Production Systems Engineering for Factory Floor Management

Lecture 1: INTRODUCTION AND COURSE OVERVIEW

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Outline

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1.1. Introduction

1.1.1. PSE: General description

- ***Production Systems Engineering*** (PSE) is an emerging branch of Engineering intended to uncover fundamental principles governing production systems and utilize them for analysis, continuous improvement, and design.
- Productions systems are machines, material handling devices, and personnel arranged to produce the desired product.
- The machines are unreliable, the material handling devices (buffers) have finite storing capacities, and the personnel may exhibit less than optimal performance.

1.1.1. PSE: General description (cont)

- All problems considered in PSE have originated on the factory floor; their solutions have been implemented on the factory floor. Many of these implementations serve as case studies for PSE.
- The main results of PSE have been summarized in the textbook: J. Li and S.M. Meerkov titled, *Production Systems Engineering*, Springer, 2009.
- An industrial version of this textbook titled *Production Systems Engineering for Factory Floor Management* (by J. Li, S.M. Meerkov and L. Zhang) is to appear by the end of 2012.

1.1.2. PSE: Purpose of the course

- **The purpose of this course is to describe the main techniques of PSE with the emphasis on practical applications.**
- Results of three types are presented:
  - Solutions of typical problems that arise on the factory floor
  - A software package, *PSE Toolbox*, which implements these solutions and which can be used for day-to-day operations management; a demo of this toolbox is available at:

    http://www.ProductionSystemsEngineering.com
  - Insights into properties of production systems, which are useful for production management.

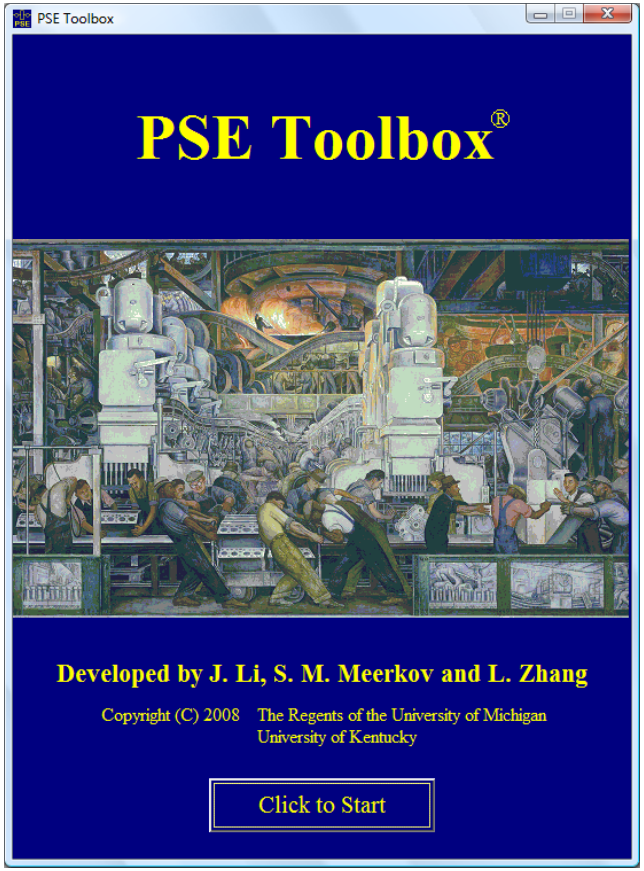
1.1.3. Examples of problems to be addressed

- In a production line, which machine is the "show stopper", i.e., the *bottleneck machine*? For instance, in a serial line with identical machines and identical buffers, which machine is the bottleneck?
- Similarly, which buffer is the "show stopper", i.e., the *bottleneck buffer*? For instance, in a system with identical machines and identical buffers, which buffer is the bottleneck?
- Given the machine characteristics, what is the smallest (i.e., *lean*) buffer capacity, which ensures the desired throughput of a production system?

1.1.3. Examples of problems to be addressed (cont)

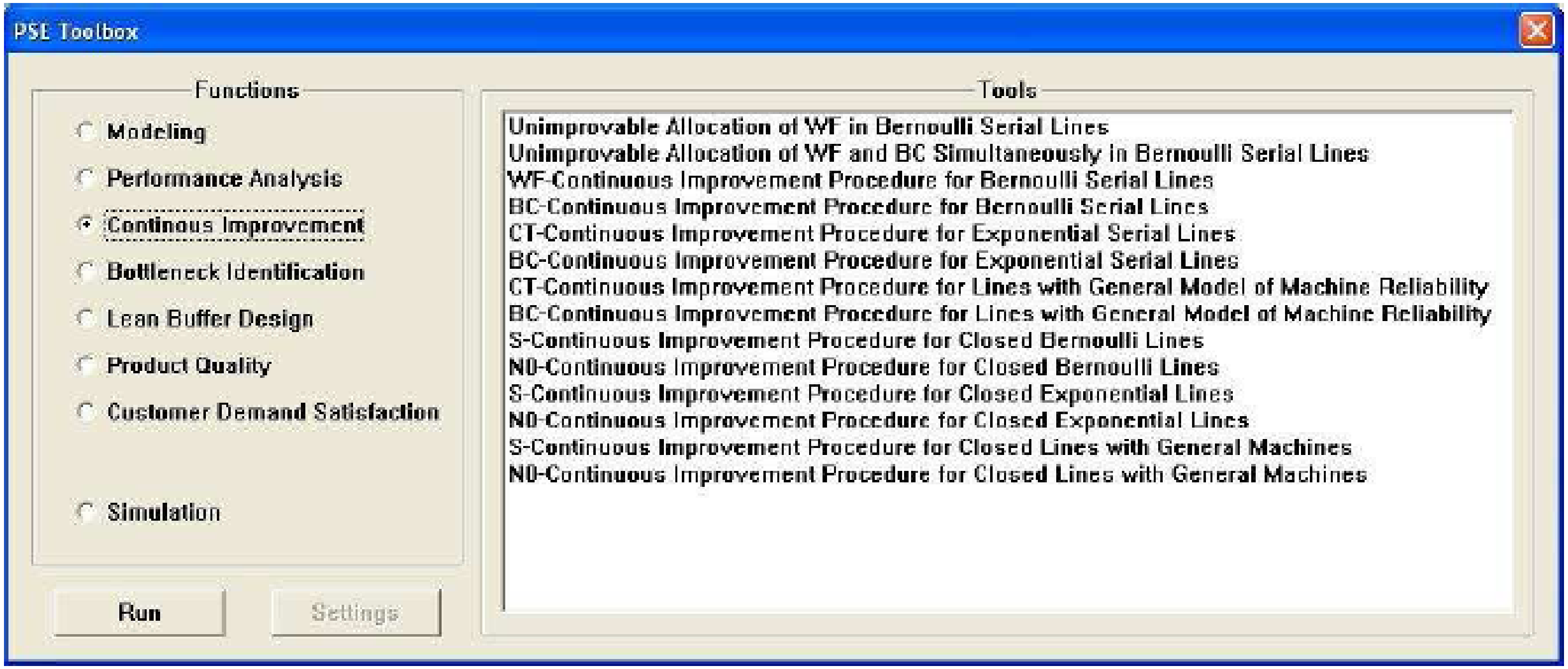
- In closed (i.e., palletized) production lines, what is the "right" number of carriers that does not impede the open line performance?
- What is the smallest finished goods buffer capacity, which is necessary and sufficient to satisfy the customer demand with the desired probability?
- Where should quality control devices be placed so that the throughput of good parts is maximized?
- If in the beginning of the shift all buffers are empty, what are the production losses due to transients and how can they be minimized?

1.1.4. Examples of tools to be used



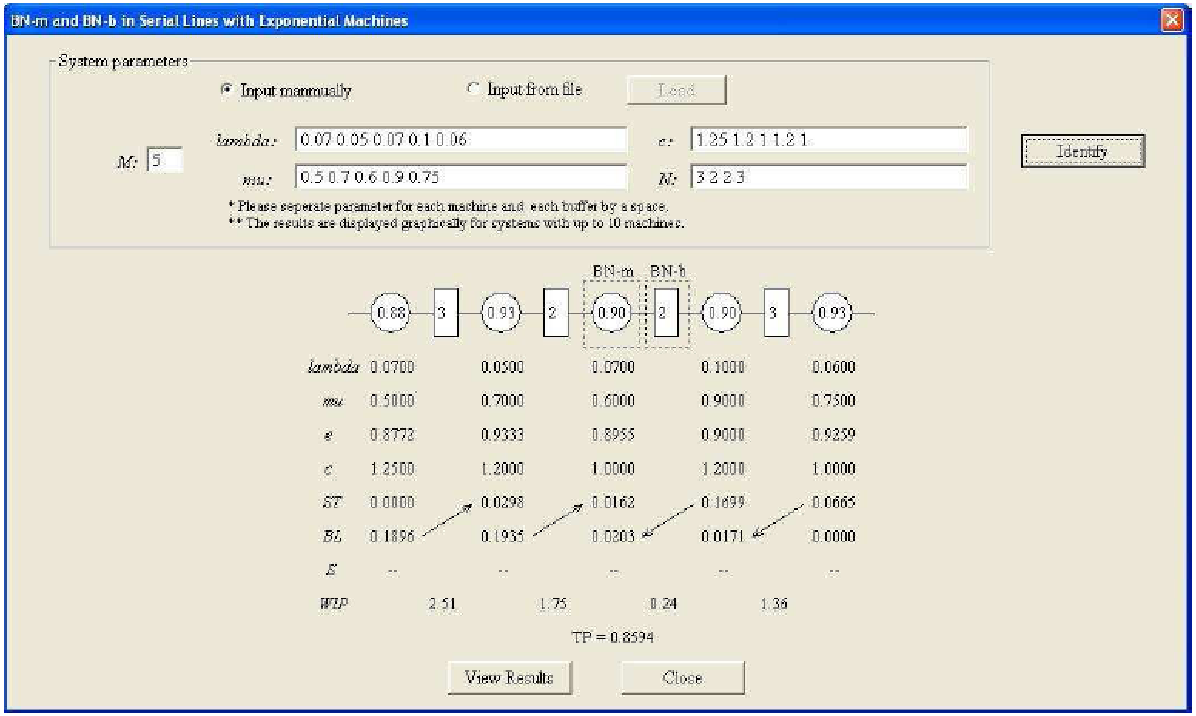
1.1.4. Examples of tools to be used (cont)

PSE Toolbox functions:



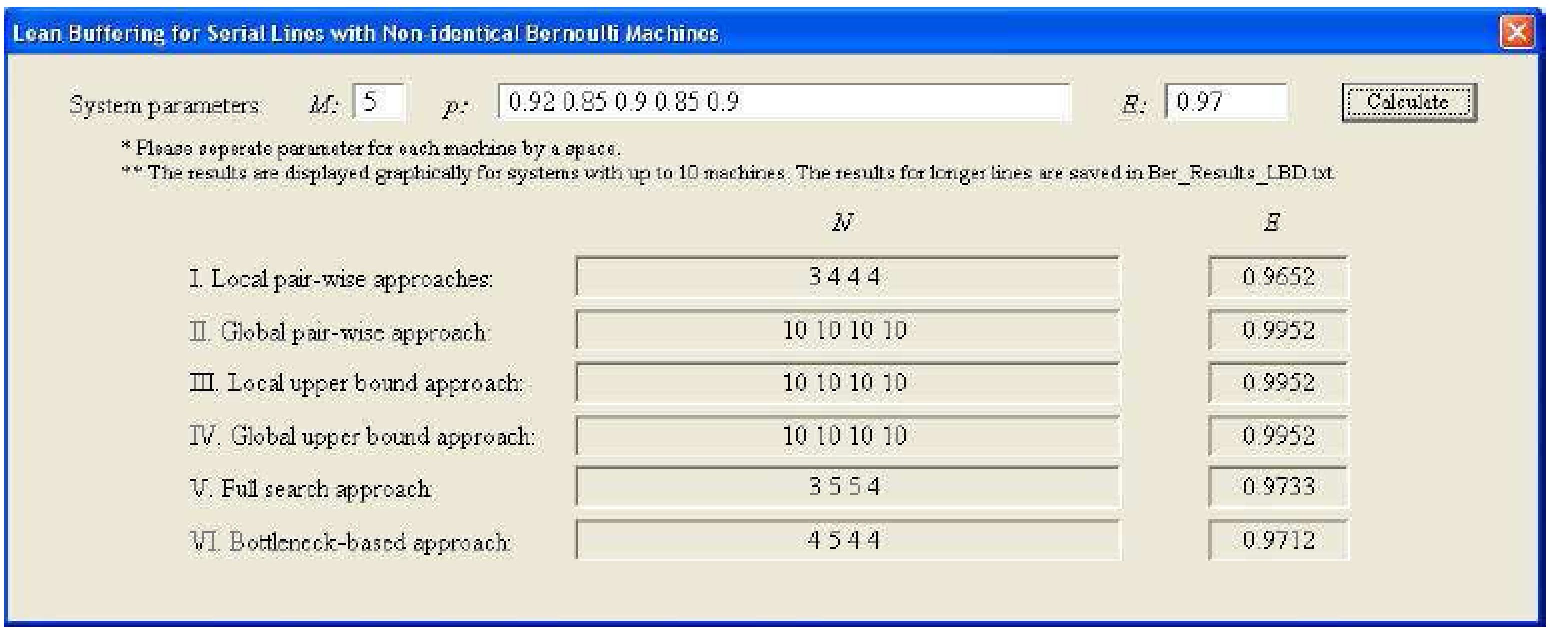
1.1.4. Examples of tools to be used (cont)

- Bottleneck identification tool:



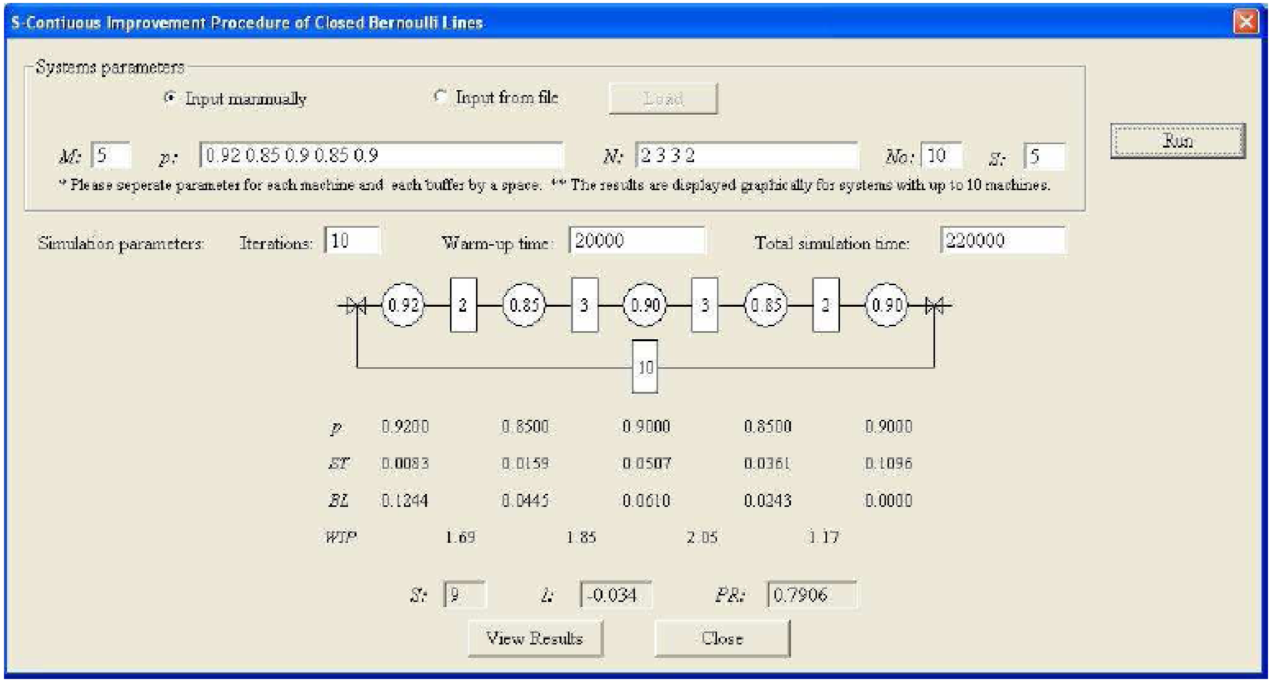
1.1.4. Examples of tools to be used (cont)

- Lean buffer design tool:



1.1.4. Examples of tools to be used (cont)

- Selecting the right number of carriers tool:



1.1.5. Examples of insights to be provided

- If all other factors are the same, is it better to have machines with shorter or longer up- and downtime?
- If either the uptime of a machine can be increased or its downtime decreased by the same factor, what is better for the overall system performance?
- How can one determine if work (or workforce) is allocated appropriately, so that the throughput is maximized?

1.1.5. Examples of insights to be provided (cont)

- How can one determine if the buffer capacity is allocated appropriately, so that the throughput is maximized?
- If all buffers are the same, what is the shape of optimal work allocation?
- If all machines are the same, what is the shape of optimal buffer capacity allocation?
- When does the throughput of a production line increase if the machine efficiency and/or buffer capacity are increased and when it does not?

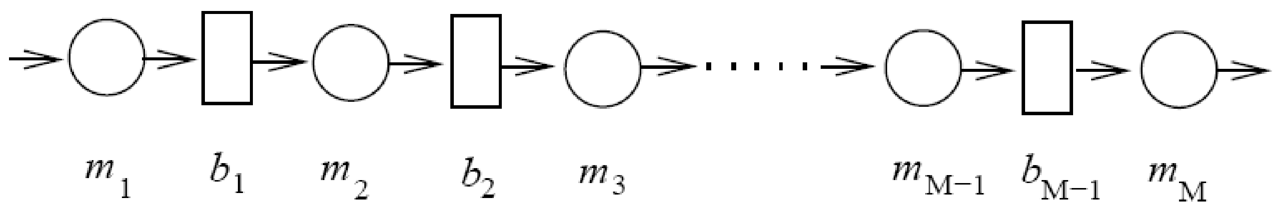
1.1.6. Course outcomes

- The methods described in this course lead to the so-called *Measurement-Based Management* (MBM) of production systems, which ensure their operation in the *Just Right* manner.
- It is expected that the participants will acquire a general understanding of PSE and its potentials as a field of teaching, research, and applications.

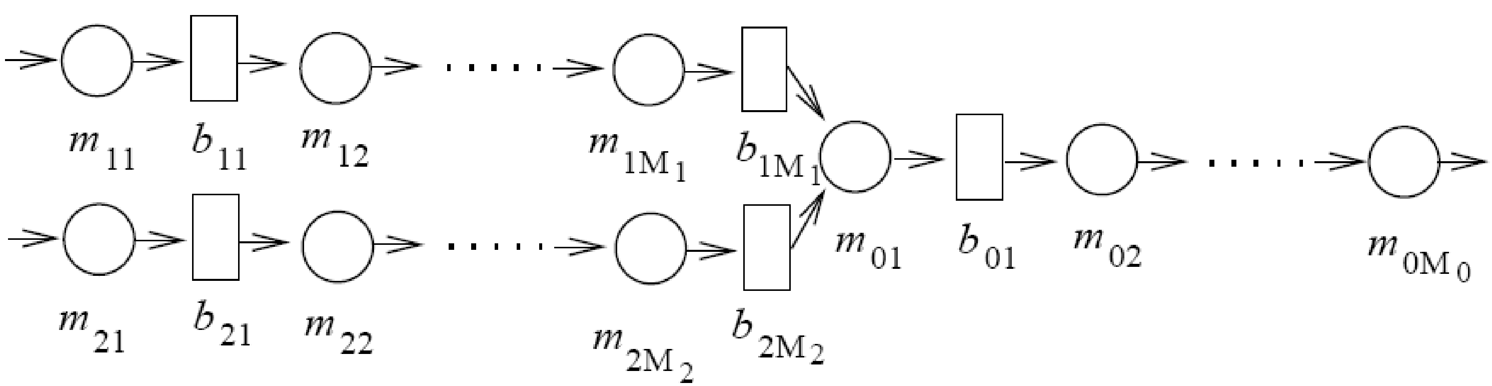
1.2. Course Overview

1.2.2. Systems considered

- *Serial lines*:

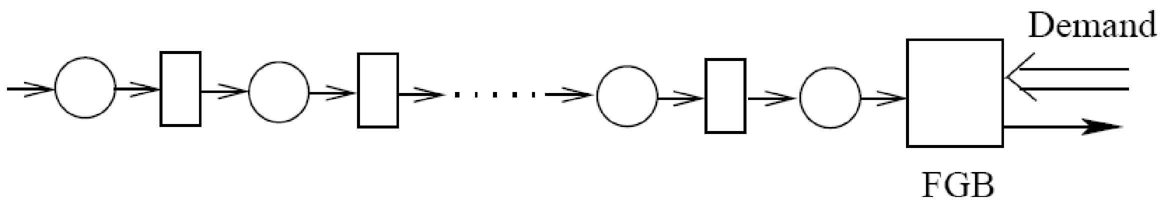


- *Assembly systems*:

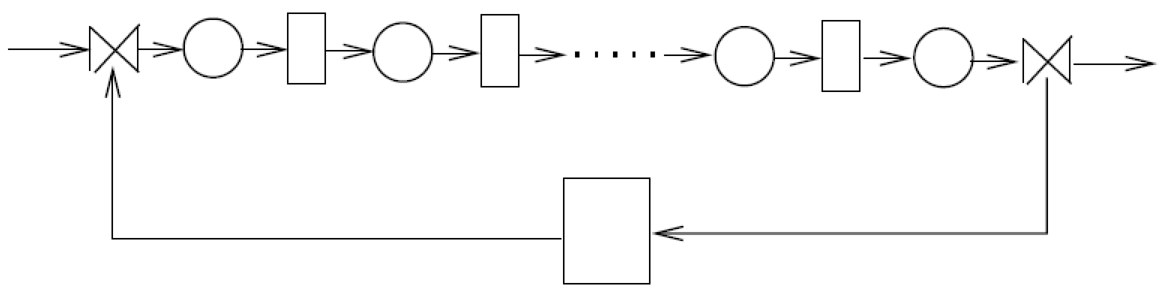


1.2.2. Systems considered (cont)

- Variations of serial lines:
  - *Serial lines with FGB*

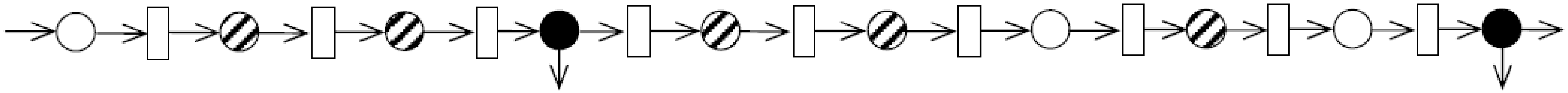


  - *Closed serial lines*

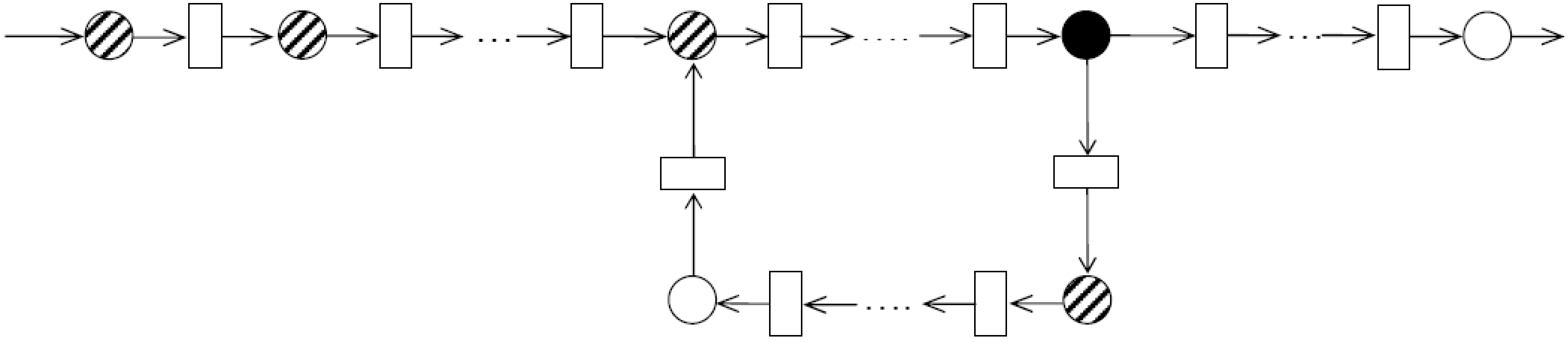


1.2.2. Systems considered (cont)

- *Serial lines with non-perfect quality and inspection machines*:



- *Serial lines with rework*:



1.2.3. Problems addressed

- **Mathematical modeling:** Methods for constructing a mathematical model of production systems at hand with an acceptable fidelity.
- **Performance analysis:** Analytical tools for calculating the steady state production rate, work-in-process, probabilities of machine blockages and starvations, transient characteristics, the level of customer demand satisfaction, etc.
- **System-theoretic properties:** Fundamental structural properties of production systems, such as monotonicity, reversibility, and the effects of up- and downtimes, etc.

1.2.3. Problems addressed (cont)

- **Bottlenecks:** Methods for identifying bottleneck machines and bottleneck buffers, i.e., machines and buffers that affect the production rate in the strongest manner. (Note: The worst machine and the smallest buffer are not necessarily bottlenecks in this sense.)
- **Lean buffer design:** Analytical tools for calculating the smallest buffer capacity, which is necessary and sufficient to obtain the desired efficiency of a production system.
- **Constrained improvability:** Methods for reallocating limited resources (such as workforce or buffer capacity) so that the throughput is increased.

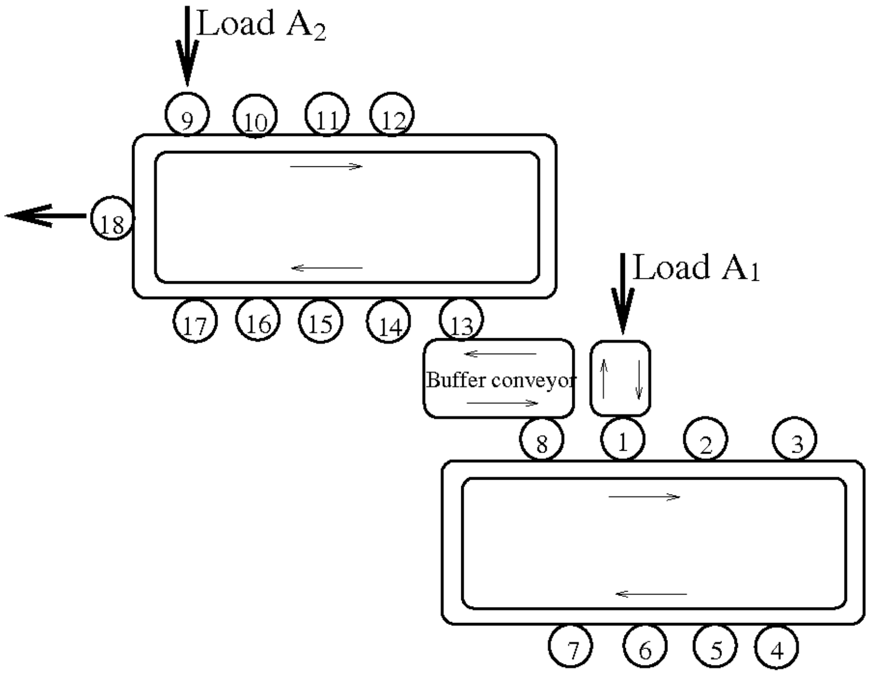
1.2.3. Problems addressed (cont)

- **Customer demand satisfaction:** Formulas for calculating the Due Time Performance, i.e., the probability to ship to the customer the desired number of parts during a fixed time interval.
- **Product quality:** Methods for evaluating performance characteristics of production systems the non-perfect quality machines.
- **Case studies:** Numerous applications of PSE in various production systems, mostly in the automotive industry.

1.3. Illustrative Example

1.3.1. System description

- System layout:



1.3.2. System performance and project goal

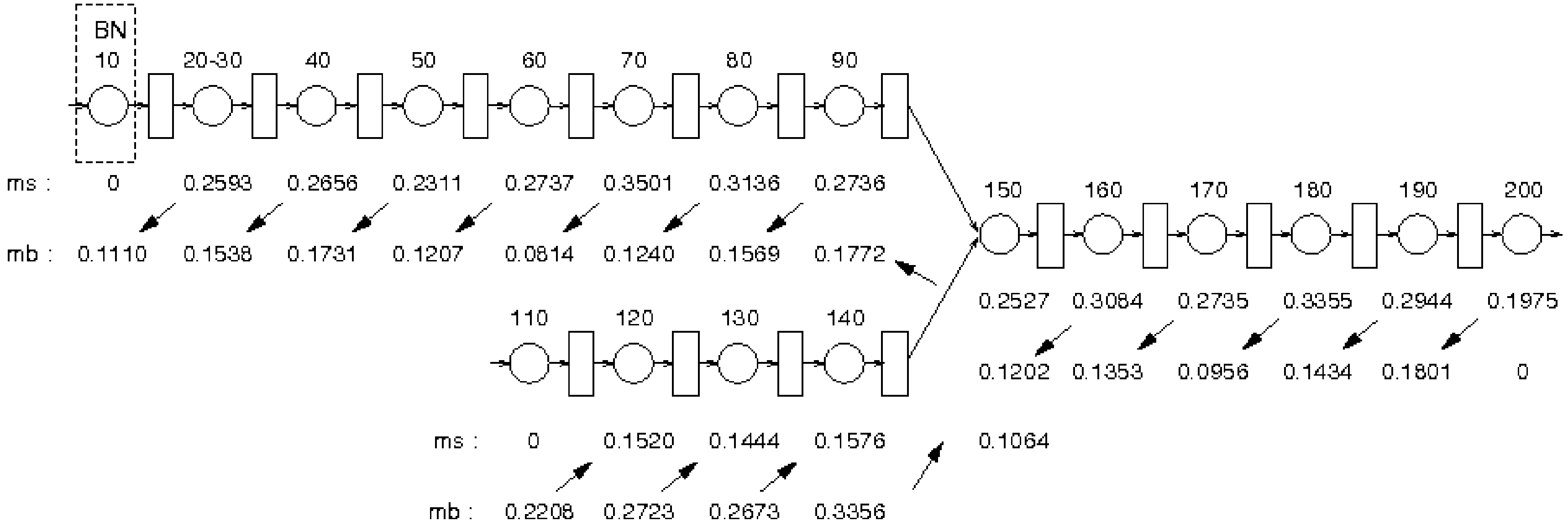
- Nominal throughput: 600 parts/hr.
- Actual throughput:

Month	May	June	July	Aug.	Sept.	Oct.
TP (parts/hr)	337	347	378	340	384	383
Losses due to machines (pts/hr)	78	66	132	102	60	108
Losses due to MHS (pts/hr)	185	187	90	158	156	109

- Average losses: 40%
  - Losses are mostly due to the material handling system (MHS).
- The goal of the continuous improvement project: Identify major causes of these losses and design a project for their elimination.

1.3.3. System modeling

- Structural model and bottleneck identification:



1.3.4. Continuous improvement project

- Resulting continuous improvement project:
  - Increase the capacity of the buffer-conveyor by adding five more carriers; this leads to 9.2% improvement of system throughput.
  - Eliminate the starvations of Ops. 10 and 110 and blockage of Op. 200; this leads to:

Month	May	June	July	Aug.	Sep.	Oct.
TP (part/hr)	372	393	403	359	415	408
Improvement(%)	12.7	17	7.6	7.2	9.2	11

- Implementation results: over 20% throughput improvement.

1.4. Summary

- This course is intended to present the foundations of Production Systems Engineering with the emphasis on issues of importance for industrial audience.
- The problems of mathematical modeling, performance analysis, and continuous improvement will be addressed.
- The methods described will be illustrated by numerous case studies.
- A suite of software, referred to as *PSE Toolbox*, will introduced and utilized during the lab sessions of this course.
- Course outcome: The participants are expected to become specialists in Measurement-Based Management (MBM).