Project as a Flow

Engineer → Fabricate → Deliver → Install

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Maximize fabrication capacity utilization & minimize material waste using design/engineering inventory
Maximize transportation capacity utilization using inventory of finished goods
Inventory to optimize use of capacity onsite

- Engineer
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WIP (inventory) and/or time to decouple operations between trades or crews enabling optimization of capacity onsite.
STOCK is where supply and demand meet

QUEUE is where a part waits for a resource
Faster = More $  

Lower $ = Slower  

Any other solution?
Critical-Path Planning and Scheduling

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No variability

Start Date

Project Duration

Finish Date = Due Date
When will it finish?
Most likely finish time

Start Date

Finish Date = Due Date

Project Duration
Most likely finish time

Start Date

Finish Date = Due Date

Early Time
What does Early Time cost?

Work in process (WIP)

Little’s Law
- WIP = Early Time × Throughput
  - *Throughput* is rate of construction

So what?
- WIP is money (reduces cash flow)
- WIP can be lost, damaged, or stolen
- WIP can become obsolete when design changes are made
What does Early Time cost?

Example: Build 1 assembly per day at $100,000 each
Deliver 2 weeks early
$1.4 million in WIP!
Not counting loss, damage, or obsolete costs
Where does the Variability come from?

- Re-sequencing
- New technology
- Material defects
- New techniques
- Material delays
- Equipment failures
- Longer completion times
- Weather delays
- Ground conditions
- Expedited permits
- More favorable locations
- Rework
What are the effects on variability on a complex project?
How does Variability effect Wait Time?

Variability behaves like an “incompressible fluid”
It must go somewhere!

\[ D(0) \rightarrow t > 0 \rightarrow D(t) \]
Variability and Waiting

Abundant capacity

\[ \sigma_2^2 = \sigma_{a2}^2 + \rho \sigma_{s2}^2 \]

Number “waiting” is the % of time the resource is busy
Variability and Waiting

Less capacity to absorb variability in demand. The variability has to go somewhere—becomes WIP.

\[ \frac{X}{\lambda} \]

\[ \frac{\mu}{\lambda} \]

\[ 1 \]

\[ \langle Q \rangle \]

\[ \rho \]

\[ Q \]

\[ \frac{\mu}{\lambda} - 1 \]
From these two graphs and a little algebra we get the VUT equation

\[
CT_q \approx V \times U \times t
\]

\[
= \left( \frac{c_a^2 + c_e^2}{2} \right) \left( \frac{u}{1-u} \right) t_e
\]
Utilization is related to Cost

Scope: 200,000 Man-Hours
Duration: 1000 Days at 10 hr/day
Rate: $50 / hr

Utilization
100%: 200 people required → $10M
80%: 250 people required → $12.5M

Cost is 25% more!
Is there an implicit amount of variability in our time-cost trade-off curve that we take for granted?
At 100% utilization, with high variability, you never hit 50 days!
What Typically Happens?

Start Date  Due Date  Finish Date
How Do We Avoid It?

Start even earlier!
With low variability, you are able to achieve 50 days!
Is inventory root of all evil?
Variability is root of evil

Inventory is its flower
How do we make optimal cost – inventory/time, variability/complexity trade-off decision in a complex project production system?
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