Supply Chain Resilience Evaluation And Mitigation

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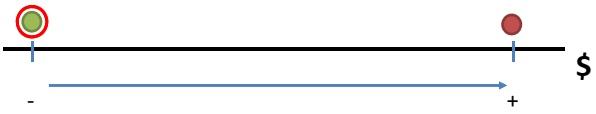
"Prediction is very difficult, especially if it's about the future." – Nils Bohr, Nobel laureate in Physics

"Estimates from risk modelling agency suggest claims from last week's Japanese earthquake could reach up to $35bn" –The telegraph investor, March 2011

How to define a SC Risk Management Strategy?

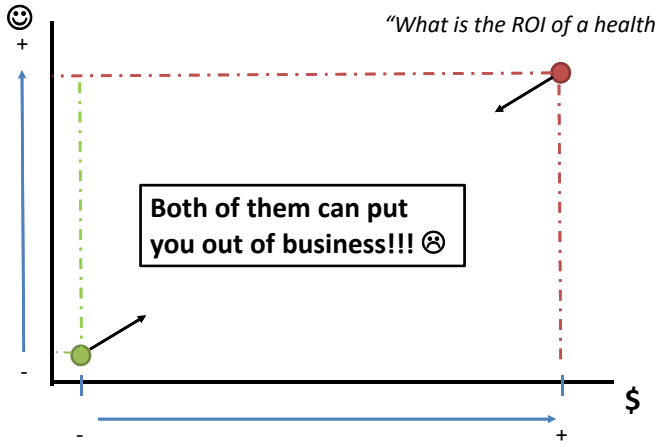
Commonly any operations management policy/strategy aims at minimizing cost, maximizing ROI, etc…

Which risk management strategy is better?



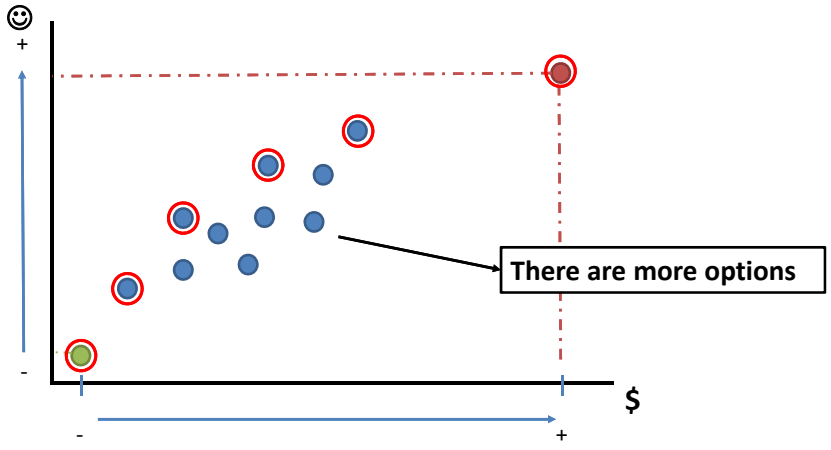
But…what about service level in case of a disruption?

Which strategy is better?



The Concept of Trade-Off

Which strategy is better?



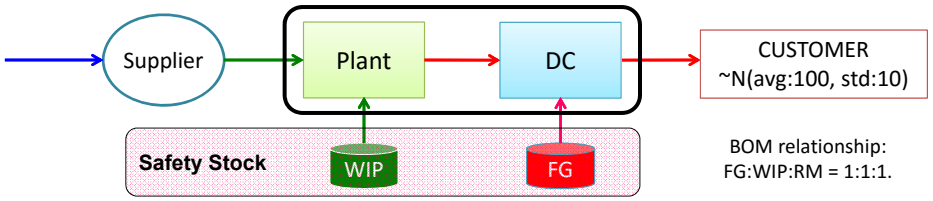
SCREAM Game

Objective: *Design a risk mitigation strategy to minimize the total supply chain cost while maximizing the order fill rate over an uncertain future*.

- Developed at MIT CTL from 2009 to 2012
- Based on project with a CPG manufacturing company
- Many contributors….
  - Dr. Mahender Singh
  - Dr. Amanda Schmitt
  - Dr. Yukun Liu enhanced
  - Dr. Shardul Phadnis created SCREAM 2.0
  - Mr. James Rice, Jr.

Widget Supply Chain Overview

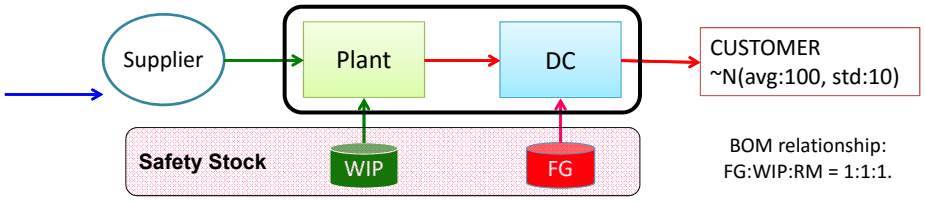
- Each team runs its own Widget supply chain which consists of:
  - Supplier: Receives raw material (**RM**) and converts into work-in-process (WIP)
  - Plant – Converts the **WIP** into finished goods (**FG**)
  - Distribution Center – Stores the **FG** for delivery to customers



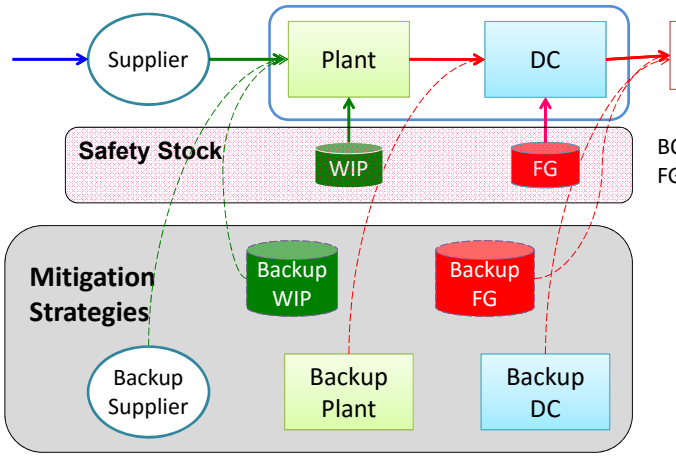
- You have control over the Plant and the DC, but not the supplier
- The demand for the finished goods are random and variable ~ 100 units per week +/- 10.
- The inventory policies at each facility are already established at the DC and Plant, and are very conservative.

Widget Supply Chain Overview

- How does a supply chain handle "normal" volatility?
  - Demand & Lead time variability => Safety Stock
- What if the supply chain is severely disrupted?
  - Supplier Disruption
  - Manufacturing Disruption
  - Distribution Disruption



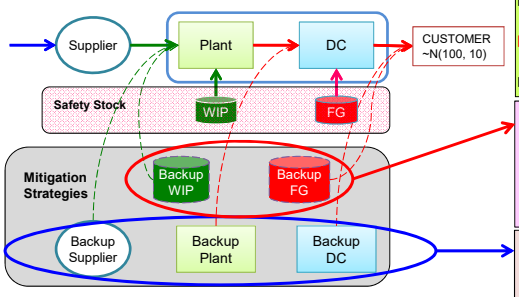
Supply Chain Disruption Mitigation Strategies



BOM relationship:
FG:WIP:RM = 1:1:1.

Backup inventory is **NOT safety stock**, but rather strategic stock that can only be used when there is/are disruptions in the upstream node(s).

Mitigation Policy



Mitigation Policy Format

FG@DC / WIP@Plant / DC / Plant / Supplier

Example: **100/100/1/1/1**

Backup inventory
- Any non-negative value
- Locations
  - WIP: @ the plant
  - FG: @ warehouse separate from DC

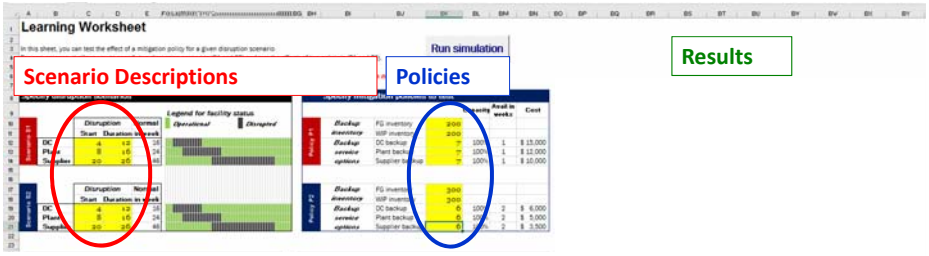
Backup facility
Choose (a) capacity level and (b) time to become available, for a specified set up fee

Backup Option	Capacity Rate	Response time (weeks)	Set Up Fee (for) DC	Plant	Supplier
1	0	-	$ 0	$ 0	$ 0
2	50%	4	$ 1,000	$ 800	$ 400
3	50%	2	$ 2,500	$ 1,800	$ 1,000
4	50%	1	$ 6,000	$ 4,000	$ 2,400
5	100%	6	$ 1,500	$ 1,000	$ 1,000
6	100%	2	$ 6,000	$ 5,000	$ 3,500
7	100%	1	$ 15,000	$ 12,000	$ 10,000

Objective of the Game

- Design a risk mitigation strategy to minimize the total supply chain cost while maximizing the order fill rate over an uncertain future.
- Costs:
  - Ordering Costs ~ $16 to $20 per order (for reference)
  - Holding Costs ~25% annually
  - Landed Product Costs (for reference)
    - Finished Goods $100 /unit
    - WIP $80 /unit
    - Raw Materials $50 /unit
  - Selling Price $225 per unit
  - No Stockout Costs
- Service Level
  - Order Fill Rate (OFR) at customer location
  - Under normal conditions, order fill rate is ~99%

SCREAM Simulation Model



SCREAM Simulation Model Details

- Users can define up to 2 disruption scenarios
  - Only enter in yellow cells
  - Define a Start and Duration of the disruption for each facility.
- Users can define up to 2 mitigation policies
  - Only enter in yellow cells
  - Enter 5 digit policy code
- Run Scenario
  - Press the "Run simulation" button
  - Run should take under 5 seconds
  - Scenario 1 runs against Policy 1, & Scenario 2 runs against Policy 2
- Review Results
  - Summary results (numeric and charts) on cover sheet
  - Scenario details on other tabs (S1 and S2)
  - Use this to compare policies or how different scenarios impact the same policy

Learn Using the Simulation Spreadsheet

- **Work in 3-Person Teams**
- **Open up your SCREAM spreadsheet**
  - Download the file SCREAM2_Student_v6.xlsm
  - Make sure you allow/enable Macros
- **Two ways to Use the Simulation**
  - Use the same policy and run it against two different scenarios
  - Test two different policies and run it against the same scenario

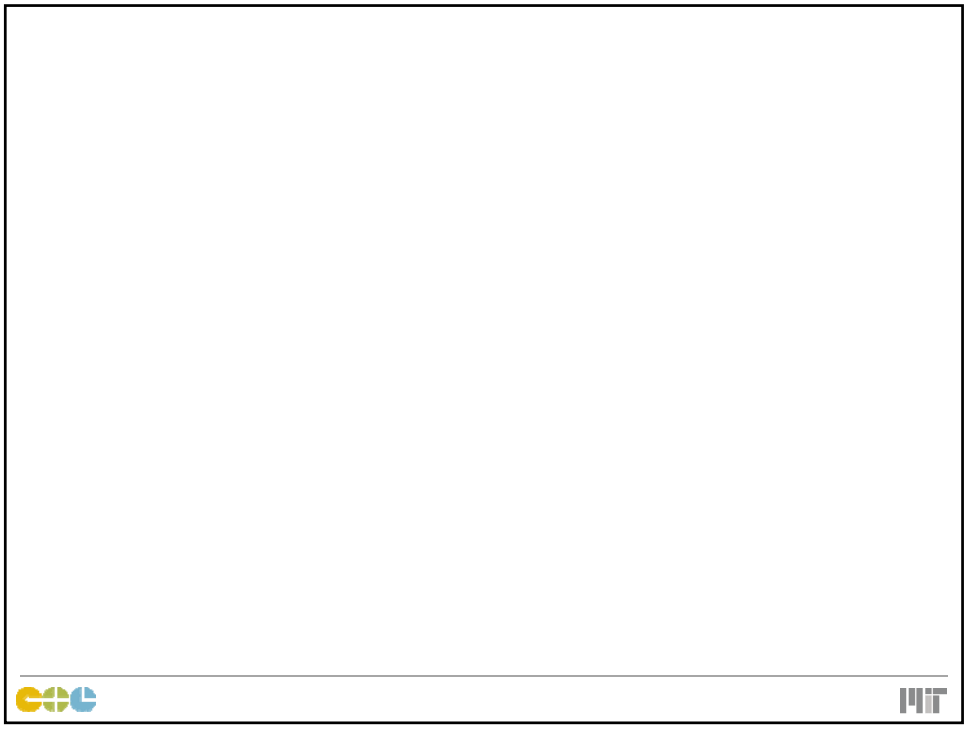
Get a feel for how the different policies interact with each other

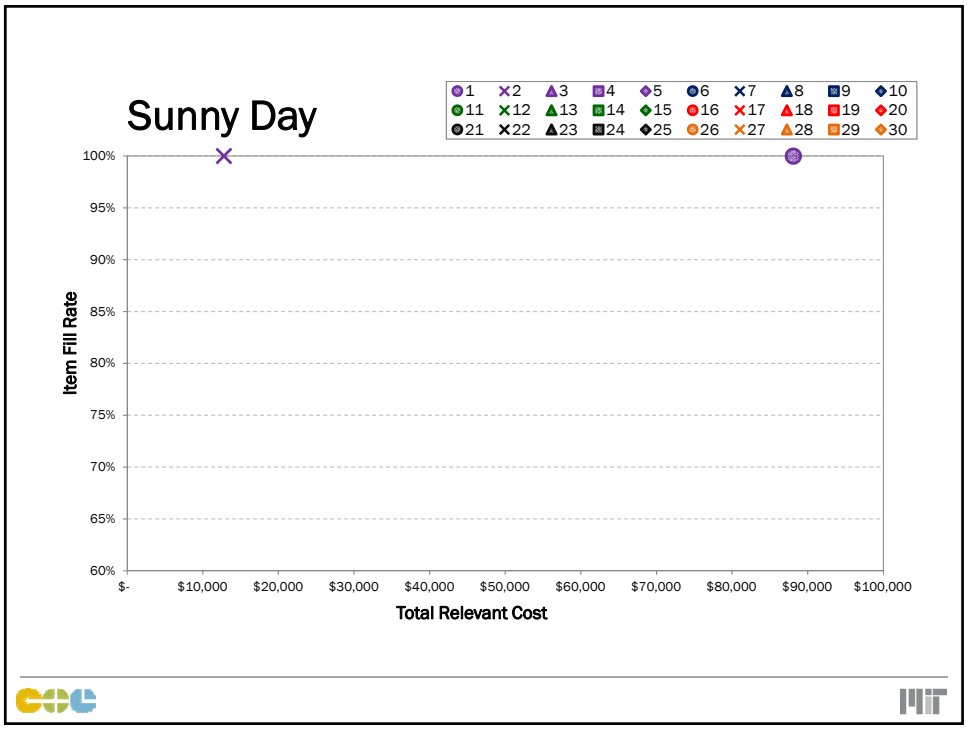
~15 minutes

http://www.online-stopwatch.com/countdown-timer/

What the Results Look Like for 2 Policy Choices

Team	Inventory		Capacity		
	FGI	WIP	DC	Plant	Sup
1	1000	1000	7	7	7
2	100	100	2	2	2




Sunny Day
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
95%
90%
85%
80%
75%
70%
65%
60%
Item Fill Rate
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$10,000
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$60,000
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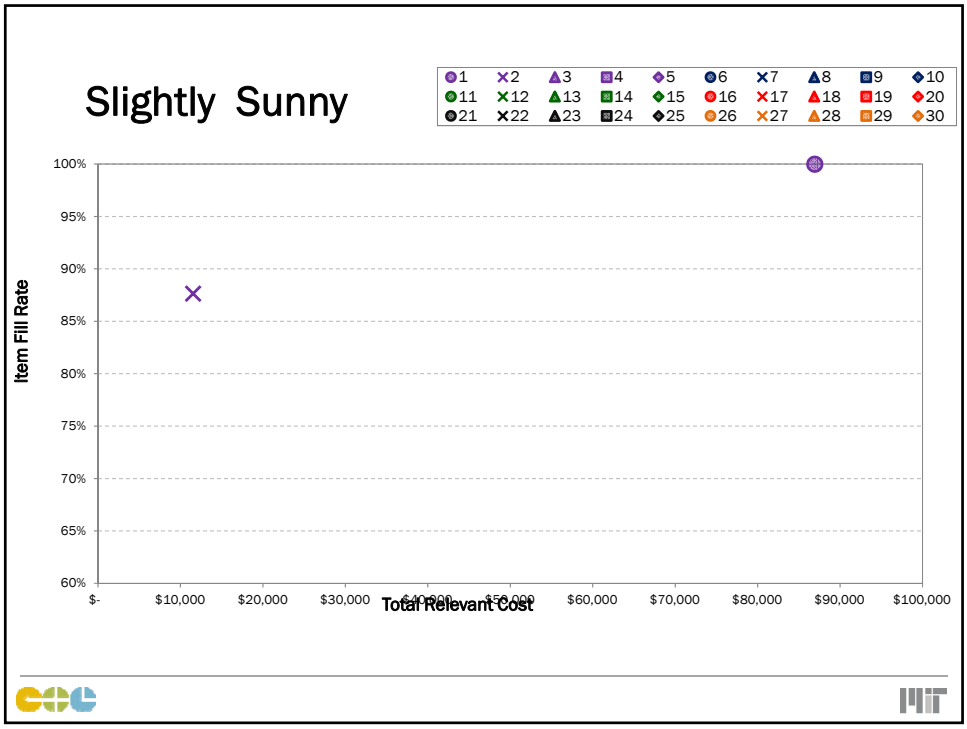
$80,000
$90,000
$100,000
Total Relevant Cost


Slightly Sunny
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11 12 13 14 15 16 17 18 19 20
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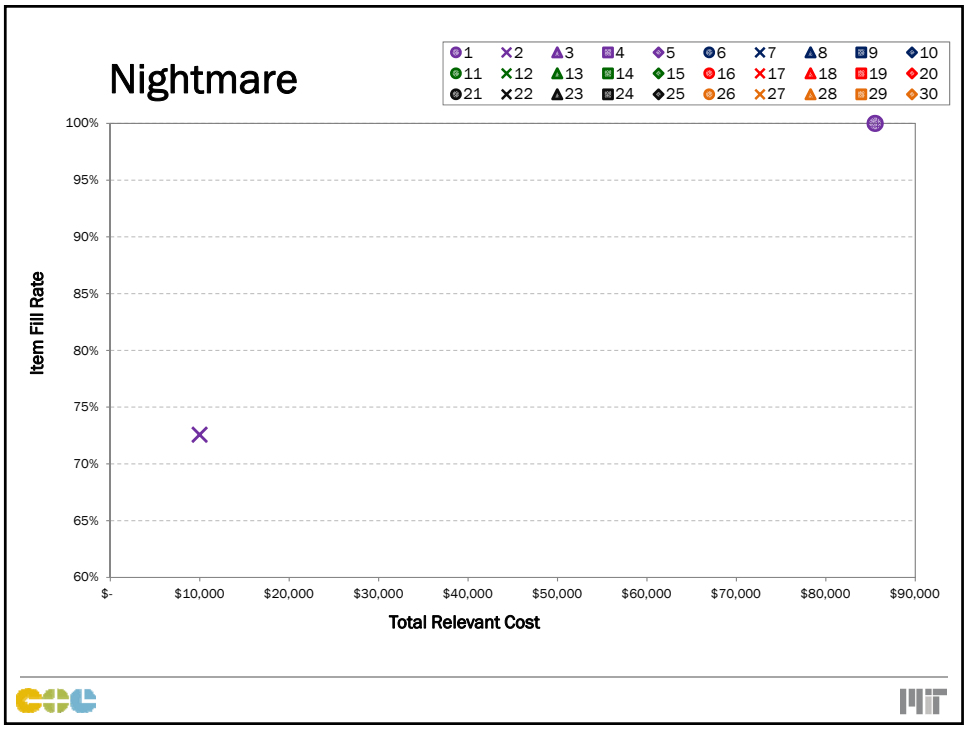
Nightmare
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
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Item Fill Rate
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$80,000
$90,000
Total Relevant Cost

Exercise Various Policies vs Various Scenarios

- Stay in your 3-Person Teams
- Test various policy choices against various scenarios

- Reminder: Two ways to Use the Simulation
  - Use the same policy and run it against two different scenarios
  - Test two different policies and run it against the same scenario

Recommend **one mitigation policy for the Widget SC**

~20 minutes. – Upload your solution to the Google Form

Note: This will be tested against a blend of several scenarios (arbitrary situations created by "experts")

Some Questions to Consider

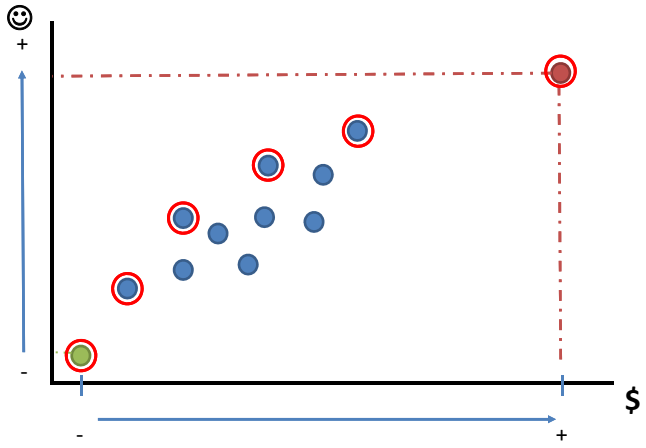
- How much is a **stockout** worth?
- Is **speed of response** more important than **capacity coverage**, or the other way around?
- **When** is it worth putting a policy in place?
- Is it important to have a uniform policy across the facilities?
- Is it better to place a full strength policy at one facility and partial at others? If so, which?
- Under what conditions is it better to use **Strategic Stock** versus **Facility Backup** plans?
- Which strategies seem to work best?

Supply Chain
Resilience Evaluation
And Mitigation

Analysis of Results

The Concept of Trade-Off

Which strategy is better?



What is the policy for building resilience in SCs?

A. Safety stock only

B. Safety stock + Backup Inventory

C. Safety stock + Backup Facility

D. Safety stock + Backup Inventory + Backup Facility

What is the most important for developing mitigation policy? Least important?

A. Supplier Disruption

B. Plant Disruption

C. DC Disruption

Teams

Numbe	Team	Number	Team3
1	Patrick - Sue & Brian	14	Falcon's
2	Brian, Sue & Patrick	15	3 Amigos
3	El Cheapo	16	Pavel, Azat and Ivan
4	Sue, Patrcik & Brian	17	Alfa
5	JUNIER	18	We Move the Goods
6	CKM	19	Igor-Matthieu
7	ams1	20	Perfect solutions, no guarantee
8	EKE	21	Screamers
9	Vicky Team	22	Grito 2 Team
10	Opti-mizers	23	K2
11	USR	24	TDA
12	GLEB & PIETER	25	The Fantastic Three
13	Grito Team !!!		

Policies chosen by Ex Ed June-2016

	Inventory		Capacity		
Team	FGI	WIP	DC	Plant	Sup
1	600	600	6	6	6
2	700	600	6	6	5
3	250	250	4	4	4
4	675	560	6	6	5
5	3000	1000	4	5	6
6	1000	1800	3	3	3
7	1000	2000	2	5	5
8	100	500	7	6	5
9	1000	1000	6	5	5
10	500	500	6	6	6
11	200	200	6	6	6
12	600	600	5	5	5
13	1000	1000	5	5	6
14	200	200	6	6	6
15	400	800	6	5	7

	Inventory		Capacity		
Team	FGI	WIP	DC	Plant	Sup
16	300	300	6	6	6
17	400	400	6	6	6
18	1500	1500	1	5	2
19	600	400	5	6	6
20	1185	200	1	5	6
21	1500	900	4	7	4
22	800	500	5	5	6
23	100	100	7	7	7
24	300	200	6	6	6
25	1400	400	1	3	6

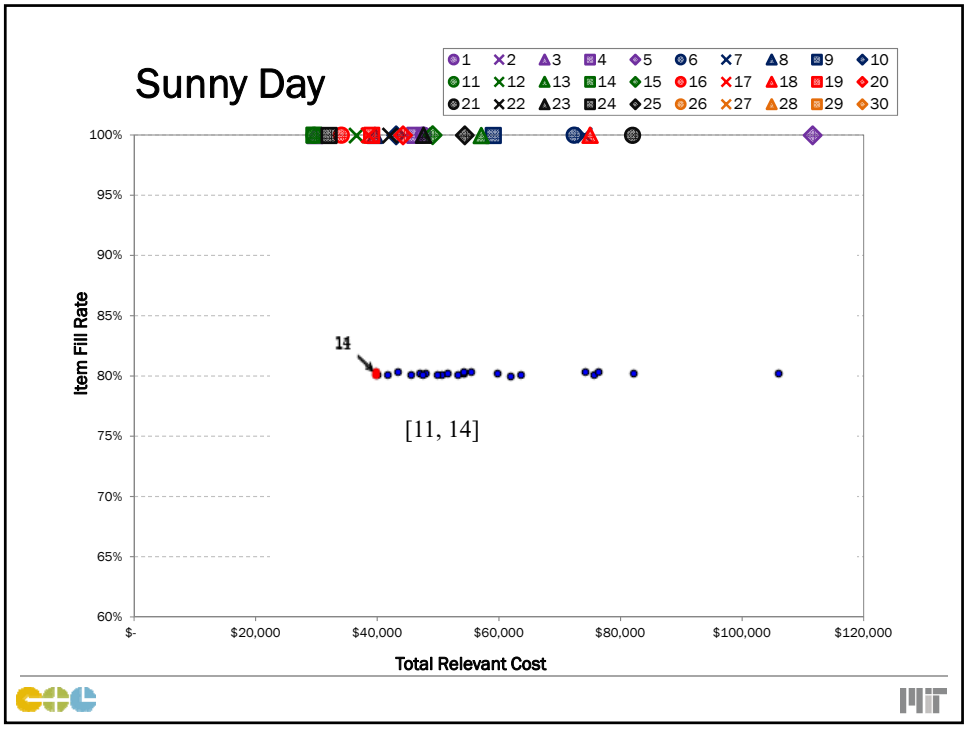
Team	Inventory		Capacity			Robustness/ Flexibility	
	FG	WIP	DC	Plant	Sup	Inv	Plant
1	600	600	6	6	6	Med	High
2	700	600	6	6	5	Med	High
3	250	250	4	4	4	Low	Med
4	675	560	6	6	5	Med	High
5	3000	1000	4	5	6	High	High
6	1000	1800	3	3	3	High	Low
7	1000	2000	2	5	5	High	Med
8	100	500	7	6	5	Low	High
9	1000	1000	6	5	5	High	High
10	500	500	6	6	6	Med	High
11	200	200	6	6	6	Low	High
12	600	600	5	5	5	Med	Med
13	1000	1000	5	5	6	High	Med
14	200	200	6	6	6	Low	High
15	400	800	6	5	7	Med	High

Team	Inventory		Capacity			Robustness/ Flexibility	
	FG	WIP	DC	Plant	Sup	Inv	Plant
16	300	300	6	6	6	Low	High
17	400	400	6	6	6	Med	High
18	1500	1500	1	5	2	High	Med
19	600	400	5	6	6	Med	High
20	1185	200	1	5	6	Med	Med
21	1500	900	4	7	4	High	High
22	800	500	5	5	6	High	High
23	100	100	7	7	7	Low	High
24	300	200	6	6	6	Low	High
25	1400	400	1	3	6	High	Med

Scenarios

	DC disruption			Plant disruption			Supplier disruption		
Scenario	Start	Duratn	Online	Start	Duratn	Online	Start	Duratn	Online
1	1	0	1	1	0	1	1	0	1
2	1	12	13	14	12	26	27	12	39
3	26	12	38	26	12	38	26	12	38
4	1	0	1	12	36	48	1	0	1
5	12	36	48	1	0	1	1	0	1
6	1	0	1	1	0	1	12	36	48
7	26	4	30	26	4	30	26	4	30
8	40	4	44	15	4	19	1	4	5
9	1	52	53	1	0	1	1	0	1
10	1	0	1	1	52	53	1	0	1

Scenarios									
Sunny Day	100%	0%	0%	0%	0%	0%	0%	0%	0%
Partly Sunny	82%	2%	2%	2%	2%	2%	2%	2%	2%
Slightly Sunny	55%	5%	5%	5%	5%	5%	5%	5%	5%
Slightly Cloudy	37%	7%	7%	7%	7%	7%	7%	7%	7%
Very Cloudy	19%	9%	9%	9%	9%	9%	9%	9%	9%
Nightmare	0%	11%	11%	11%	11%	11%	11%	11%	12%
Short Overlapping	0%	0%	0%	0%	0%	0%	100%	0%	0%
Supplier Down Longterm	0%	0%	0%	0%	0%	100%	0%	0%	0%
DC Down Longterm	0%	0%	0%	0%	100%	0%	0%	0%	0%
Even Probability	10%	10%	10%	10%	10%	10%	10%	10%	10%


Sunny Day
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
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Item Fill Rate
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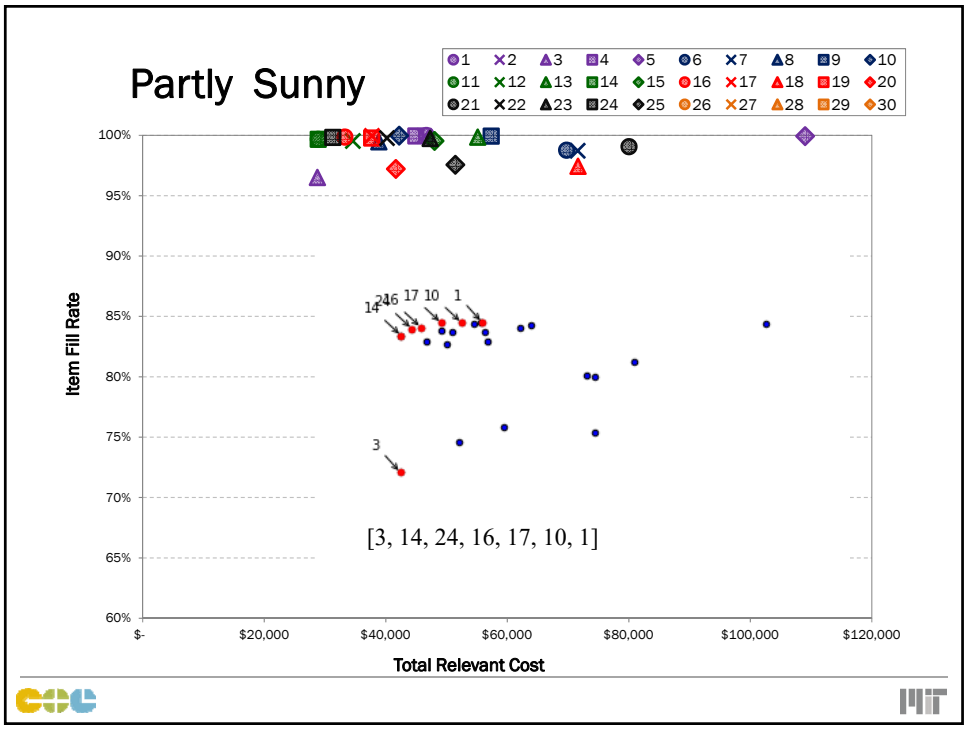
Total Relevant Cost


Partly Sunny
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Item Fill Rate
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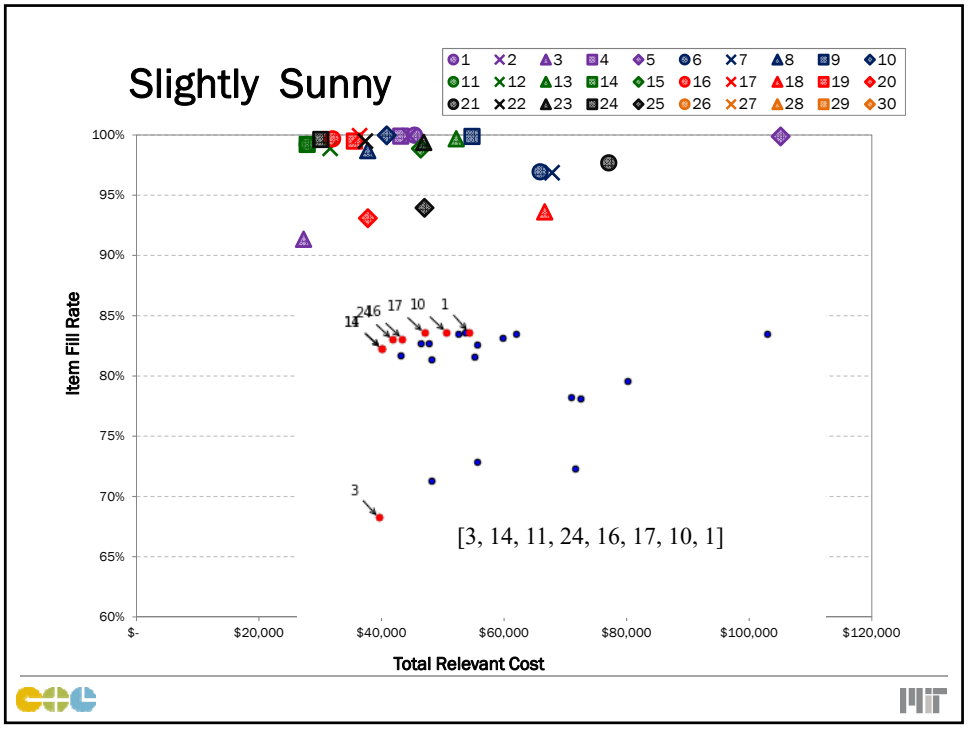
Total Relevant Cost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Total Relevant Cost
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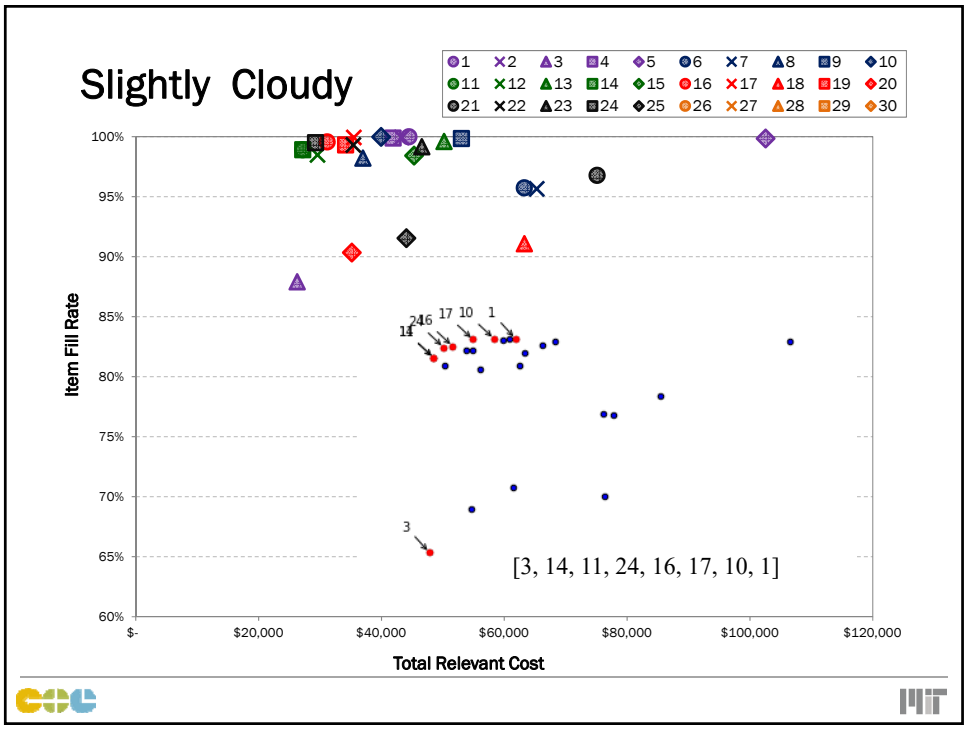
Slightly Cloudy
1 2 3 4 5 6 7 8 9 10
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100%
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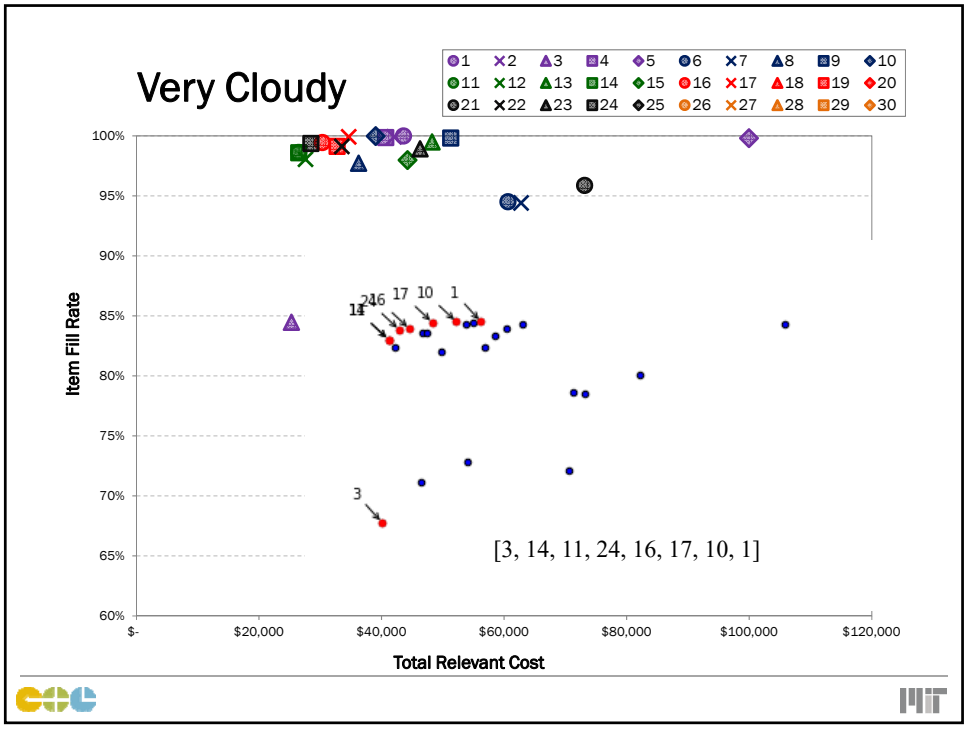
Very Cloudy
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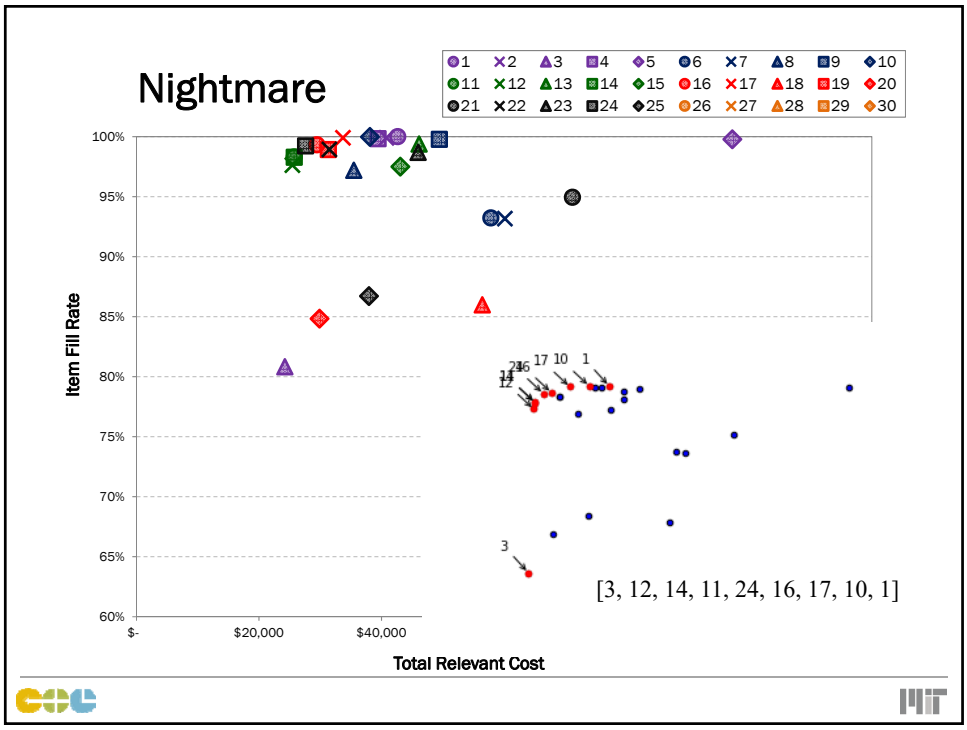
Nightmare
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Item Fill Rate
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Total Relevant Cost
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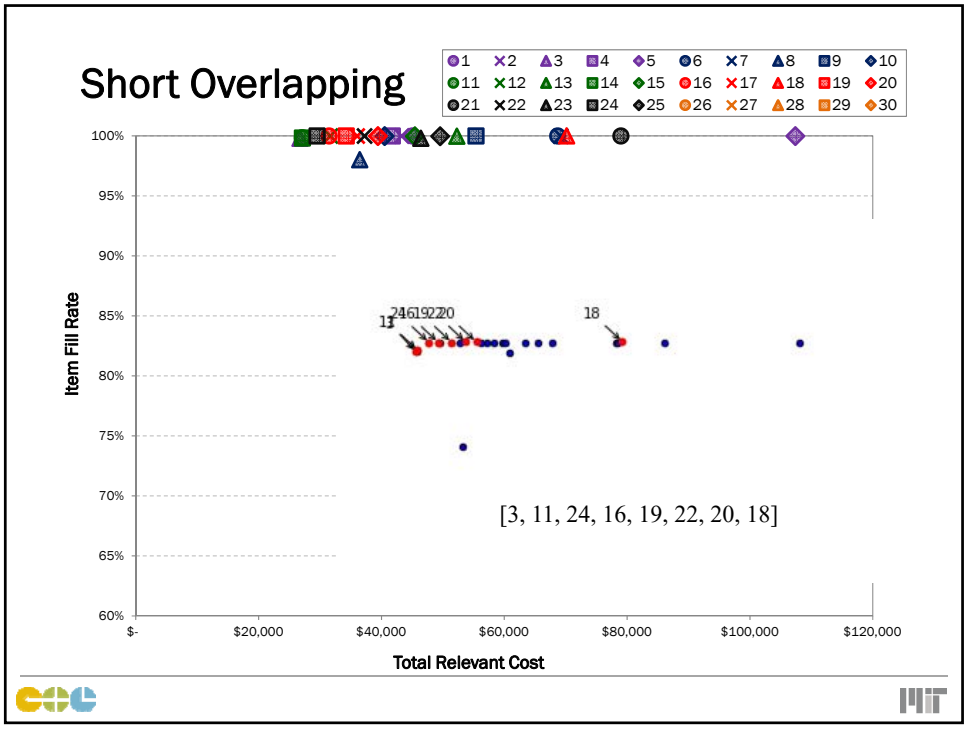
Short Overlapping
1 2 3 4 5 6 7 8 9 10
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Total Relevant Cost
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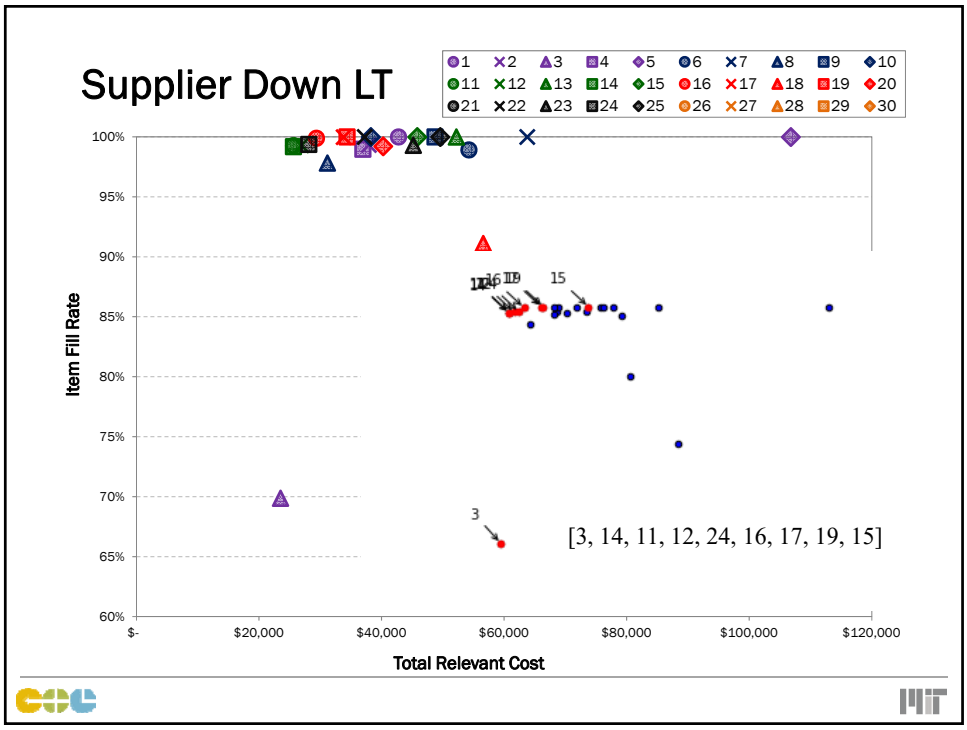
Supplier Down LT
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
95%
90%
85%
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75%
70%
65%
60%
Item Fill Rate
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$20,000
$40,000
$60,000
$80,000
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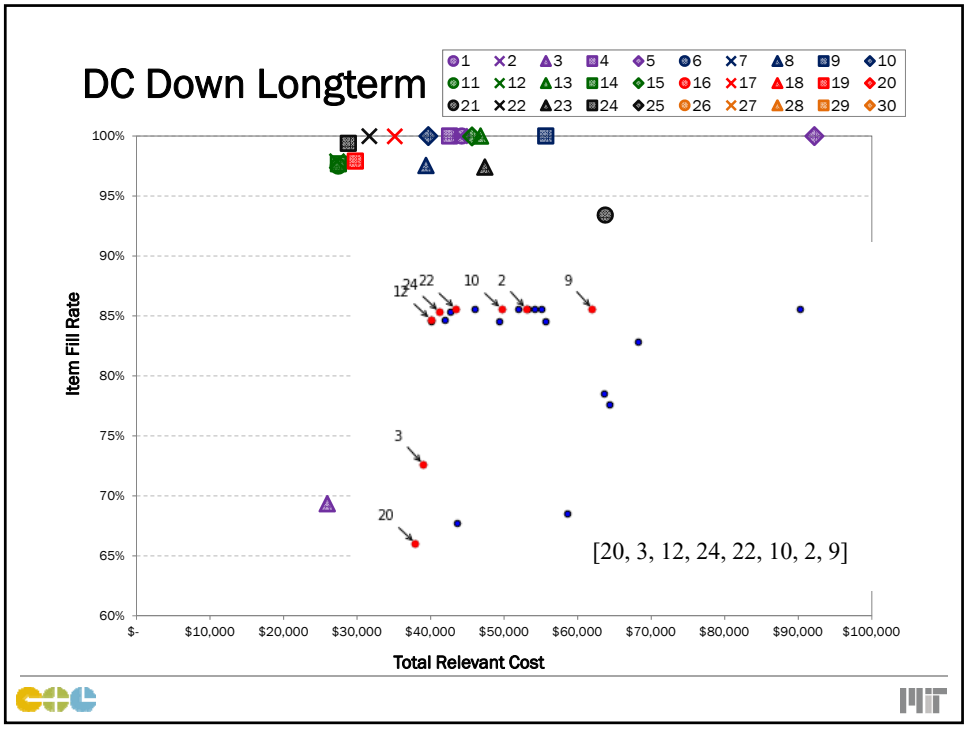
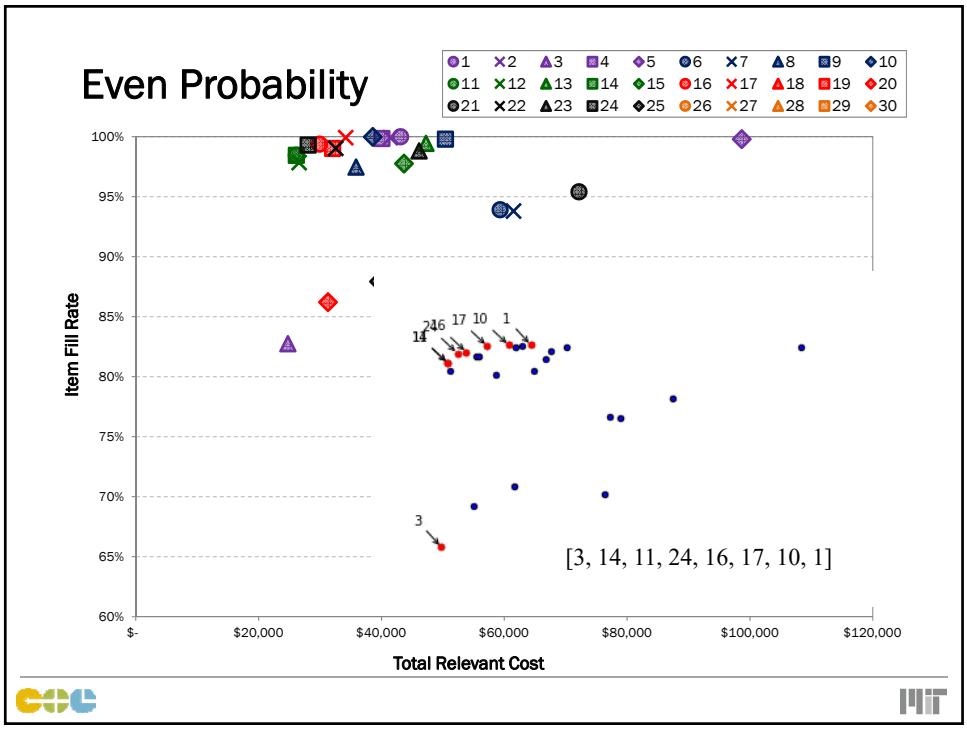
$120,000
Total Relevant Cost
[3, 14, 11, 12, 24, 16, 17, 19, 15]


DC Down Longterm
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
95%
90%
85%
80%
75%
70%
65%
60%
Item Fill Rate
12 24 22 10 2 9 3 20
[20, 3, 12, 24, 22, 10, 2, 9]
$- $10,000 $20,000 $30,000 $40,000 $50,000 $60,000 $70,000 $80,000 $90,000 $100,000
Total Relevant Cost


Even Probability
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
100%
95%
90%
85%
80%
75%
70%
65%
60%
Item Fill Rate
14 24 16 17 10 1 3
[3, 14, 11, 24, 16, 17, 10, 1]
$- $20,000 $40,000 $60,000 $80,000 $100,000 $120,000
Total Relevant Cost

The Winner

Team	Score	Team	Score
3	1	20	20
24	1	8	21
11	2	15	21
14	2	5	23
16	2	9	23
17	4	23	24
1	7	13	27
10	8	25	32
12	9	6	33
19	10	21	37
2	12	18	38
22	12	7	46
4	14		

- You have to pitch 1 minute to sell your approach
- Vote here: http://kahoot.it

Observations from the SCREAM Game

- Different policies do well under different scenarios
- **Combination of Redundancy & Flexibility** is typically a reasonable approach
  - Redundant inventory covers before backup capacity available
  - Flexibility (backup capacity) covers for longer term
- Understanding the **right scenario** portfolio is key
- Scenario creation is an informed process -Consider the vulnerabilities of your supply chain

Key learnings

- ***"What is the ROI of a health insurance?"***
  - ROI is hard to assess in these type of problems –Communication of the trade-offs is key
- ***…"Nobody gets credit for solving problems that didn't happen"*** –Repenning & Sterman (2001)
- Usually, the longer the lead time the more time you have to react/respond to disruptions
  - DC disruption might be the most dangerous
- The "optimality" condition of the SC Resilience problem – Pareto Front

Thanks!

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