The Logic of Flow: Some Indispensable Concepts

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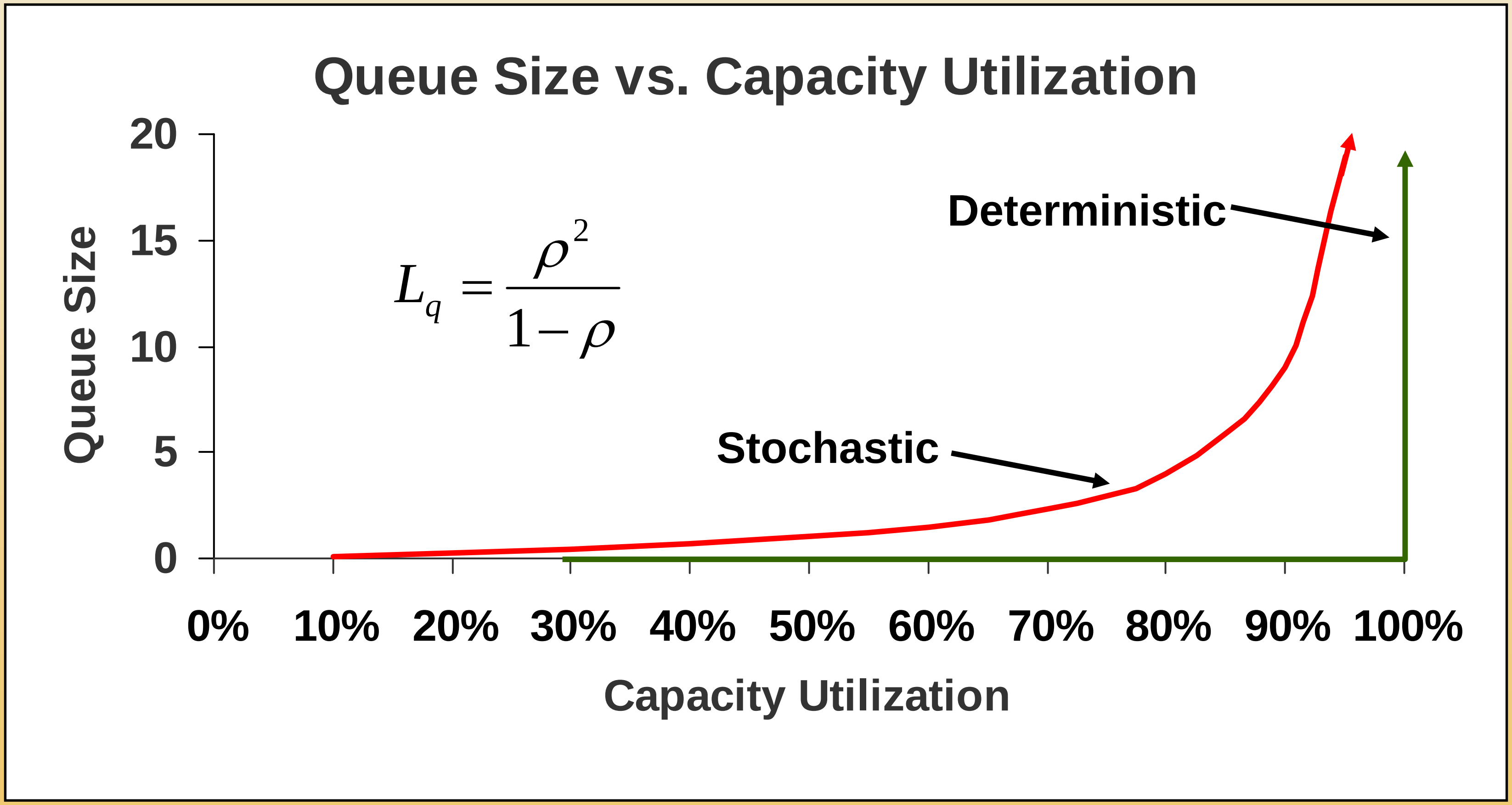
Objectives

- Discuss some key scientific and economic concepts behind flow.
  - Queueing
  - Batch size reduction
  - Fast feedback
  - Congestion control
- Interest you in exploring more advanced ideas.

Queueing

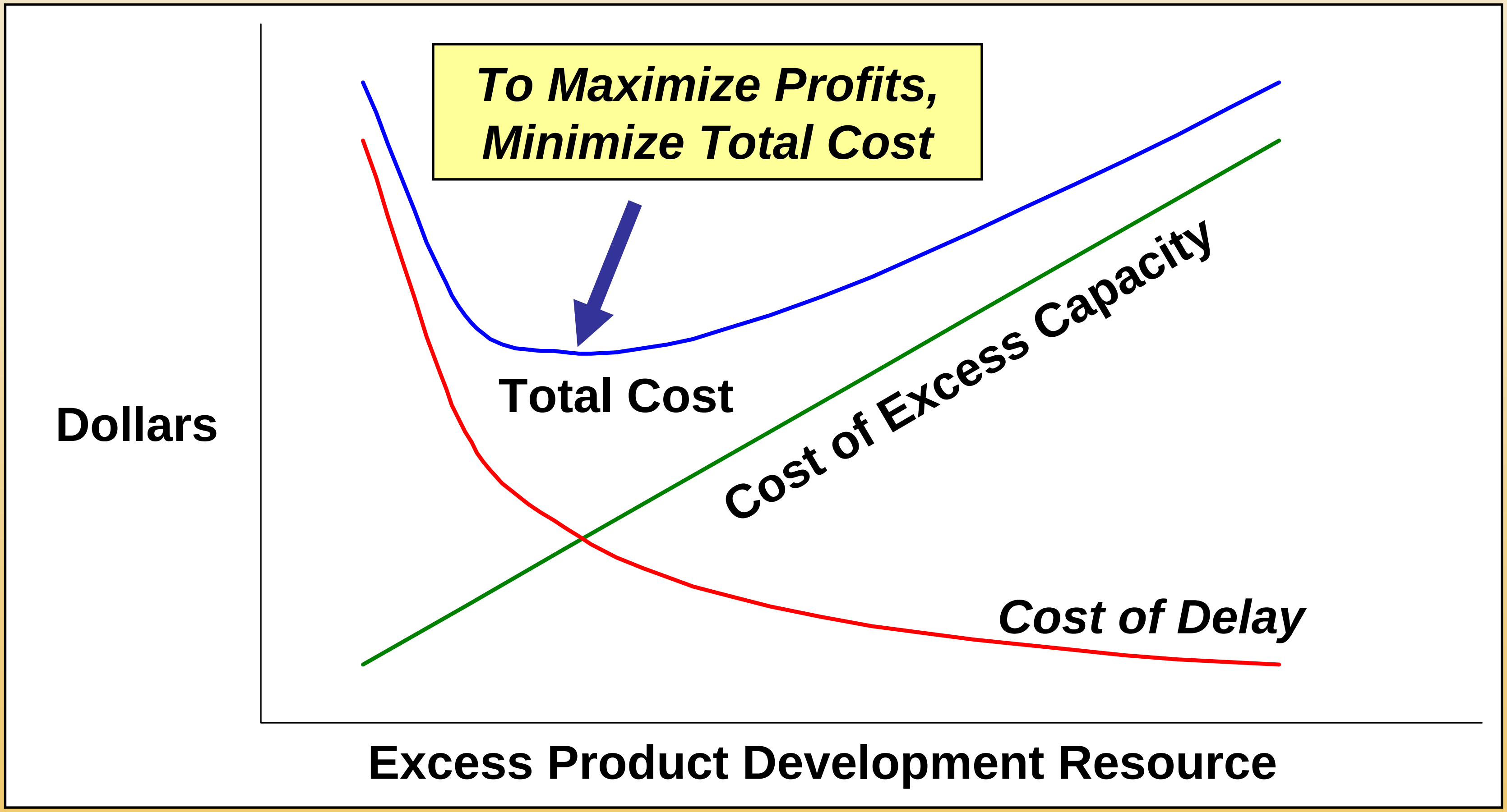
Traffic at rush hour illustrates the classic characteristics of a queueing system.

The Effect of Capacity Utilization

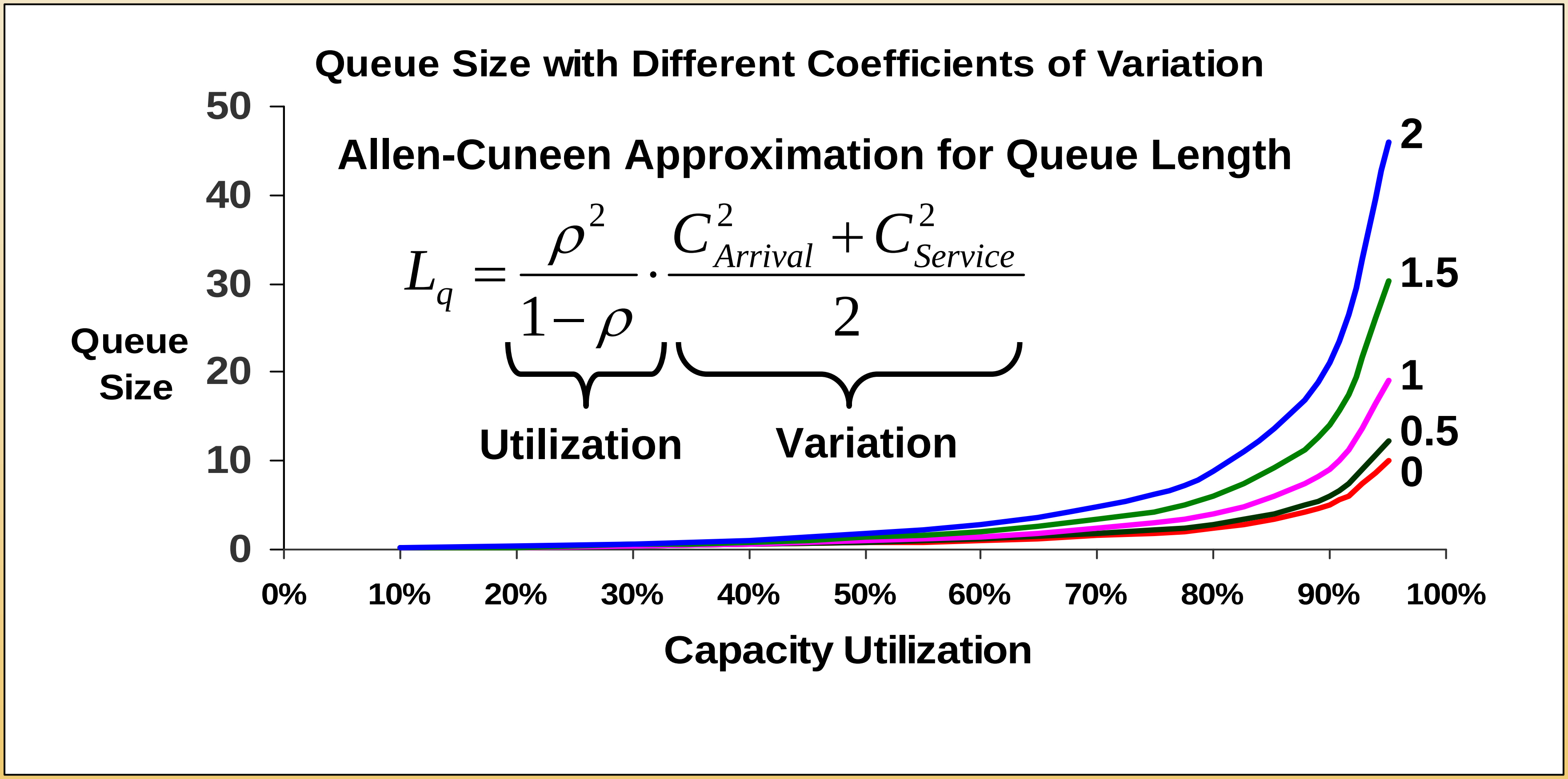


Notes: Assumes M/M/1/∞ Queue, ρ = Capacity Utilization, L_q = Length of Queue

The Economic Tradeoff



The Effect of Variability

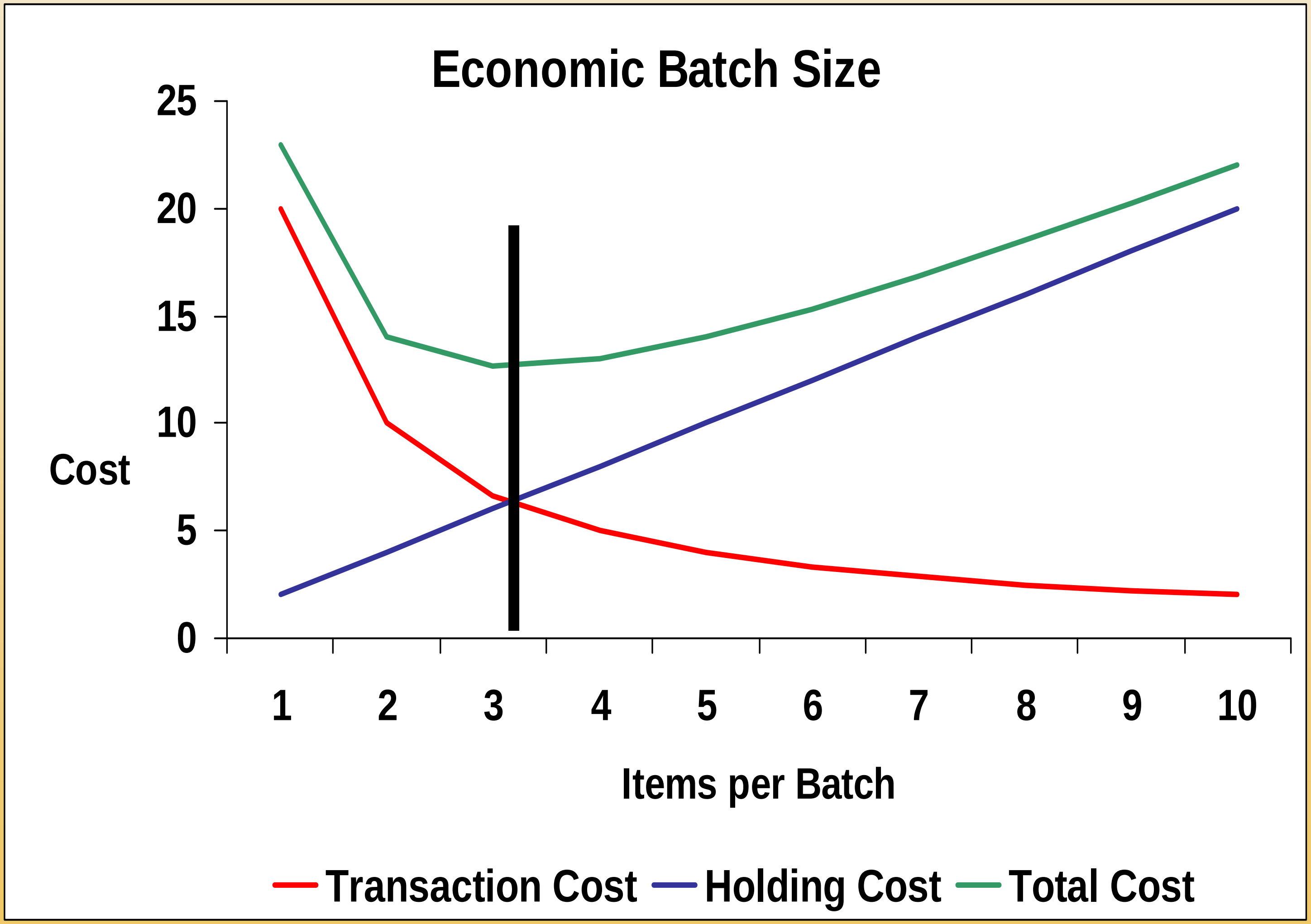


Notes: Assumes M/G/1/∞ Queue, ρ = Capacity Utilization

C = Coefficient of Variation (σ/μ), Coefficient for exponential distribution = 1

Batch Size Reduction

Finding Optimal Batch Size



“There are not many men who understand the theory underlying the economic size of lots, and so a knowledge of it should be of considerable value.”

Ford W. Harris
Production Engineer
Factory,
The Magazine of Management
Volume 10, Number 2
February 1913
pp. 135-136, 152

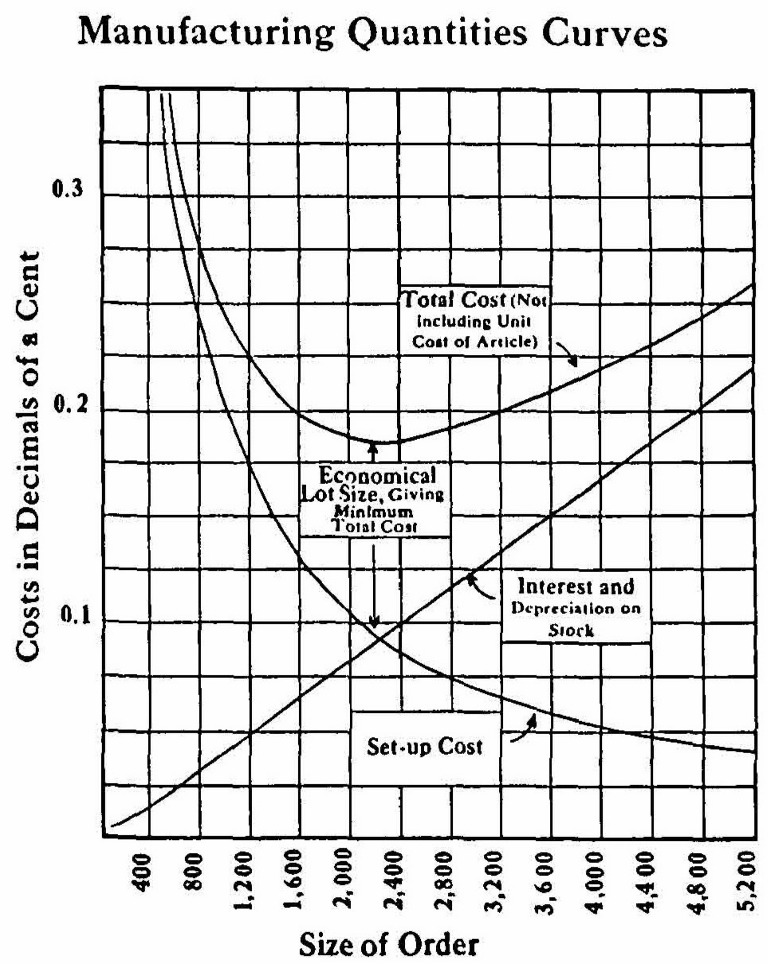


Figure I. An increase in the size of the order results in an increased interest charge and a decreased set-up cost. The curves show this graphically and indicate a minimum total cost in this case at 2,200 units.

Economic Lot Size

$$C_T = C_t + C_h$$

$$C_T = \frac{FN}{Q} + \frac{QVH}{2}$$

$$\frac{dC_T}{dQ} = 0 = -\frac{FN}{Q^2} + \frac{VH}{2}$$

$$\frac{FN}{Q^2} = \frac{VH}{2}$$

$$Q^2 = \frac{2FN}{VH}$$

$$Q = \sqrt{\frac{2FN}{VH}}$$

Optimal Lot Size!

C_T = Total Cost per year

C_t = Cost of all batches per year

C_h = Holding Costs per year

F = Fixed cost per batch

N = Total items per year

Q = Items per batch

H = Holding Cost per year (as percent of item cost)

V = Cost per item in batch

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Optimal Lot Size

C_T = *Total Cost per year*

C_t = *Cost of all batches per year*

C_h = *Holding Costs per year*

F = *Fixed cost per batch*

N = *Total items per year*

Q = *Items per batch*

H = *Holding Cost per year (as percent of item cost)*

V = *Cost per item in batch*

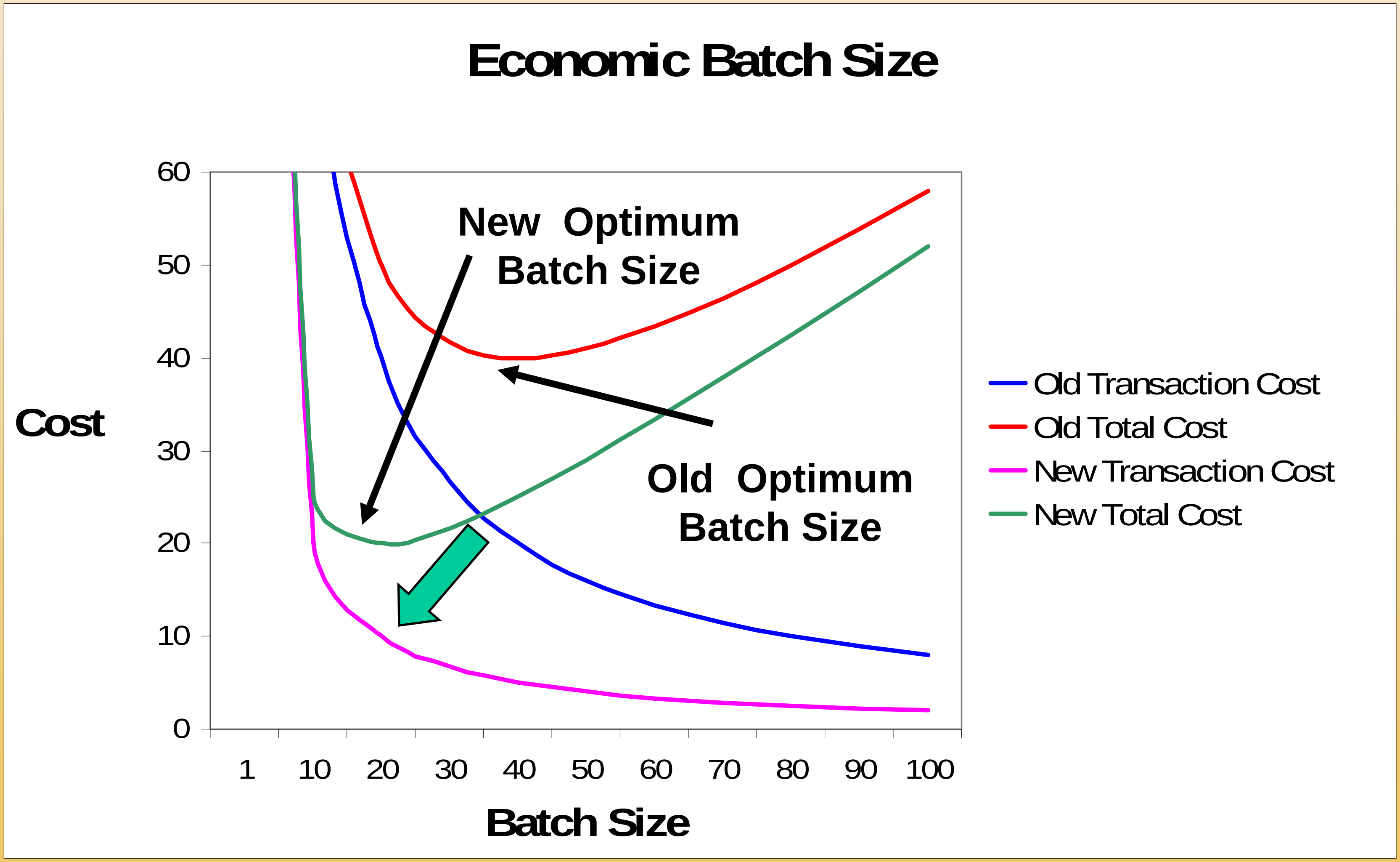
The Effect of Transaction Cost

- **When we decrease the fixed transaction cost we create a smaller optimal batch size.**
- **When we adopt this new optimal batch size we obtain a lower total cost.**
- **Thus, our one-time investment in enabling smaller batches is returned in form of a recurring stream of lower total costs.**

Total Cost at Optimal Batch Size

$$T_C = \sqrt{2FNVH}$$

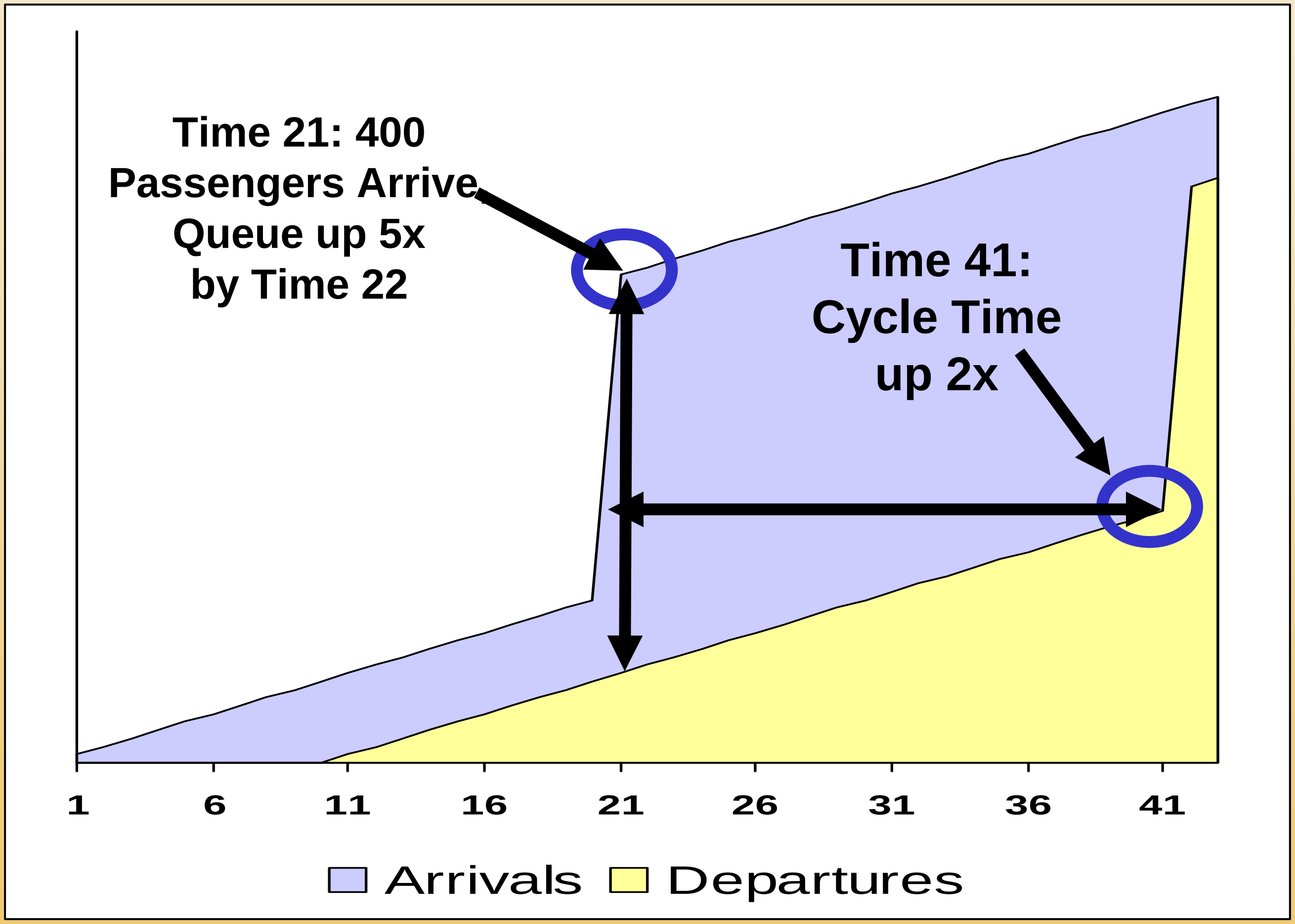
Transaction Cost Drives Total Cost



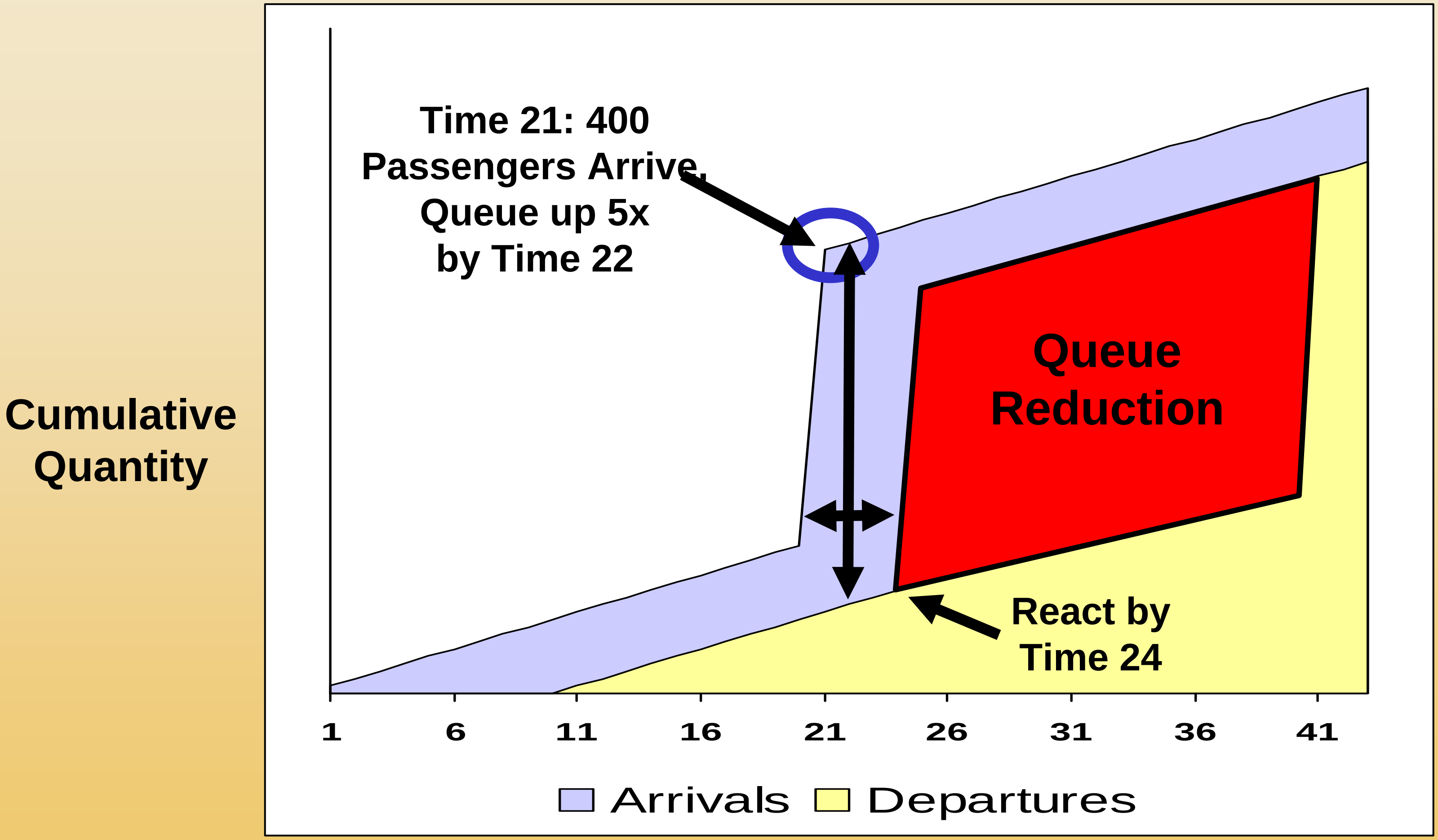
Fast Feedback

Better to Monitor Queues than Cycle Time

Cumulative Quantity



React Quickly to Rising Queues



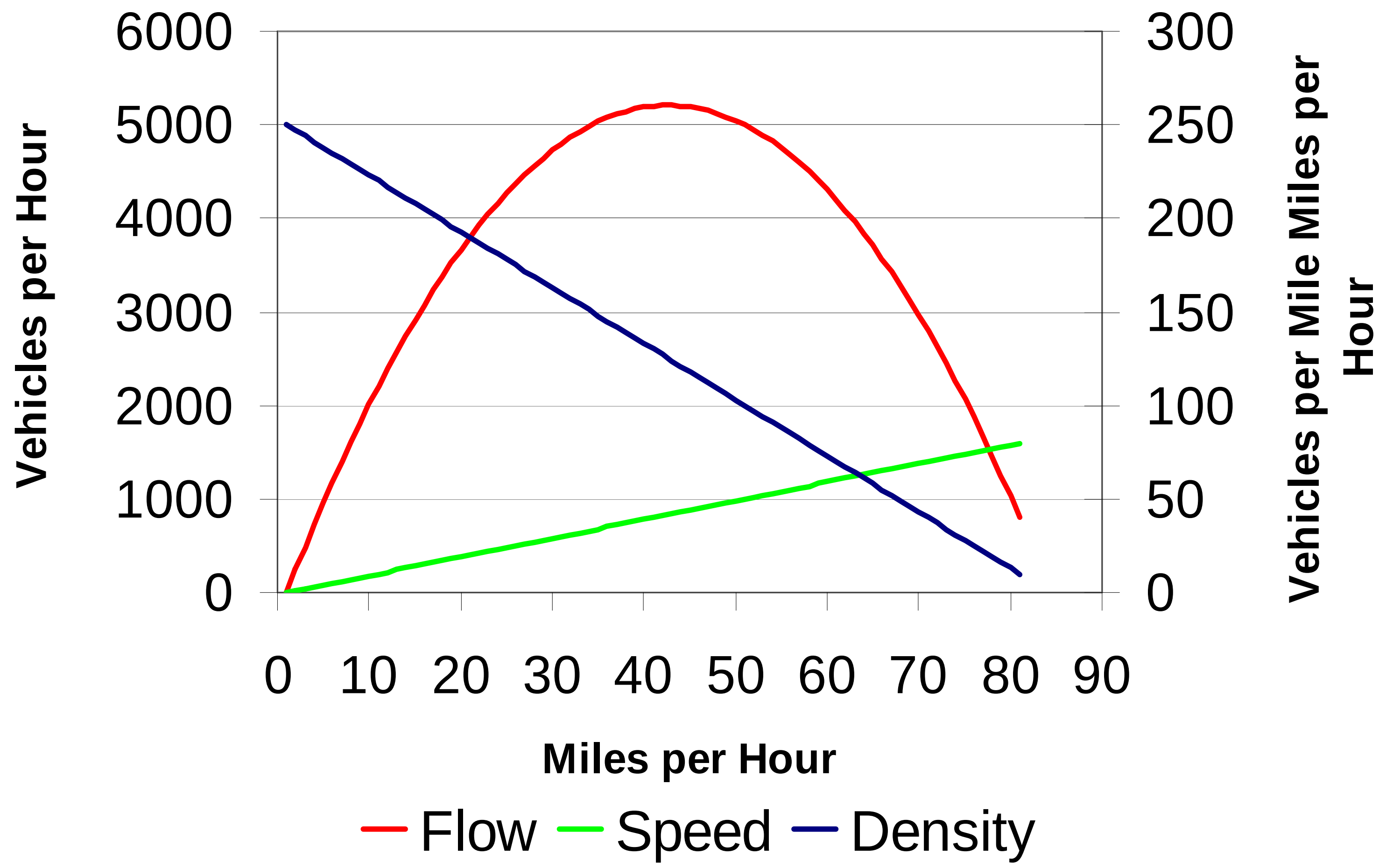
Congestion Control

Traffic Flow

Flow = Speed x Density

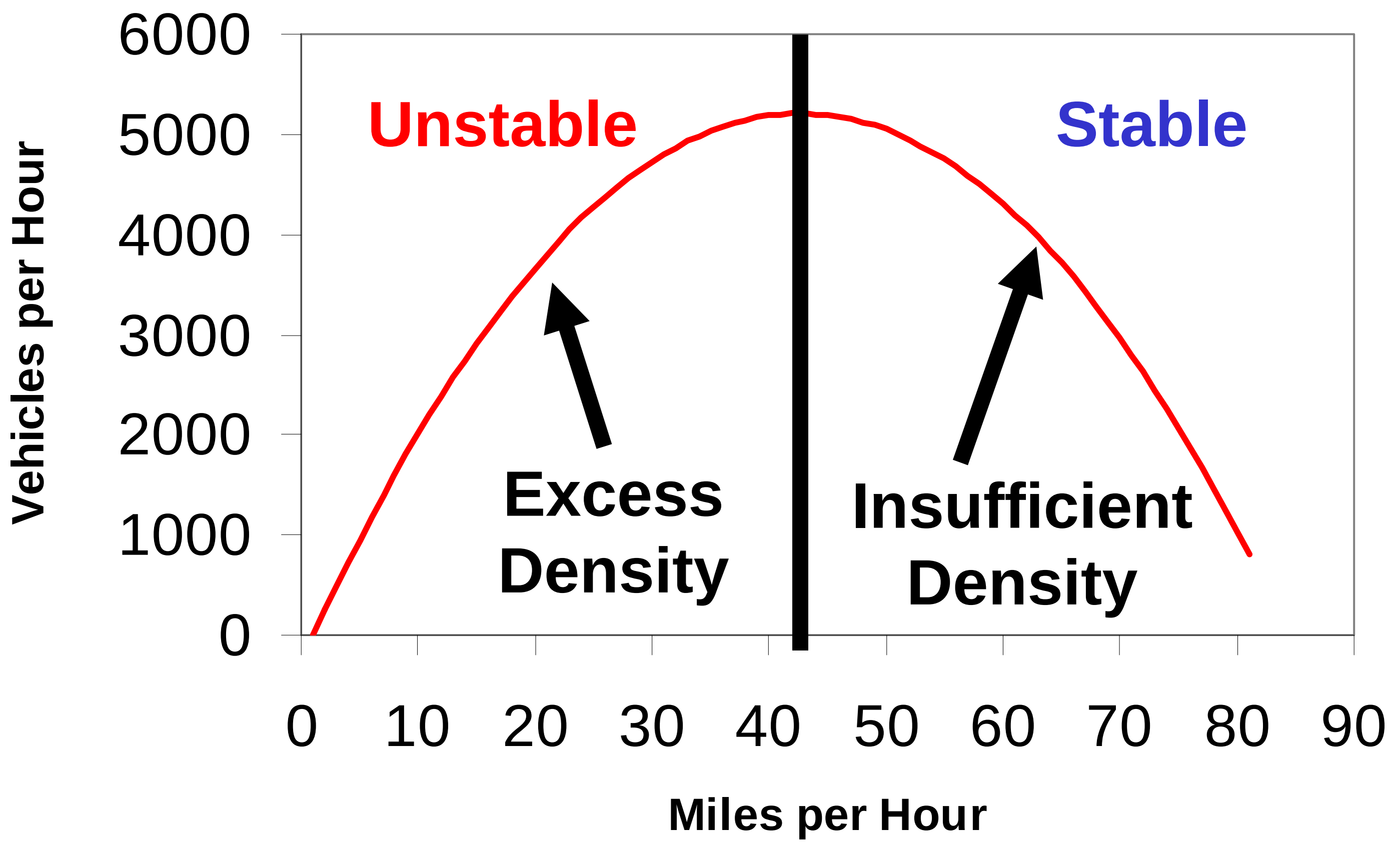
$$\frac{\text{Vehicles}}{\text{Hour}} = \frac{\text{Miles}}{\text{Hour}} \times \frac{\text{Vehicles}}{\text{Mile}}$$

Highway Throughput



Originally observed by Bruce Greenshields in 1934.

Feedback Effects



Where should we operate this system?

Learning from Transportation Networks I.

1. Maximum flow does not occur at either maximum speed or maximum occupancy.
2. Optimization requires tradeoffs between speed vs. occupancy.
3. Flow is unstable when occupancy exceeds the optimum level and stable below this point.
4. Fast responses are critical because queues grow faster than they shrink.
5. We should exploit both provisioning and active congestion management.
6. Smoothing flows before bottlenecks raises throughput.

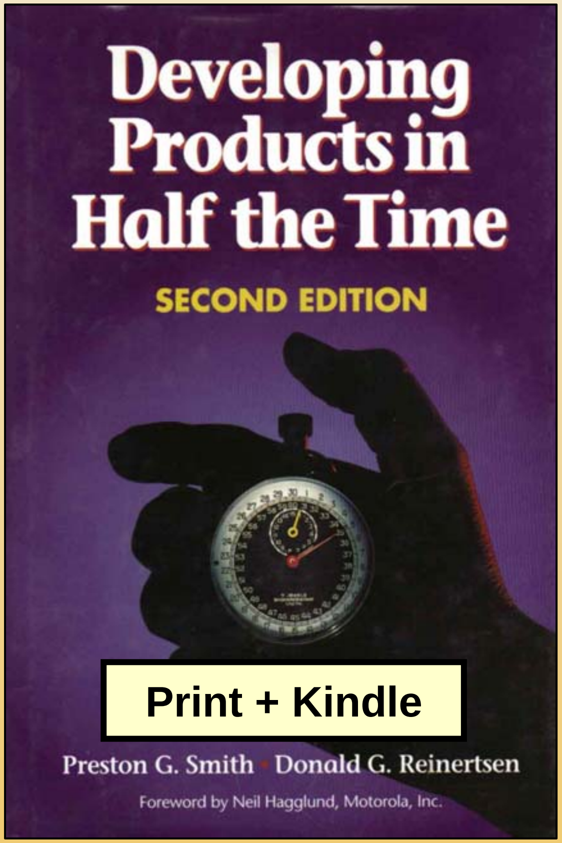
Learning from Transportation Networks II.

7. We should add capacity margin in zones of high variation.
8. Adaptive controls aid flow.
9. Queues produce spontaneous variation.
10. Lane changing can improve flows or worsen them.
11. Queue control improves with scale; scheduling becomes more difficult with scale.
12. We can make fast effective adjustments by combining centralized information and decentralized control.

Some Take Aways

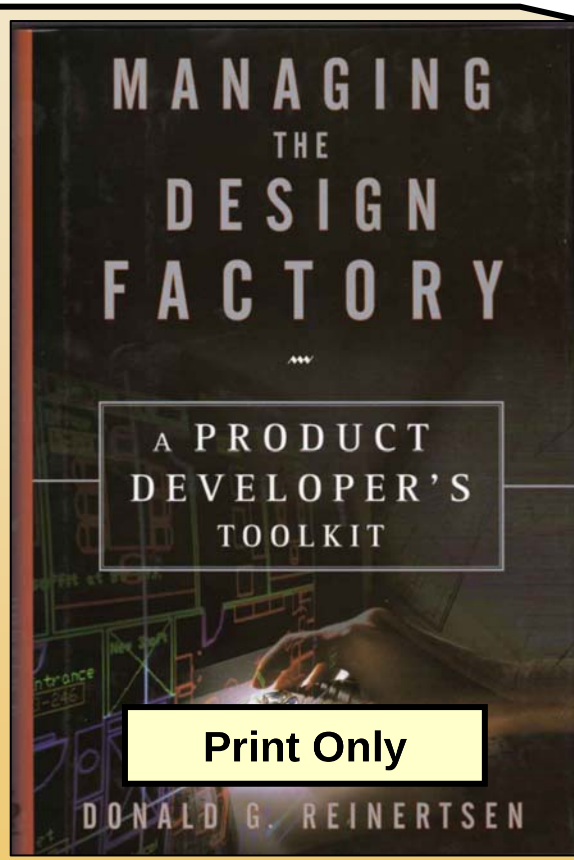
1. Both capacity and queues cost money.
2. Quantify the economics of your tradeoffs.
3. Know the Cost-of-Delay.
4. Exploit the flat bottom of the U-curve.
5. Reduce batch size before adding capacity.
6. Enable smaller batches by reducing transaction costs.
7. Transaction cost reduction will usually pay for itself.
8. Monitor queues instead of cycle time.
9. React quickly to expanding queues.
10. Design your process to tolerate variability.
11. Operate your process to minimize the effect of variability.
12. Look beyond the ideas of manufacturing.

"It's wonderful and dense. Filling and satisfying even in small bites. Like fine cheese."
– Torbjörn Gyllebring (@drunkcod)



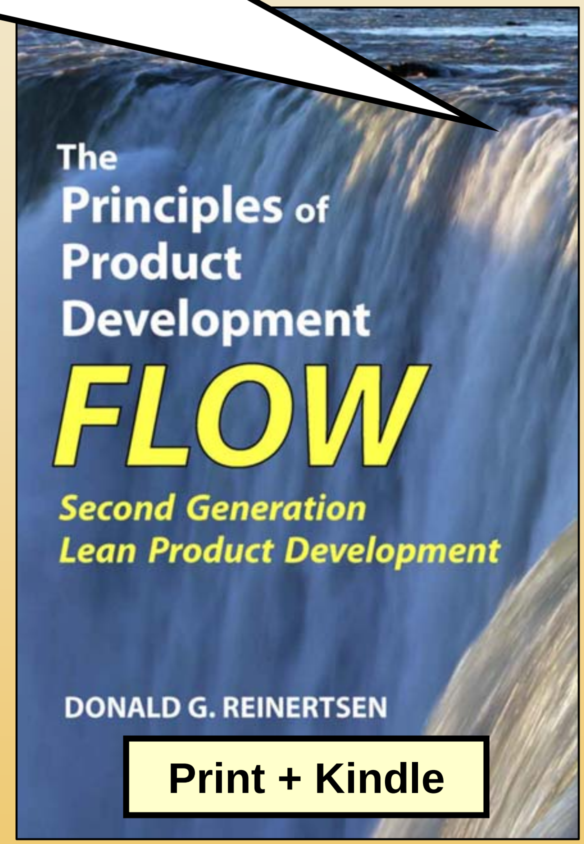
Print + Kindle

1991 / 1997



Print Only

1997



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2009