Modeling and control of manufacturing systems

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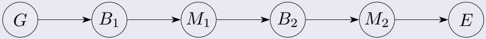
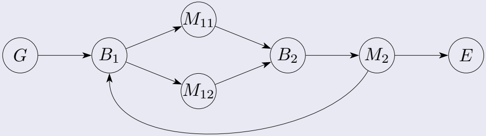
Contents

Manufacturing Systems

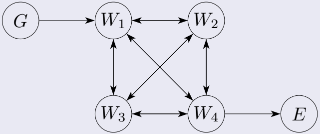
Line



Re-entrant



Job-shop



Process times

Disturbances

- setups
- machine failure
- machine maintenance (software upgrade)
- operators (talking, breaks)
- rework
- ...

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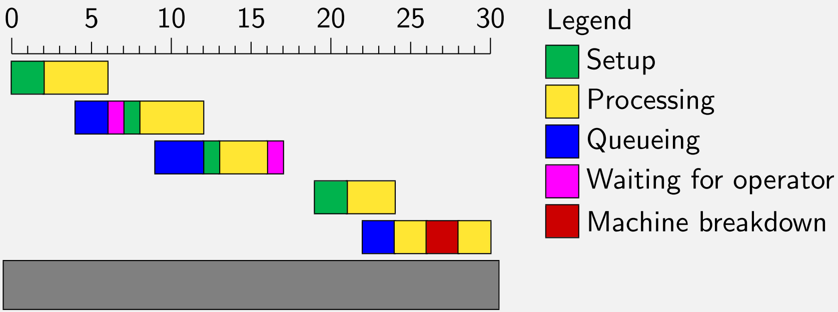
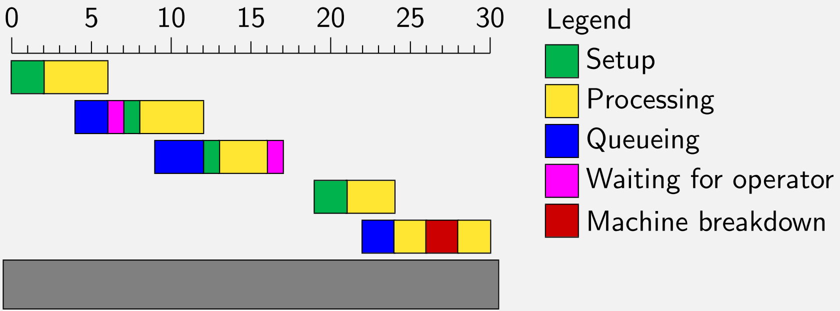
Effective Process Times

Combine all disturbances in one single EPT distribution

Effective Process Times



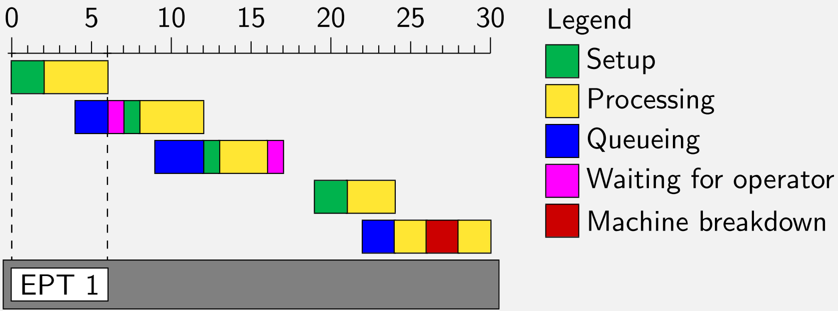
Effective Process Times



Important question

What is the aggregate model?

Effective Process Times



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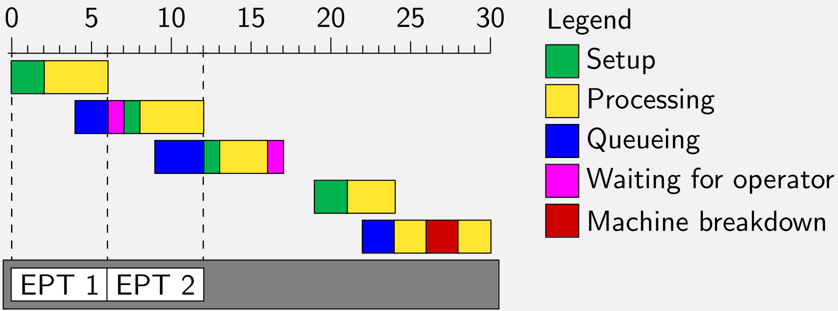

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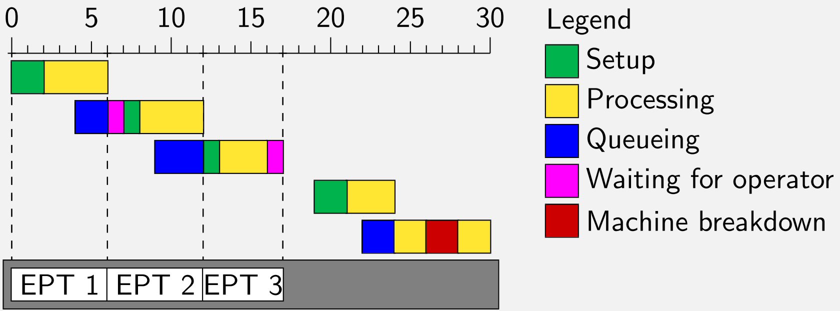

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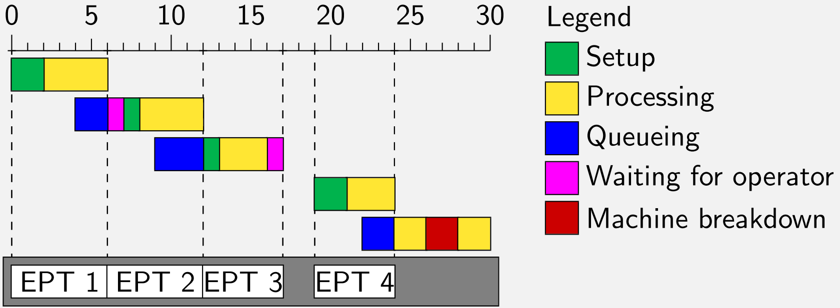

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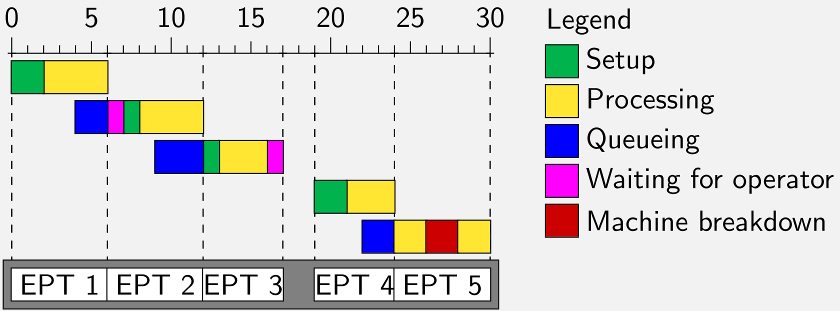

Important question

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Fluid models

Modeling manufacturing flow

- density $\rho(x,t)$,
- speed $v(x,t)$,
- flow $u(x,t) = \rho(x,t)v(x,t)$,
- Conservation of mass: $\frac{\partial \rho}{\partial t}(x,t) + \frac{\partial \rho v}{\partial x}(x,t) = 0$.
- Boundary condition: $u(0,t) = \lambda(t)$

Note

Several options for additional equation(s)

Fluid models: several options

Armbruster et al.:

- Single queue: $\frac{1}{v(x,t)} = \frac{1}{\mu}(1 + \int_0^1 \rho(s,t)\,\mathrm{d}\,s)$
- Single queue: $\frac{\partial \rho v}{\partial t}(x,t) + \frac{\partial \rho v^2}{\partial x}(x,t) = 0$
  $$\rho v^2(0,t) = \frac{\mu \cdot \rho v(0,t)}{1+\int_0^1 \rho(s,t)\,\mathrm{d}\,s}$$
- Re-entrant: $v(x,t) = v_0 \left(1 - \frac{\int_0^1 \rho(s,t)\,\mathrm{d}\,s}{W_{\max}}\right)$
- Re-entrant: $\frac{\partial \rho v}{\partial t}(x,t) + \frac{\partial \rho v^2}{\partial x}(x,t) = 0$
  $$\rho v^2(0,t) = \rho v(0,t) \cdot v_0 \left(1 - \frac{\int_0^1 \rho(s,t)\,\mathrm{d}\,s}{W_{\max}}\right)$$

Lefeber et al.:

- Line of m identical queues: $v(x,t) = \frac{\mu}{m+\rho(x,t)}$

Fluid models

DE model only

DE model & 3 PDE Models

Contents

Networks of switching servers with setup times

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Problem

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How to control these networks?

Decisions: When to switch, and to which job-type

Goals: Maximal throughput, minimal flow time

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Current approach

Start from policy, analyze resulting dynamics

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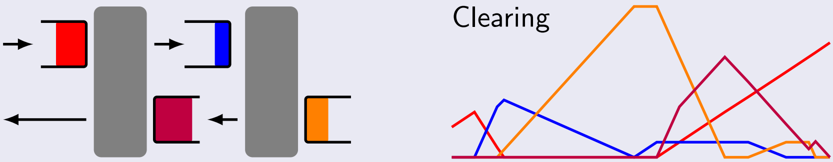
Kumar, Seidman (1990)



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Current status (after two decades)

Several policies exist that guarantee stability of the network

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Open issues

- Do existing policies yield satisfactory network performance?
- How to obtain pre-specified network behavior?

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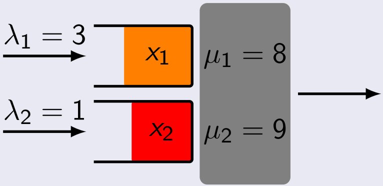
- How to obtain pre-specified network behavior?

Important observation

"The main interest is in the resulting behavior. So why not use that as a starting point?"

Example

Single machine



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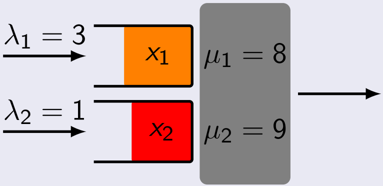
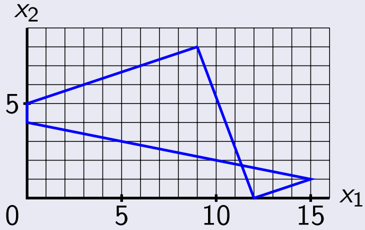


Desired behavior



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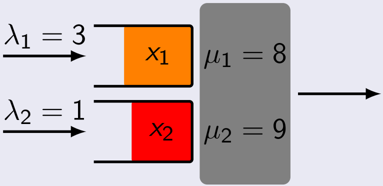

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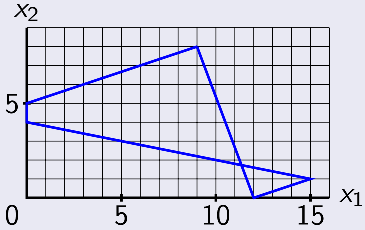

Resulting Controller

- When serving type 1:
  1. empty buffer
  2. serve until $x_2 \geq 5$
  3. switch to type 2
- When serving type 2:
  1. empty buffer
  2. serve until $x_1 \geq 12$
  3. switch to type 1

Conclusions

Modeling

Aggregation

- Effective Proces Times
- PDE models

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Control

Given a desired periodic orbit, a controller can be derived.

Approach can deal with

- General networks
- Finite buffers
- Transportation delays