PRODUCTION SYSTEMS ENGINEERING

Chapter 1: Introduction and Course Overview

Instructors: J. Li, S.M. Meerkov, and L. Zhang

- Motivation:
  - The purpose of this chapter is to place PSE in the general field of Manufacturing and to describe the contents of the course.
  - To accomplish this, five main areas of Manufacturing are described, systems addressed of PSE are characterized, and the main problems considered in PSE are outlined.
  - In addition, an example the course project is described.

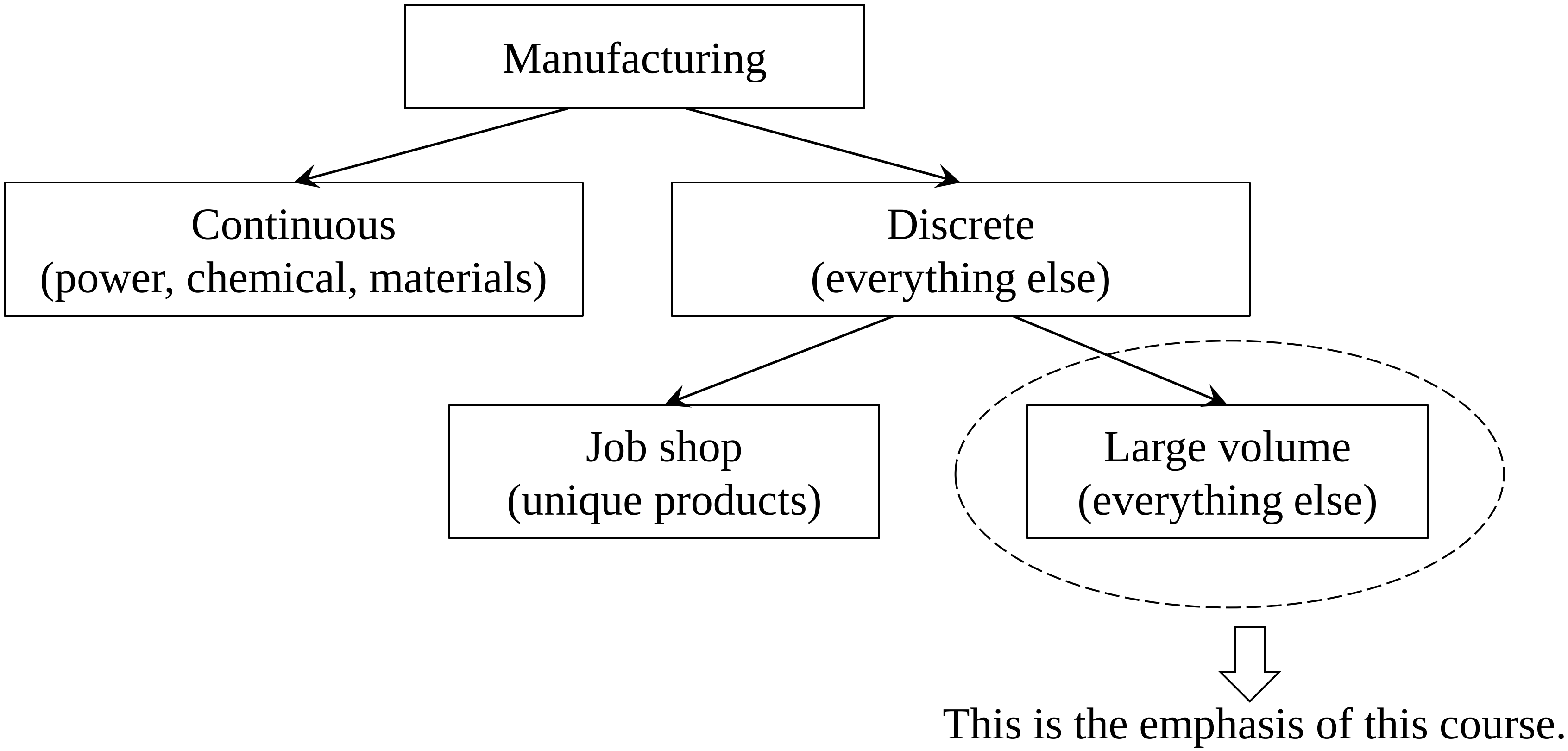
OUTLINE

1. PSE in the General Context of Manufacturing
2. Systems Addressed in PSE
3. PSE Problems
4. PSE Approach
5. Sample of Course Outcomes
6. Summary
7. Example of the Project

1. PSE in the General Context of Manufacturing

- *Manufacturing* – everything done on or for the factory floor.
- *Manufacturing matters* – the wealth of a ***nation*** is either taken from the ground (i.e., agriculture and natural resources) or manufactured.
- Efficient manufacturing – sufficient (and often a necessary) condition for the nation's prosperity.

1.1 Crude Classification of Manufacturing



1.2 Five Areas of Manufacturing

- From the engineering perspective, large volume manufacturing consists of the following five areas:
  - Machine tools and material handing devices (MHD).
  - Production systems – sets of machines and MHD (viewed as buffers) arranged so as to produce the desired product.
  - Planning and scheduling.
  - Quality assurance systems.
  - Work systems – how to train and pay workers so that they optimize system performance through their own self-interest.

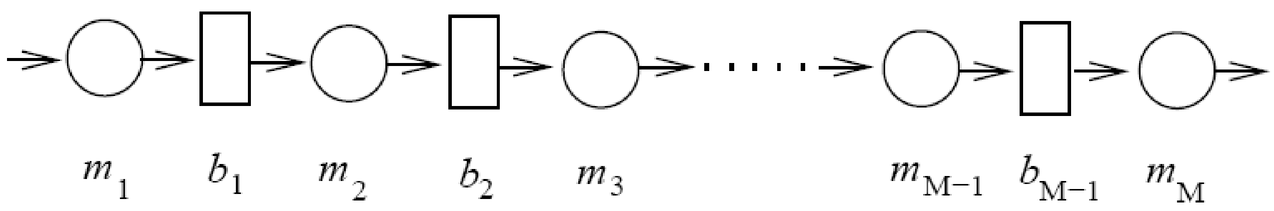
1.3 The Topic of this Course

- This course is devoted to one of these areas: Production Systems (although in the framework of production systems, the issues of quality are also addressed)
- The goal is to present the field of Production Systems at the same level of rigor as EE, ME, etc. Therefore, the term *Engineering* is used (PSE).
- Only practical problems are addressed.

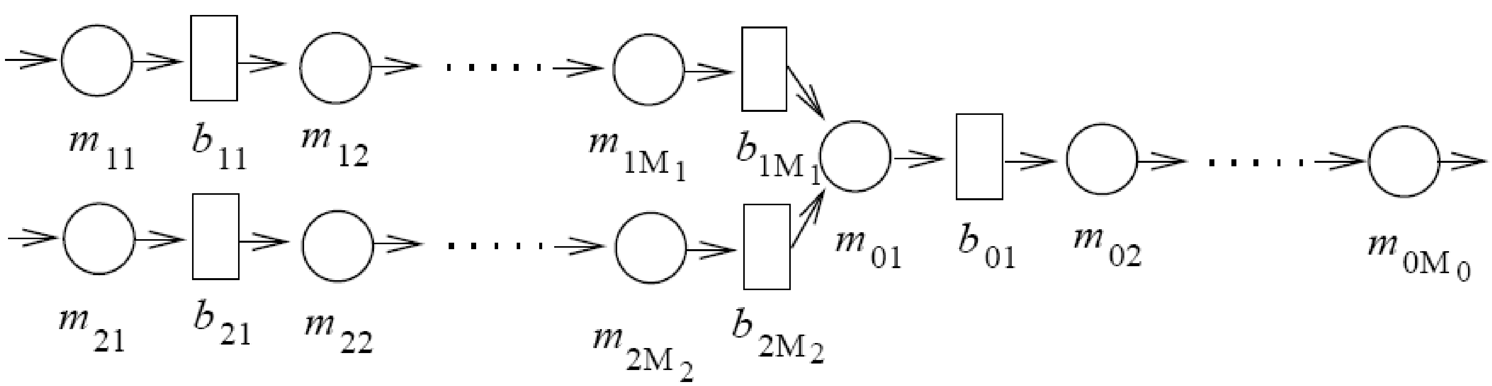
2. Systems Considered

2.1 Structural Models

- Serial lines

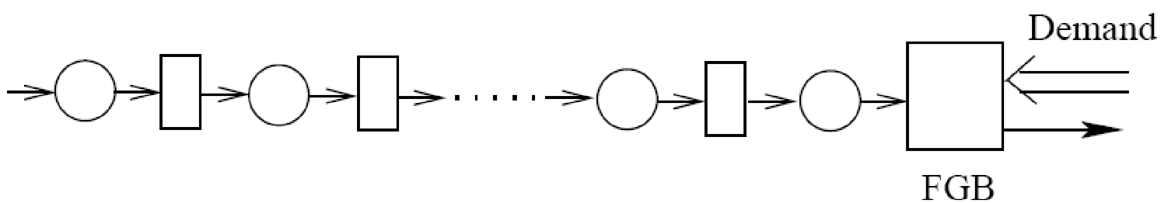


- Assembly systems

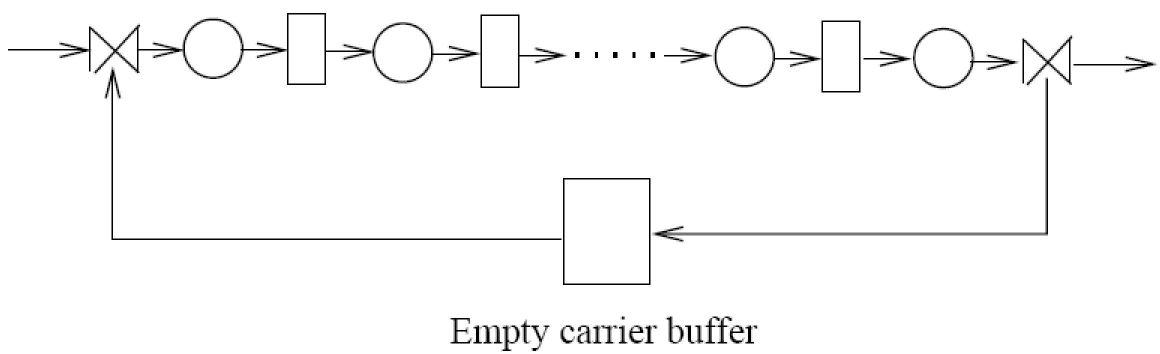


2.1 Structural Models (cont)

- Serial lines with finished goods buffers

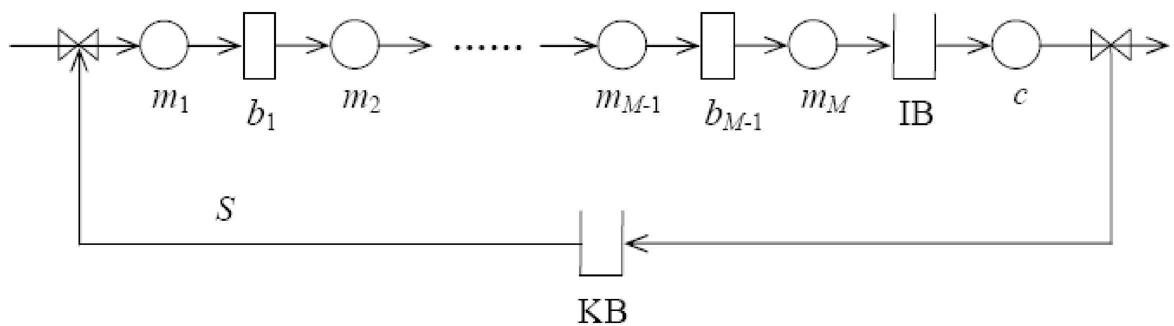


- Closed (palletized) serial lines



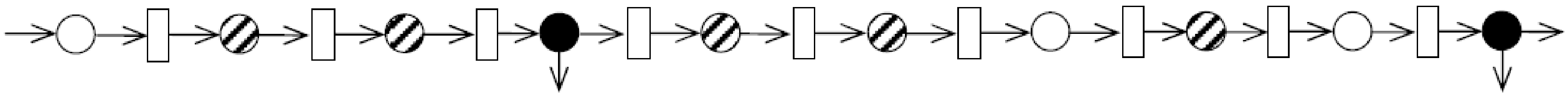
2.1 Structural Models (cont)

- Production lines with feedback-controlled release (e.g., kanban)

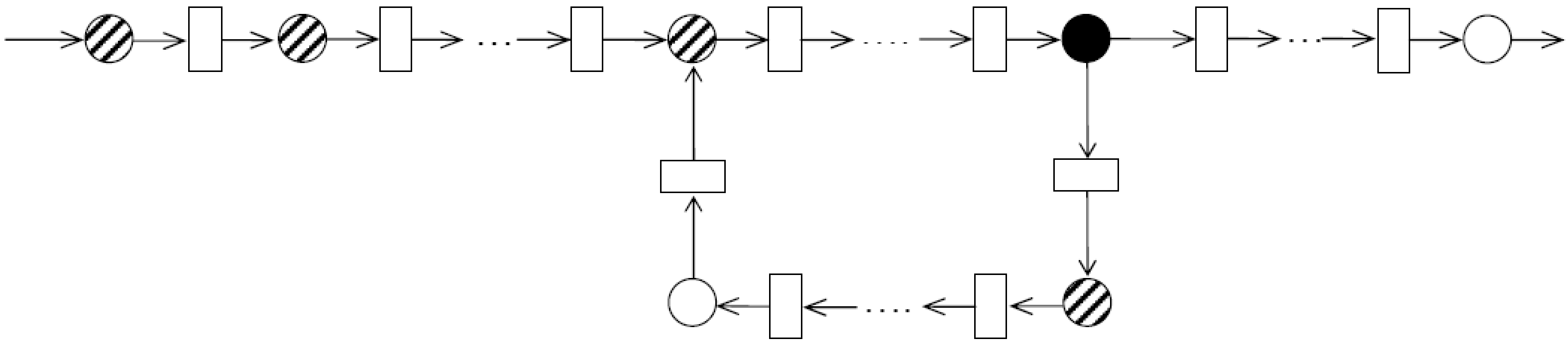


2.1 Structural Models (cont)

- Serial lines with non-perfect quality and inspection machines

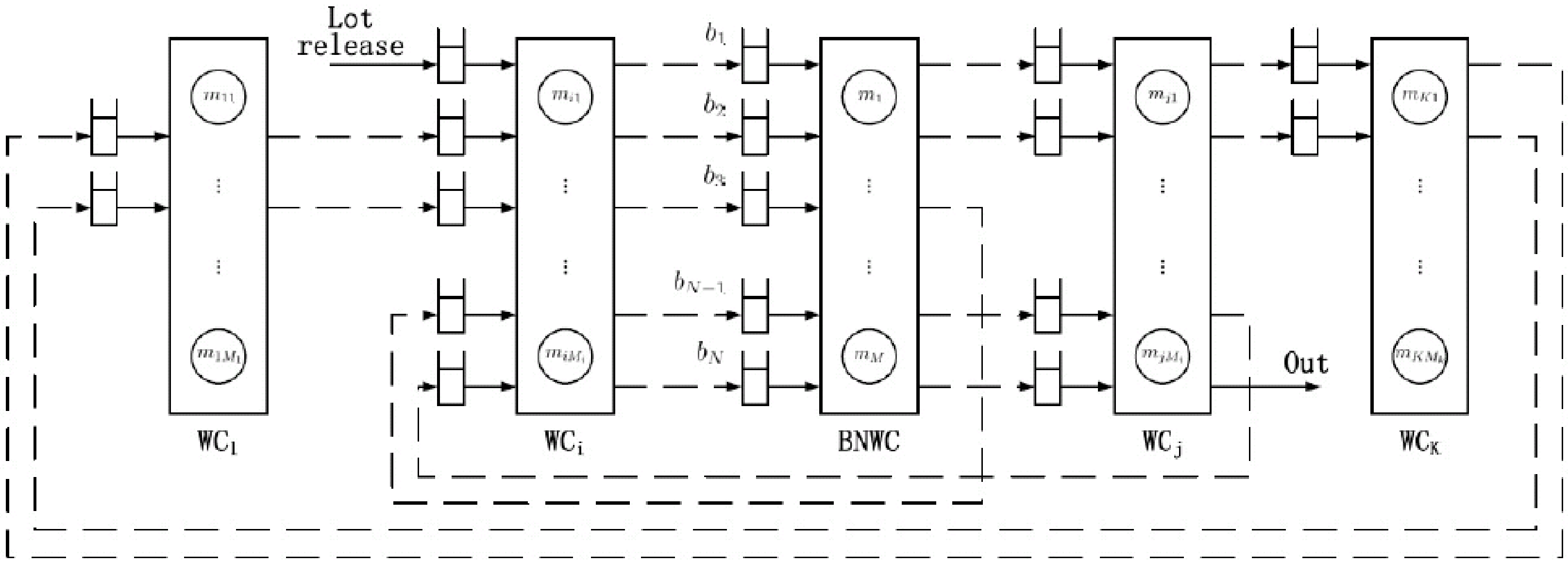


- Serial lines with rework



2.1 Structural Models (cont)

- Re-entrant lines



- **Practically every production line in large volume manufacturing can be reduced to one of the above (with a sufficient level of fidelity)**

2.2 Machine Reliability Models

- **The machines are described by the following reliability models:**
  - Bernoulli model: the status of the machine is an i.i.d. sequence of Bernoulli random variables;
  - Geometric model (constant breakdown and repair probabilities): the state of the machine is described by a Markov chain;
  - Exponential model (constant breakdown and repair rates): the state of the machine is described by a continuous time, discrete space Markov process;
  - Non-Markovian models (time-dependent breakdown and repair rates): Weibull, Rayleigh, Gamma, log-normal pdf's;
  - General model: the state of the machine is described by a random process of an unknown nature.
- **In this formalization, a production system is a set of random processes interacting in a nonlinear manner (due to finite buffering)**

3. PSE Problems

- **Mathematical modeling:** Provides methods for constructing mathematical models of production systems at hand with acceptable fidelity.
- **Performance analysis:** Offers analytical tools for calculating the steady state throughput, work-in-process, probabilities of machine blockages and starvations, the level of customer demand satisfaction, etc.
- **Constrained improvability:** Develops methods for re-allocating limited resources (such as buffer capacity or workforce or cycle time) so that the throughput is increased.

3. PSE Problems (cont)

- **Bottleneck identification:** Provides methods for identifying bottleneck machines and bottleneck buffers, i.e., machines and buffers, which affect the production rate in the strongest manner.
- **Lean buffer design:** Offers analytical tools for calculating the smallest buffer capacity, which is necessary and sufficient to obtain the desired throughput of a production system.
- **Customer demand satisfaction:** Develops 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:** Presents methods for analysis and improvement of production systems with non-perfect quality of parts produced.

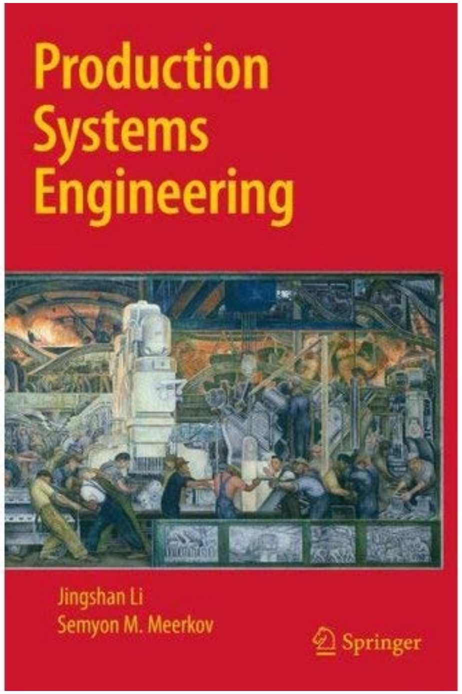
3. PSE Problems (cont)

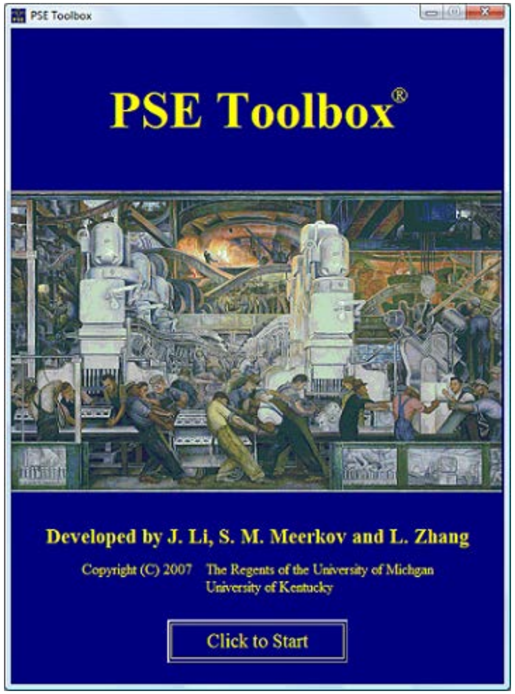
- **System-theoretic properties:** Investigates fundamental structural properties of production systems; in addition to improvability, these properties reversibility, monotonicity and effects of up- and downtimes
- **Transient analysis:** Studies temporal properties of reaching steady states in production systems.
- **Preventive maintenance:** For machines with maintenance-reliability coupling, determines PM's feasibility and, if so, optimal PM rate.
- **PSE Toolbox:** Provides a user-friendly set of C++ programs that implement the methods and algorithms developed in PSE.
- **Case studies:** Describes numerous applications of PSE in various production systems.

3. PSE Problems (cont)

- The solutions of these problems are summarized in the textbook and toolbox:

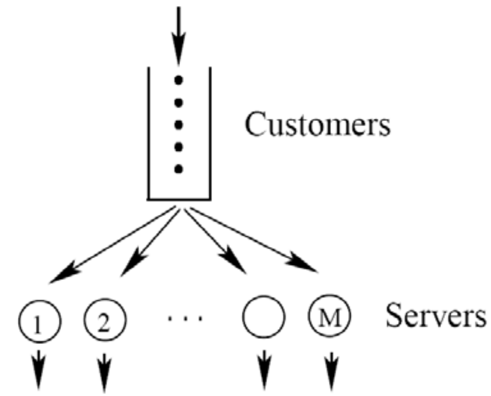
www.ProductionSystemsEngineering.com





4. PSE Approach

- Not used: queuing theory (QT)
  - Reasons:
    - Typical structure of QT model:



    - Main formula (Little's Law):

$$TP = \frac{WIP}{RT},$$

where *RT* is the residence time of a part in the system. One equation and three unknowns!

4. PSE Approach (cont)

- Used: Systems Theory approach.
  - Study nonlinear stochastic systems at hand
  - Direct analytical solutions of most problem is impossible.
  - Simplifications are used.
  - The main simplification tool – aggregation of many-machine systems into two-machine lines.
  - As a result,
    - calculation formulas are derived,
    - fundamental laws of production systems are investigated.

5. Sample of Course Outcomes

As an outcome, you will be able to answer the following questions:

- **Question 1:** In your production system, would you prefer machines with long or short up- and downtime, provided that machine availability remains the same?
- **Question 2:** In a serial line with machines of identical availability and buffers of identical capacity, which machine is the bottleneck? If the availability and capacities are not identical, is the machine with the smallest availability always the bottleneck? If not, which one is?

5. Sample of Course Outcomes (cont)

- **Question 3:** In your production system, would you prefer to maintain buffers full, empty, or neither? In the latter case, which buffer occupancy is preferable?
- **Question 4**: Is an in-process buffer of capacity 1000 lean? How about of capacity 10? Similarly, is a finished goods buffer of capacity 1000 lean?
- **Question 5:** In a production system with parts transported from one operation to another on carriers, how would you select the number of carriers so that the throughput is maximized? In particular, will adding a carrier increase the throughput and removing a carrier decrease it?

And so on…

6. Summary

- Manufacturing matters.
- There are five main areas in manufacturing.
- This course is devoted mostly to one of them – PSE.
- There are twelve main problem of PSE.
- This course addresses all of them.
- System-theoretic approach is used.