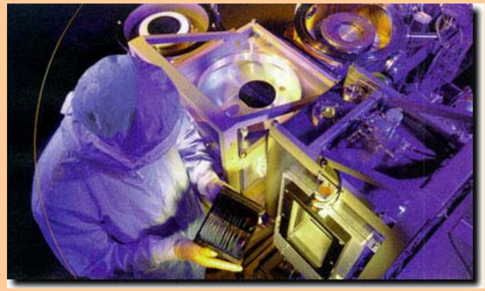
- **Industry**
  - Infineon Technologies AG, Munich and Dresden
  - AMD Saxony LLC & Co. KG, Dresden
  - KBA Planeta, Radebeul (Offset Printing Machines)
  - Airbus Deutschland GmbH, Hamburg

- **Academia**
  - Arizona State University, Tempe, AZ, USA
  - Singapore Institute of Manufacturing Technology
  - Georgia Institute of Technolgy, Atlanta, GA, USA
  - FernUni Hagen, Germany
  - Fraunhofer IPA, Stuttgart, Germany

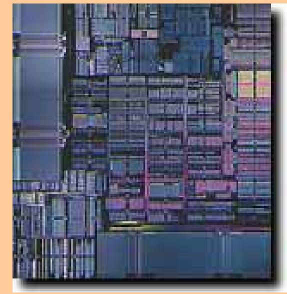
Semiconductor Manufacturing

Front End

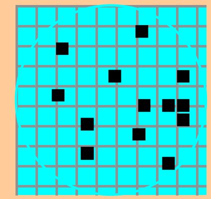




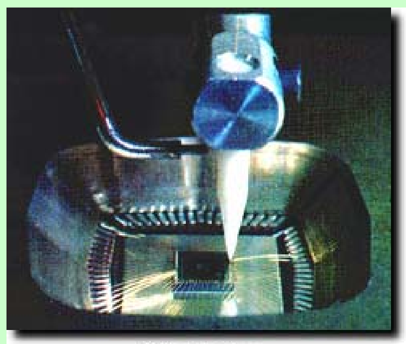
Wafer Fab

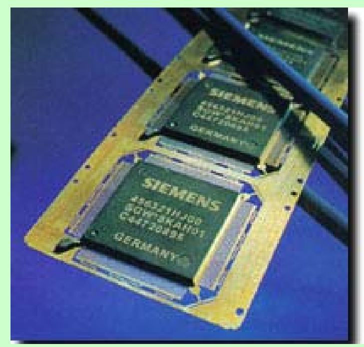


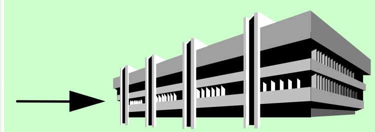
Probe



Back End



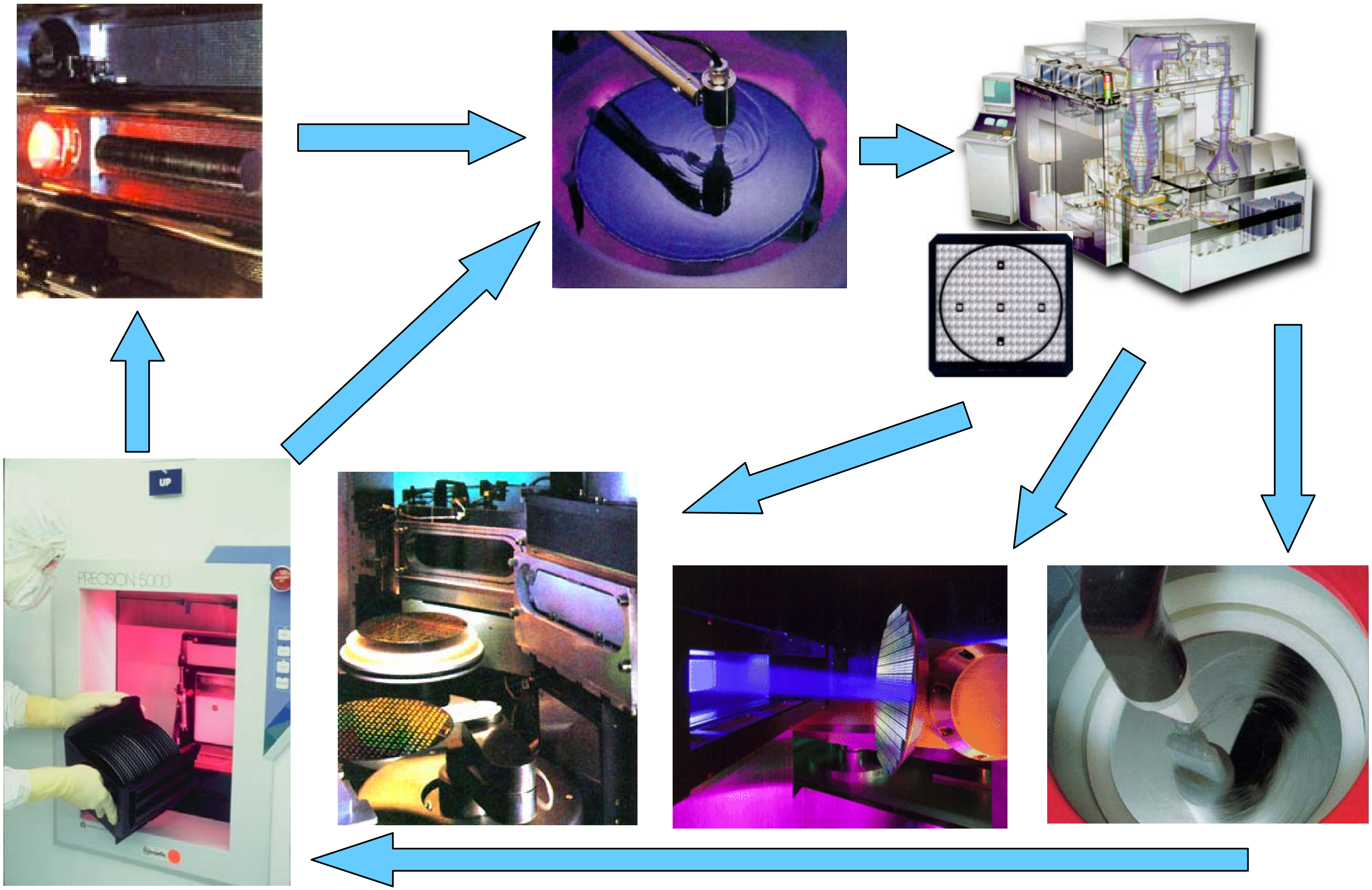




Assembly

Test

Flow of material



Fotos: Fullman-Kinetics, Varian, Sematech International

Characteristics of wafer fabrication facilities

- ▷ Large number of processing steps, typically several hundreds
- ▷ Large number of tools of different types: photo equipment, ovens, etching equipment, ion implanters, ...
- ▷ Wafer are build up in layers: reentrant flow of material, jobshop type way of production
- ▷ Machine breakdowns (typical availability: 70-90%)
- ▷ Auxiliary resources, e.g., reticles (photo masks)
- ▷ Batch tools with complex batching criteria
- ▷ Sequence dependent setups

Important performance measures

- ▷ Cycle time: low
- ▷ Output: high
- ▷ Machine utilization: high
- ▷ Inventory (work in process, WIP): low
- ▷ Yield (percentage of good dies on a wafer): high
- ▷ Cost per die: low

Conflicting goals!

Motivation for simple models

- Traditionally, only full detail models used for operational planning and control of semiconductor fabs

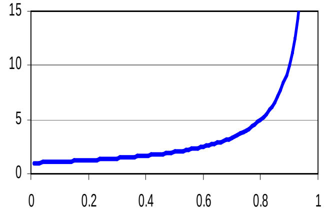
- Consequences:
  - Long run times of simulation experiments
  - Long run times of scheduling algorithms
  - Too complex to be included in enterprise models for SCM (Supply Chain Management)

- Need for simple fab models

Simple modeling approaches

▷ Requirements

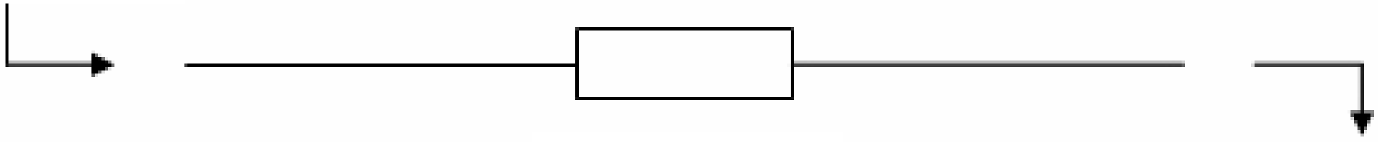
- Correct representation of characteristic curve (cycletime-over-utiliziation curve), i.e., typically 1/(1-utilization) shape



- Same cycle time distributions as for real fab
- Mimic typical behavior of fab over time

▷ Very simple model: **cycle time distribution**

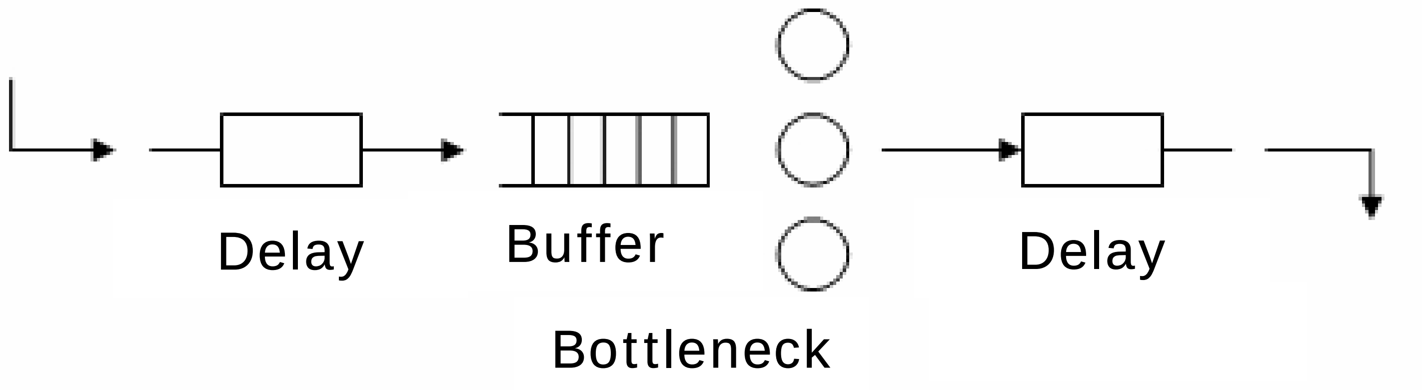
- Does not depend on utilization
- Has no capacity



Delay

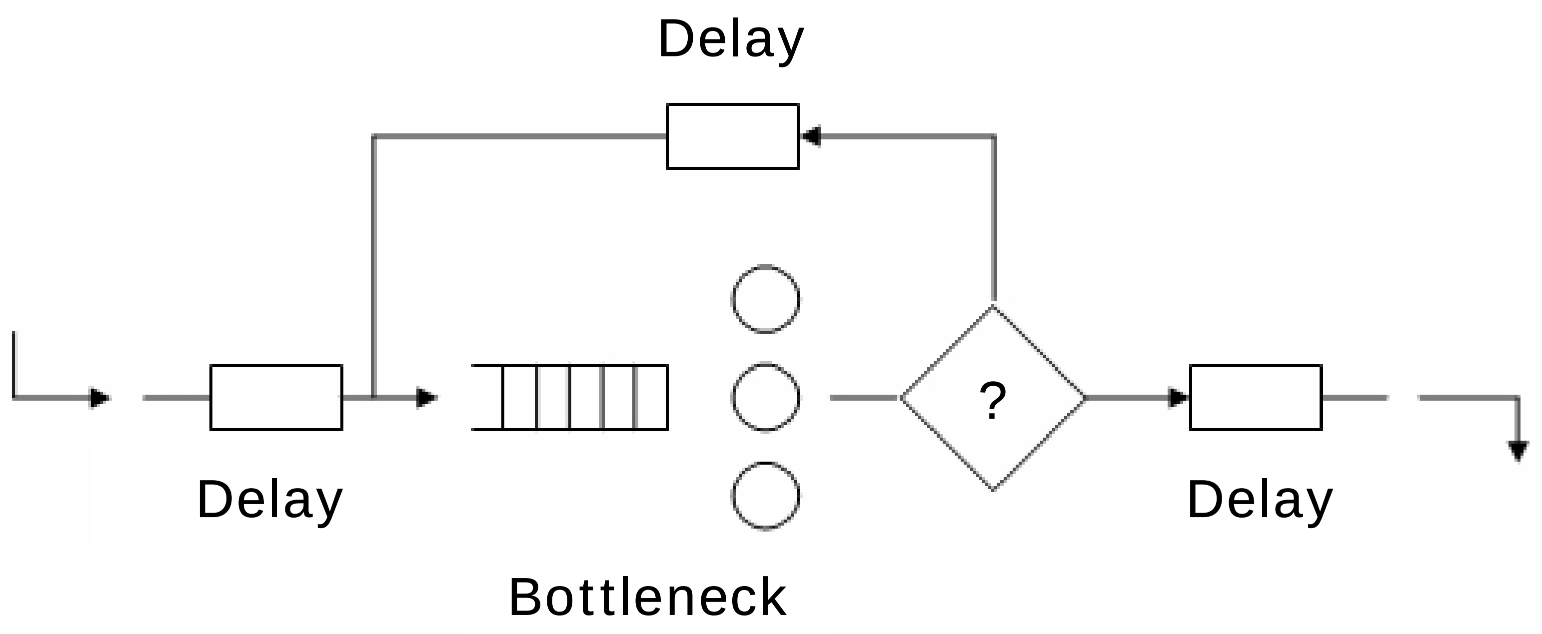
Simple modeling approaches

- ▷ **Simple queuing system**
  - Behavior over time not appropriate
  - In general, shape of characteristic curve problematic



Simple modeling approaches

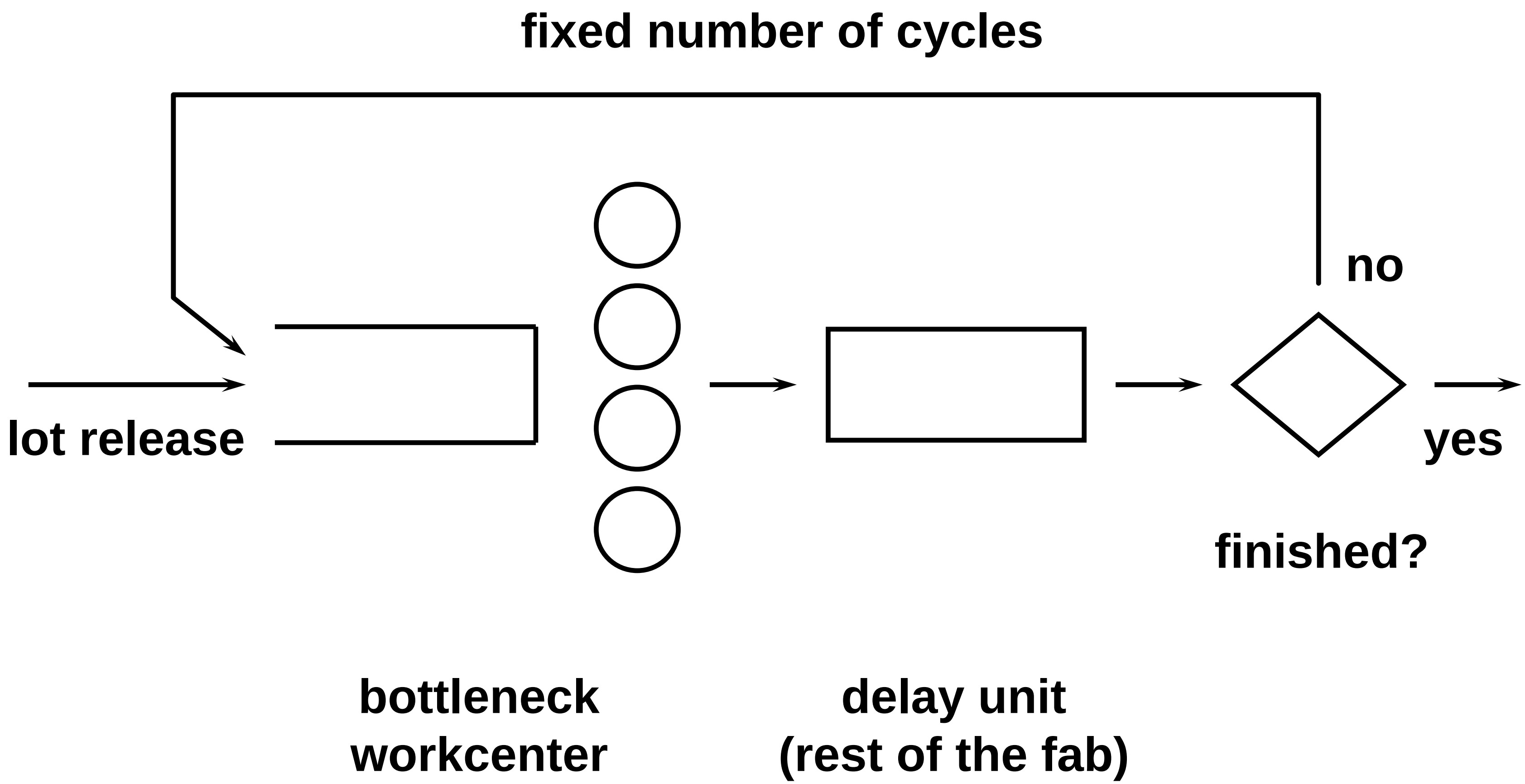
- **Simple queuing system with loop**
  (re-entrant flow of material)



Mimic behavior of real fab

- Goal of the study: **Estimate the transient behavior of a wafer fab after recovery from a catastrophic failure**
- Motivation: fab engineers reported that large amounts of WIP are present in the fab even weeks after end of repair
- Problem of the analysis: estimation of the required inventory curves not feasible with full model; hundreds of replications of experiment needed

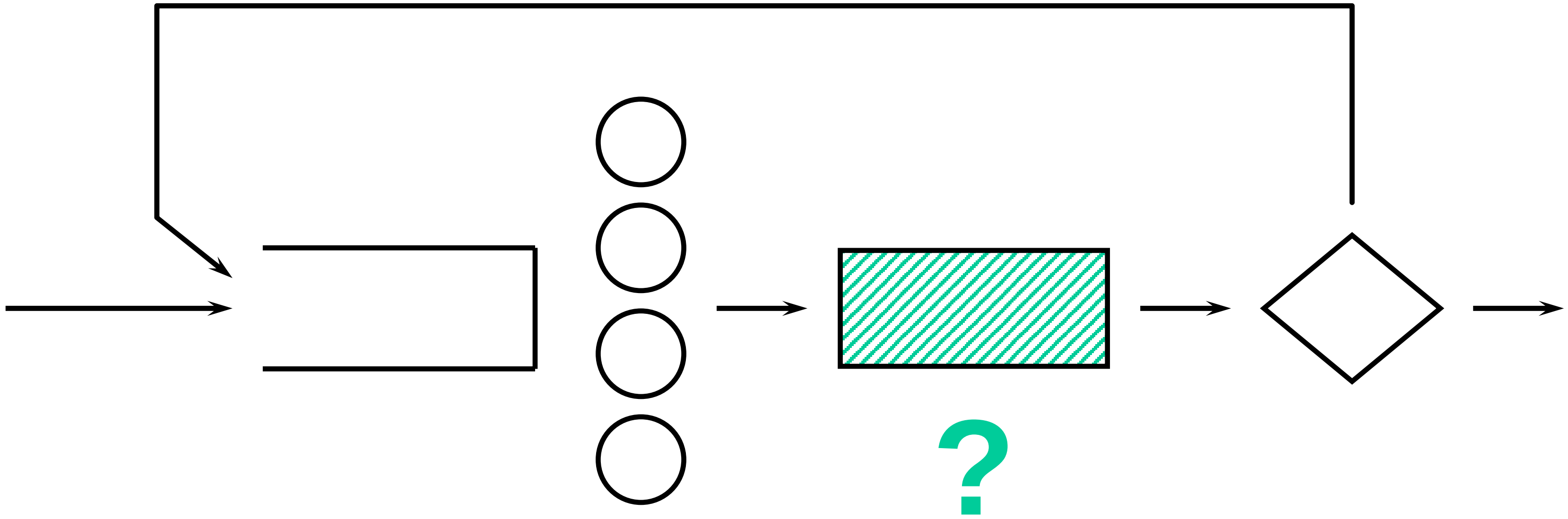
Simple fab model



Model details

- ▷ Dispatching strategies:
  - FIFO
  - Critical Ratio
  - Slack Time
- ▷ Delay time distributions of the delay unit
- ▷ Lot release policy
- ▷ Partial bottleneck breakdowns

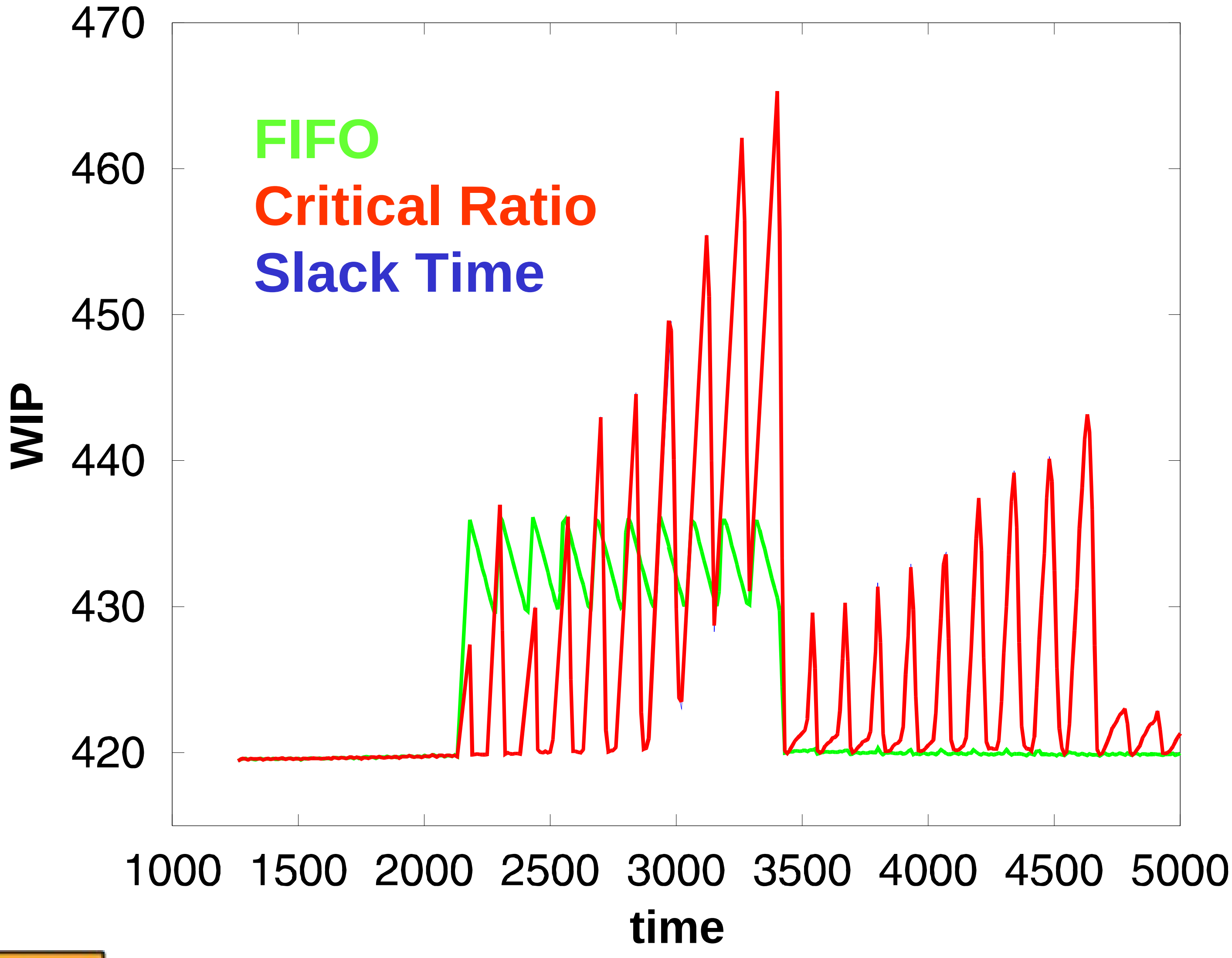
Modeling the Rest of the Fab



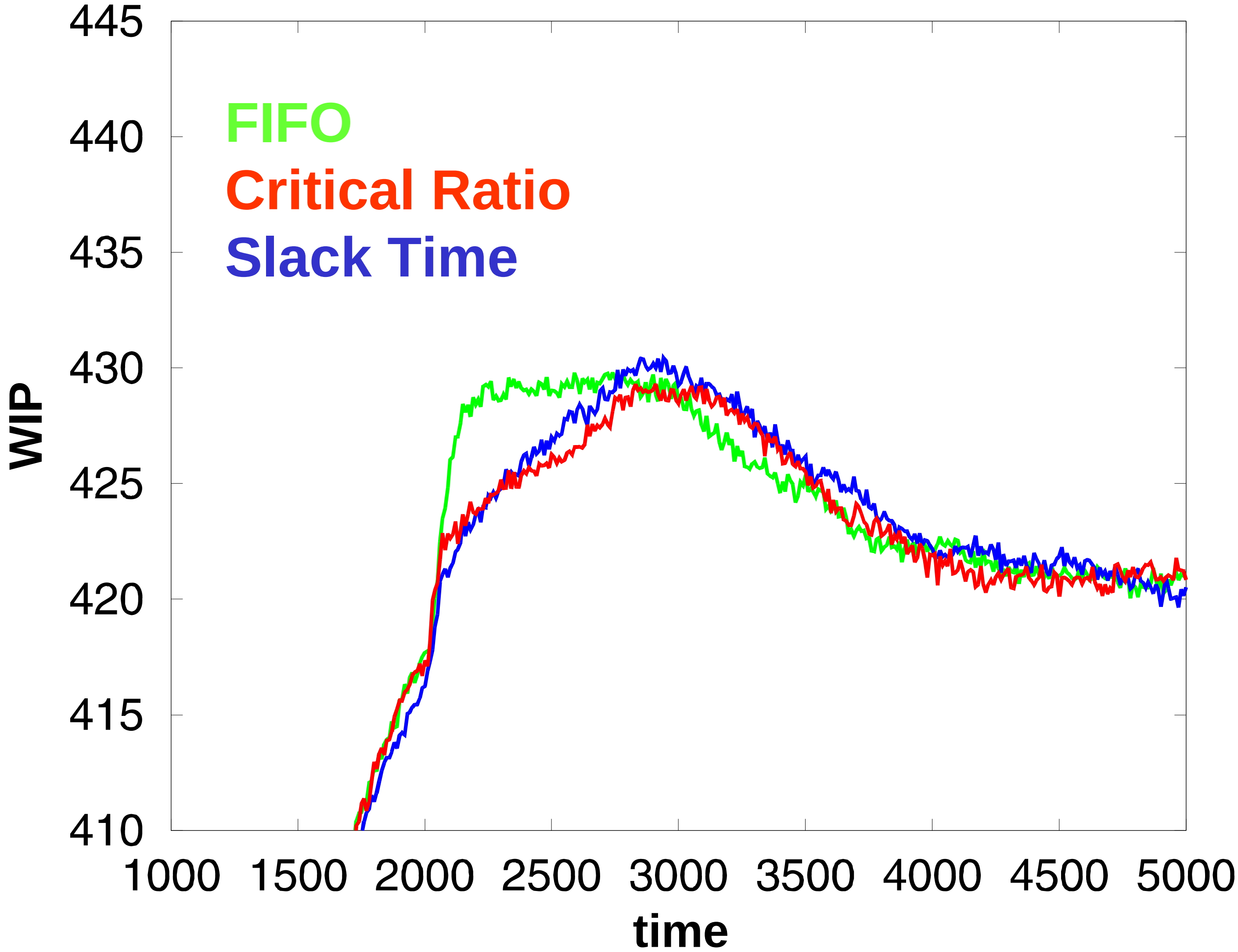
Delay time distributions

- ▷ Constant amount of time for sum of processing times
- ▷ Distributions of different variability for sum of non-processing times (waiting times, transport times, etc.):
  - Constant (coefficient of variation: 0.0)
  - Erlang-5 (coefficient of variation: 0.447)
  - Exponential (coefficient of variation: 1.0)
- ▷ Independence of consecutive and parallel delays assumed

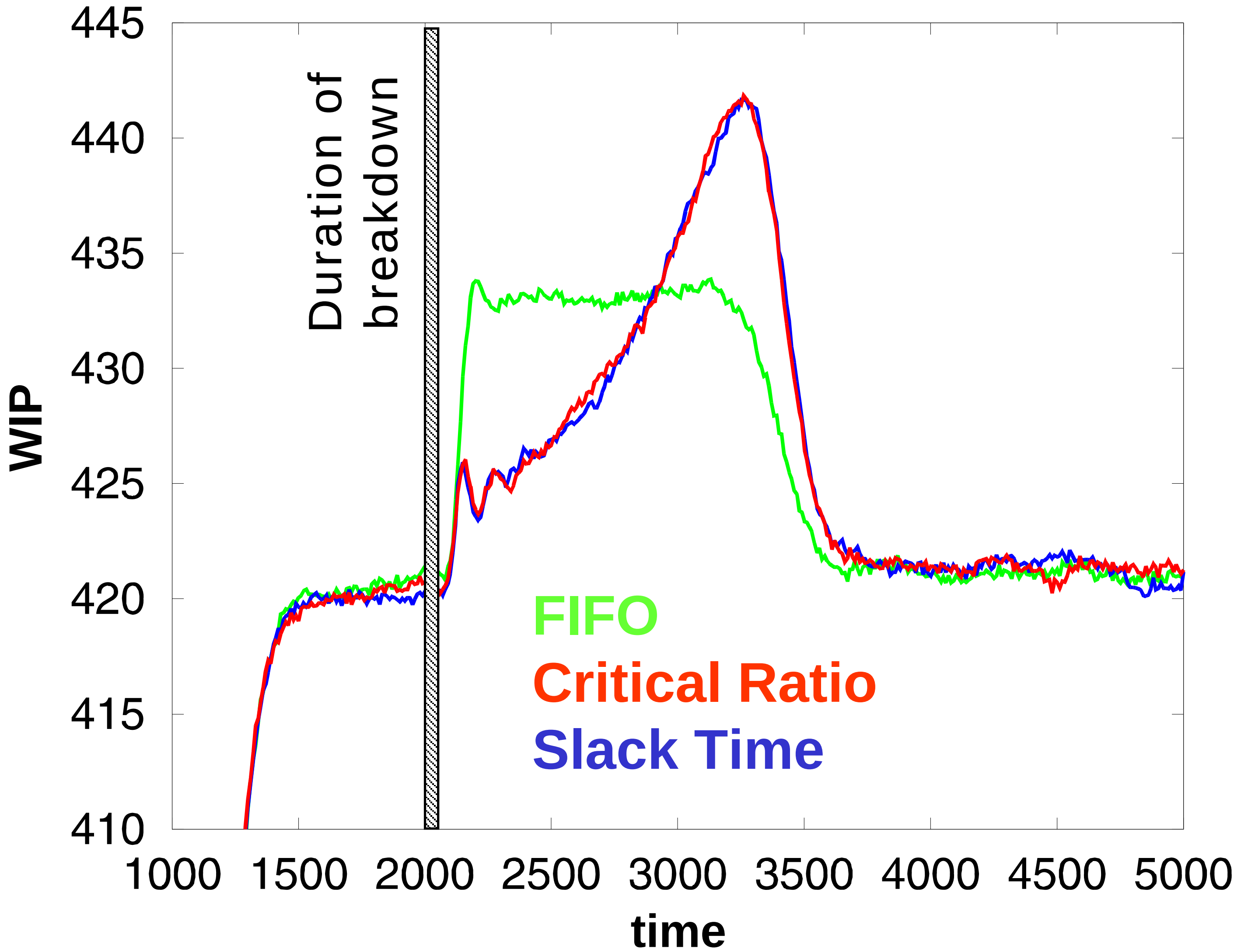
Constant Delay



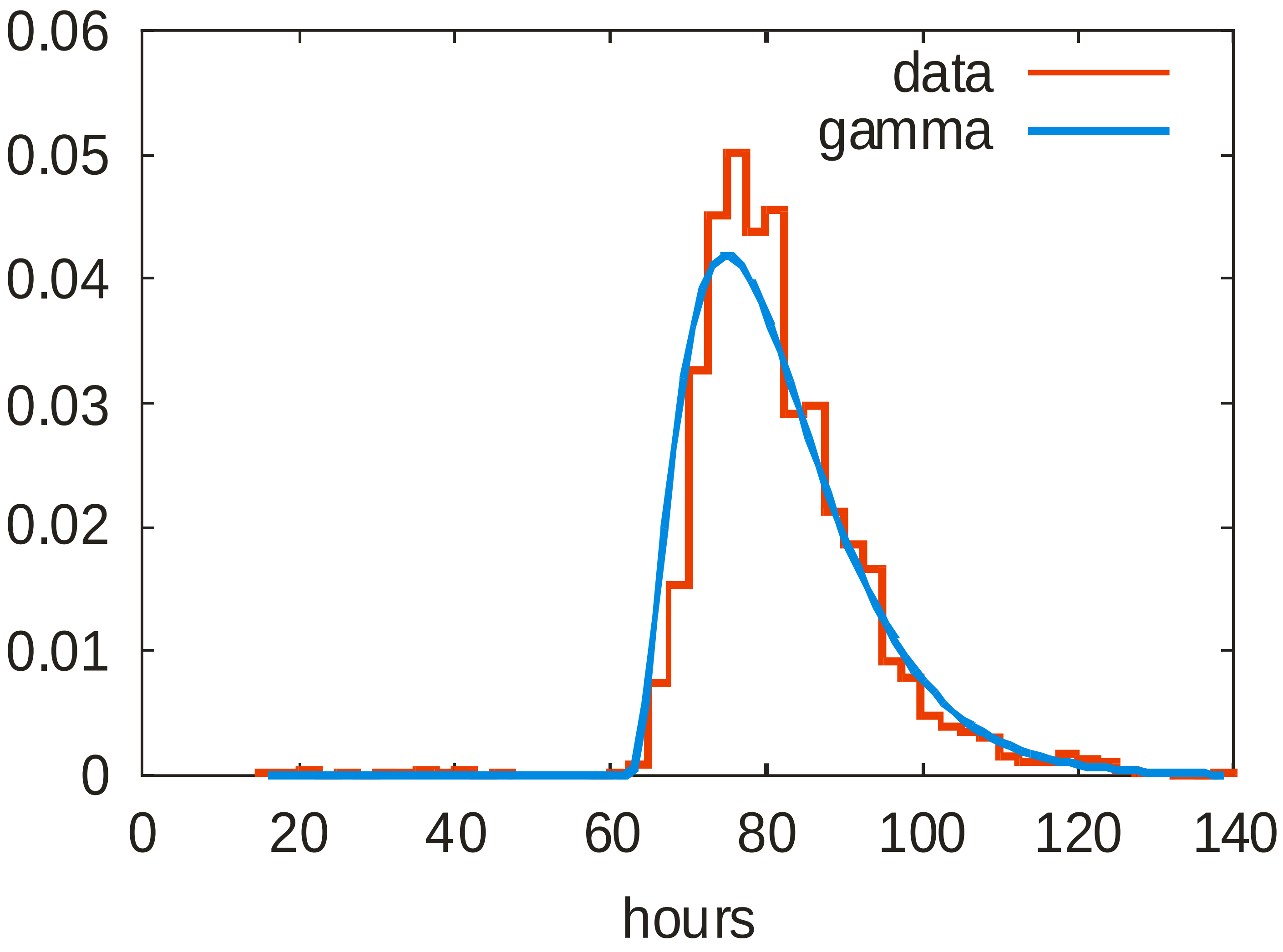
Shifted Exponential Delay



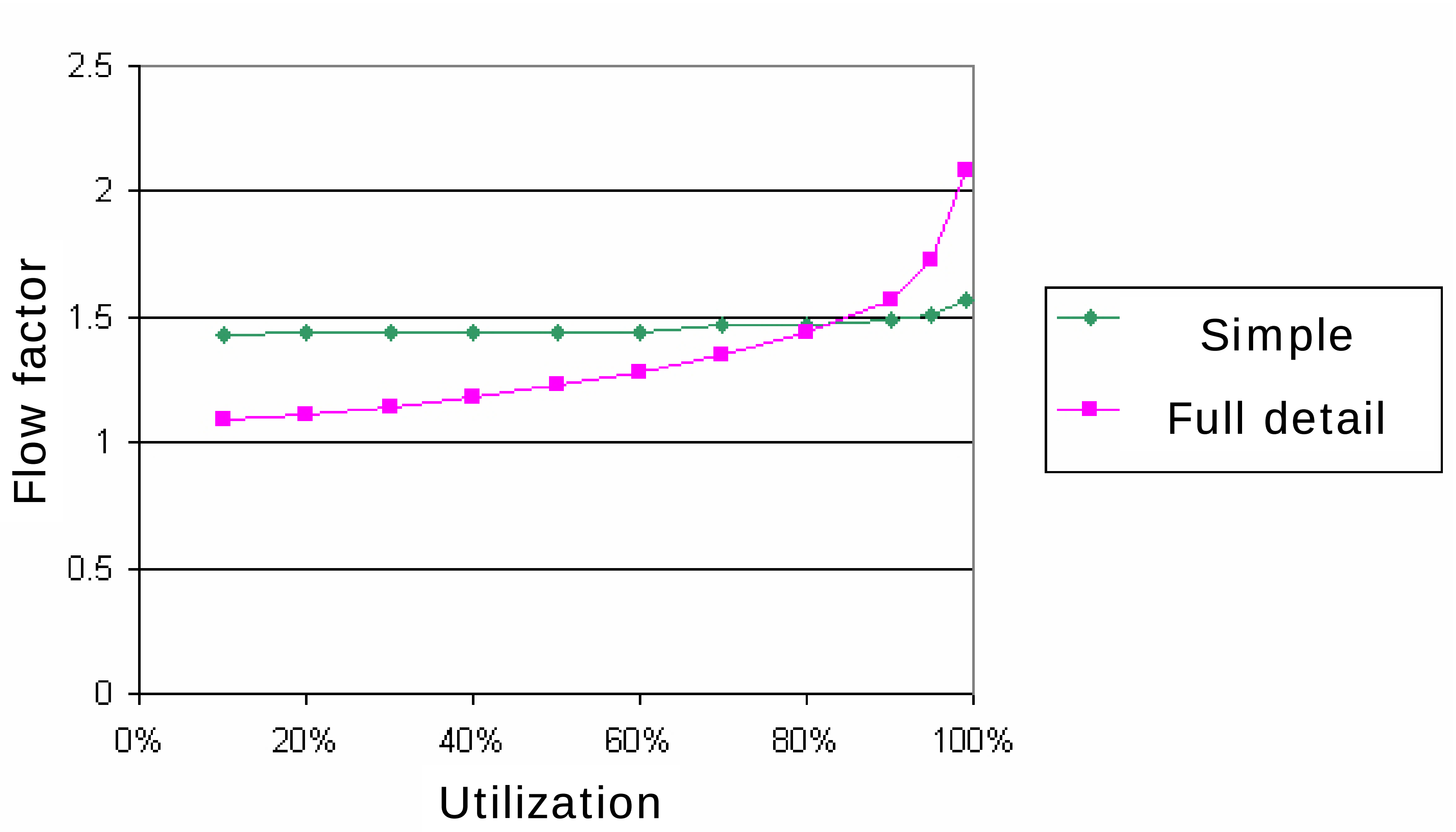
Shifted Erlang Delay



Delay Distribution from Real Data

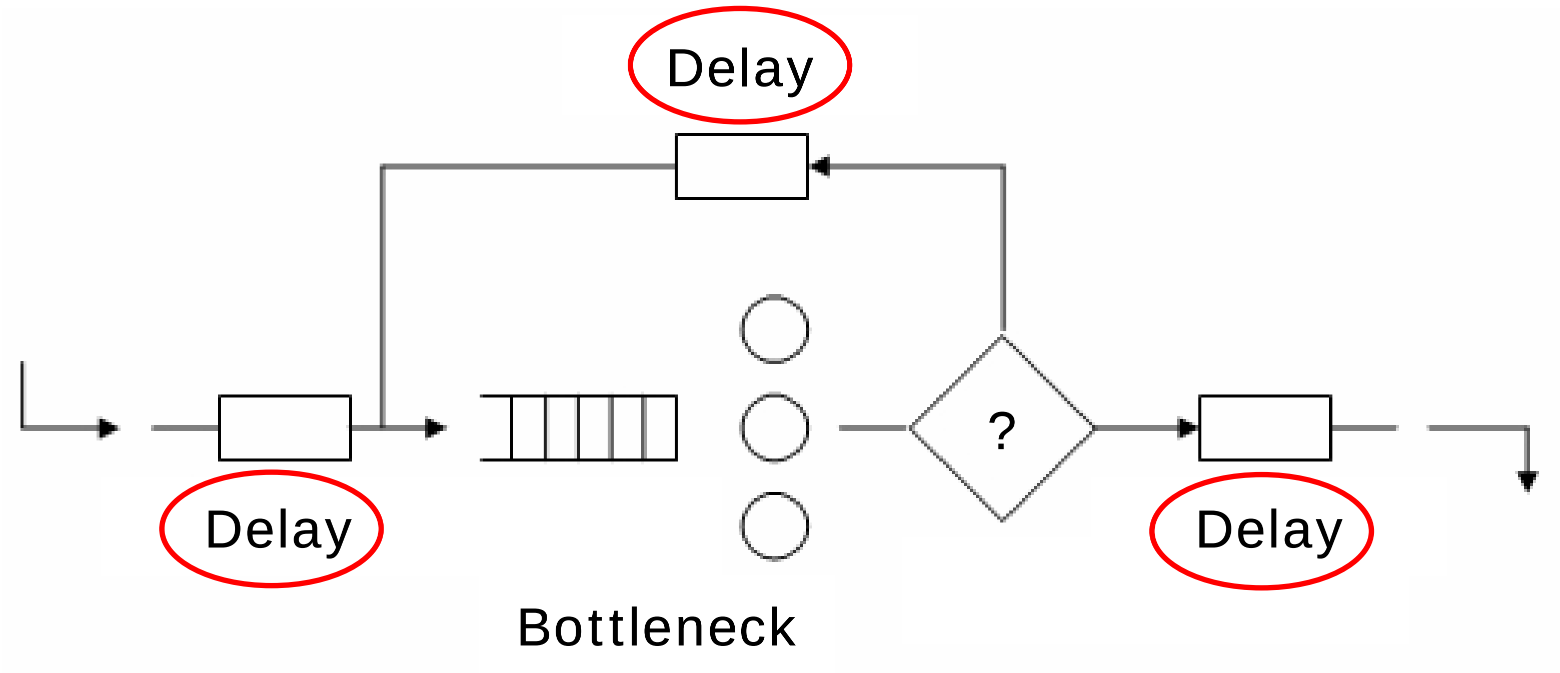


Characteristic curve



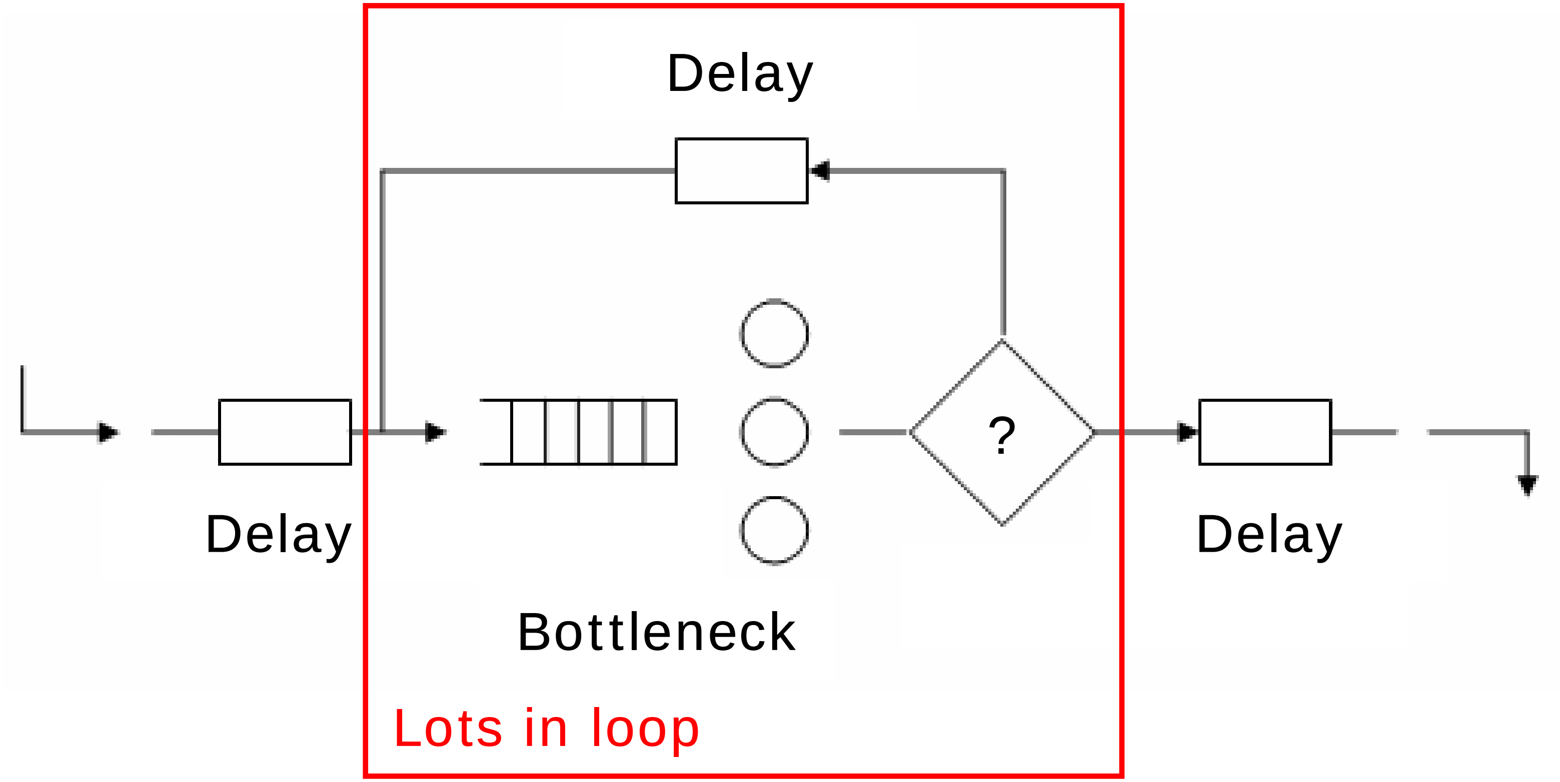
Model improvement approach

- Make delays load dependent!
- But how to measure load?



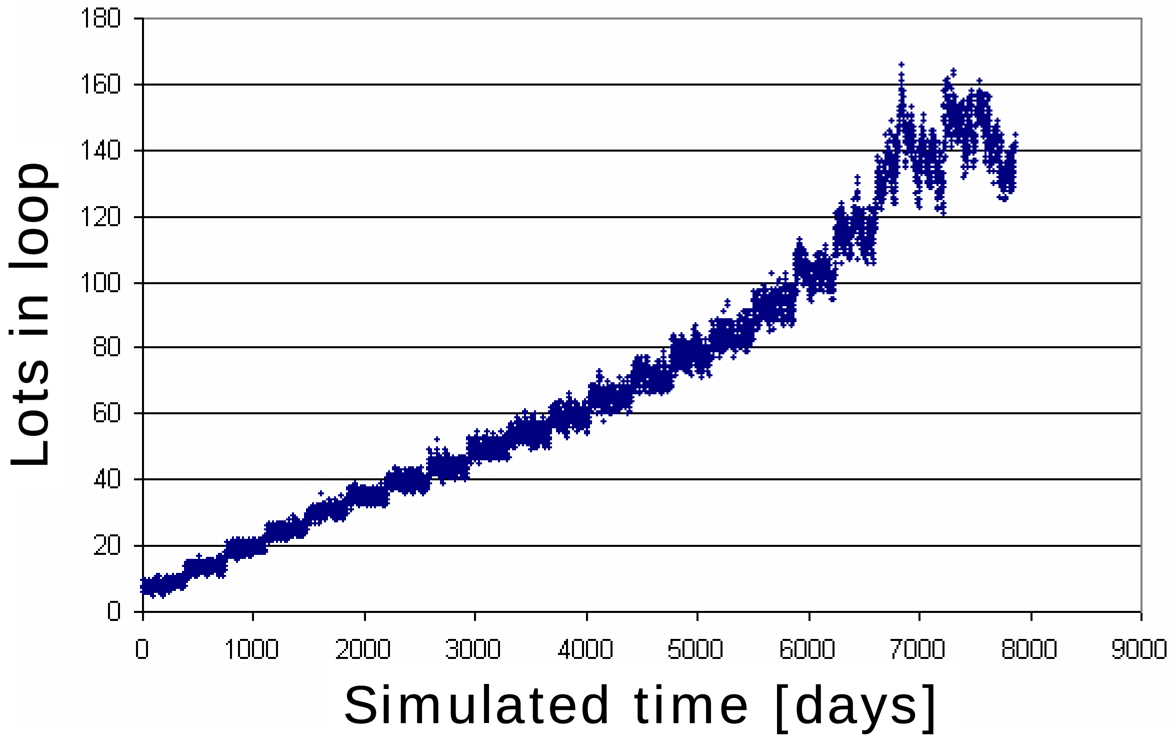
Load measurement

- ▷ Simply count lots in loop!

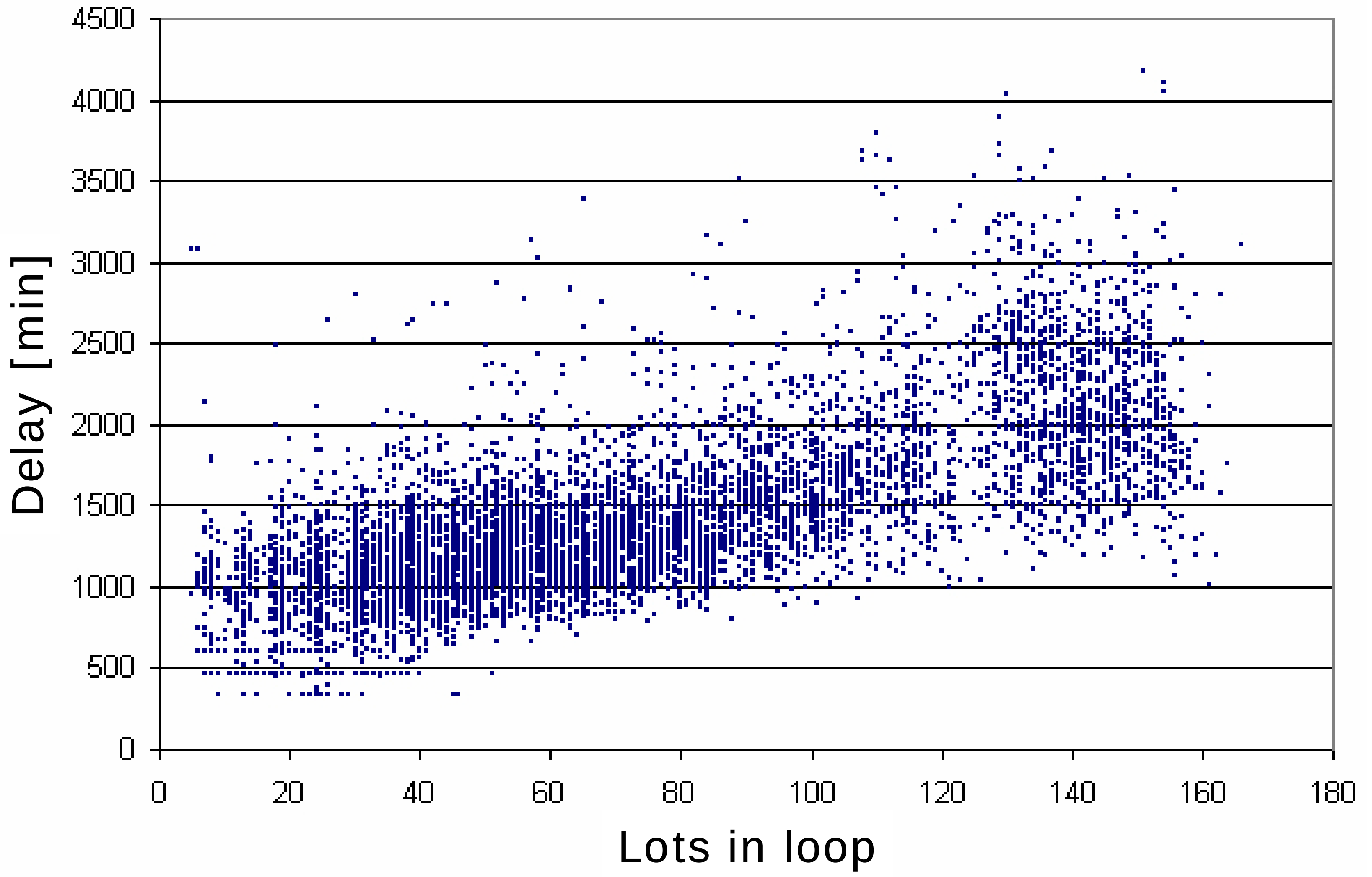


Generation of the load dependent data

- Very long simulation run with stepwise (5% steps) increase of fab load
- Collection of the delays for given range of lots in loop (interval width of 5 lots)

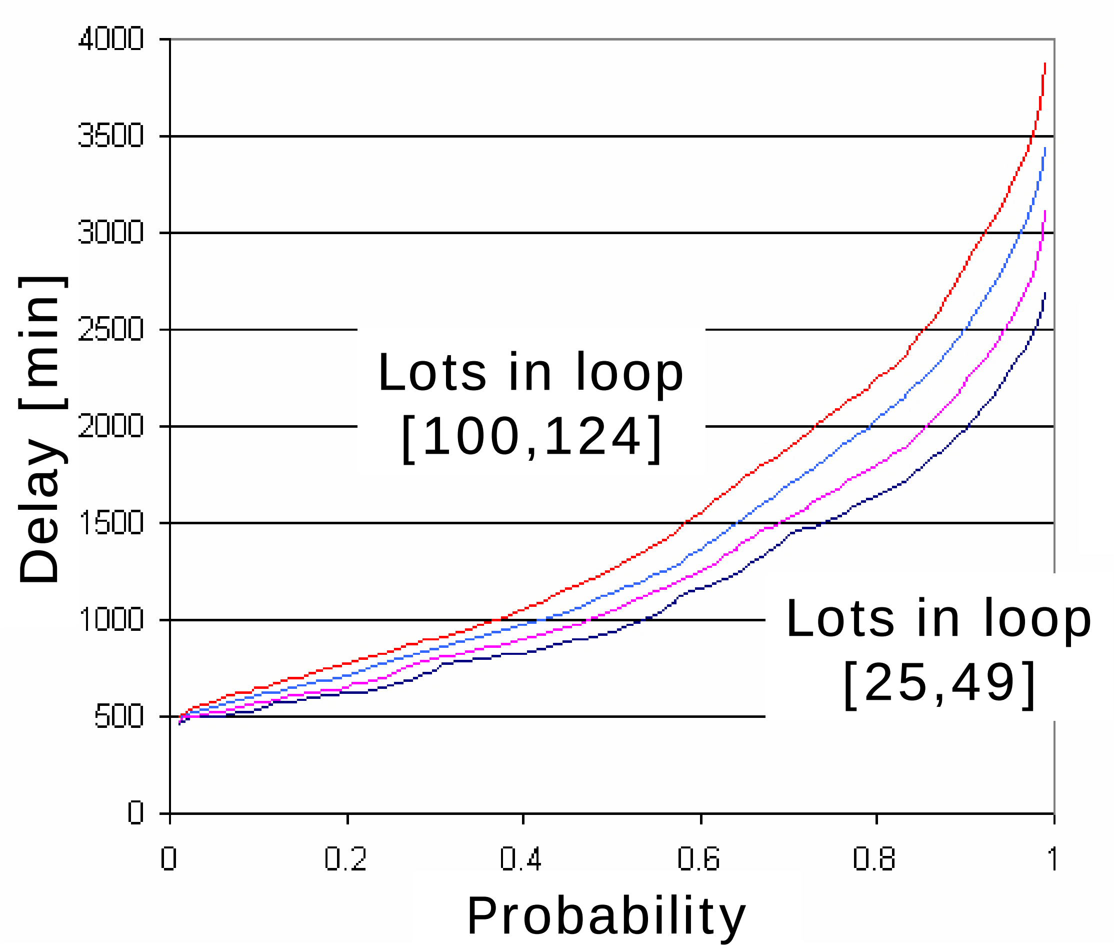


Load dependent “loop” delays

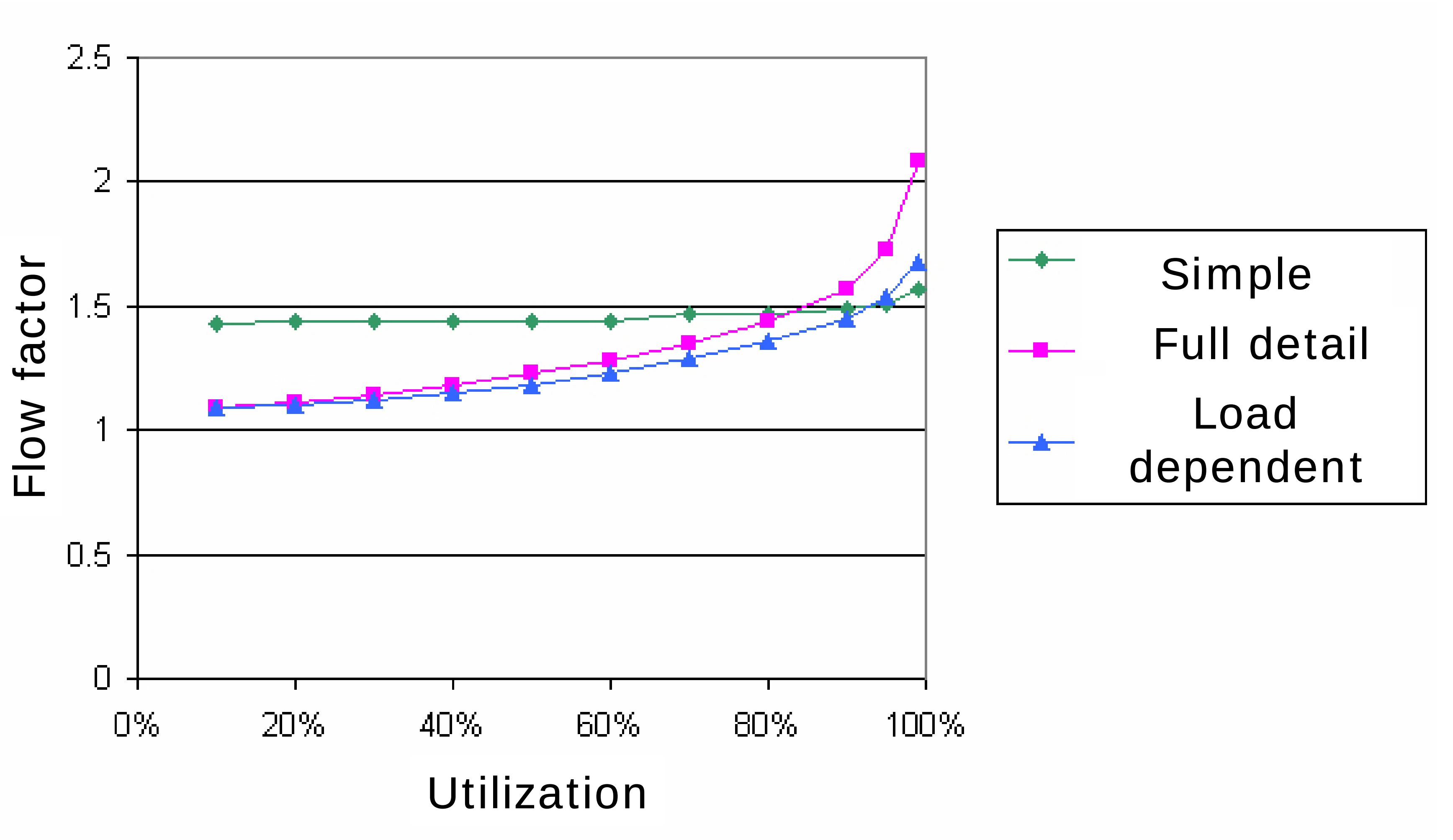


Delay time percentiles

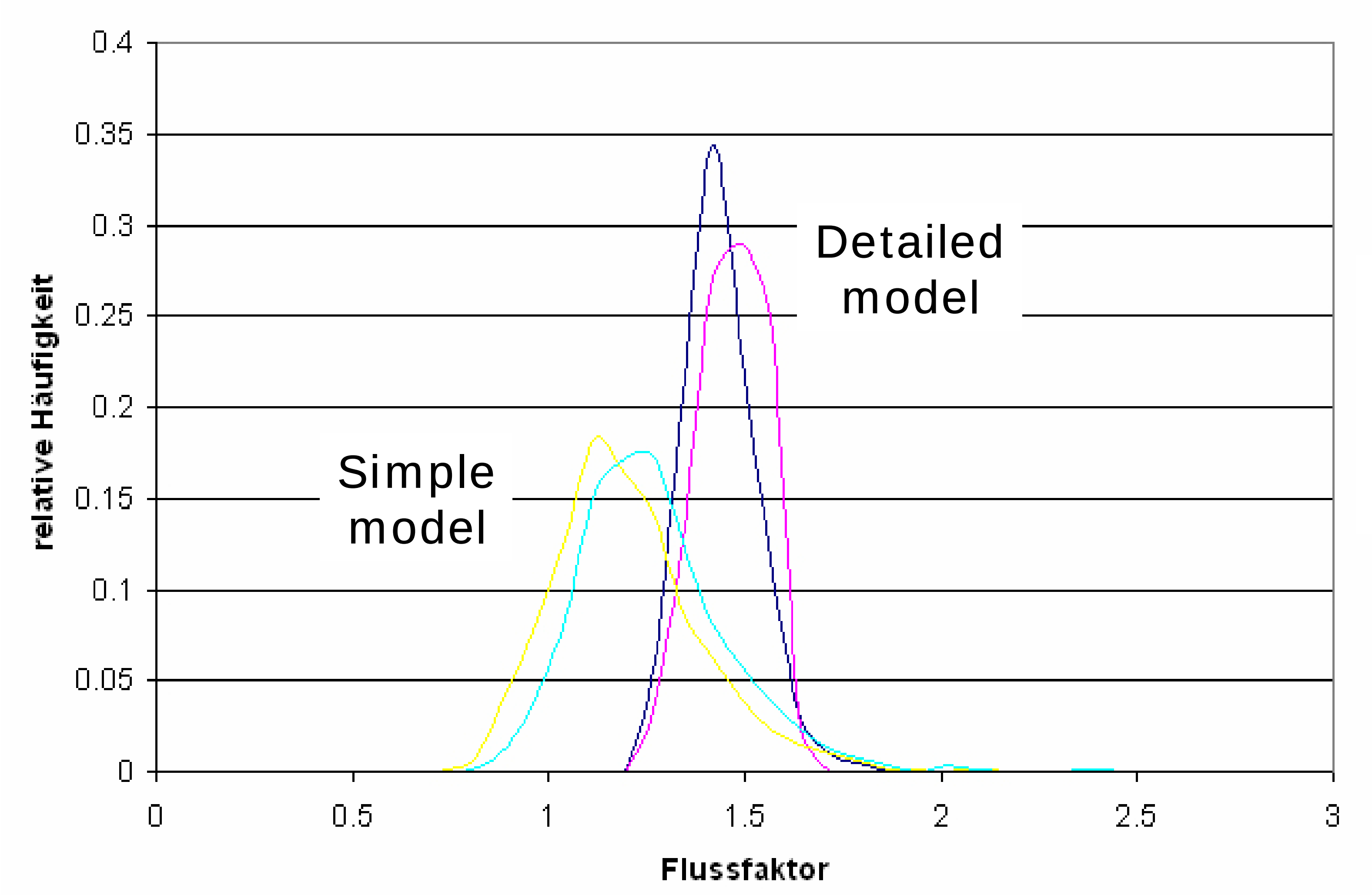
- ▷ In most cases, very close to exponential (correlation > 90%)



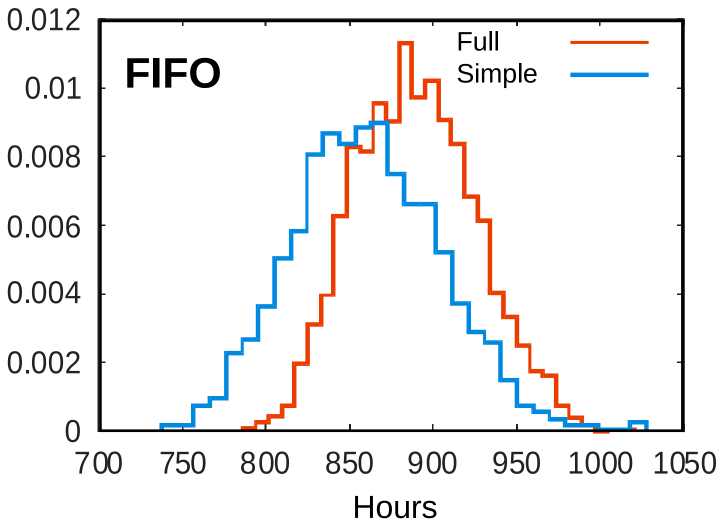
Improvement of the characteristic curve

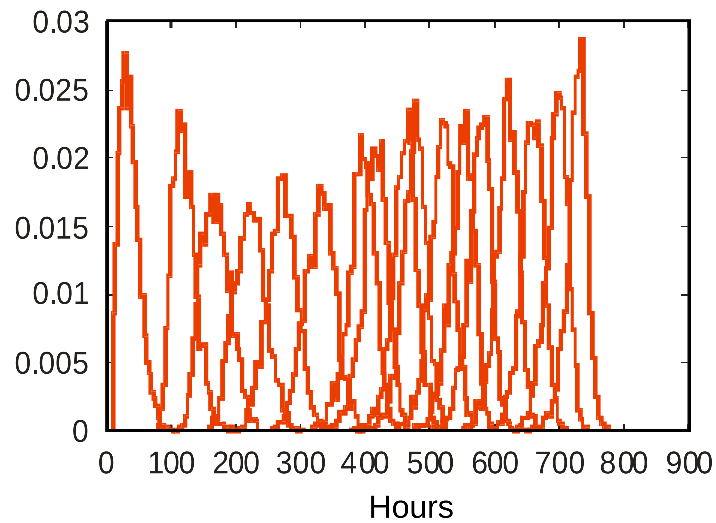


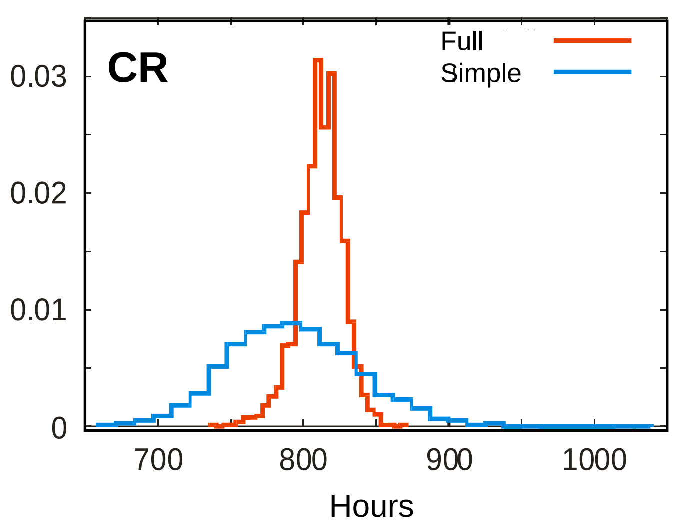
Estimation of cycle time distributions

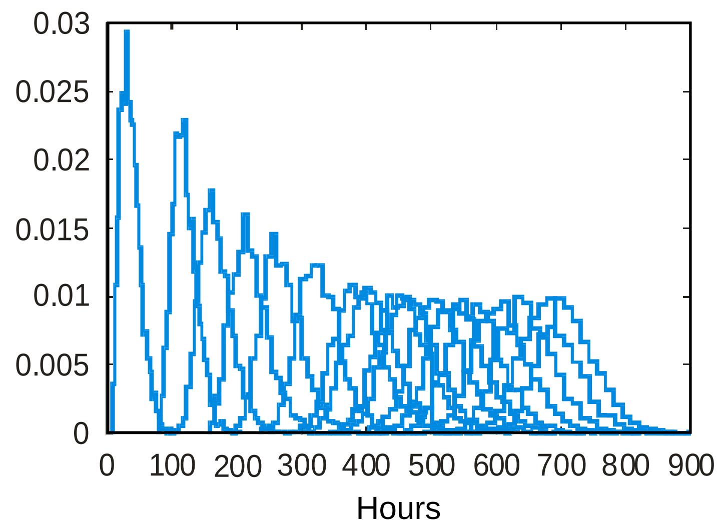


Estimation of cycle time distributions









Conclusions

- Simple models useful for analyzing and understanding complex production systems
- Not a tool for beginners
- Not appropriate for all problems
- Pitfall of oversimplification
- Simplification must not be the goal but only the method to reach the goal
- Keep the model as simple as possible but not simpler!