Factory Physics

Methods for Efficient Project Management in a Scientific Environment—Part I: Operations Science

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What is Factory Physics?
Description of the way factories behave
Title of a book first published in 1996
Name of a company that offers services to manufacturing companies

Why Factory Physics?
Definitions

\[ r_b = \text{Capacity: max units/tasks that can be done per unit time} \]
\[ \text{TH} = \text{Throughput: units/tasks completed per unit time} \]
\[ u = \text{Utilization: fraction of capacity that is used, } u = \frac{\text{TH}}{r_b} \]
\[ \text{CT} = \text{Cycle Time: time from start to finish of a unit/task} \]
\[ \text{WIP} = \text{the number of incomplete units/tasks} \]
Inventory, WIP, Stock and Queues
Modeling

Analytic and Queueing

Monte Carlo Discrete Event Simulation
Little’s Law: $WIP = CT \times TH$

TH is demand
WIP is “visible cycle time”
What is “Pull?”

WIP and TH are ‘leading’ indicators, CT lags

Pull controls WIP, Push controls TH

Pull is more robust than Push

Performance Curves
Variability

Demand and Production are never synchronized
There is always variability!
Variability in a production system will be buffered with some combination of:

1. Inventory
2. Time
3. Capacity
Almost everything we do involves operations
Manufacturing
Transportation
Medical services
Project execution

Operations Science
Science, not just mathematical models
Little’s Law = Little’s Tautology
Does throughput always go up with additional WIP?
How do the three buffers interact?


Operations Science

The study of the transformation of entities using resources to create and distribute goods and services that satisfy a given demand

Operations Science describes
Demand processes
Resource utilization
Variability due to randomness and lack of information
Buffering and synchronization
Work in process, cycle time, throughput
Stocks, backorders and lost demand
Process

Example: Engineer, Fabricate, Deliver, Install
Process begins by accumulating all needed resources
Proceeds through a sequence of operations

Demand

Represents the desire of a “customer” for an entity or a set of entities with particular attributes
The “customer” can be individuals or the downstream process or the sponsor of a project
Entities demanded can be physical, information, services
Demand is always satisfied by a process
Projects

Creation of a unique device, structure, software, etc.
The creation is unique but composed of many repetitive processes
Maintain the Rates → Make the Dates

Schedule = Demand / Should

Production System = Supply / Will

TAKT

TH

Dates & Progress

Rates / Throughput

Variability and Buffer Interactions
Simple production-inventory system

Queue $\lambda, \psi$  
Operation $\mu, c^2$  
Stock $S$  
Demand $\Delta, \psi^2$

Queue + Operation + Stock = Basestock = S  
(stock can be negative—backorders)

Buffers
- Time—demand waits on unit or task
- Inventory—units or tasks wait on demand
- Capacity—productive ability that exceeds average demand
Time and Inventory Buffers mirror each other

Time-Inventory Buffer

Capacity Buffer mitigates Time-Inventory Buffer

Explore buffer relationships with simulation
Time-Inventory Buffer

The standard deviation of lead time demand

Capacity Buffer

Capacity less Average Demand
Let $\psi^2 = c^2 = V$

Vary $V$ and $\mu - \lambda$ while keeping $\sigma_{LTD}$ constant

$\lambda = 1, \mu = 1.25 \rightarrow 1.05$
$\psi^2 = c^2 = 0.93 \rightarrow 0.22$

$\sigma_{LTD} \approx 4.4$
\[(\mu - \lambda) \sigma_{TI} \approx \frac{\sigma_P^2 + \sigma_D^2}{2}\]

- Capacity Buffer
- Inventory / Time Buffer

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Can you have an inventory of completed projects?
Must have a capacity buffer to avoid the “time buffer”

Being overly “efficient” means being late

Project Duration
Too much WIP
long cycle times
inefficient production
Too little WIP
insufficient production
Production System Model

Data Science

Operations Science

Production System Control Policies

CT = RPT + BT + MT + QT + SDT + WTMT + PTB

CT = WIP / TH

Little's Law:

Cycle Time Formula:

RPT = PT + ST + DT

BT = (Waiting for Batch) + (Waiting in Batch)

WIP

Cycle Time

Utilization

Throughput

Questions?