Factory Physics

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

Mark L. Spearman, PhD

26 October 2021

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What is Factory Physics?

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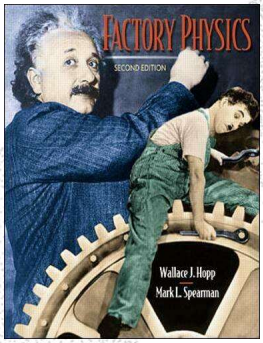

Description of the way factories behave

Title of a book first published in 1996

Name of a company that offers services to manufacturing companies

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Why Factory Physics?

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Context

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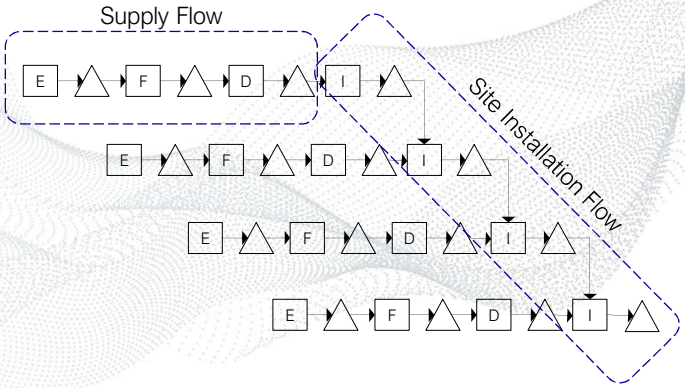

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Definitions

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r_b = Capacity: max units/tasks that can be done per unit time

TH = Throughput: units/tasks completed per unit time

u = Utilization: fraction of capacity that is used, $u = \mathrm{TH}/r_b$

CT = Cycle Time: time from start to finish of a unit/task

WIP = the number of incomplete units/tasks

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Inventory, WIP, Stock and Queues

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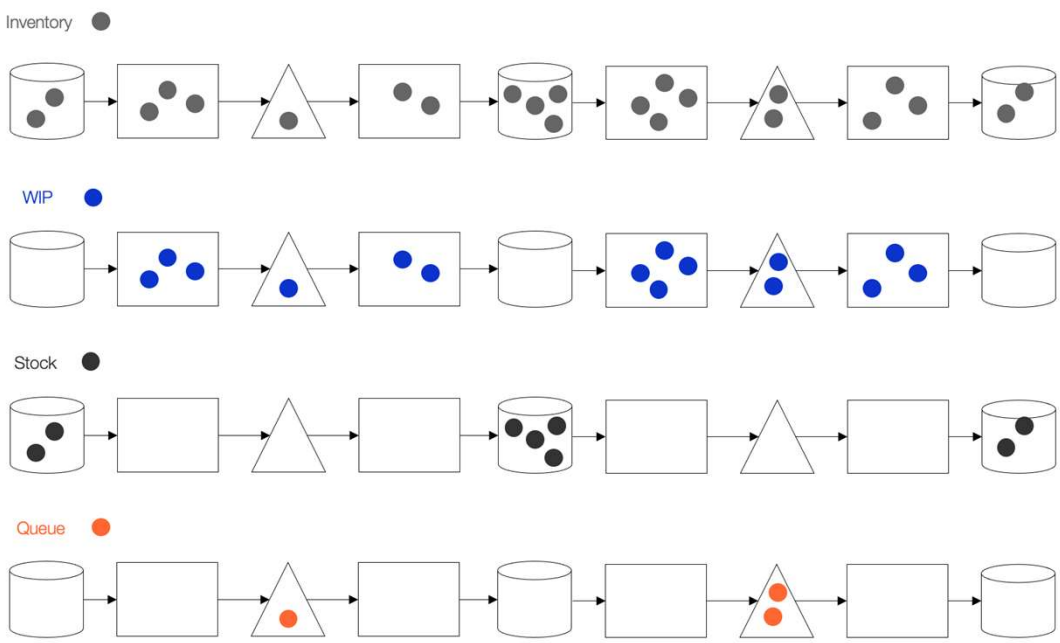

Modeling

Analytic and Queueing

Monte Carlo Discrete Event Simulation

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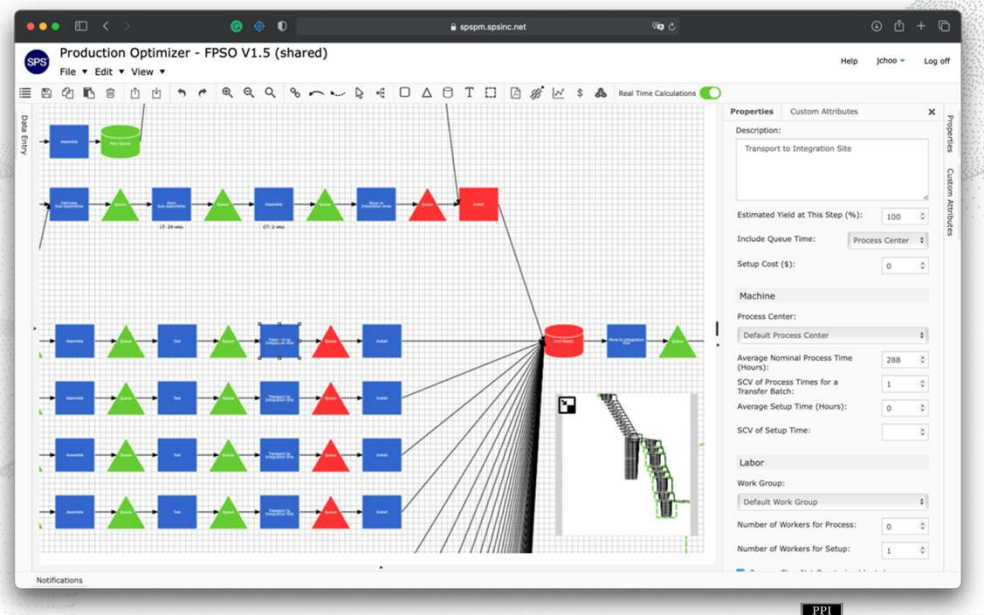

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Fundamentals

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Little's Law:

$$WIP = CT \times TH$$

TH is demand

WIP is "visible cycle time"

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What is "Pull?"

WIP and TH are 'leading' indicators, CT lags

Pull controls WIP, Push controls TH

Pull is more robust than Push

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Performance Curves

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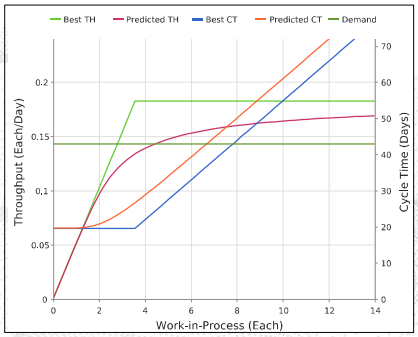
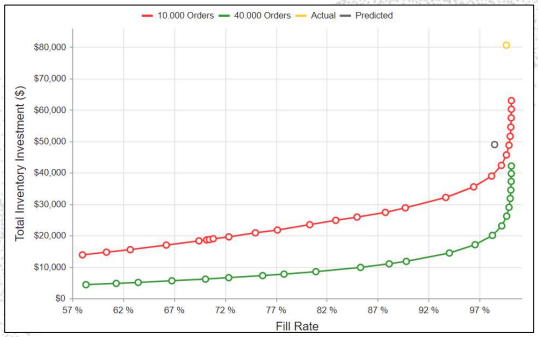
FLOW



STOCK



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Variability

Demand and Production are never synchronized

There is always variability!

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Variability in a production system will be buffered with some combination of:

1. Inventory
2. Time
3. Capacity

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Operations Science

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Almost everything we do involves operations

Manufacturing

Transportation

Medical services

Project execution

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Operations Science

Science, not just mathematical models

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Little's Law = Little's Tautology

Does throughput always go up with additional WIP?

How do the three buffers interact?

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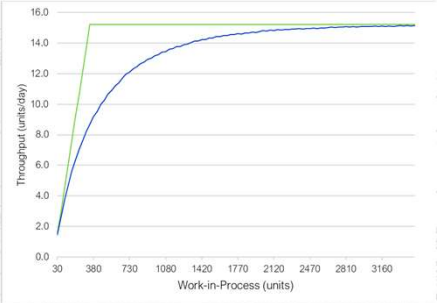
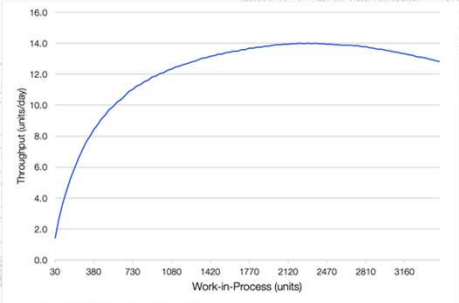
Operations Research and Operation Science





Adan, I., J. Van der Wal. 1989. Monotonicity of the Throughput of a Closed Queueing Network in the Number of Jobs. *Operations Research*, 5 (6), 953-957.

Spearman, M.L., W.J. Hopp. 2021 The Case for a Unified Science of Operations, *Production and Operations Management,* 30 (3), 802-814

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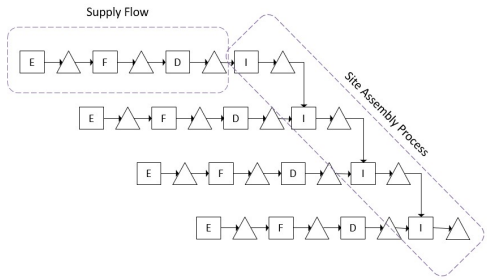
Operations Science



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

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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

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Process

Example: Engineer, Fabricate, Deliver, Install

Process begins by accumulating all needed resources

Proceeds through a sequence of operations

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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

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Projects

Creation of a unique device, structure, software, etc.

The creation is unique but composed of many repetitive processes

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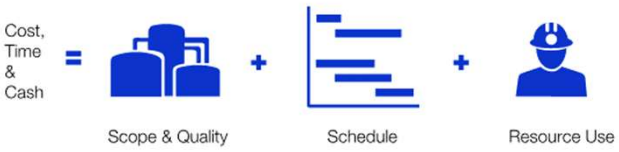
PROJECT MANAGEMENT



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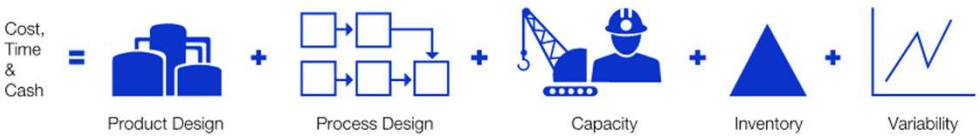
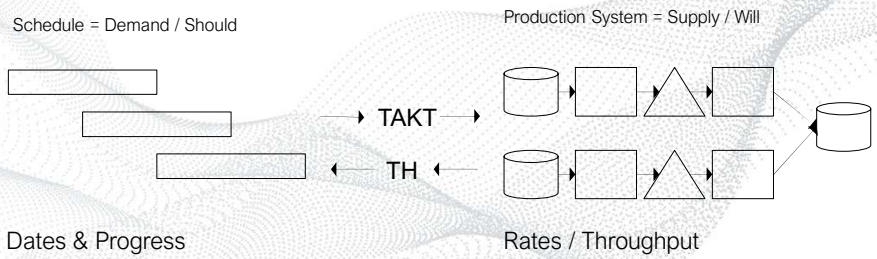


Maintain the Rates → Make the Dates



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Variability and Buffer Interactions

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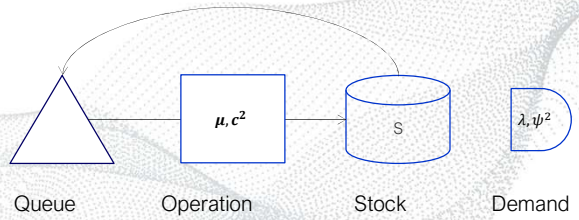
Simple production-inventory system



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

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Buffers

Time—demand waits on unit or task

Inventory—units or tasks wait on demand

Capacity—productive ability that exceeds average demand

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Time and Inventory Buffers mirror each other

Time-Inventory Buffer

Capacity Buffer mitigates Time-Inventory Buffer

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Explore buffer relationships with simulation

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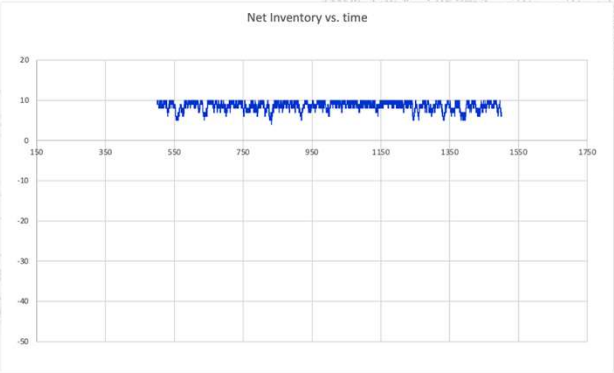
High Utilization, High Variability



Low Utilization, Low Variability

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Time-Inventory Buffer

The standard deviation of lead time demand

Capacity Buffer

Capacity less Average Demand

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Let $\psi^2 = c^2 = V$

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

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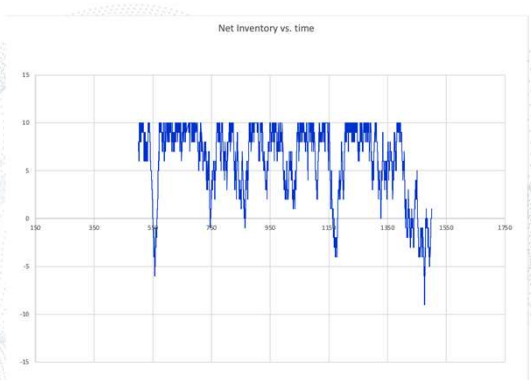
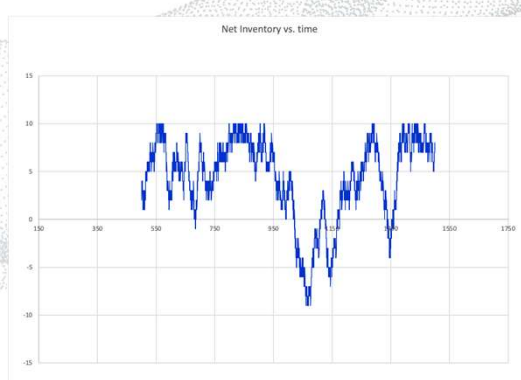
$$\lambda = 1, \mu = 1.25 \rightarrow 1.05$$
$$\psi^2 = c^2 = 0.93 \rightarrow 0.22$$





$$\sigma_{LTD} \approx 4.4$$

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

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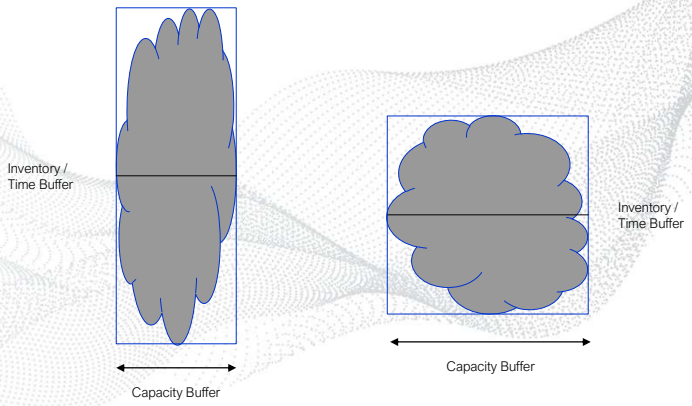

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Can you have an inventory of completed projects?

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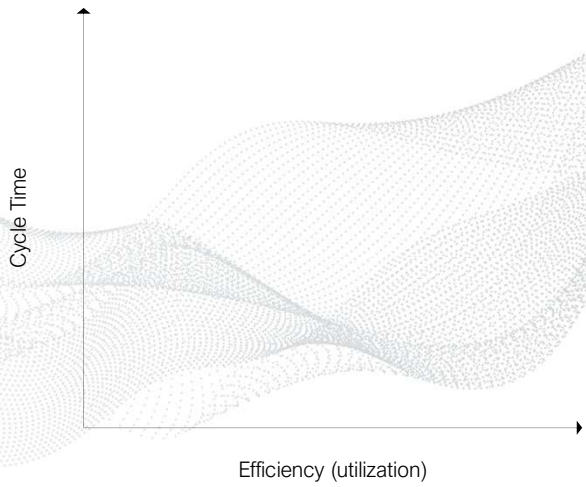

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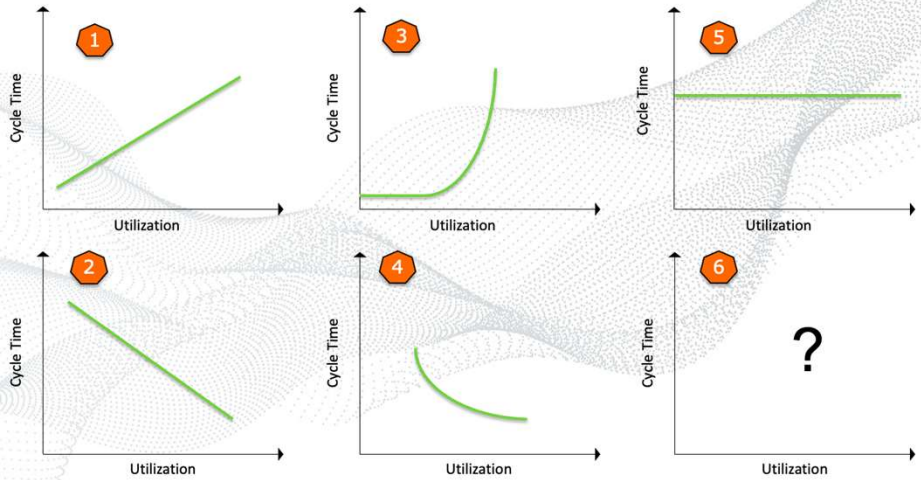

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Must have a capacity buffer to avoid the “time buffer”

Being overly “efficient” means being late

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Project Duration

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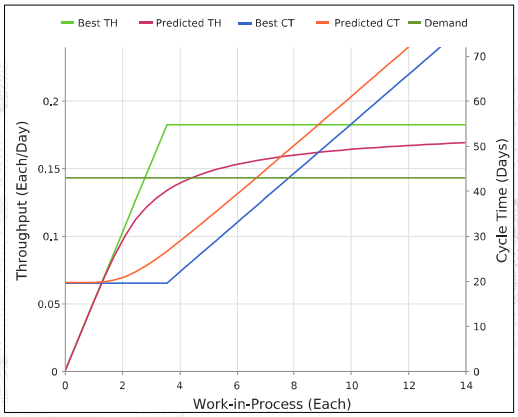

Too much WIP

long cycle times

inefficient production

Too little WIP

insufficient production

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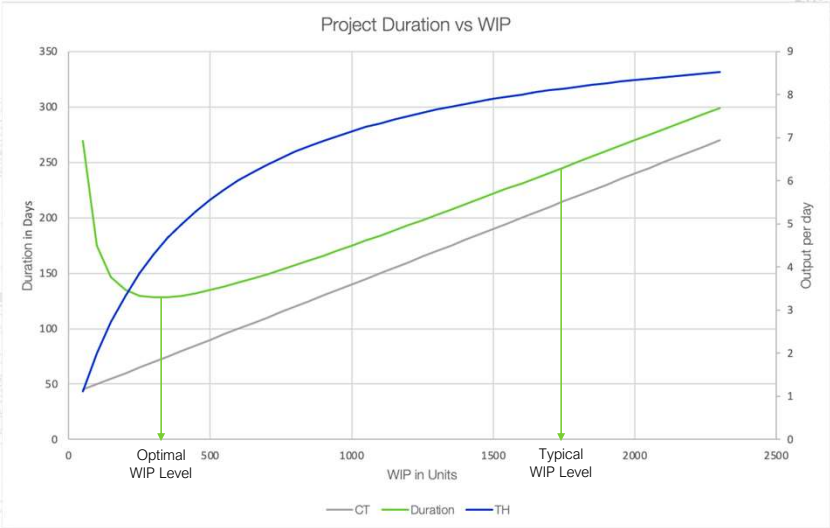

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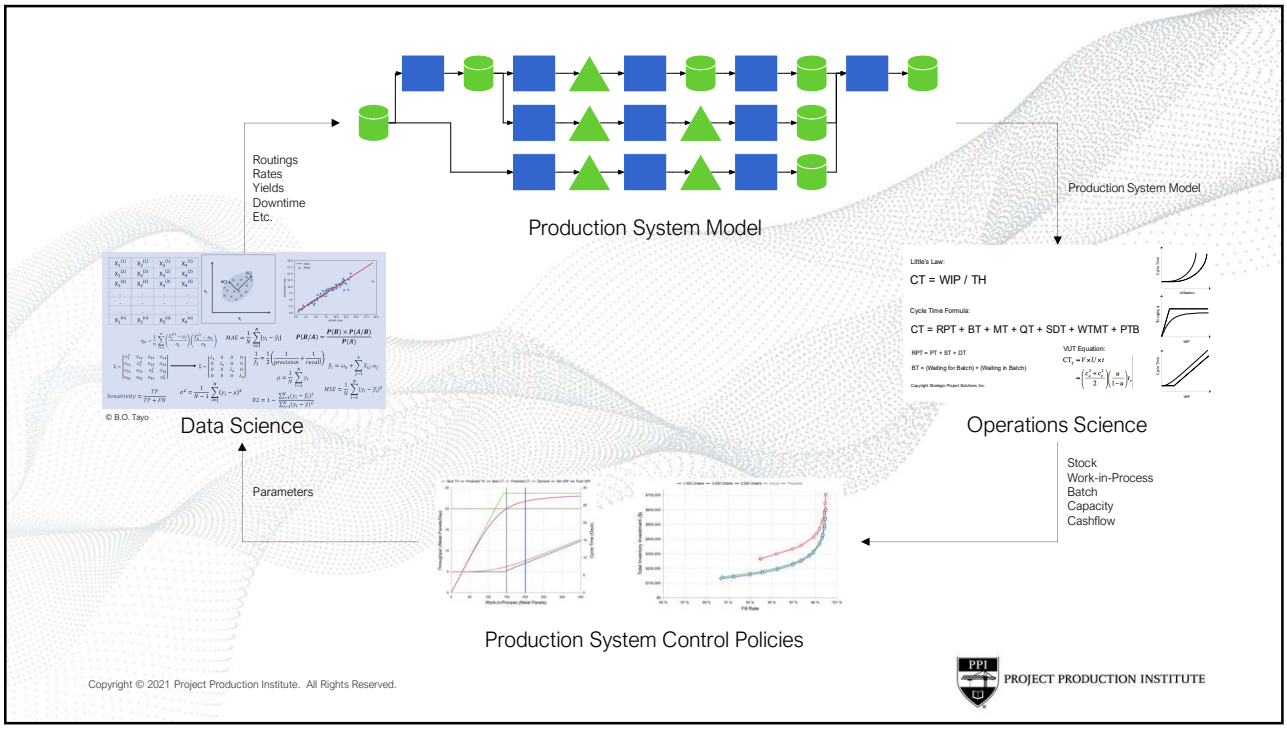

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Questions?

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