MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Supply Chain Resilience Evaluation And Mitigation

(SCREAM 2.0)

Dr. Shardul Phadnis

Dr. Chris Caplice

Plan for the Session

Thursday Afternoon (2:00 – 3:15)

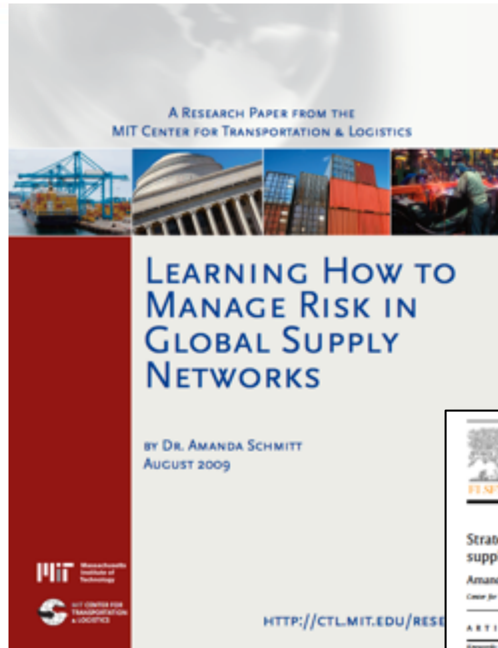
- Overview of the SCREAM Game (20 minutes)
- Student Experimenting with Tool (15 minutes)
- Quick Status Check (10 minutes)
- Teams Develop and Submit Final Policy (30 minutes)

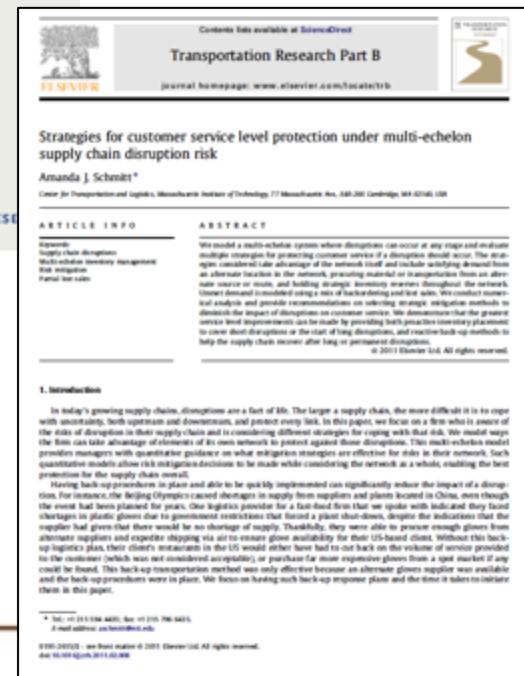
Thursday Afternoon (4:30 – 5:00)

- Discuss results and conclusions (30 minutes)

Supply Chain Risk Evaluation and Mitigation Game

- Developed at MIT CTL from 2009 to 2012
- Based on project with a CPG manufacturing company
- Dr. Mahender Singh & Dr. Amanda Schmitt developed original simulation
- Dr. Yukun Liu enhanced and ported it to Excel
- Dr. Shardul Phadnis improved and created SCREAM 2.0



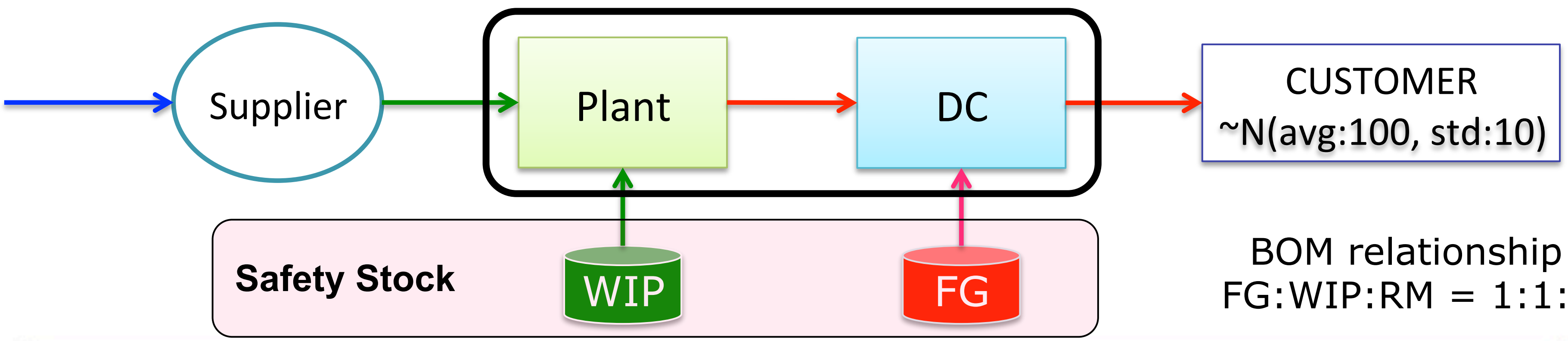

Transportation Research Part B

Strategies for customer service level protection under multi-echelon supply chain disruption risk

Amanda J. Schmitt*

Widget supply chain

- 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 **FG** for delivery to customers
- You have control over the Plant and the DC, but not the supplier
- Demand for finished goods random and variable
- Conservative inventory policies at DC and Plant already established



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

Widget supply chain

- How does a supply chain handle "normal" volatility?
  - Demand or Lead Time Variability => Safety Stock

Safety Stock = $k\sigma_L$

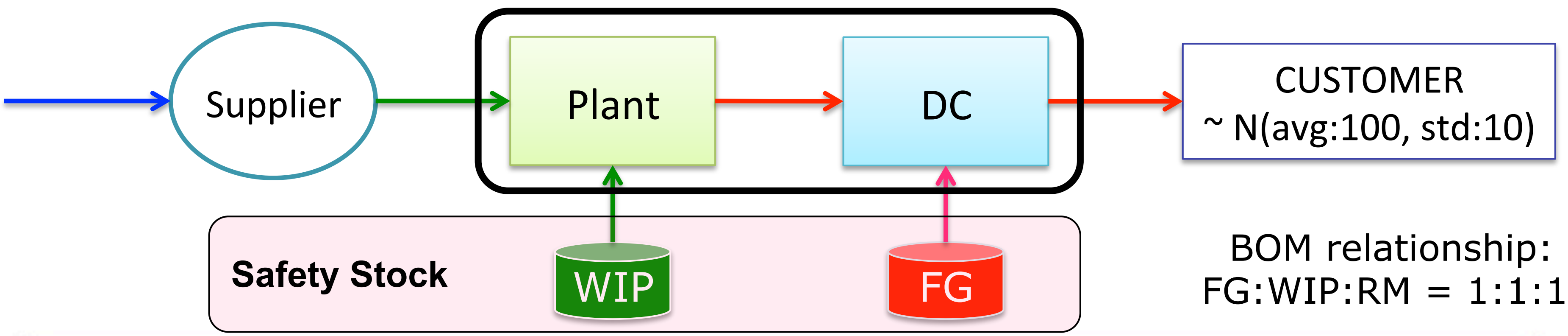
Where:

k = Safety factor

σ_L = RMSE of Forecast

$$E(D_{Leadtime}) = E(L)E(D)$$

$$\sigma_{Leadtime} = \sqrt{E(L)\sigma_D^2 + \left(E(D)\right)^2 \sigma_L^2}$$



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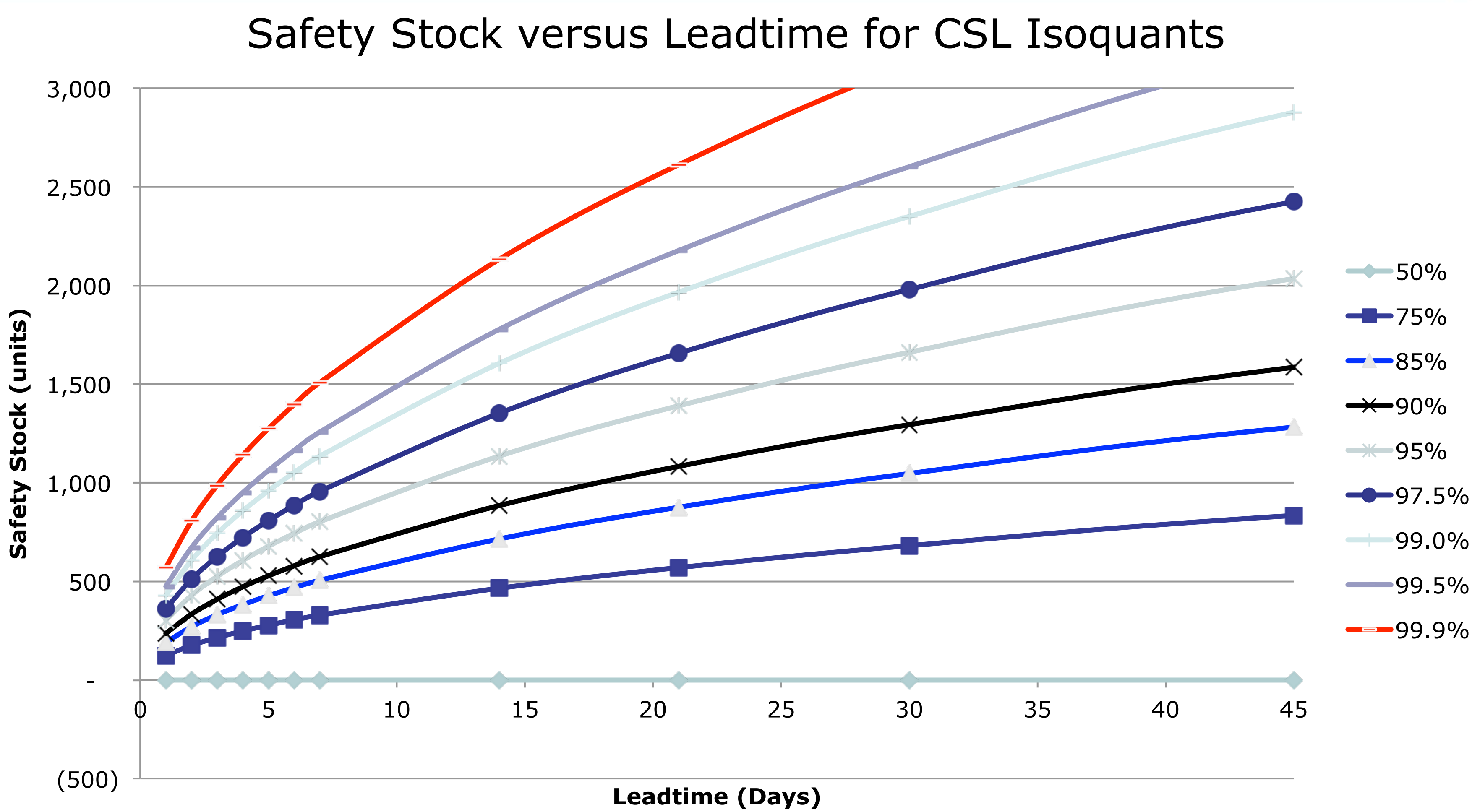
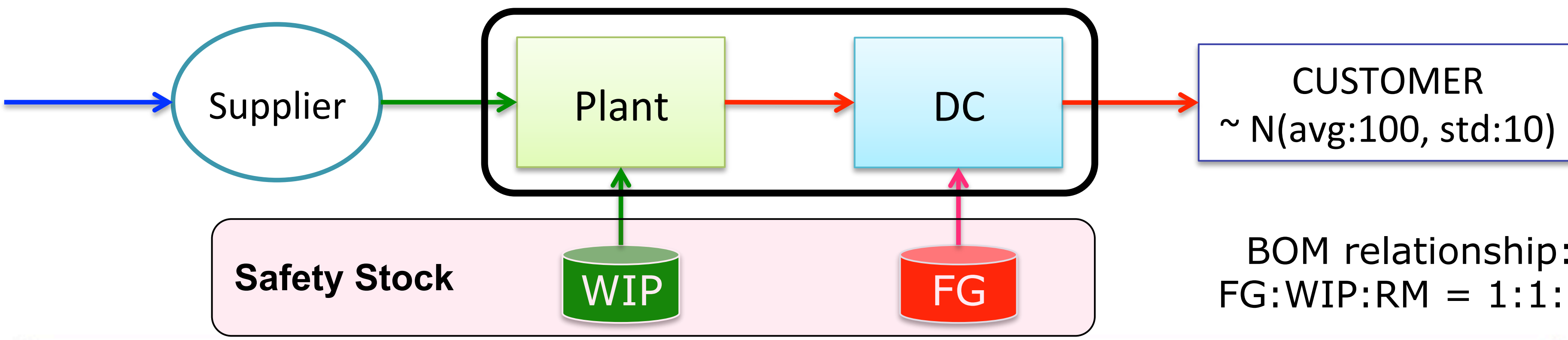
Trade-Off between Lead Time & Safety Stock



Widget supply chain

- 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



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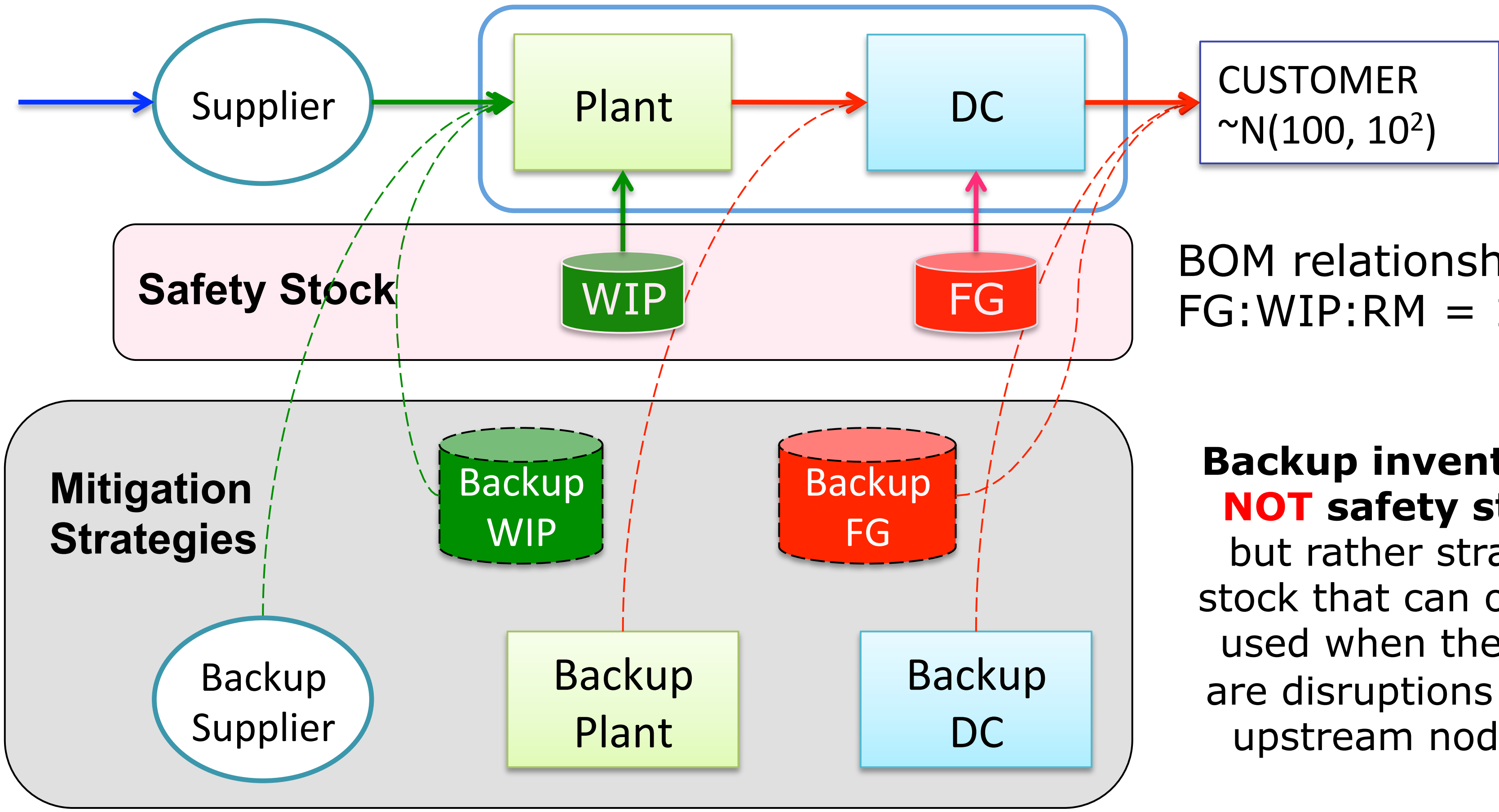
Disruption mitigation strategies



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

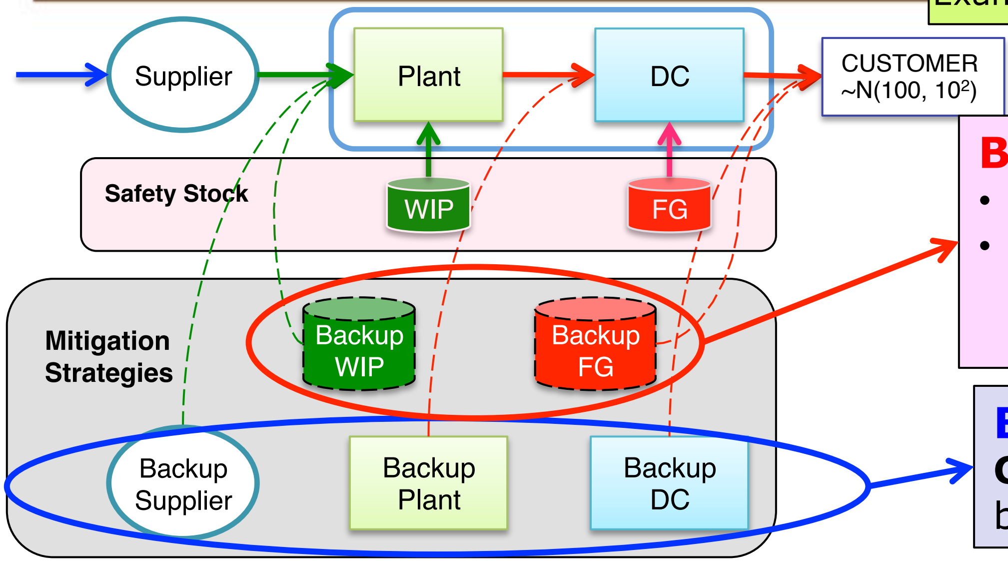
Backup inventory is **NOT safety stock**, but rather strategy stock that can only be used when there is/are disruptions in the upstream node(s).

Mitigation strategy

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

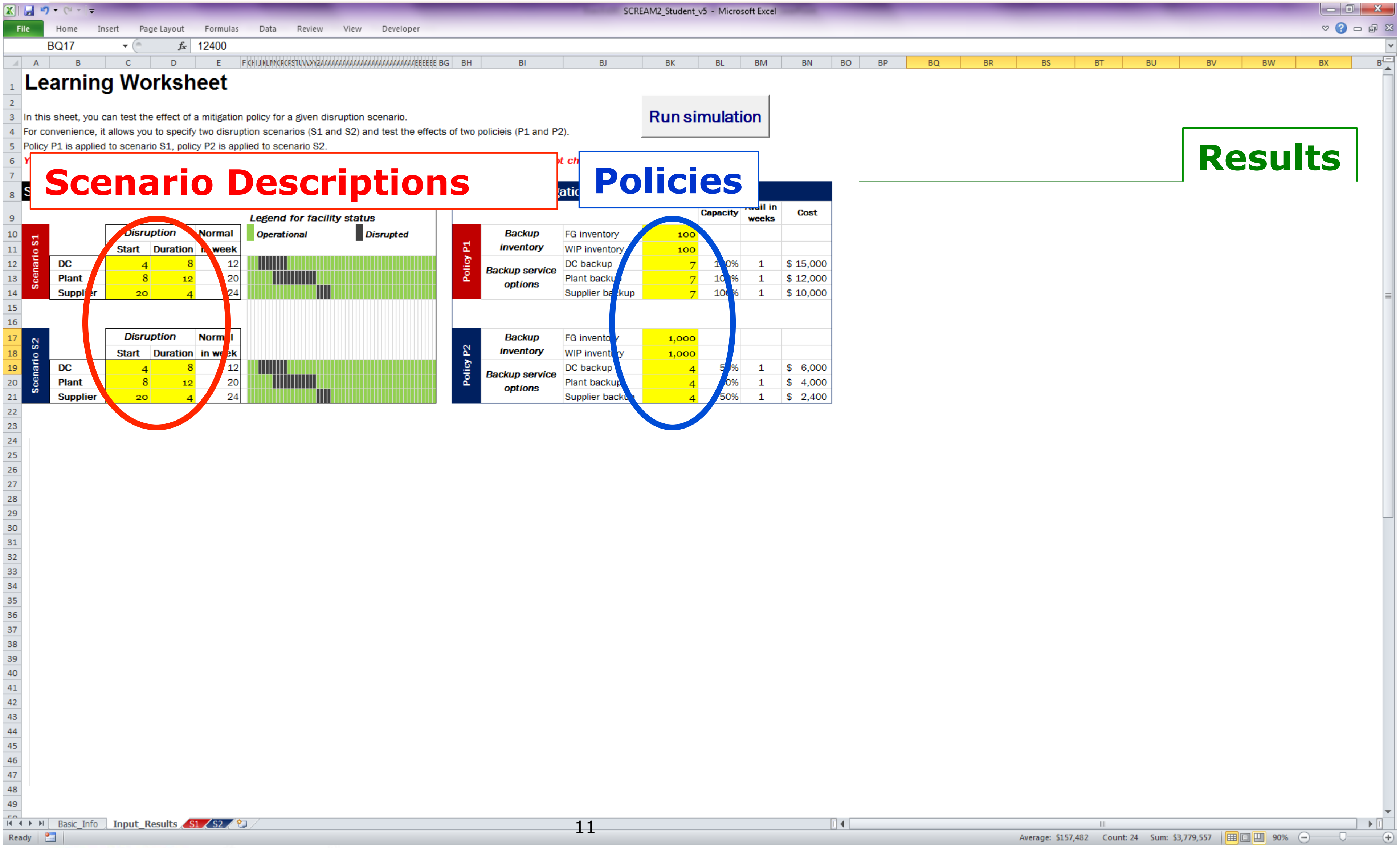
Backup facility
Choose (a) capacity level and (b) time to become available, for a specified set up fee

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
  - Holding Costs ~25% annually
  - Product Landed Costs
    - Finished Goods 100 $/unit
    - WIP 80 $/unit
    - Raw Materials 50 $/unit
  - Selling Price $225 per unit
  - No Stockout Costs
- Service Level
  - Order Fill Rate at customer location
  - Under normal conditions, OFR is ~99%

SCREAM simulation spreadsheet



SCREAM simulation spreadsheet: Details

- Define up to 2 disruption scenarios
  - Only enter in yellow cells
  - Start and Duration for each facility.
- Define up to 2 mitigation policies
  - Only enter in yellow cells
  - Enter 5 parameter 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

Start Playing Around

- **Move to 3 Person Teams**

- **Open up your SCREAM spreadsheet**
  - Download the file SCREAM2_Student_v2.xlsm
  - Make sure you allow Macros
- **Two ways to Play**
  - Use the same policy and run against two different scenarios
  - Test two different policies and run against the same scenario

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

Status Check
@2:30

Some questions to ponder . . .

- 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?

Final Decision Due @ 3:15

MIT Center for Transportation & Logistics

Analysis of Results

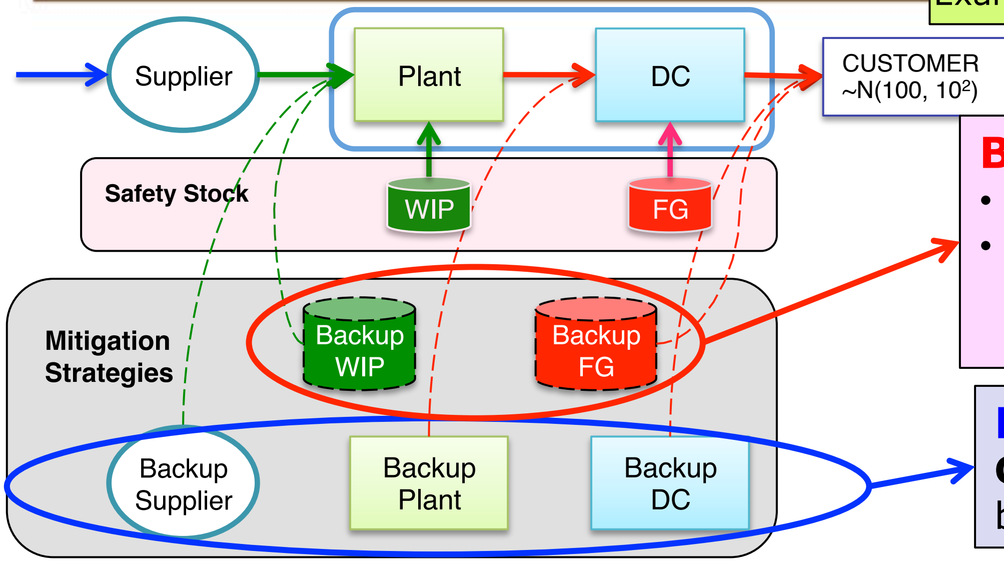
MIT Center for Transportation & Logistics

Mitigation policy

Mitigation Policy Format

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

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



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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

Policies chosen by the teams

Team	Inventory FGI	Inventory WIP	Capacity DC	Capacity Plant	Capacity Sup	Name
1	2500	1000	5	2	2	Brazilians
2	1000	1000	4	4	7	Wheeler
3	1250	800	5	5	5	Hidour/Bourgoin/Vlakos
4	800	1000	4	5	3	Americo
5	400	400	6	6	6	Jay/Tom
6	1000	400	5	6	5	Terremoto
7	1200	200	5	5	6	Mosquito
8	400	1200	6	6	5	P&G
9	200	200	6	3	6	Tomasetti/Piotti/Wagle
10	1250	750	5	5	5	Sylvie/Saber

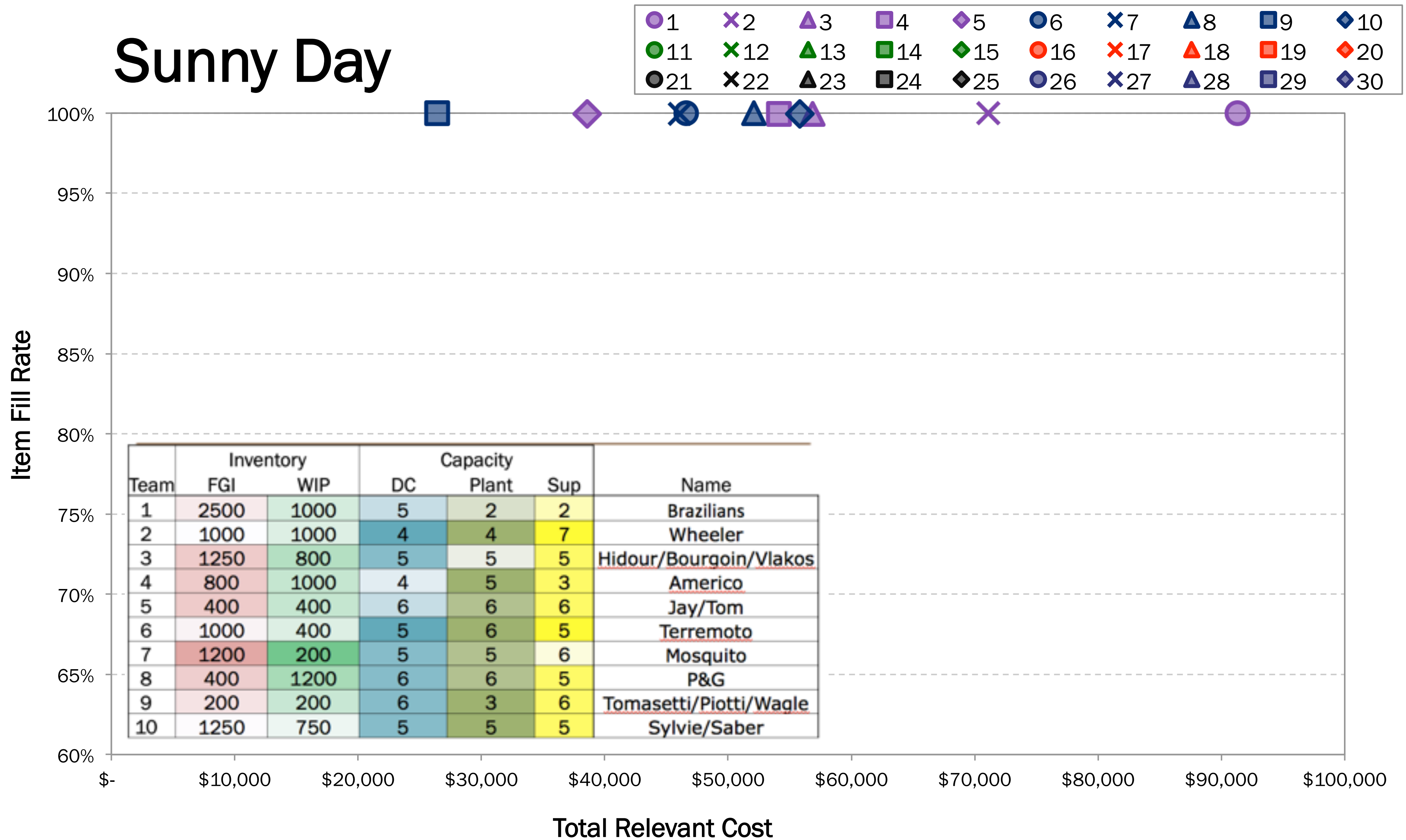
Scenarios

	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 used to test policies

Scenarios -->	1	2	3	4	5	6	7	8	9	10
Sunny Day	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Partly Sunny	82%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Slightly Sunny	55%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Slightly Cloudy	37%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Very Cloudy	19%	9%	9%	9%	9%	9%	9%	9%	9%	9%
Nightmare	0%	11%	11%	11%	11%	11%	11%	11%	11%	12%
Short Overlapping	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Supplier Down Longterm	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
DC Down Longterm	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Even Probability	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

Sunny Day



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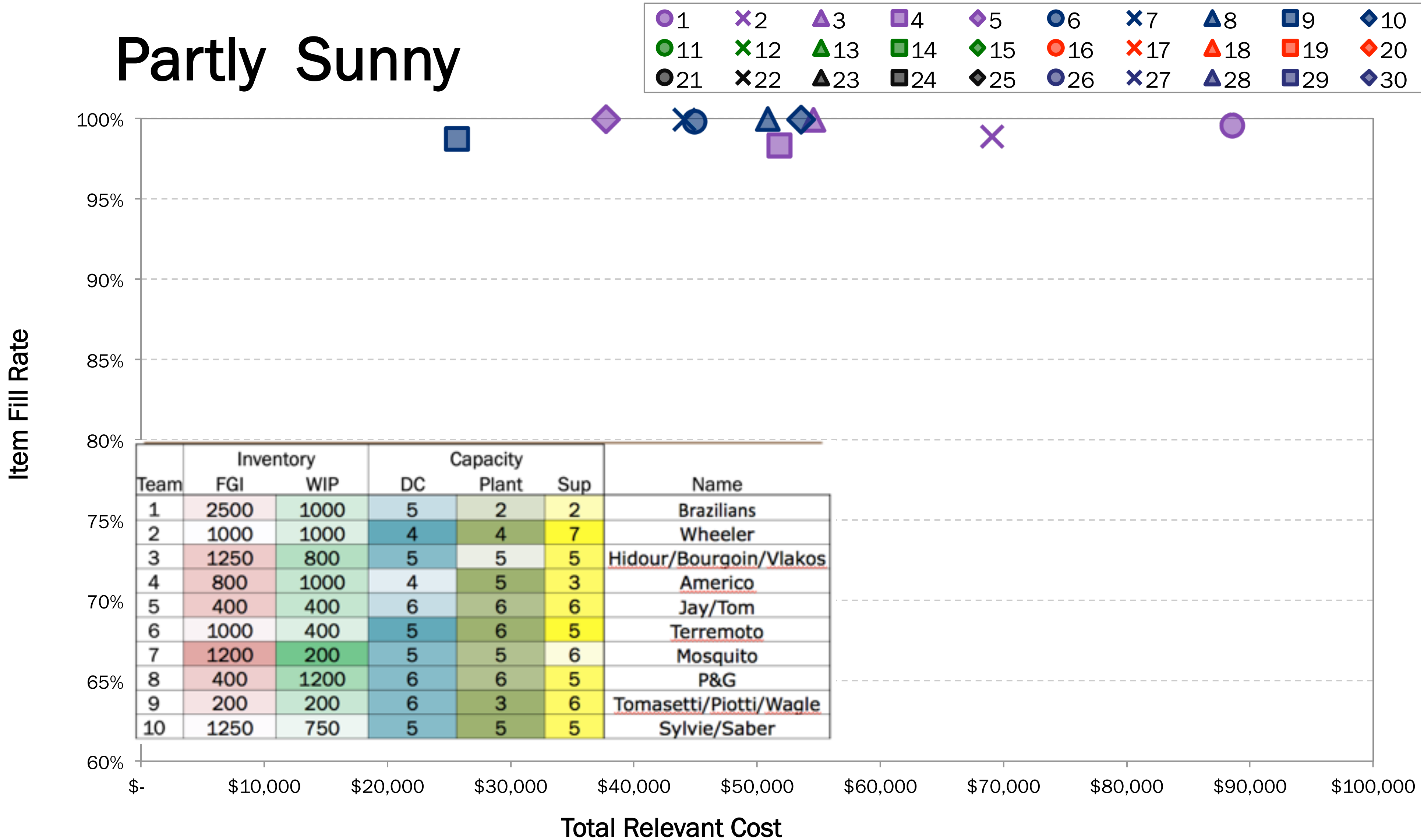
10	1250	750	5	5	5	Sylvie/Saber

Partly Sunny



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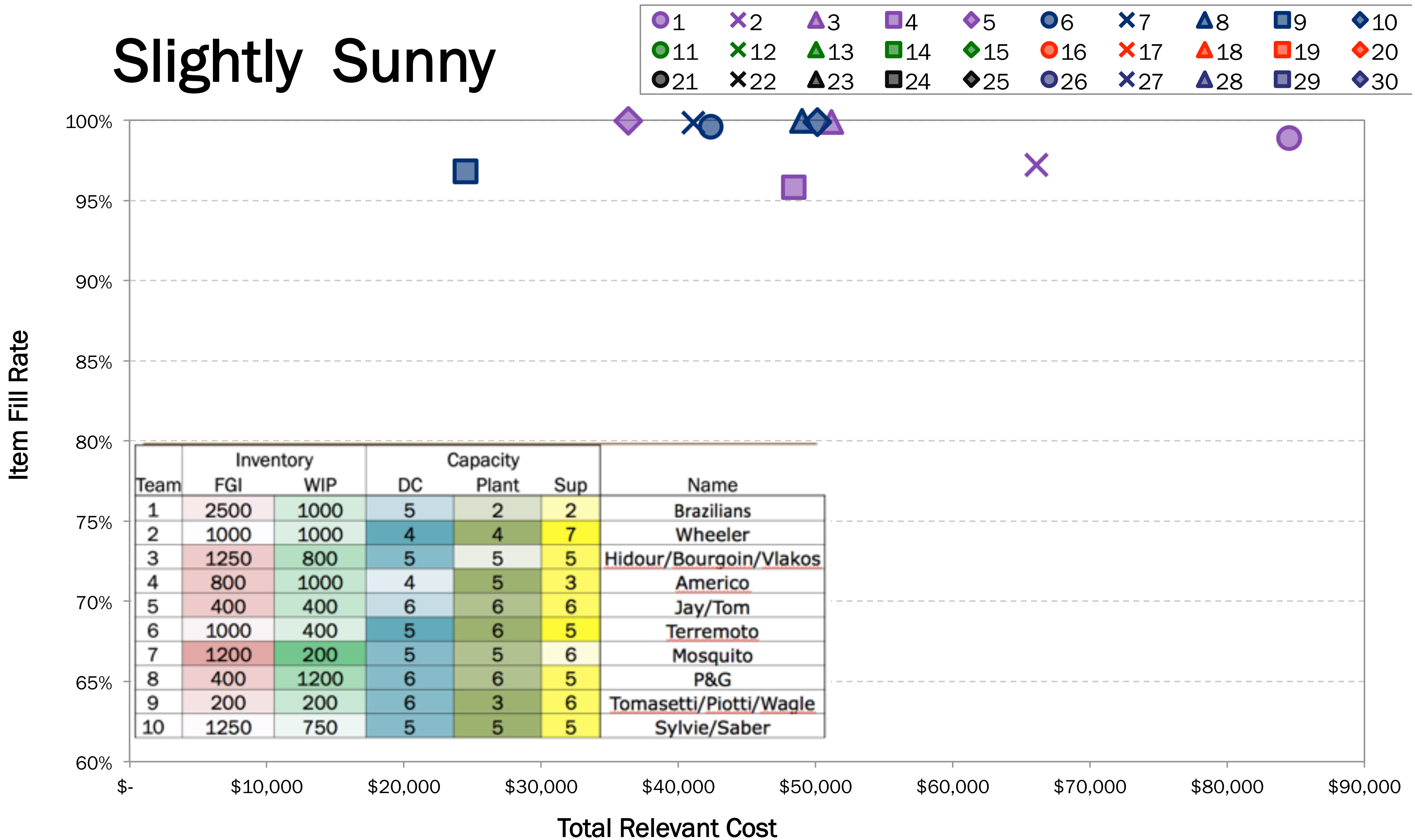

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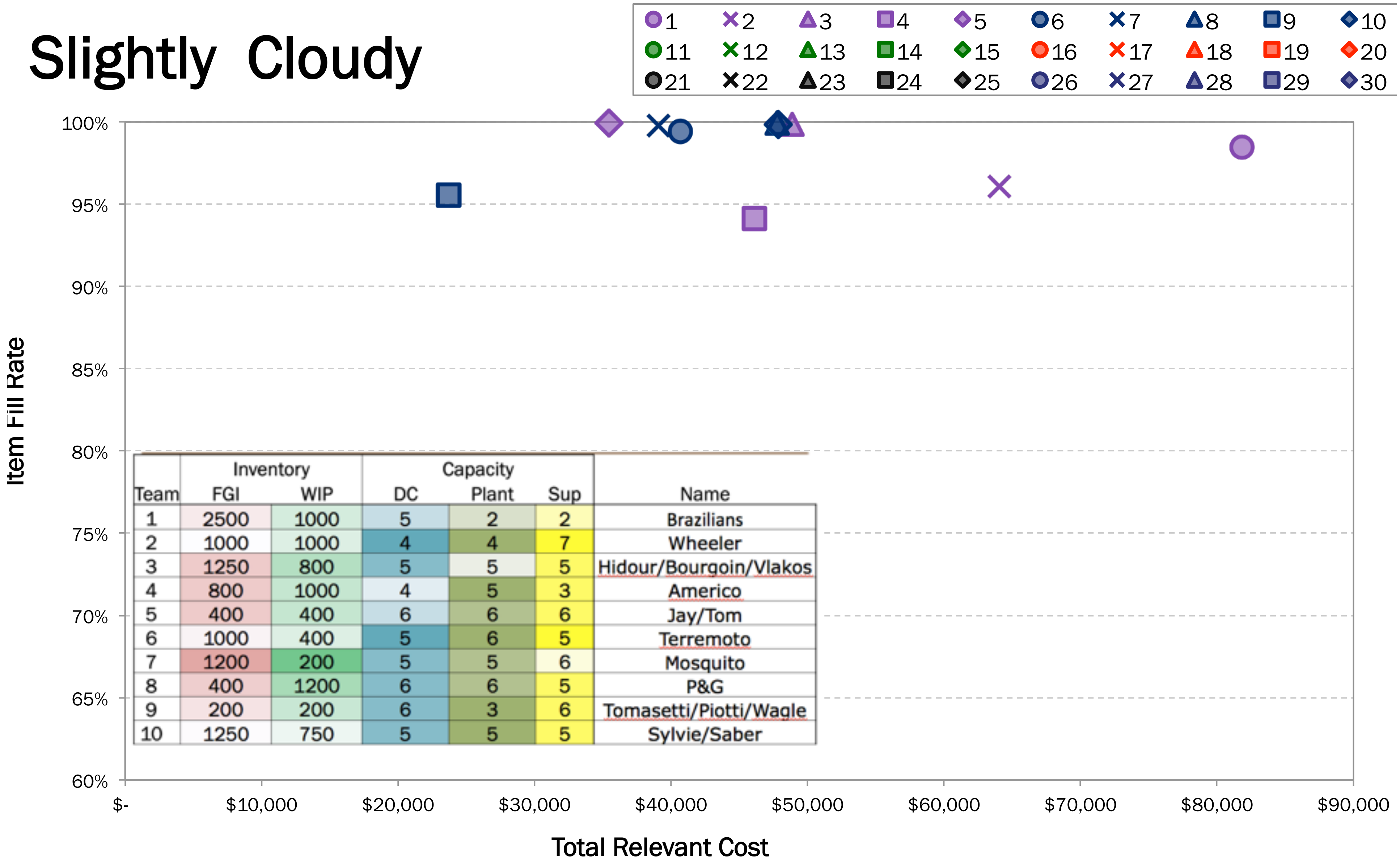

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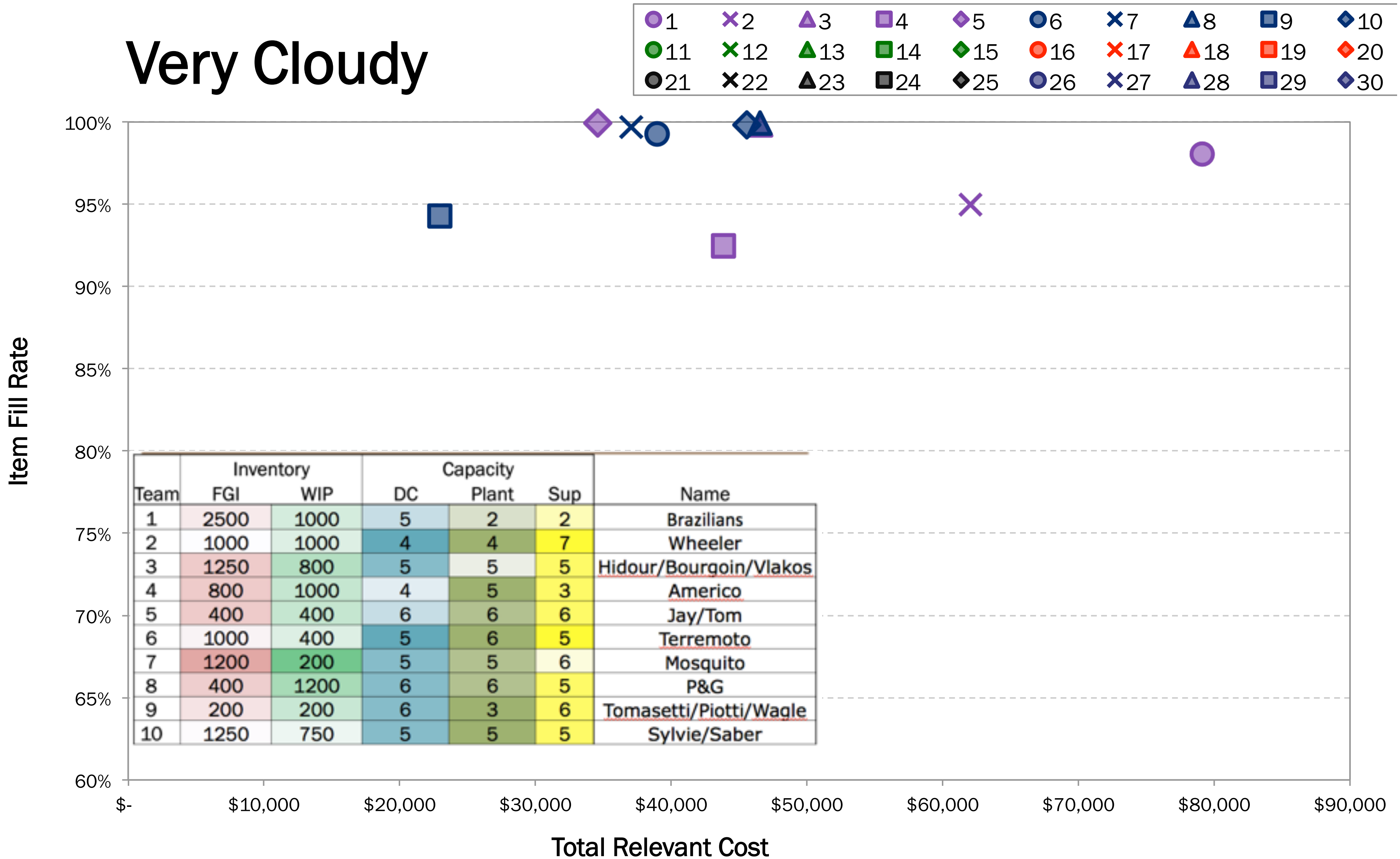
Very Cloudy



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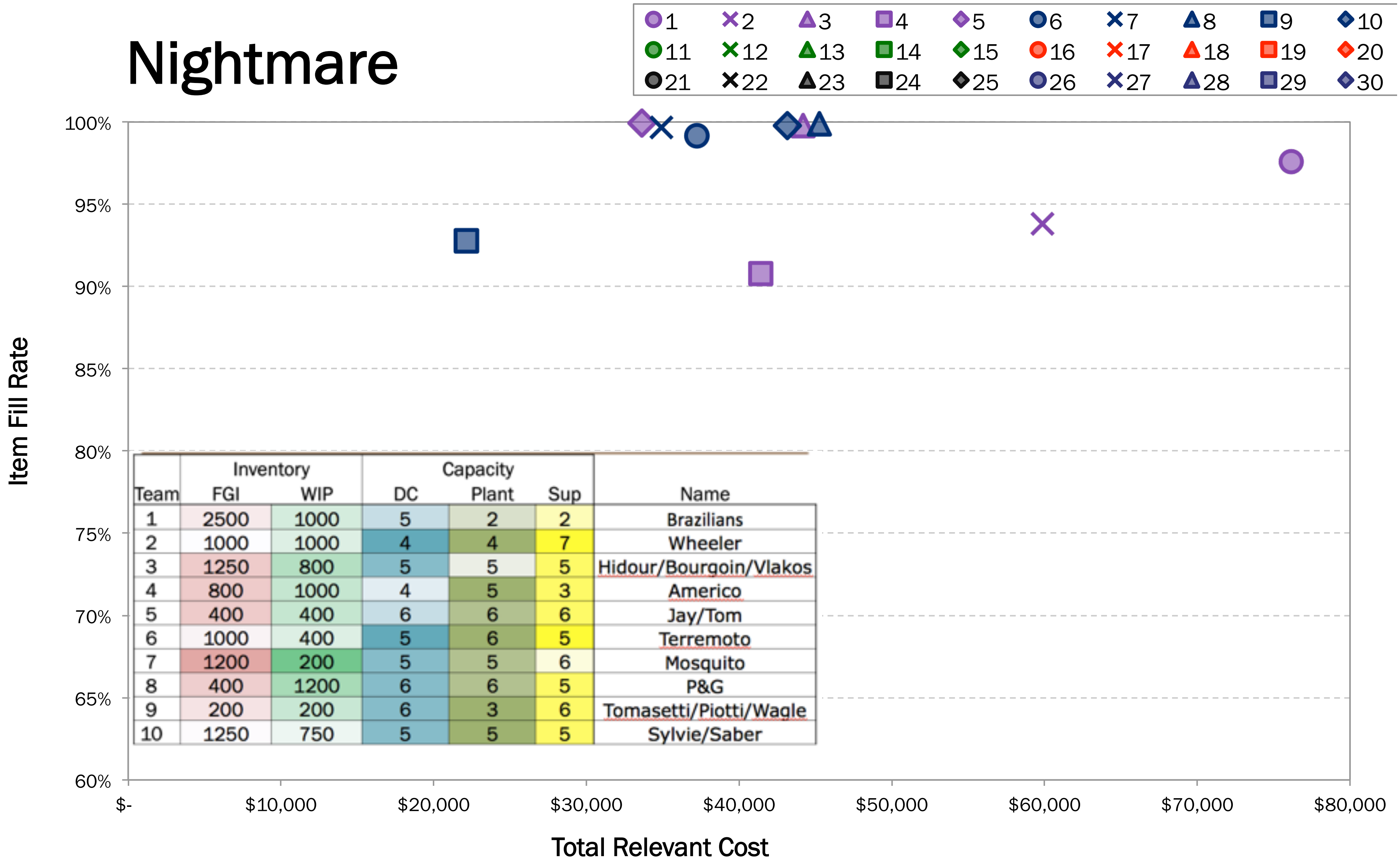
Nightmare



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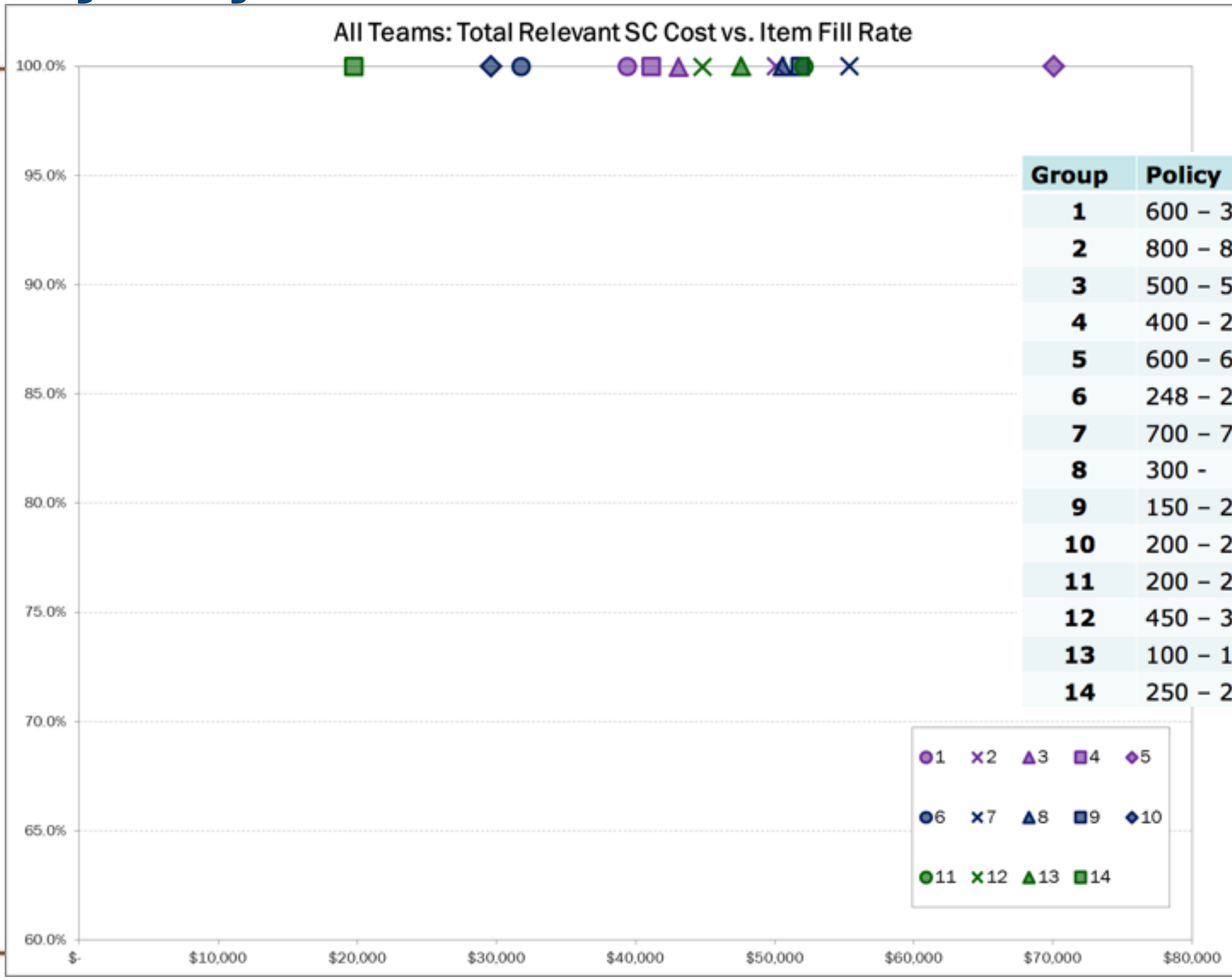
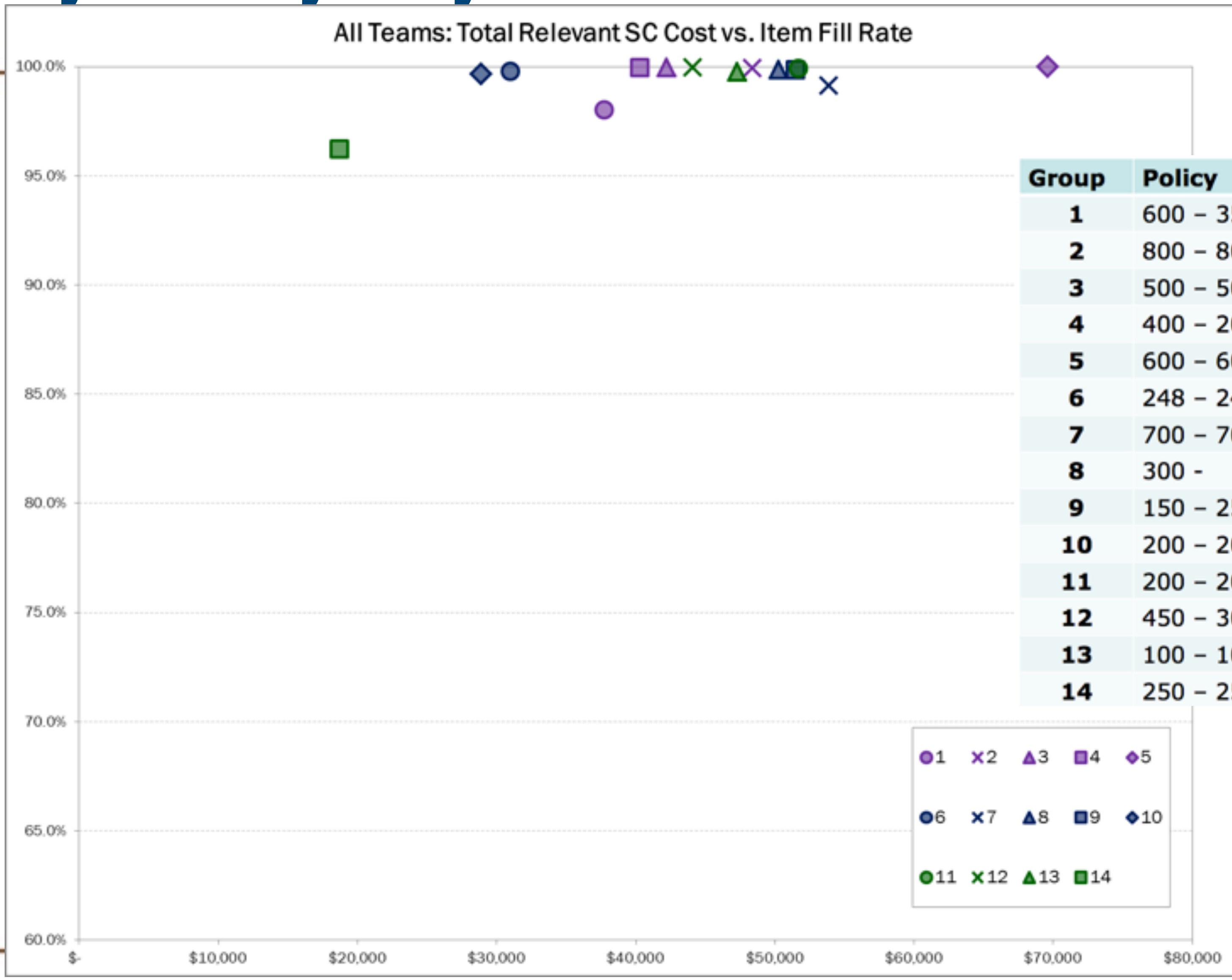
Older Runs

Sunny Days Scenario



Group	Policy
1	600 – 350 – 4 – 3 – 6
2	800 – 800 – 6 – 5 – 5
3	500 – 500 – 6 – 6 – 6
4	400 – 200 – 6 – 6 – 7
5	600 – 600 – 7 – 7 – 7
6	248 – 248 – 6 – 6 – 6
7	700 – 700 – 7 – 3 – 3
8	300 - 0 – 7 – 7 – 7
9	150 – 250 – 7 – 7 – 7
10	200 – 200 – 6 – 6 – 6
11	200 – 200 – 7 – 7 – 7
12	450 – 300 – 6 – 7 – 6
13	100 – 100 – 7 – 7 – 7
14	250 – 250 – 2 – 5 – 2

Partly Sunny Days Scenario



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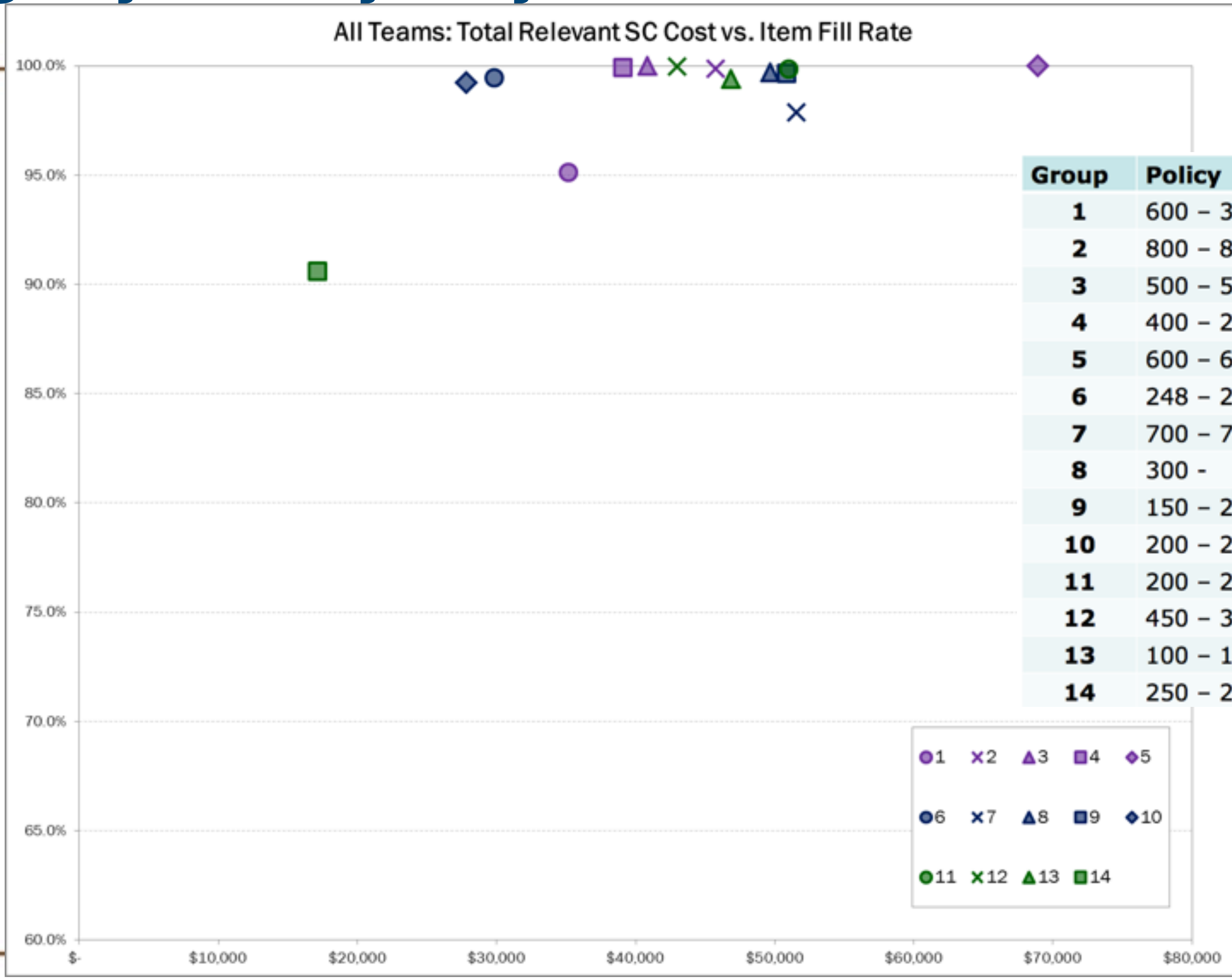

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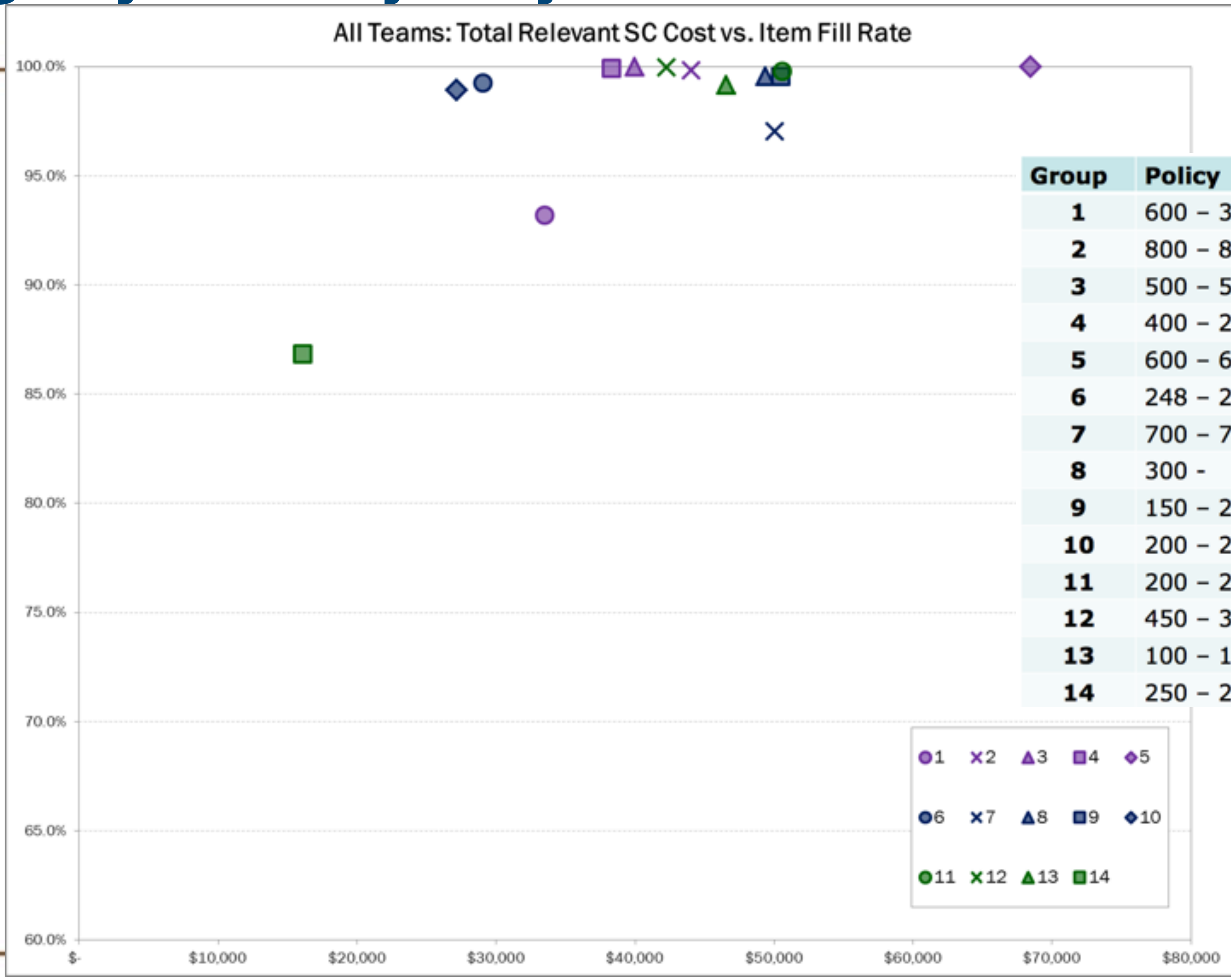

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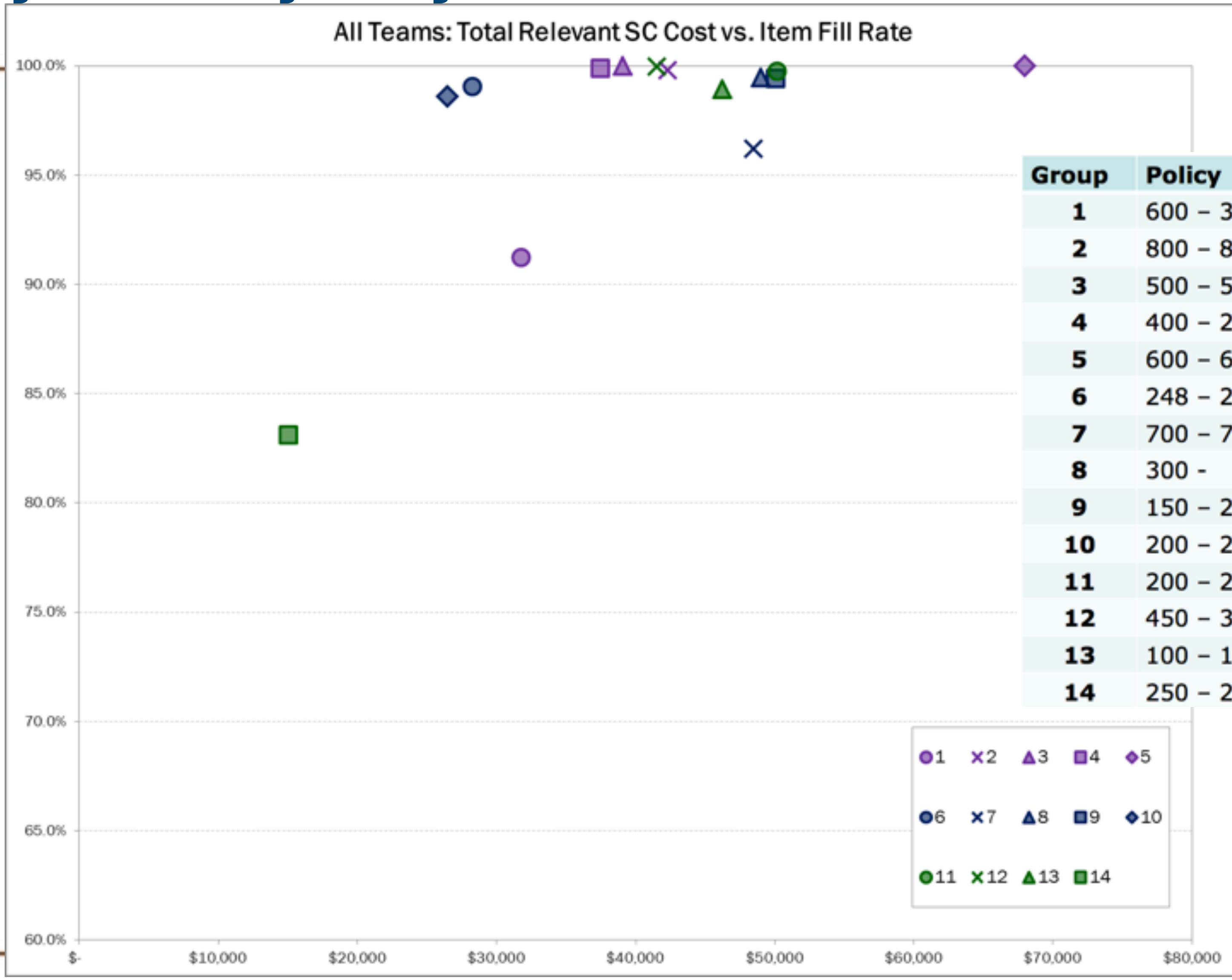

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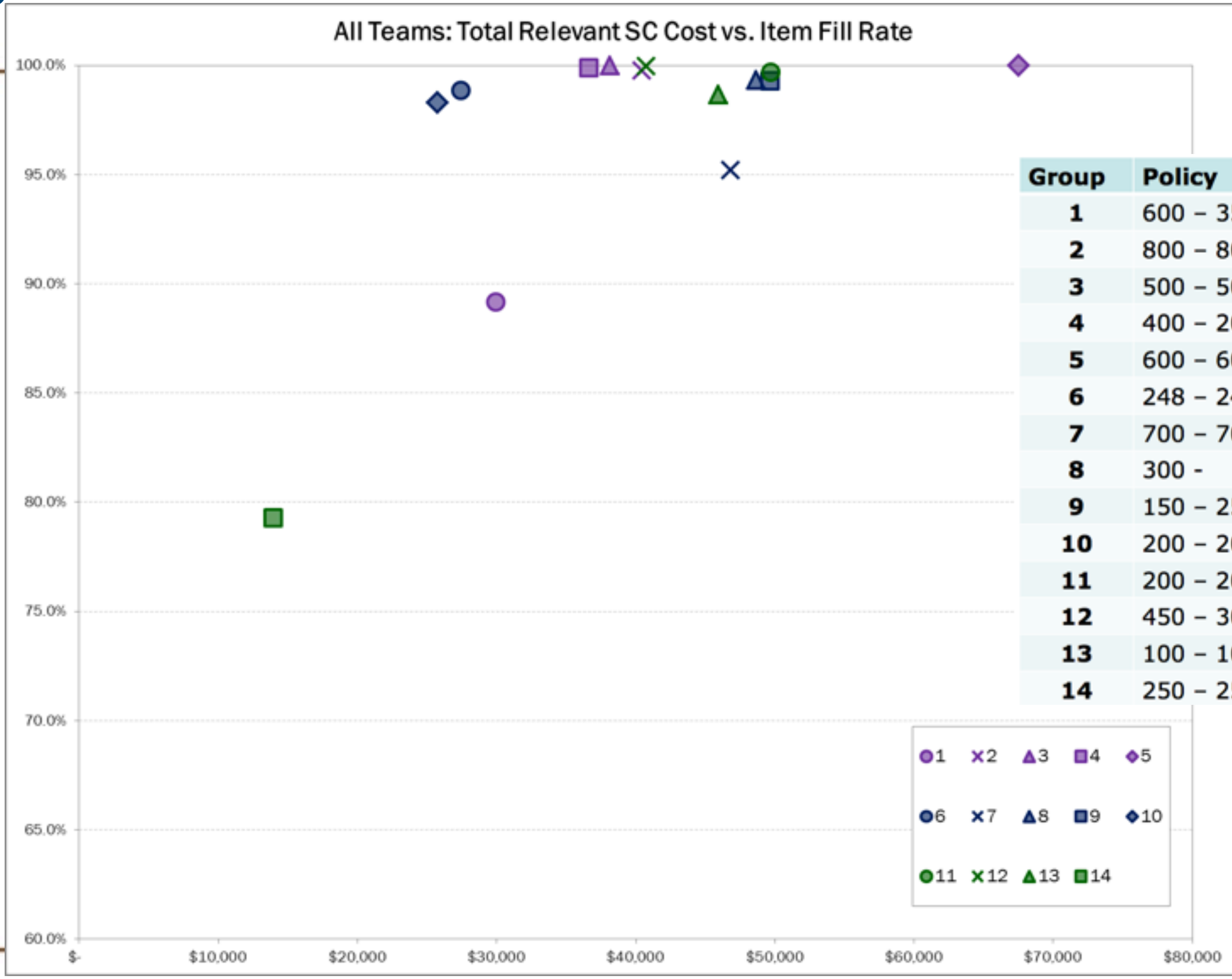
Nightmare Scenario



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Thoughts?

- What factors affect the performance?
- How can you improve your mitigation strategy?
- What did you learn from the game?

Key takeaways: Mitigation policy

- **Multiple ways to protect – at different costs**
  - Different policies do well under different scenarios
  - Test policies against a portfolio of scenarios
- **Scenario creation is an informed process**
- **Downstream matters more than Upstream**
  - For this supply chain – not necessarily universally true
  - DC protection helps mitigation Plant and Supplier failure
- **Combination of Redundancy & Flexibility**
  - Typically most reasonable approach is mixed
  - Redundant inventory covers before backup capacity activated
  - Flexibility (backup capacity) covers for longer term

Supplementary reading

- Amanda J. Schmitt. *Strategies for customer service level protection under multi-echelon supply chain disruption risk*, Transportation Research Part B 45 (2011) 1266–1283.
- Amanda J. Schmitt, Mahender Singh. *Quantifying supply chain disruption risk using Monte Carlo and discrete-event simulation*, Proceedings of the 2009 Winter Simulation Conference, 1237-1248.
- Amanda J. Schmitt, Mahender Singh. *A Quantitative Analysis of Disruption Risk in a Multi-Echelon Supply Chain*.
- Amanda J. Schmitt. *Learning how to manage risk in global supply networks*, white paper, Aug. 2009.
    - Global supply chain risk management. MIT CTL white paper