

University of Michigan  
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EECS 569

# PRODUCTION SYSTEMS ENGINEERING

## Chapter 1: Introduction

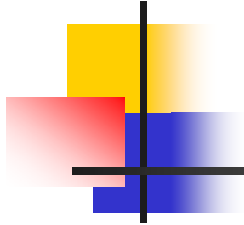
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- Motivation:
  - The purpose of this chapter is to place PSE in the general field of Manufacturing.
  - To accomplish this, five main areas of Manufacturing are described and three main areas of PSE are characterized.



# 1. Placing the Course within the General Field of MANUFACTURING

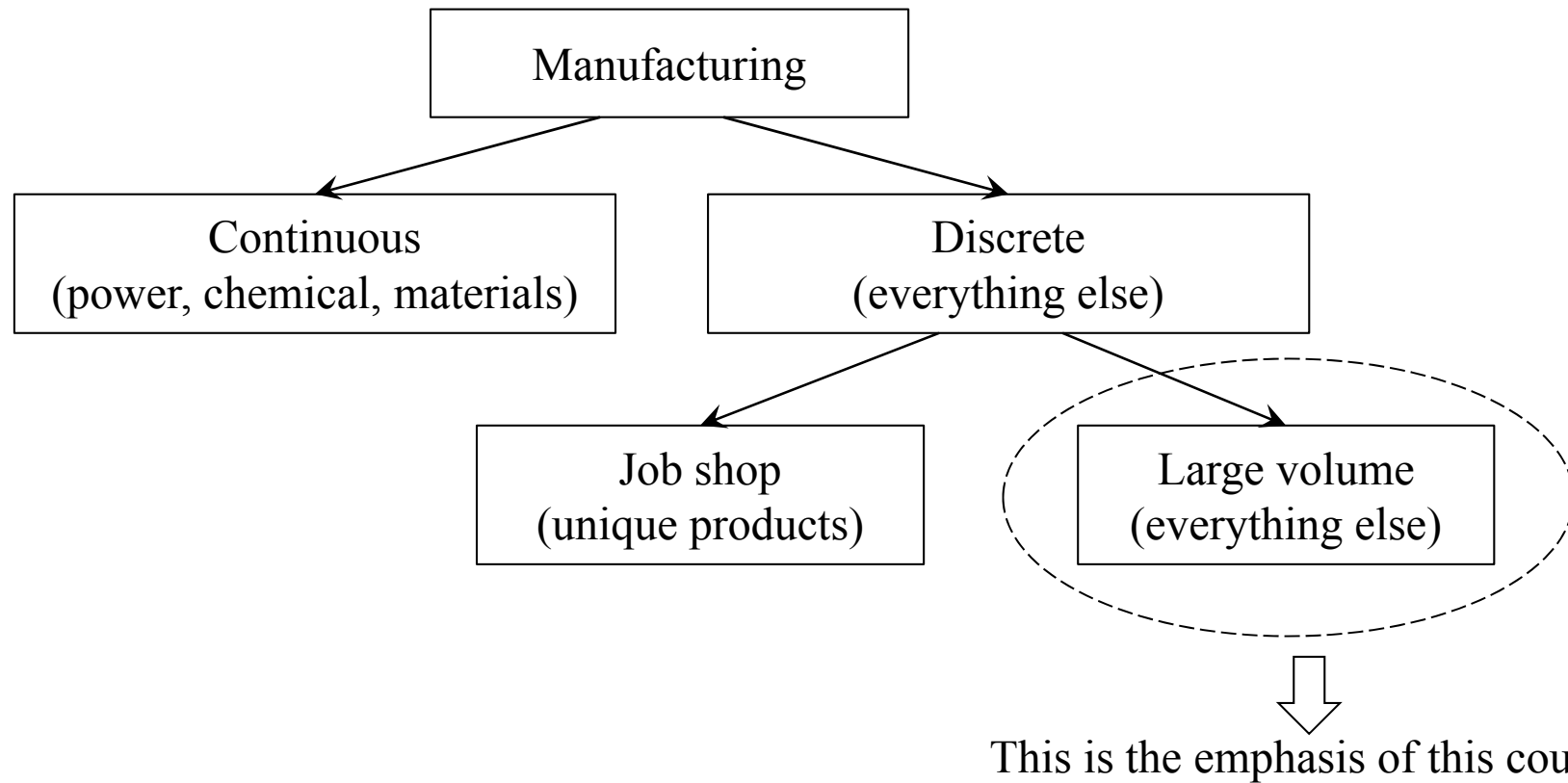
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- *Manufacturing* – everything done on or for the factory floor.
- *Manufacturing matters* – the wealth of a **nation** is either taken from the ground (i.e., agriculture and natural resources) or manufactured.
- Efficient manufacturing – sufficient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



## 1.1 Crude classification of Manufacturing

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## 1.2 Five areas of Manufacturing

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- From the engineering perspective, large volume manufacturing consists of the following five areas:
  - Machine tools and material handling 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.



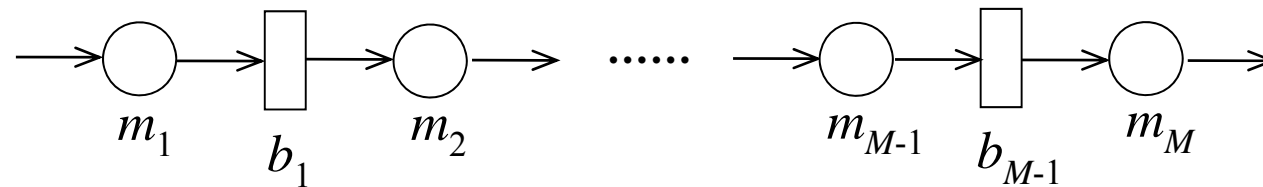
## 1.3 The topic of this course

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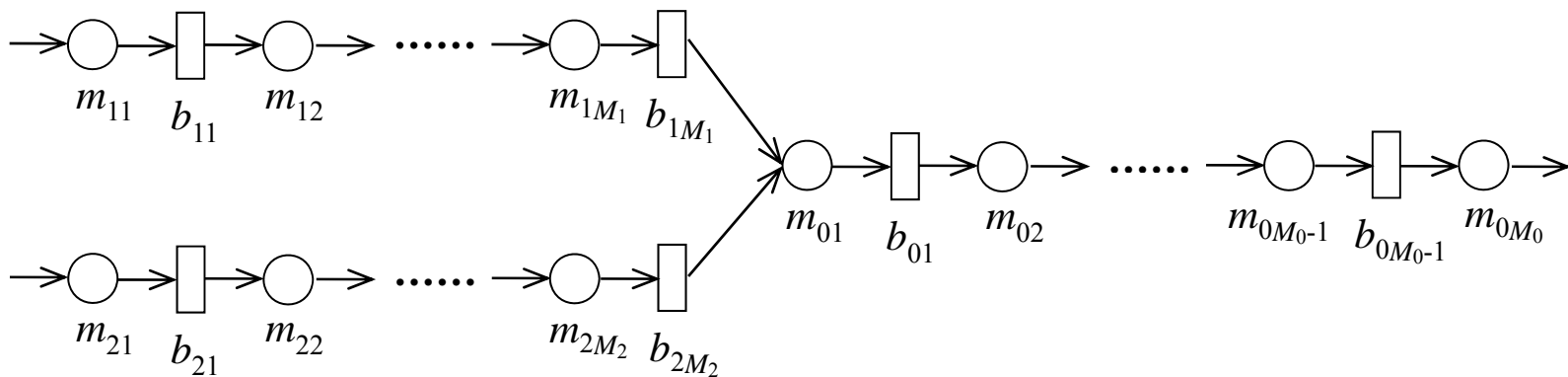
- This course is devoted to one of these areas: Production Systems (although in the framework of production systems, the issues of quality are also addressed)
- The goal is to present the field of Production Systems at the same level of rigor as EE, ME, etc. Therefore, the term *Engineering* is used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

## 2. Typical Systems Studied in PSE

- Serial lines:



- Assembly systems:





## 2.1 Main features

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- Complicating phenomena – *machine breakdowns*.
- Resulting effects – *blockages and starvations* – loss of production.
- To alleviate these effects, buffers are used.
- All problems of PSE are related to methods of analysis, continuous improvement, and design, which allow for the elimination of losses due to blockages and starvations, thus leading to smooth “flow” of parts.



## 3. Six Main Problems of PSE

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### 3.1 Analysis

- Given the machine and buffer parameters, calculate
  - throughput ( $TP$ )
  - work-in-process ( $WIP$ )
  - probabilities of blockages and starvations ( $BL$  and  $ST$ )



## 3.2 Continuous improvement

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- Given the machine and buffer parameters,
  - redistribute workforce or buffer capacity so that  $TP$  is increased (*constrained improvability*);
  - identify and eliminate bottleneck machine (BN-m) and bottleneck buffer (BN-b) (*unconstrained improvability*)

[Questions to ponder:

- If a single buffer is available, where should it be placed?
- If a single machine can be replaced, which one should it be?
- In a serial line with identical machines and buffers, which ones are BN-m and BN-b?]



## 3.3 Design

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- Given the desired  $TP$ , identify the *minimum* requirements on productivity and reliability characteristics of the machines and capacities of the buffers so that the desired performance is achieved.

[Questions to ponder:

- Should one use machines with longer or shorter up- and downtime, given that the efficiency remains the same?
- How many downtimes a buffer should be able to accommodate so that the desired fraction of the maximum  $TP$  is achieved?]



## 3.4 Quality issues

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- Given a production system, position quality inspection devices so that  $TP$  of good parts is maximized.

[Question to ponder:

- If only the first machine can produce defective parts and only one inspection device is available, where should it be placed so that  $TP$  is maximized?]



## 3.5 Customer demand satisfaction:

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- Given a production system and the characteristics of the customer demand, determine the smallest finished goods inventory so that the demand is satisfied with the desired probability.

[Question to ponder:

- What is the relationship between the smallest finished goods inventory and the shipping period, which guarantee a fixed level of customer demand satisfaction?]



## 3.6 Transient behavior

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- Given a production system and initial buffer occupancy, how long it will take to reach the steady state of the system operation.

[Questions to ponder:

- What is the smallest initial buffer occupancy so that no throughput losses due to transients take place?
- Are the transients faster in systems with more or with less efficient machines?
- Which transients are faster, those of *TP* or of *WIP*?]



## 3.7 PSE outcomes

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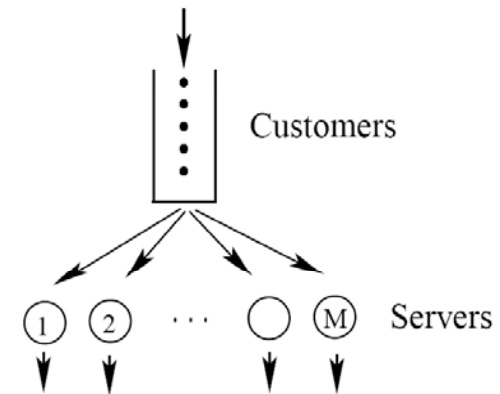
- PSE provides methods for solving all six problems mentioned above.
- Offers the *PSE Toolbox*, which implements these solutions as a set of user-friendly C++ programs. A demo of the toolbox can be downloaded at

<http://www.ProductionSystemsEngineering.com/>

## 4. Approach of PSE

- 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. Approach of PSE (cont)

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- 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. Summary

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