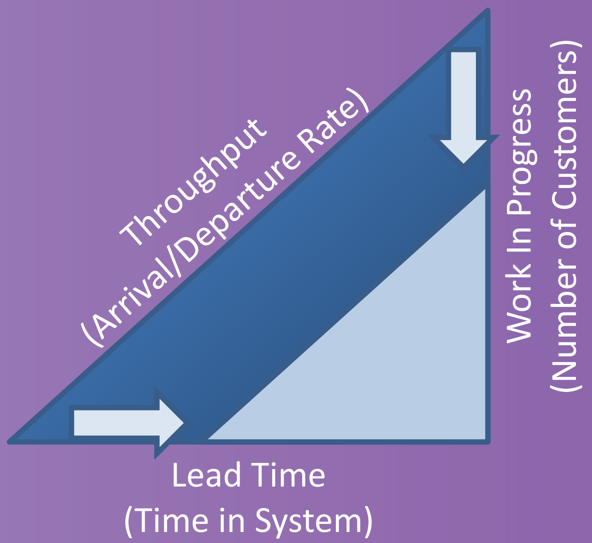
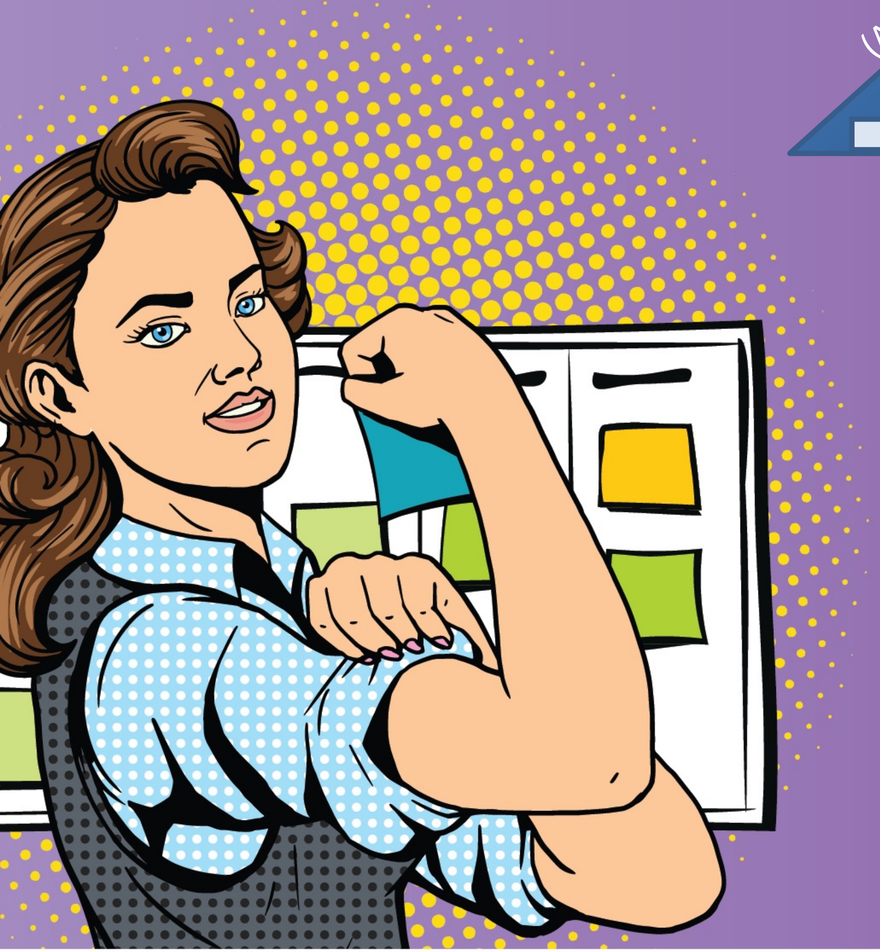


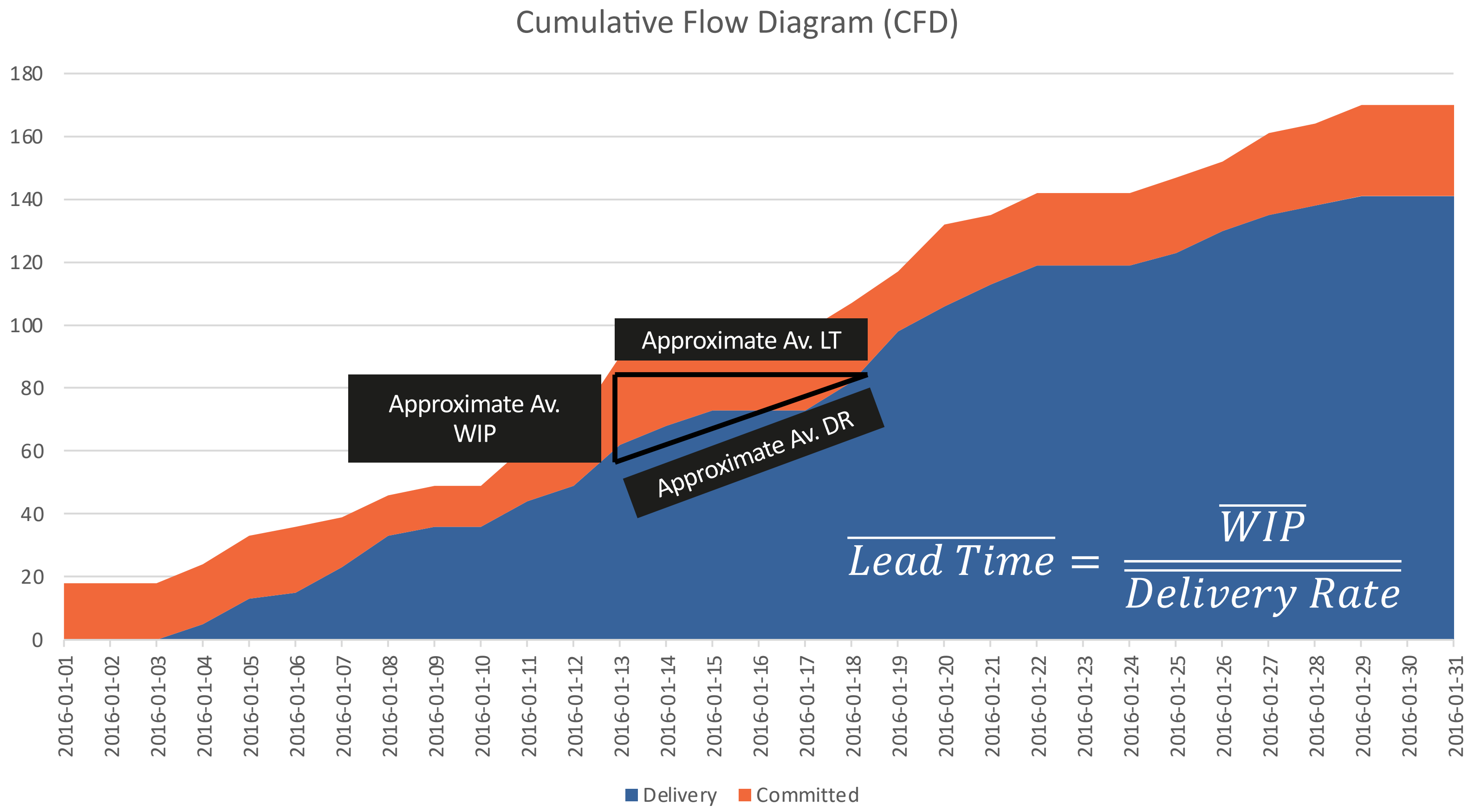



# Exploring Little's Law

Todd Little
Chairman Kanban University

# Estimate the # of Jelly Beans


# Little's Law – a Relationship of Averages




$$\overline{Lead\ Time} = \frac{\overline{WIP}}{\overline{Delivery\ Rate}}$$

!

Assumes that the system is not "trending" over the period of averaging.
The number of items entering and leaving system must be similar, and the average "age" of items in progress must not be increasing or decreasing.

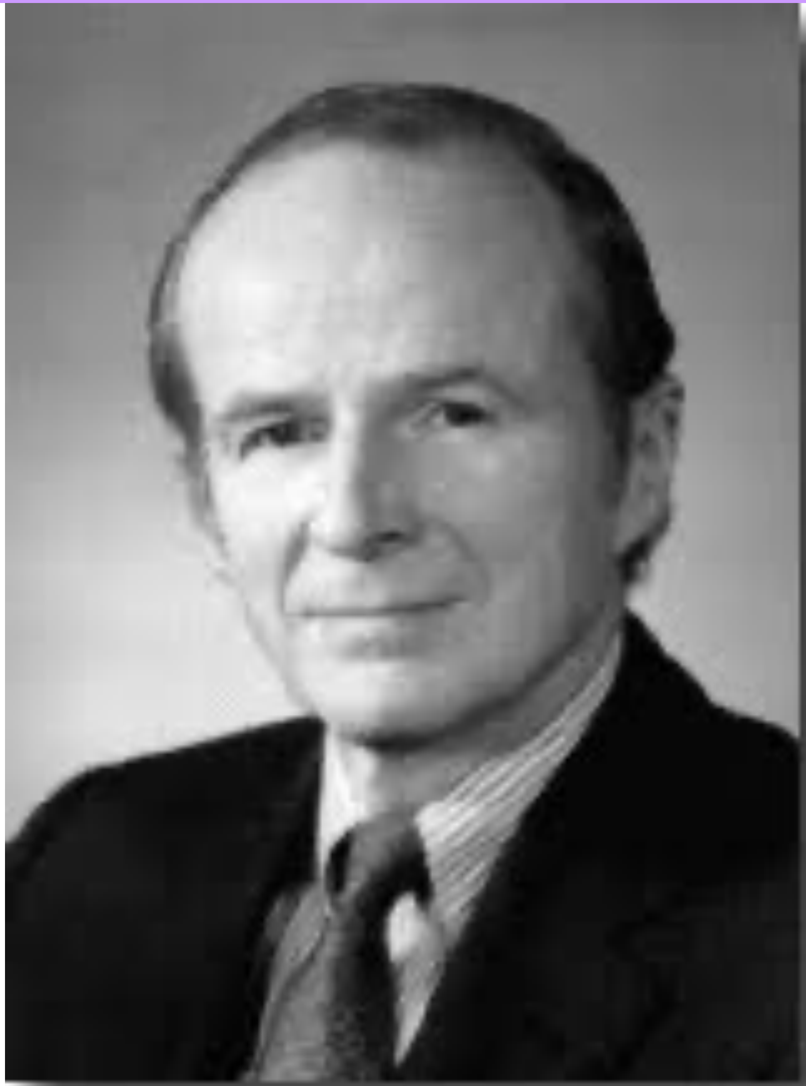
In spite of this restriction, the formula has proven its usefulness in many circumstances for understanding **how flow systems behave as WIP changes**.

# Little's **LλW** (John D. C. Little version)

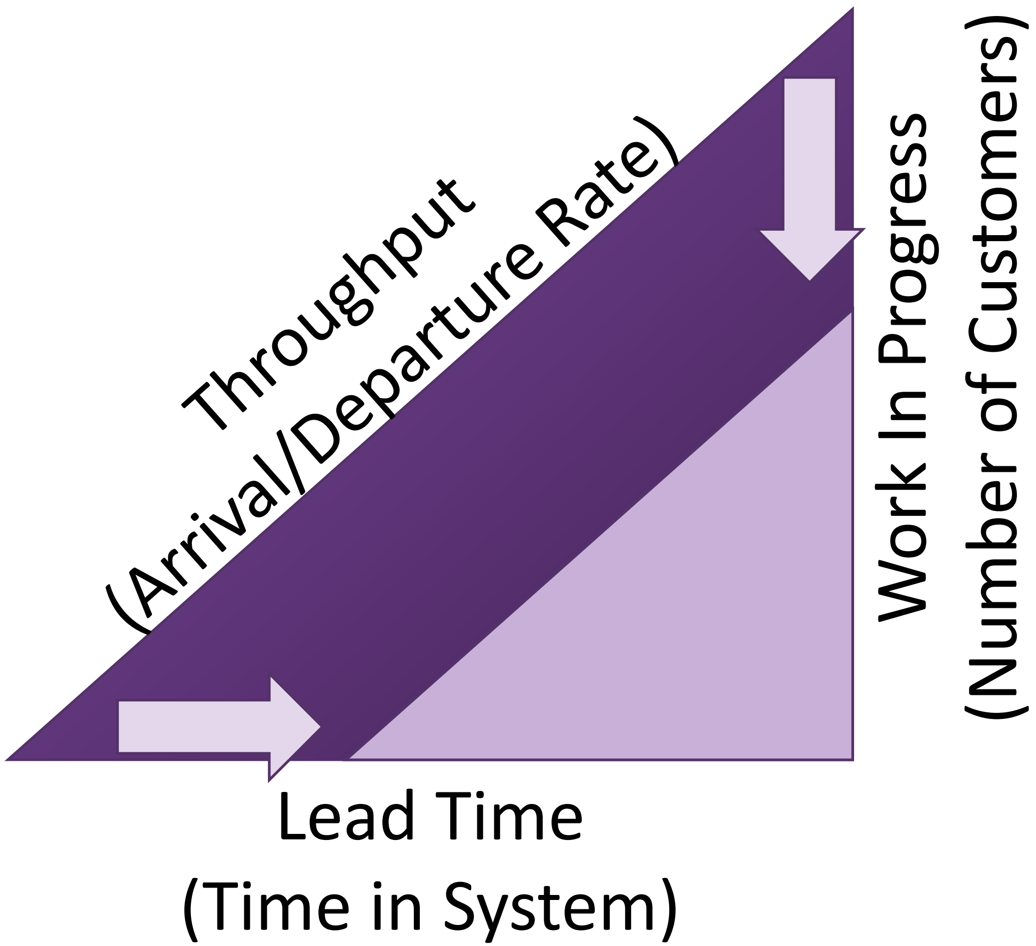
"The average number of customers in a system (over some interval) is equal to their average arrival rate, multiplied by their average time in the system."

Average Length of Queue **L** = λ**W** Average Wait Time (λ: Average Arrival Rate)

$$\overline{\text{Delivery Rate}} = \frac{\overline{\text{WIP}}}{\overline{\text{Lead Time}}}$$



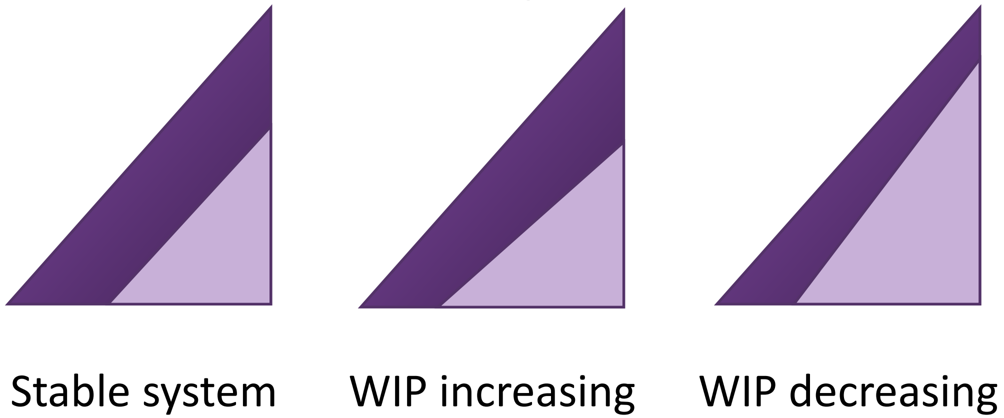
# Little's Law in Knowledge Work




**Little's Law Assumptions – The System is Stable and running at capacity**

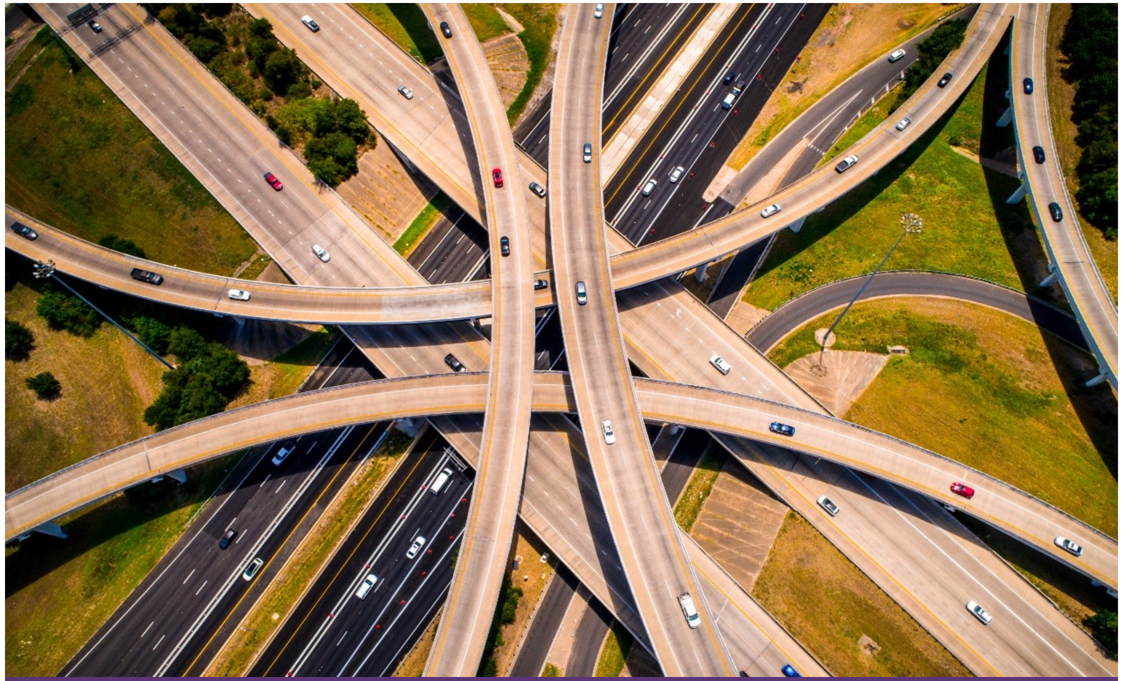
- The average Arrival Rate is equal to the average Departure Rate

**Cumulative Flow Diagrams**



# Introduction: Flow Efficiency

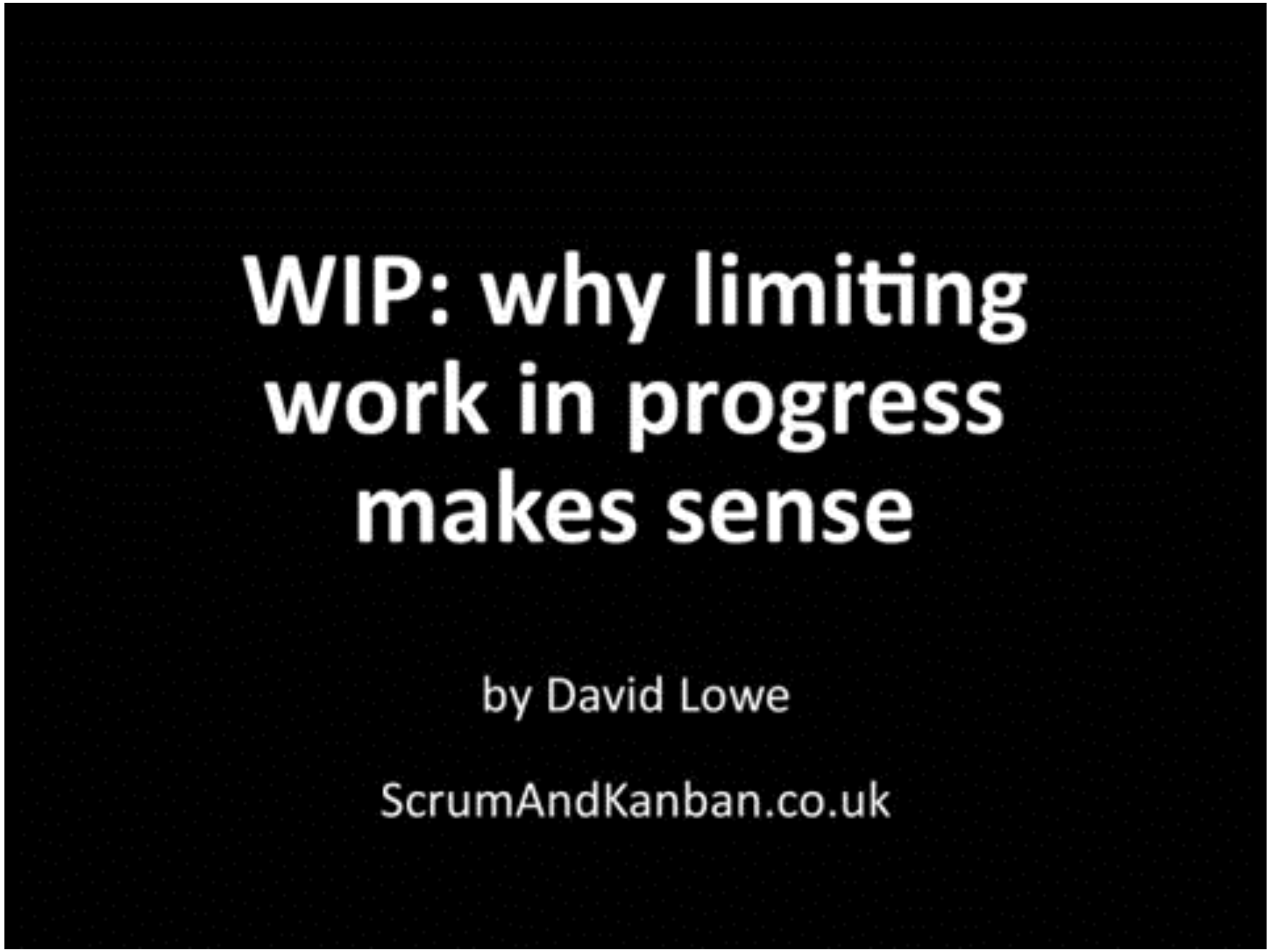
**Where would you prefer to travel?**
**How fast and smooth will your travel be?**



Few delays

Traveling time largely determined by delays.

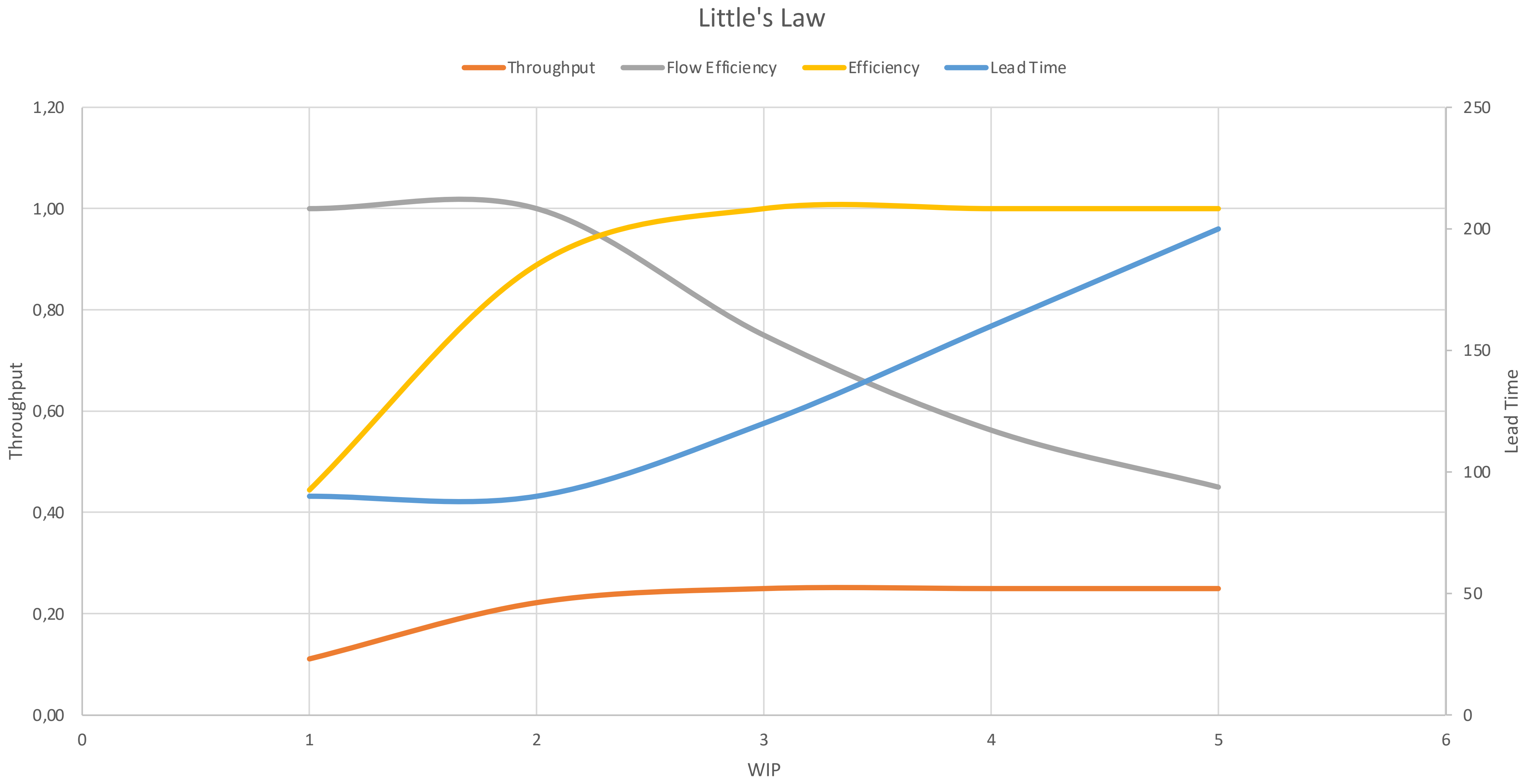
# Little's Law in Action



# Summary of Video Results

| WIP | Lead Time | Throughput | Flow Efficiency | Efficiency |
|---|---|---|---|---|
| 1 | 90 | 0.11 | 1.00 | 0.44 |
| 2 | 90 | 0.22 | 1.00 | 0.89 |
| 3 | 120 | 0.25 | 0.75 | 1.00 |
| 4 | 160 | 0.25 | 0.56 | 1.00 |
| 5 | 200 | 0.25 | 0.45 | 1.00 |

# Flow Efficiency, Efficiency, Lead Time and Throughput



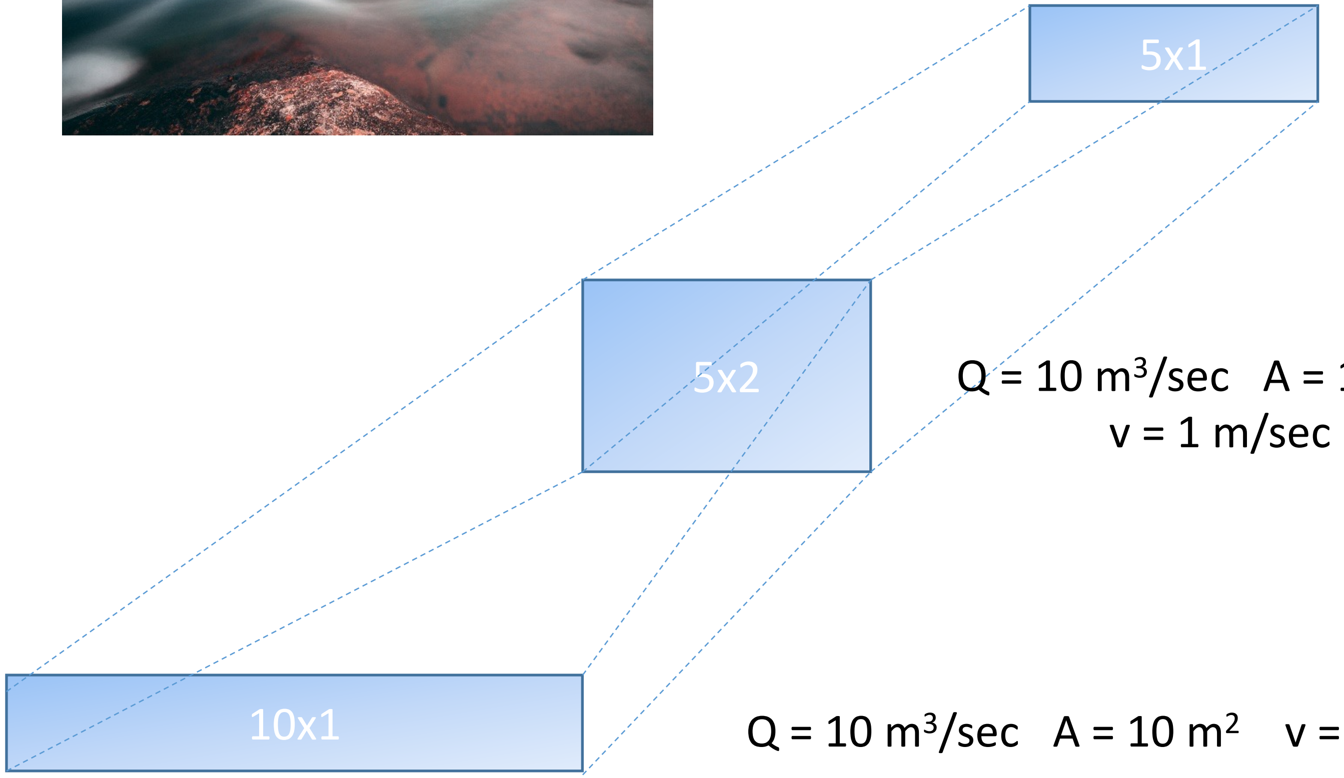
# What does Little’s Law say about multitasking?

# Design for Flow

# Be Like Water- Continuity Equation

$$Q = A * v$$

$Q = 10\ m^3/sec$   $A = 5\ m^2$   $v = 2\ m/sec$




$Q = 10\ m^3/sec$   $A = 10\ m^2$
$v = 1\ m/sec$

$Q = 10\ m^3/sec$   $A = 10\ m^2$   $v = 1\ m/sec$

# Be Like Water – College Chem E Version
# Input – Output = Accumulation

Input

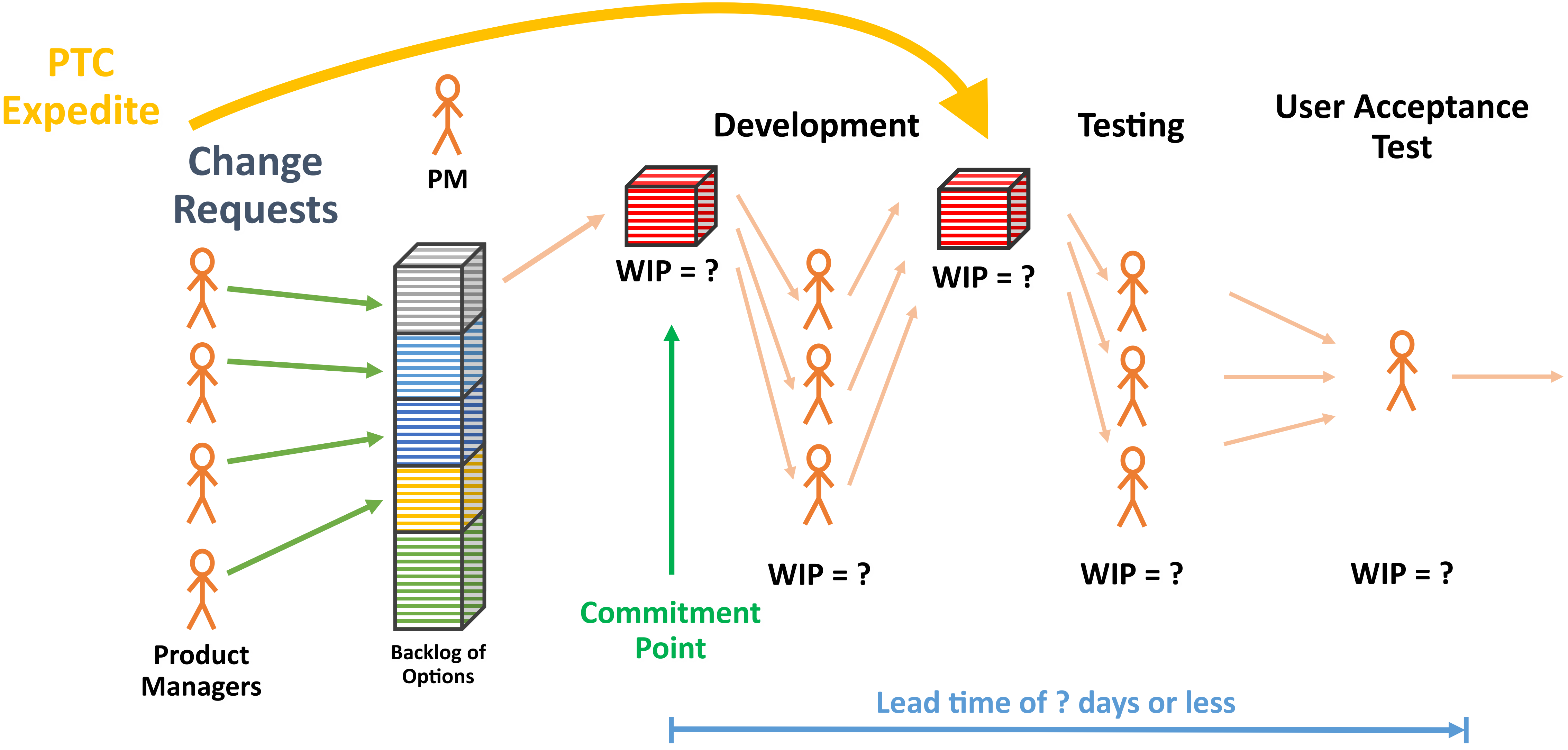
Process

Ouput

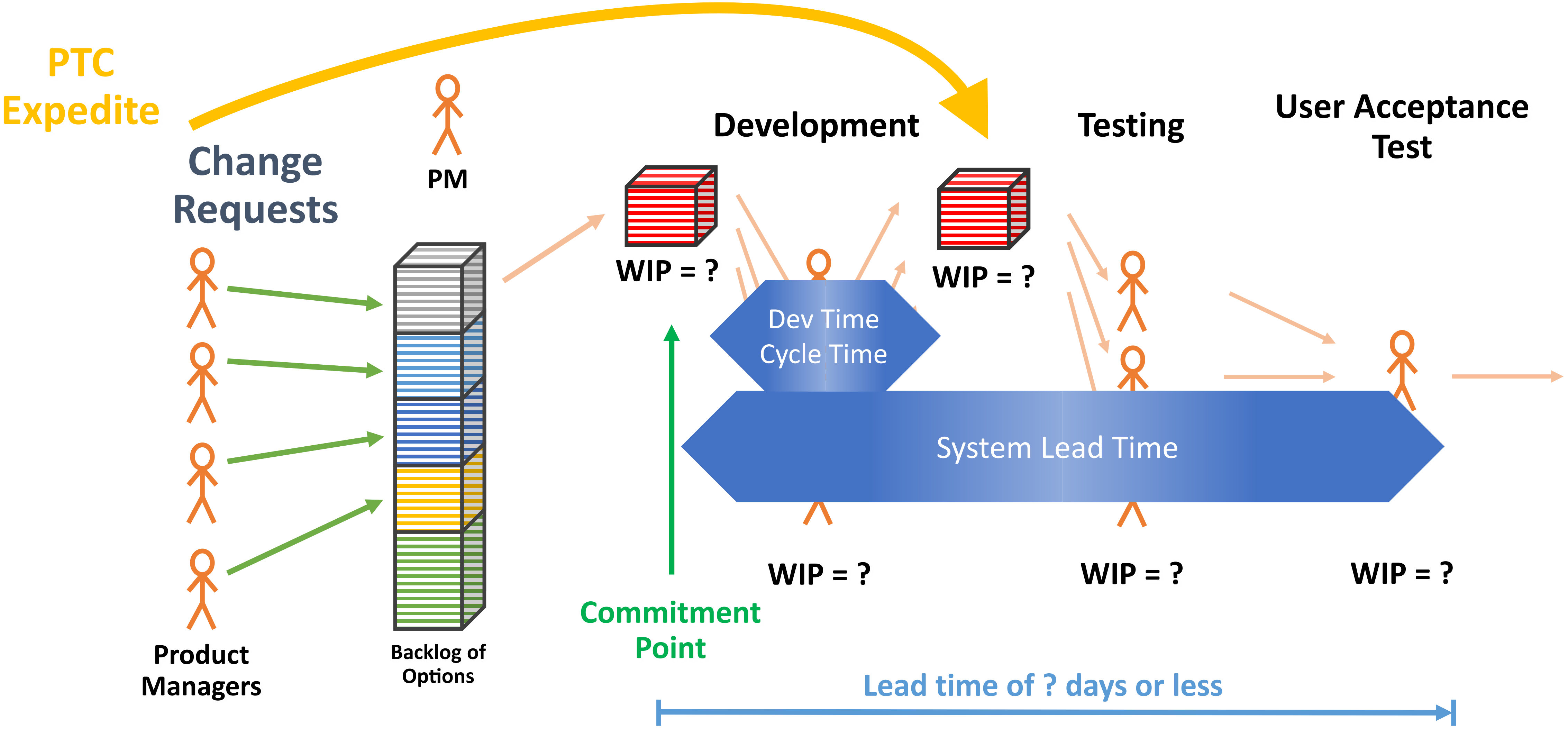
Accumulation

# Smooth Flow Throughout
# Optimize the Bottleneck

# Kanban System Design for XIT



# Kanban System Design for XIT



# Design Rules

- Start with what data you have. It need not be perfect
- Design for the bottleneck
  - For XIT - Engineering and Test
- Throughput is constant through the flow
- Queues – large enough to prevent starvation, small enough to keep lead time small
- Difference between WIP Limit and Average WIP

# Let’s get started

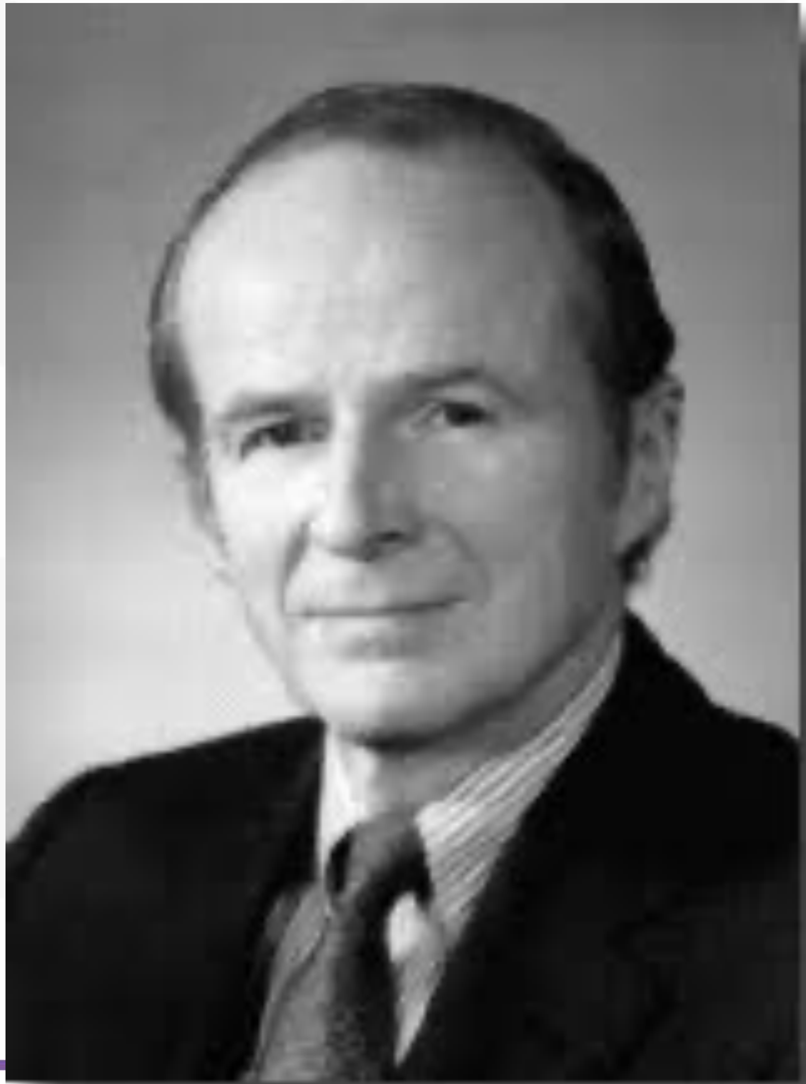
# Little's LλW (John D. C. Little version)

$$\overline{\text{Delivery Rate}} = \frac{\overline{\text{WIP}}}{\overline{\text{Lead Time}}}$$

Not Little's Law, but sometimes useful

$$\overline{\text{Delivery Rate}} = \frac{Max\ WIP}{Max\ Lead\ Time}$$

$$Min\ \text{Delivery Rate} = \frac{\overline{\text{WIP}}}{Max\ Lead\ Time}$$

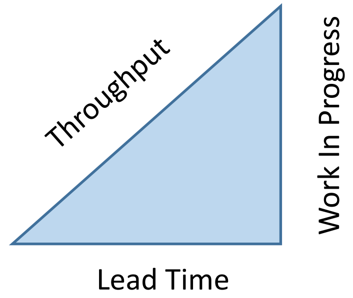


# Little's Law @XIT

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | | | | | | | |
| WIP Average | | | | | | | |
| Ave Lead Time | | | | | | | |
| WIP Limit | | | | | | | |
| Max Lead Time | | | | | | | |

# Determining an Expectation of Service Delivery

- Engineering effort (touch time)
  - Average engineering time was 11 days with outliers > 24 days
- Demand rate is 10-12 CR per month – can we meet it?
- Delivery rate estimate
  - Without estimation interruptions or multitasking, we have:
    - WIP = 6 (3 dev + 3 test)
    - Average Lead Time = 11 days
    - $Average\ Throughput = \frac{Average\ WIP}{Average\ LT} = \frac{6}{11} = 0.55$ items/day $= 11$ items/mo




- Queuing & buffering time estimates
  - Queues: large enough to prevent starvation, small enough to keep Lead Time small.

# Little’s Law @XIT

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | | | | 0.55 | | 0.55 | |
| WIP Average | | | | 3 | | 3 | |
| Ave Lead Time | | | | 5.5 | | 5.5 | |
| WIP Limit | | | | 3 | | 3 | |
| Max Lead Time | | | | 12 | | 12 | |

# Little’s Law @XIT - Smooth flow throughout

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | | | | 3 | | 3 | |
| Ave Lead Time | | | | 5.5 | | 5.5 | |
| WIP Limit | | | | 3 | | 3 | |
| Max Lead Time | | | | 12 | | 12 | |

# Queues and WIP limits

- Ready Queue
  - Replenishment will be weekly.
  - Allow 2X buffer
  - What is Starting WIP, Ending WIP, Average WIP?
  - Average Throughput of 2.7 items/week ( 5 x 0.55 )
  - Start with WIP limit of 5 to allow 2x buffer
  - Beginning WIP of 5, Ending WIP of 5-2.7=2.3
  - Average WIP of 5-(5-2.7)/2 = 3.65

# Little's Law @XIT - Replenishment

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | | | 3.65 | 3 | | 3 | |
| Ave Lead Time | | | 6.6 | 5.5 | | 5.5 | |
| WIP Limit | | | 5 | 3 | | 3 | |
| Max Lead Time | | | 10 | 12 | | 12 | |

# Queues and WIP limits

- Dev Done Queue
  - 3 items will be in Test with average Lead Time of 6 days.
  - How frequent does a Test slot free up?
  - On average, Test will free one slot every 2 days
  - Assume average Lead Time of 2 in Dev Done Queue

# Little's Law @XIT - Dev Done Buffer

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | | | 3.65 | 3 | 1.1 | 3 | |
| Ave Lead Time | | | 6.6 | 5.5 | 2 | 5.5 | |
| WIP Limit | | | 5 | 3 | 2 | 3 | |
| Max Lead Time | | | 10 | 12 | 3.6 | 12 | |

# Queues and WIP limits

- UAT
  - Max Lead Time of 10 days.
  - WIP Limit of 10 * 0.55 = 5.5 -> 6
  - Assume Average WIP of ½ limit = 3

# Little's Law @XIT - UAT Buffer

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | | | 3.65 | 3 | 1.1 | 3 | 3 |
| Ave Lead Time | | | 6.6 | 5.5 | 2 | 5.5 | 5.5 |
| WIP Limit | | | 5 | 3 | 2 | 3 | 6 |
| Max Lead Time | | | 10 | 12 | 3.6 | 12 | 10 |

# Little’s Law @XIT - System

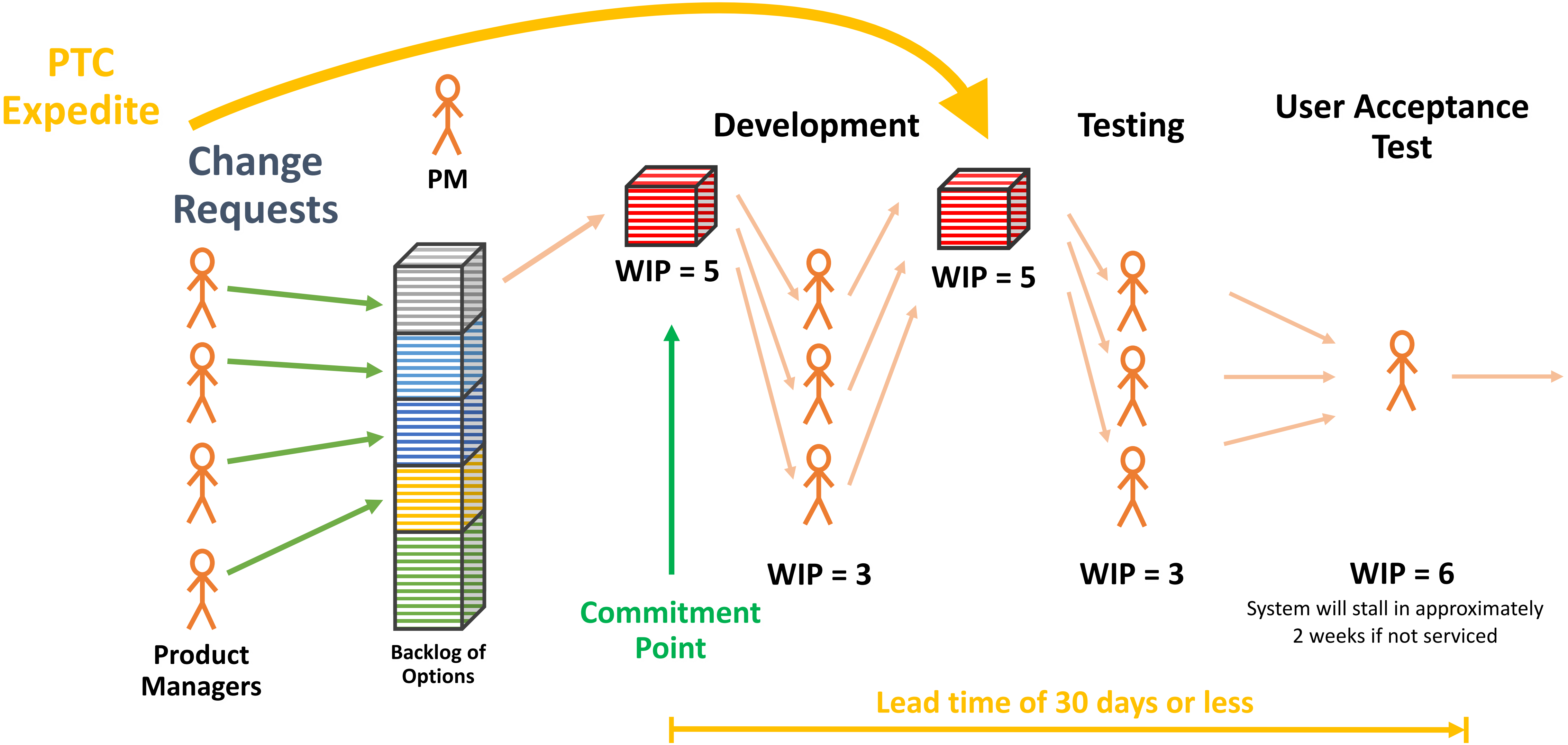
| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | 13.7 | | 3.65 | 3 | 1.1 | 3 | 3 |
| Ave Lead Time | 25.1 | | 6.6 | 5.5 | 2 | 5.5 | 5.5 |
| WIP Limit | 19 | | 5 | 3 | 2 | 3 | 6 |
| Max Lead Time | 47.6 | | 10 | 12 | 3.6 | 12 | 10 |

## Can we meet a target Lead Time of 30 days with a high (98%) Service Expectation?

## What knobs might you tweak to help meet the SLE?

| | System | | Ready | Dev | Dev Done | Test | UAT |
|---|---|---|---|---|---|---|---|
| Ave Throughput | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| WIP Average | 13.7 | | 3.65 | 3 | 1.1 | 3 | 3 |
| Ave Lead Time | 25.1 | | 6.6 | 5.5 | 2 | 5.5 | 5.5 |
| WIP Limit | 19 | | 5 | 3 | 2 | 3 | 6 |
| Max Lead Time | 47.6 | | 10 | 12 | 3.6 | 12 | 10 |

# Kanban System Design for XIT



# Let’s play a game

## Google Spreadsheet

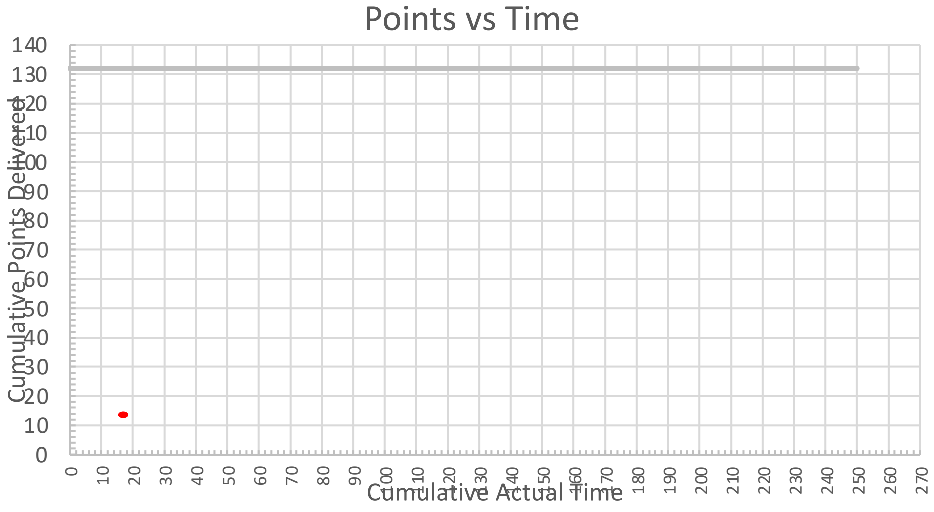
bit.ly/3PGymF9

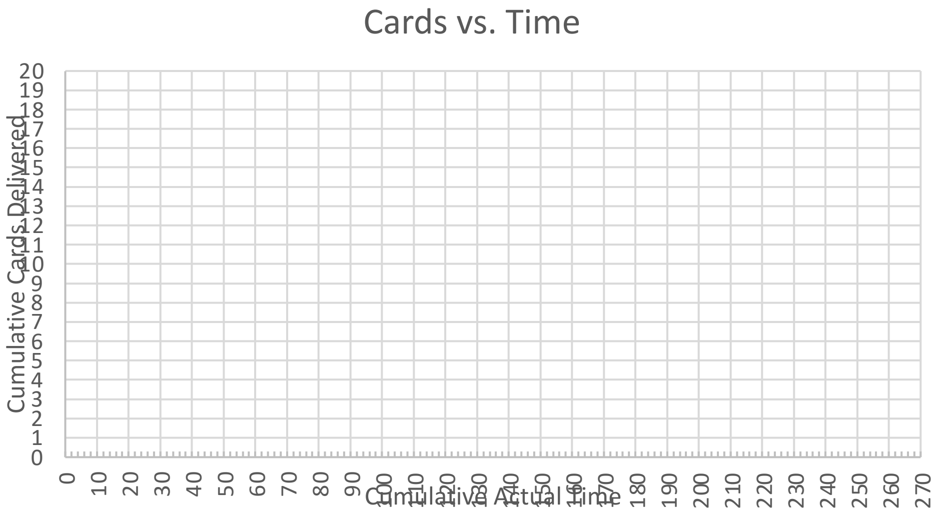
## Old School

| Little's Law Tally Sheet | | | | | | | |
|---|---|---|---|---|---|---|---|
| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
| **Card** | **Size** | **Die roll** | **Actual Time** | **Cummulative Actual** | **Cummulative Size** | **Size Forecast** | **Count Forecast** |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | | | | | | |
| 16 | | | | | | | |
| 17 | | | | | | | |
| 18 | | | | | | | |
| 19 | | | | | | | |
| 20 | | | | | | | |

# Serious Old School

| Little's Law Tally Sheet | | | | | | | |
|---|---|---|---|---|---|---|---|
| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
| Card | Size | Die roll | Actual Time | Cummulative Actual | Cummulative Size | Size Forecast | Count Forecast |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | | | | | | |
| 16 | | | | | | | |
| 17 | | | | | | | |
| 18 | | | | | | | |
| 19 | | | | | | | |
| 20 | | | | | | | |



# Per Table

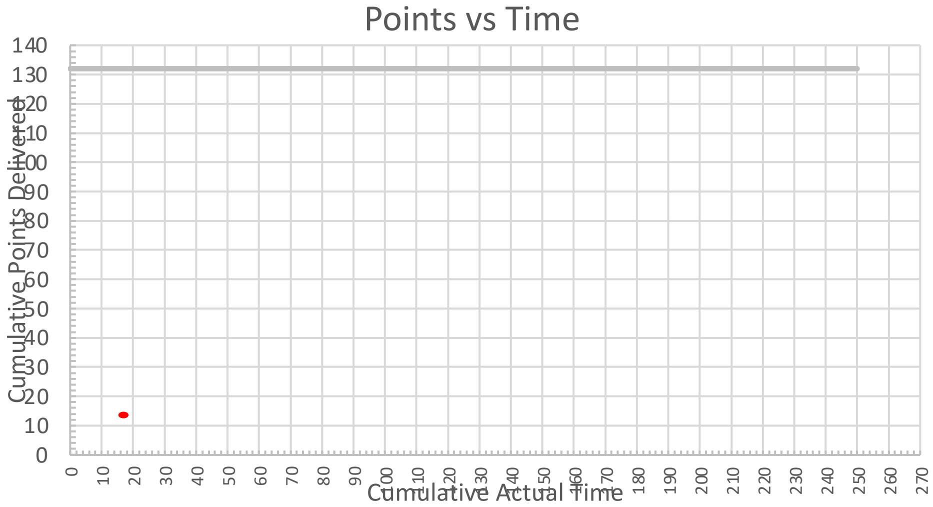
## Deck of Cards

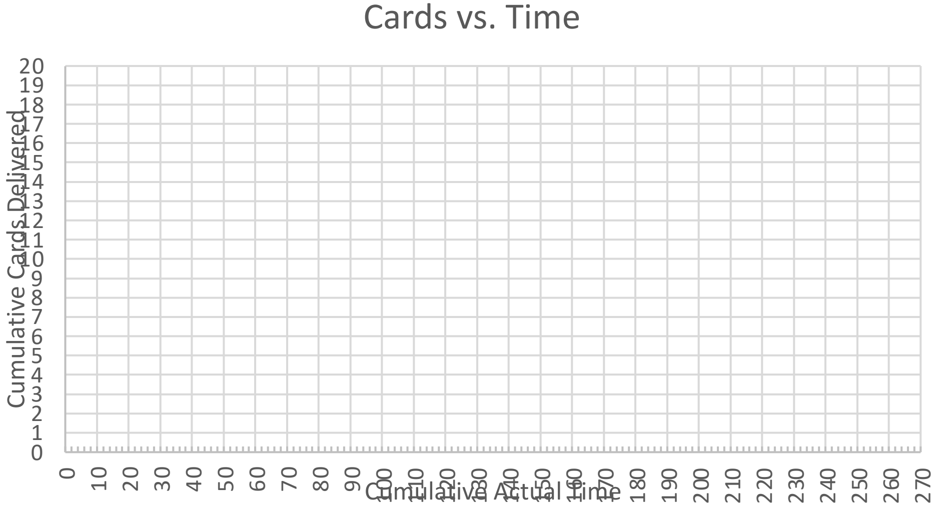

## Adjustment Table

| | Card Value | | | | | |
|---|---|---|---|---|---|---|
| Die | 2 | 3 | 5 | 8 | 13 | 20 |
| 1 | 1 | 2 | 3 | 4 | 8 | 13 |
| 2 | 1 | 2 | 4 | 6 | 10 | 16 |
| 3 | 2 | 3 | 5 | 8 | 13 | 20 |
| 4 | 2 | 3 | 5 | 8 | 13 | 20 |
| 5 | 4 | 6 | 7 | 11 | 16 | 25 |
| 6 | 6 | 8 | 10 | 16 | 22 | 30 |

# Per person

| Little's Law Tally Sheet | | | | | | | |
|---|---|---|---|---|---|---|---|
| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
| **Card** | **Size** | **Die roll** | **Actual Time** | **Cummulative Actual** | **Cummulative Size** | **Size Forecast** | **Count Forecast** |
| **1** | | | | | | | |
| **2** | | | | | | | |
| **3** | | | | | | | |
| **4** | | | | | | | |
| **5** | | | | | | | |
| **6** | | | | | | | |
| **7** | | | | | | | |
| **8** | | | | | | | |
| **9** | | | | | | | |
| **10** | | | | | | | |
| **11** | | | | | | | |
| **12** | | | | | | | |
| **13** | | | | | | | |
| **14** | | | | | | | |
| **15** | | | | | | | |
| **16** | | | | | | | |
| **17** | | | | | | | |
| **18** | | | | | | | |
| **19** | | | | | | | |
| **20** | | | | | | | |



# Background

Each card represents a story in the backlog.

They have been estimated through rigorous Planning Poker

We will process cards sequentially,

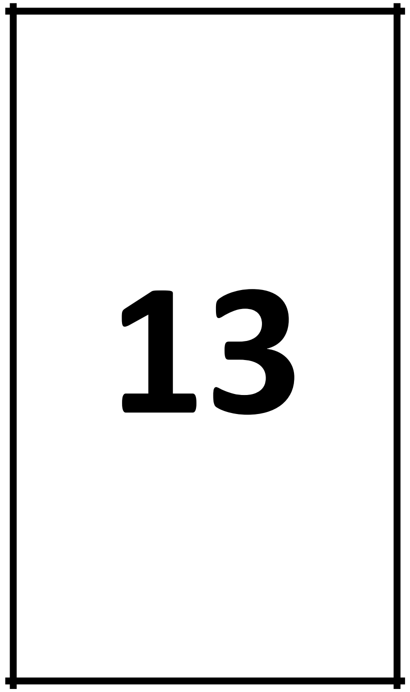
but each table will have a different order

- Please shuffle the deck of cards (but not after each draw)
- Cards will then be pulled sequentially

Each person will implement the story by rolling their die

The die will tell us how accurate the estimate was and how long it really takes

# Example:
# Draw a card to be used by everyone at the table




Now each person rolls their die

# Adjustment Table

| | Card Value | | | | | |
|---|---|---|---|---|---|---|
| Die | 2 | 3 | 5 | 8 | 13 | 20 |
| 1 | 1 | 2 | 3 | 4 | 8 | 13 |
| 2 | 1 | 2 | 4 | 6 | 10 | 16 |
| 3 | 2 | 3 | 5 | 8 | 13 | 20 |
| 4 | 2 | 3 | 5 | 8 | 13 | 20 |
| 5 | 4 | 6 | 7 | 11 | 16 | 25 |
| 6 | 6 | 8 | 10 | 16 | 22 | 30 |

# Little's Law Tally Sheet

| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
|---|---|---|---|---|---|---|---|
| **Card** | **Size** | **Die roll** | **Actual Time** | **Cummulative Actual** | **Cummulative Size** | **Size Forecast** | **Count Forecast** |
| 1 | 13 | 5 | 16 | 16 | 13 | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

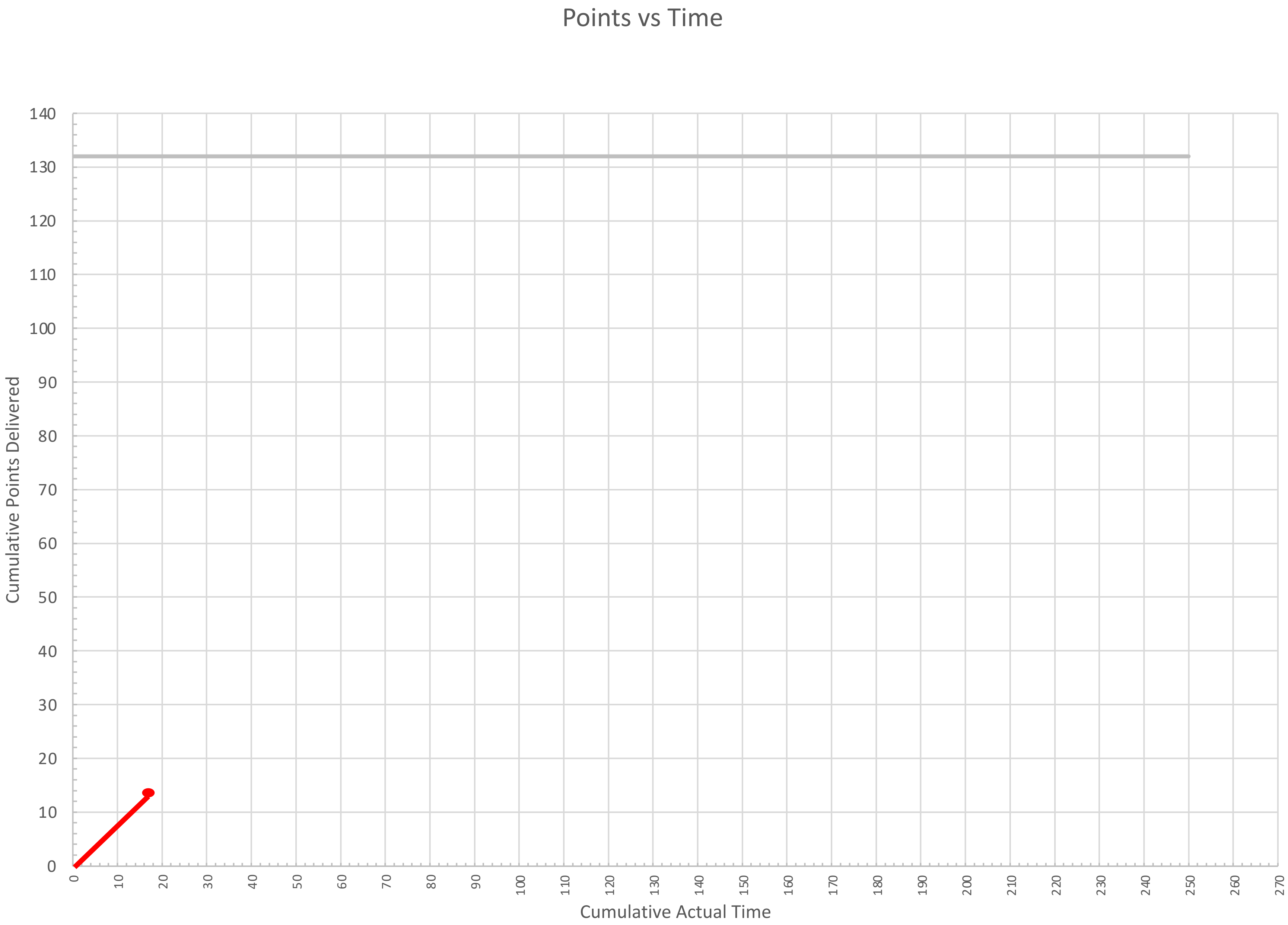
Card

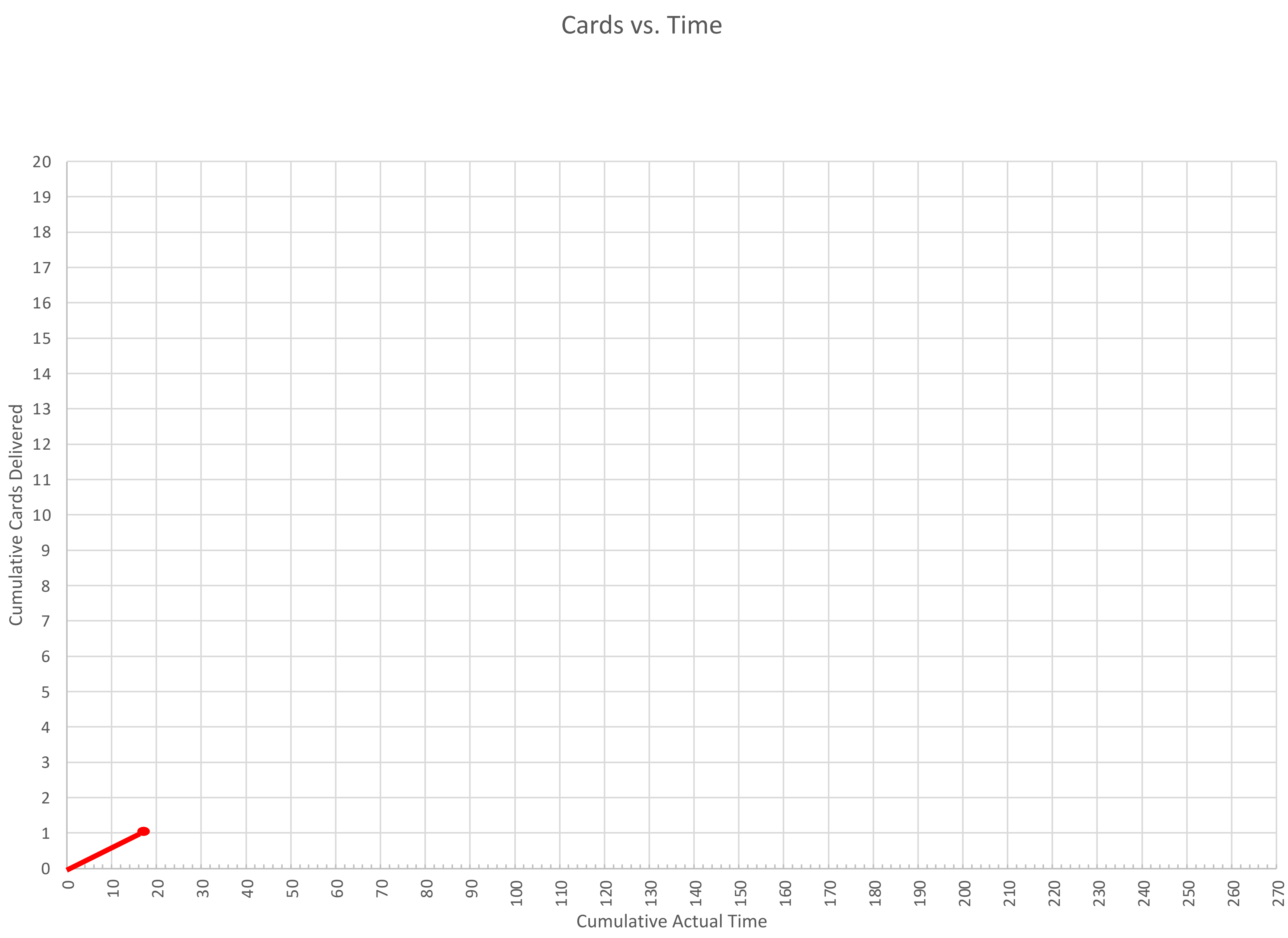
Die

Lookup

Sum Actual

Sum Size


Points vs Time
Cumulative Points Delivered
Cumulative Actual Time
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270



Cards vs. Time
Cumulative Cards Delivered
Cumulative Actual Time
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270

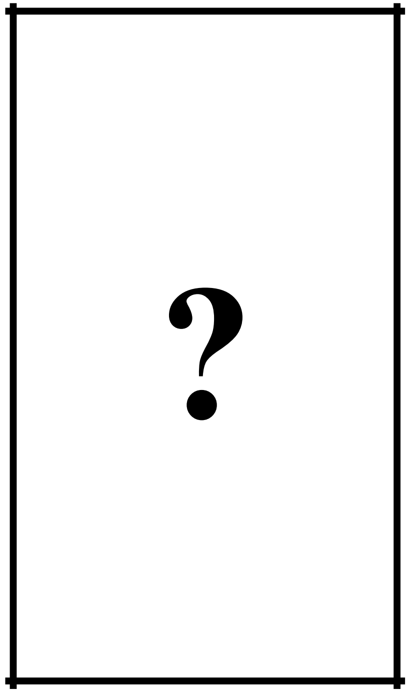
## Google Spreadsheet

bit.ly/3PGymF9

## Old School

| Little's Law Tally Sheet | | | | | | | |
|---|---|---|---|---|---|---|---|
| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
| **Card** | **Size** | **Die roll** | **Actual Time** | **Cummulative Actual** | **Cummulative Size** | **Size Forecast** | **Count Forecast** |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | | | | | | |
| 16 | | | | | | | |
| 17 | | | | | | | |
| 18 | | | | | | | |
| 19 | | | | | | | |
| 20 | | | | | | | |

# Let’s do 1 card
# Draw a card to be used by everyone at the table



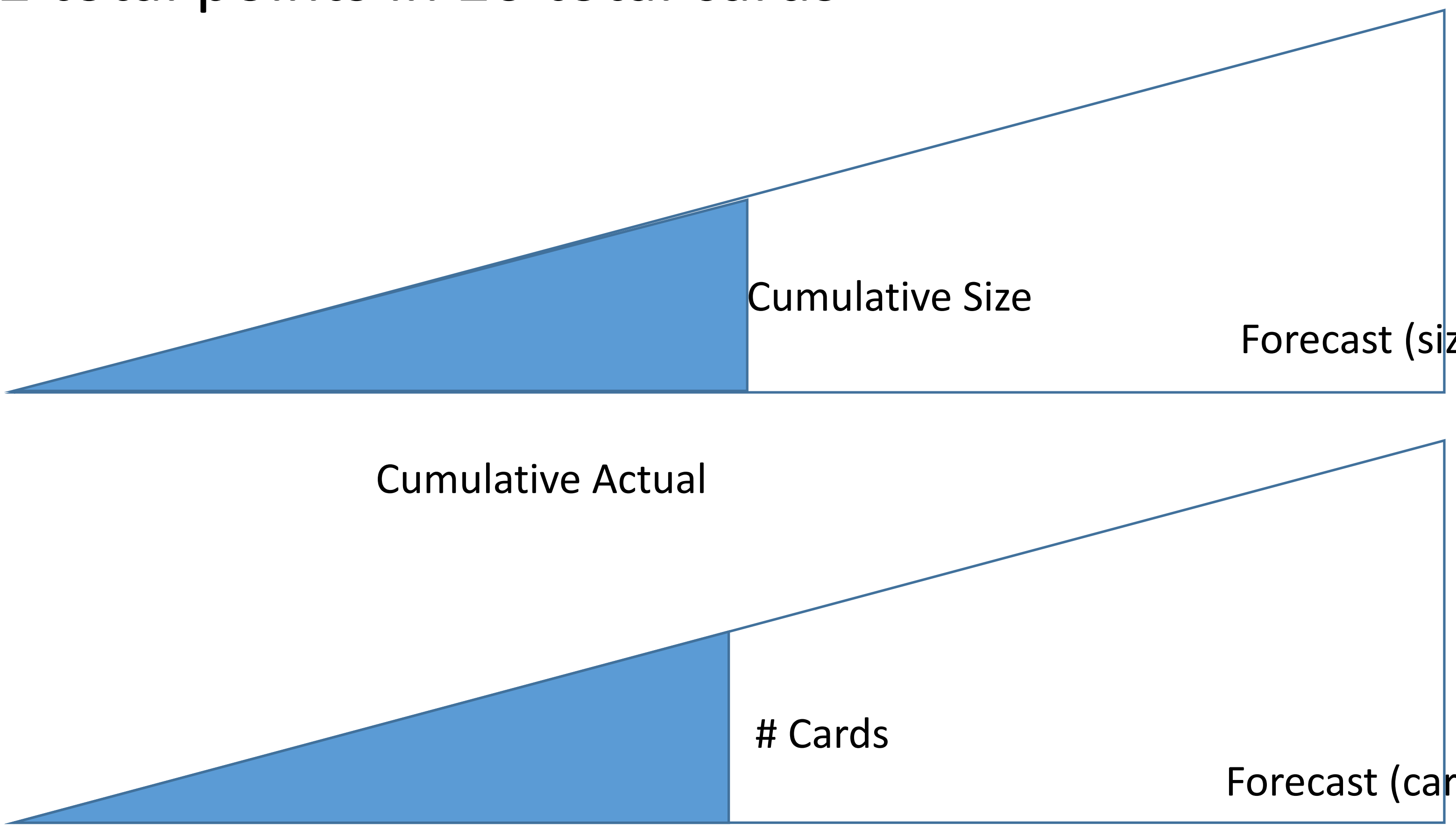

Now each person rolls their die

# Task switching – Sometimes batches are better

- Run through 5 cards recording on the Tally Sheet
- Calculate the Forecast based on the trends of the first 5 cards
  - Size Forecast = Cum Actual (E)*132 / Cum Size (F)
  - Count Forecast = Cum Actual (E) *20 / # Cards (A)
- Continue with the remaining 15 cards in batches of 5
- Old School – plot away

# Forecasting

132 total points in 20 total cards



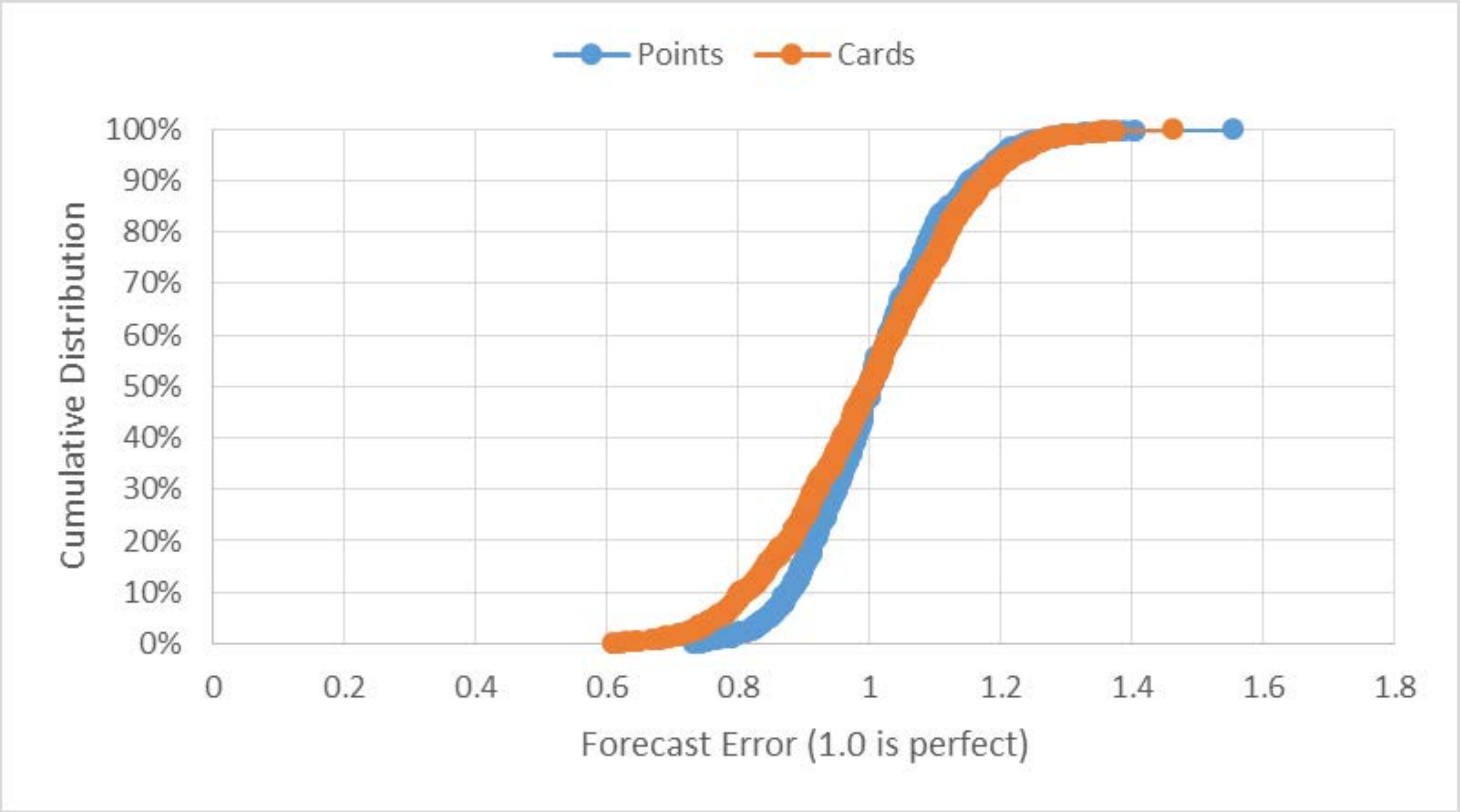
# Little's Law Tally Sheet

| Y(cards) | | | | X | Y(points) | =Cum Actual (E)*132 / Cum Size (F) | =Cum Actual (E) *20 / # Cards (A) |
|---|---|---|---|---|---|---|---|
| **Card** | **Size** | **Die roll** | **Actual Time** | **Cumulative Actual** | **Cumulative Size** | **Size Forecast** | **Count Forecast** |
| **1** | 13 | 5 | 16 | 16 | 13 | | |
| **2** | 5 | 3 | 5 | 21 | 18 | | |
| **3** | 8 | 2 | 6 | 27 | 26 | | |
| **4** | 2 | 6 | 6 | 33 | 28 | | |
| **5** | 5 | 1 | 3 | 36 | 33 | 144 | 144 |
| **6** | | | | | | | |
| **7** | | | | | | | |
| **8** | | | | | | | |
| **9** | | | | | | | |
| **10** | | | | | | | |

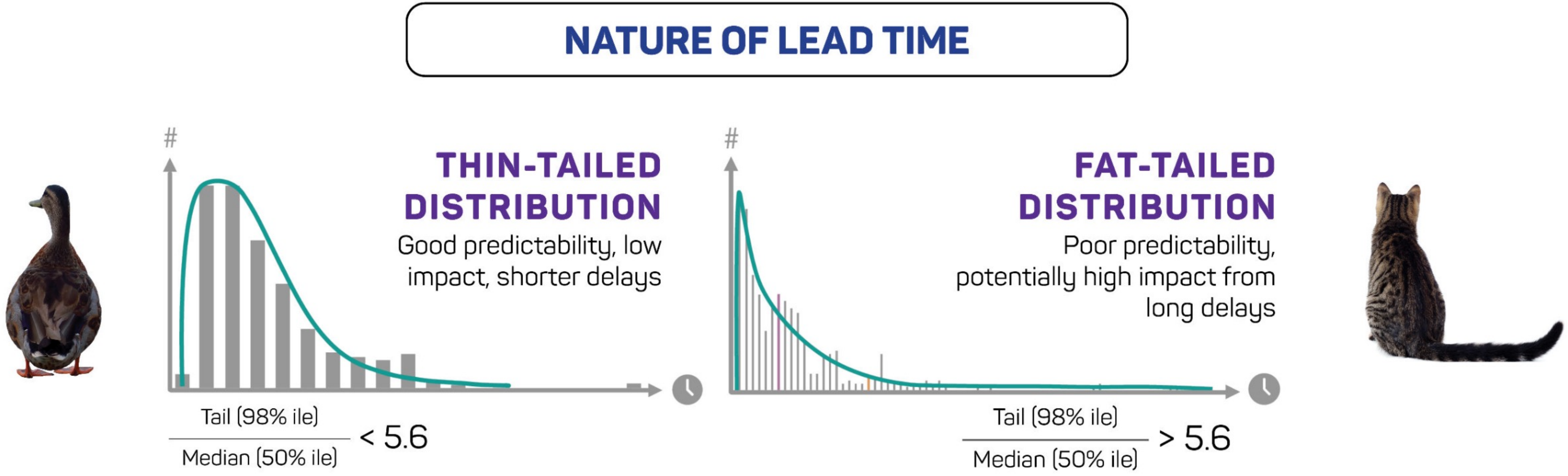
# Final Summary

| Card | Size | Die roll | Actual Time | Cumulative Actual | Cumulative Size | Size Forecast | Count Forecast |
|---|---|---|---|---|---|---|---|
| 5 | | | | | | | |
| 10 | | | | | | | |
| 15 | | | | | | | |
| 20 | | | | | | | |

# Monte Carlo Simulation Results



# Data needs to be Thin-tailed for Little's Law




P90/P10 <20

# Estimate the # of Jelly Beans