DELIVERY CONFIDENCE MODEL

Forecasting Projected Throughput in a Complex Assembly Manufacturing System using Neural Networks and Capacity Simulation

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Operations Analysis - Industrial Engineering

LOCKHEED MARTIN

LOCKHEED MARTIN OVERVIEW

- One of the world's leading aerospace, defense, security, and technology companies.
- Over 100,000 Employees worldwide.
- Developed and produced iconic military aircraft such as the U-2, SR-71, F-16, C-130, and F-117 stealth fighter.
- Current largest contract is the F-35 Joint Strike Fighter.
  - 5th generation, multi-role stealth fighter.
  - CTOL, STOVL, and CV.

Lockheed Martin.
Your Mission is Ours.™

MANUFACTURING SYSTEM STUDIED

System Highlights:

- Global aeronautics defense production program.
- Currently a low throughput system with a growing customer base and demand for product.
- Thousands of parts and install operations.
- Complex installations with demanding specifications.
- Large scale customer visibility.

PROJECT BACKGROUND OVERVIEW

CASE FOR MODEL CREATION

Original Question:

- As of time now, what is the probability that I will hit my annual production throughput goal for the next 3 years?

Old answer to that question:

- Take the current production schedule and forecast a performance regression to a recovery point and build a detailed schedule using Microsoft Excel.
    - Manual creation, siloed execution between production areas.
    - Build 1 area's schedule out at a time.
    - No variation in performance is included.

Results leave more questions with unknown answers:

- You didn't study variation, so does this mean I will make my goal 100% of the time?
- What variables are driving any risks to reaching that goal?
- Which variables have the greatest influence on the output?
- Is the learning curve applied actually feasible?
- Etc.

WHAT REALLY NEEDS TO BE STUDIED?

Problem Statement:

- As of time now, what is the probability that I will hit my annual production throughput goal for the next 3 years?

Understanding:

- Problem is way more complicated than saying this task takes X days and in the future I believe I can perform at Y.
    - Will parts be available, is manpower trained and available, what is my defect rate, etc.?

What do I really need in order to solve answer:

- Ability to understand the thousands of complex intervariable relationships and how that effects the production span for a given area.
- Need a integrated schedule tool that understands capacity relationships.
- Needs to study variation in performance.
- Trusted forecasts for all known inputs in the production system that can effect span and the associated change risks.
- Ability to identify risk and tests mitigation strategies and goals prior to implementation.

STRATEGIES USED TO CREATE MODEL

INTEGRATING NEURAL NETWORKS WITH CAPACITY SIMULATION

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QUICK GLOSSARY OF TERMS

Terms

- Neural Network – An artificial intelligence algorithm that is created based on historical relationships between input variables and a known output, in order to predict a future output with known input variables and an unknown relationship between those variables.

- Markov Chain - Is a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.

- Deviation Distribution – A distribution based on the deviation ratio of the actual value from the expected value.

VARIABLES STUDIED IN NEURAL NETWORK

Variables in Delivery Confidence Model

- Material Shortage Forecasts
- Product Variant Mix
- Production Performance
- Scrap, Rework, and Repair
- Out of Station Work quantity and how far it travels downstream
- Staffing Headcount Levels
- Knowledge, Skills, and Abilities of Employees
- In-plant fabrication supplier performance metrics
- Takt Rate
- Span of Individual Areas
- Production Learning Curve Rates
- Continuous Improvement Initiatives
- Seasonality
- Seasonality of Work Force Attendance and Performance Trends

HOW IS THIS ACCOMPLISHED?

PALISADE

Distribution analysis and additional changes to neural projections

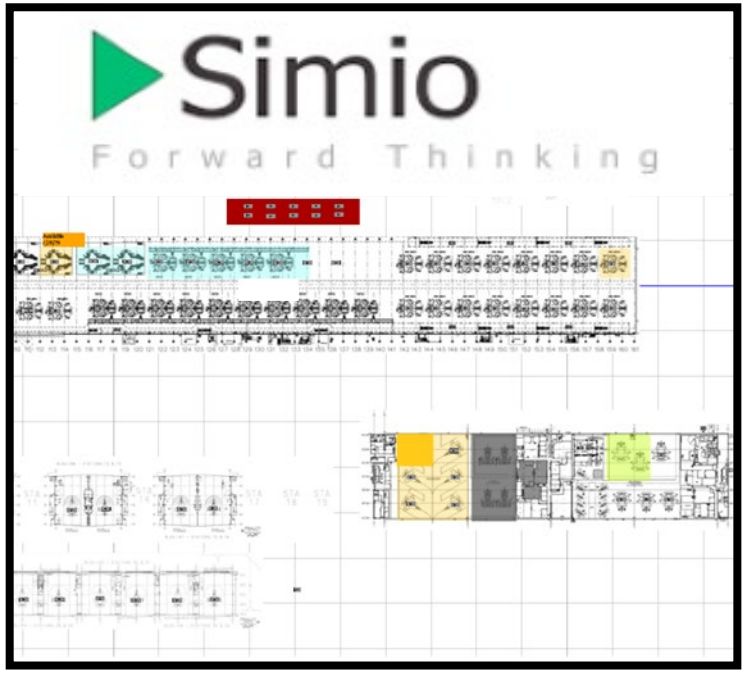
python

Neural Network Creation & Unknown Variable Forecasting

SAP HANA

Back End Data Source

Simio
Forward Thinking



Capacity Simulation with Scenario Analysis

tableau
SOFTWARE

Scenario Output Analysis and Viewer

SIMIO LOGIC AND USES

Data Driven Model (Data Tables)

- Entity Arrival table loaded with Span Projections using Markov Chain Deviation Distribution from the expected value
- Task Sequences enable more granular modeling and tracking
- Custom work schedules, including planned and unplanned maintenance and downtime by resource

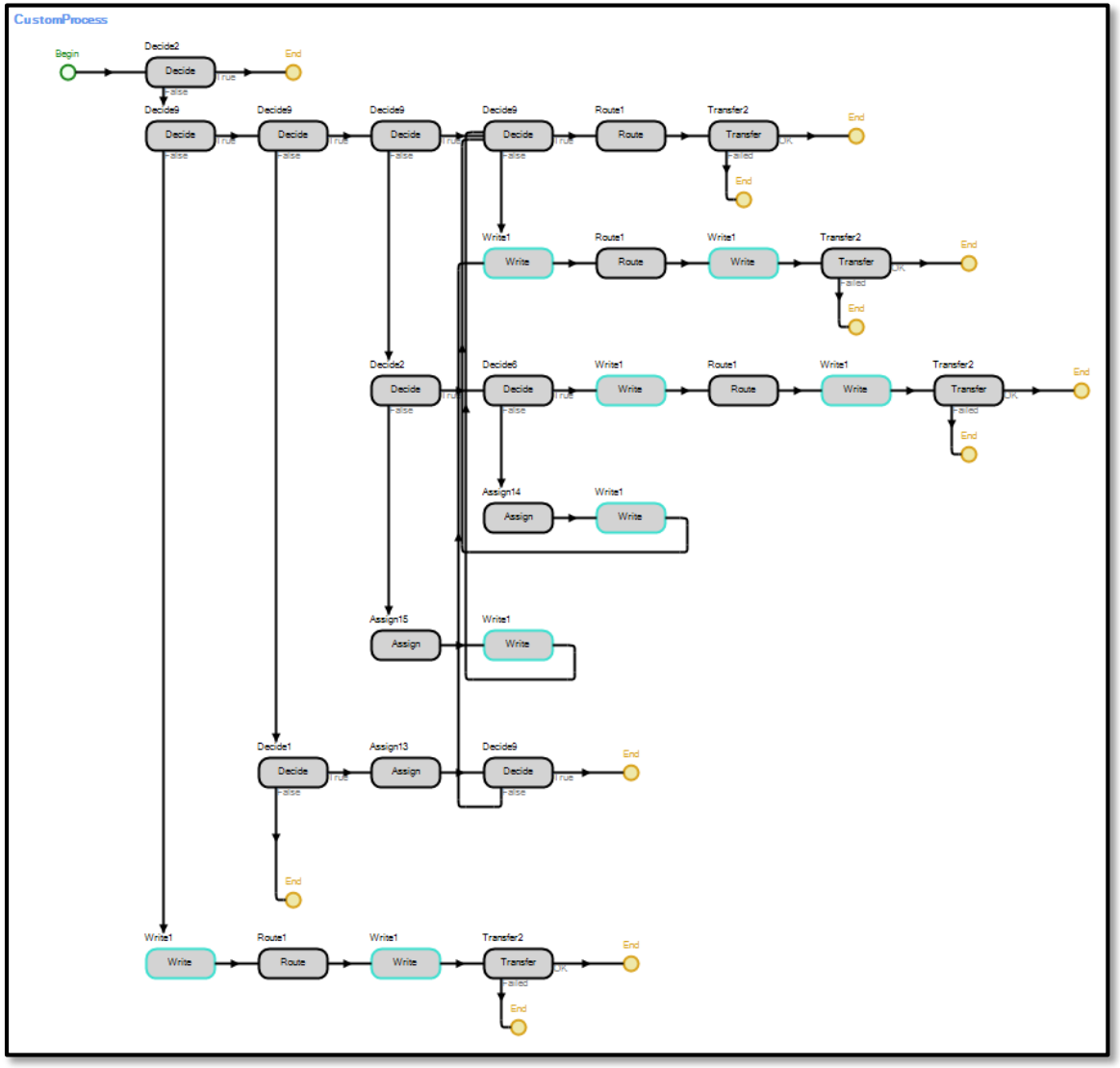
Entity Flow and Logic

- Routing Groups used to regulate variable entity flow between component area rate stations
- Add-on Processes enable custom scenario routing logic based on inputs and model conditions

Model Validation and Results Analysis

- Resource and Entity Gantt Charts utilized for quick model troubleshooting and validation
- Write out steps used to capture key metrics and load into custom output visuals:
  - Milestone start and complete dates for each task and resource
  - Resource utilization analysis
- Experiments and Operational Planning (Risk Analysis) used to build confidence intervals for given scenarios

CUSTOM PROCESS



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SCENARIO ANALYSES STUDIED

	Increased Throughput	Capacity Planning	Risk Identification	Risk Mitigation
SPAN/SCHEDULE	Annual Year over year Increase in Production Demand	Gain Insight in regards to adequate facility capacity vs. WIP Projection?	Need to quickly identify and quantify varying risk impacts outside isolated area.	Need for a tool to understand potential programmatic changes for improvement.
VARIATION	Does span performance variation limit our ability to reach our increasing demand profile?	Does variation or maintenance downtime cause a bottleneck?	Which variables cause the most disruptive and frequent variation to production performance?	What variables should I target with improvement initiatives to reduce variation?
BUSINESS CASE	Missing Demand Profile, means loss in Company Value	ROI of fixing Capacity Bottleneck	More enhanced analyses on what is truly driving production performance risk vs. gut feel.	In depth analytics to accurately reflect risk mitigation strategies and success rates.




TABLEAU DEMO VIEWER

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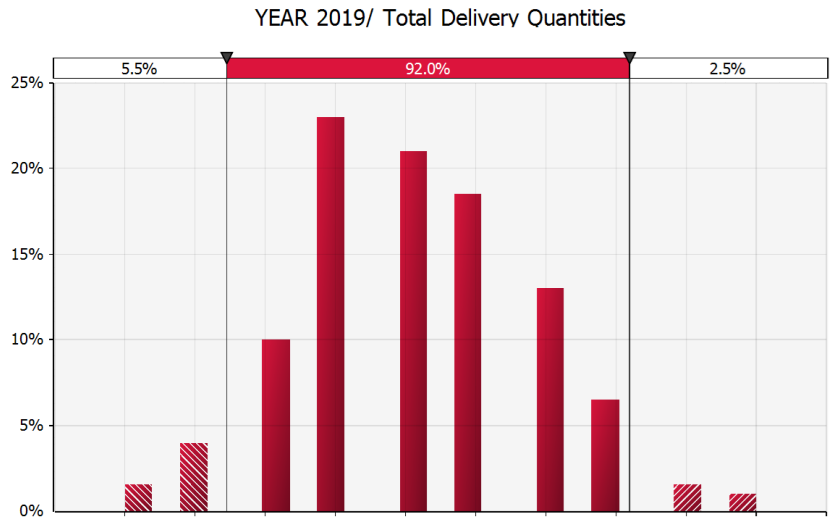
PROGRAM LEVEL VIEW



ANNUAL THROUGHPUT PROBABILITY

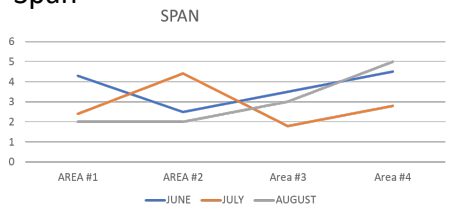
92%

Variables to Toggle (Default Forecast Shown):

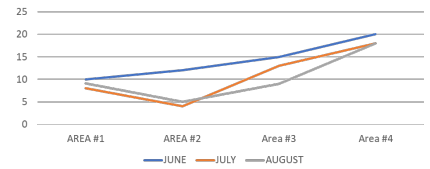
Category	Area # 1	Area # 2	Area # 3	Area # 4	Area # 5	Area # 6	Area # 7	Area # 8	Area # 9	Area # 10
Variable # 1	15%	8%	18%	23%	20%	25%	30%	12%	15%	70%
Variable #2	10	8	2	6	2	15	38	12	3	1
Variable #3	10	8	2	6	2	15	38	12	3	1
Variable #4	310	180	137	625	190	379	627	168	98	160
Variable #5	150	70	220	350	60	250	460	N/A	20	N/A
Variable #6	48%	39%	37%	15%	35%	17%	14%	29%	30%	51%
Variable #7	100%	105%	90%	100%	110%	95%	95%	100%	95%	90%
Variable #8	58	18	24	25	66	21	30		10	26

Output Charts: Component Area

Span

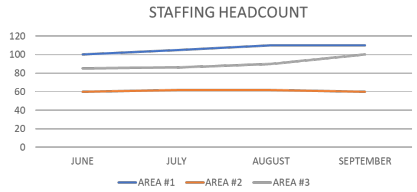


WIP



Quality Variation

STAFFING LEVELS



Forecasted Output:

Category	Area # 1	Area # 2	Area # 3	Area # 4	Area # 5	Area # 6	Area # 7	Area # 8	Area # 9	Area # 10
6 Month Build Span Avg	30	40	50	60	50	40	30	20	10	10
6 Month -12 Month Build Span Avg	28	37	52	61	45	37	33	18	9	8
12 month-2 Years	25	35	47	57	40	35	30	18	9	6
2019 Annual Quantity	A	B	C	D	E	F	G	H	I	J

Component Area: AREA # 1

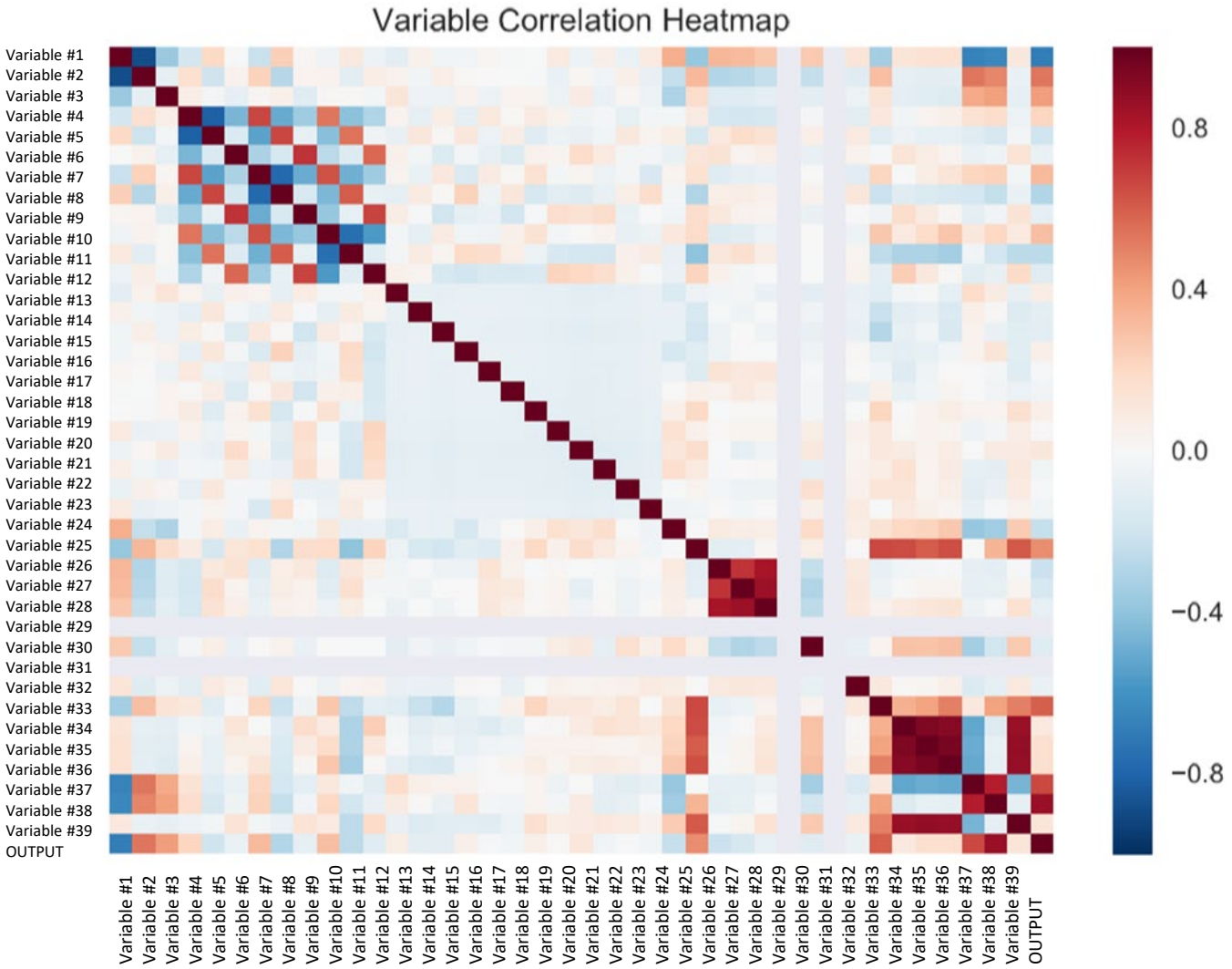
Top Correlated Variables to Output

Top Correlated Variables to Span	Value	Span Impact
Variable # 37	.758	.05 days/event
Variable # 33	.645	.12 days/event
Variable #25	.412	.08 days/event
Variable # 2	.432	.5 days/event
Variable #16	.097	Not Correlated
Etc.	X	N/A

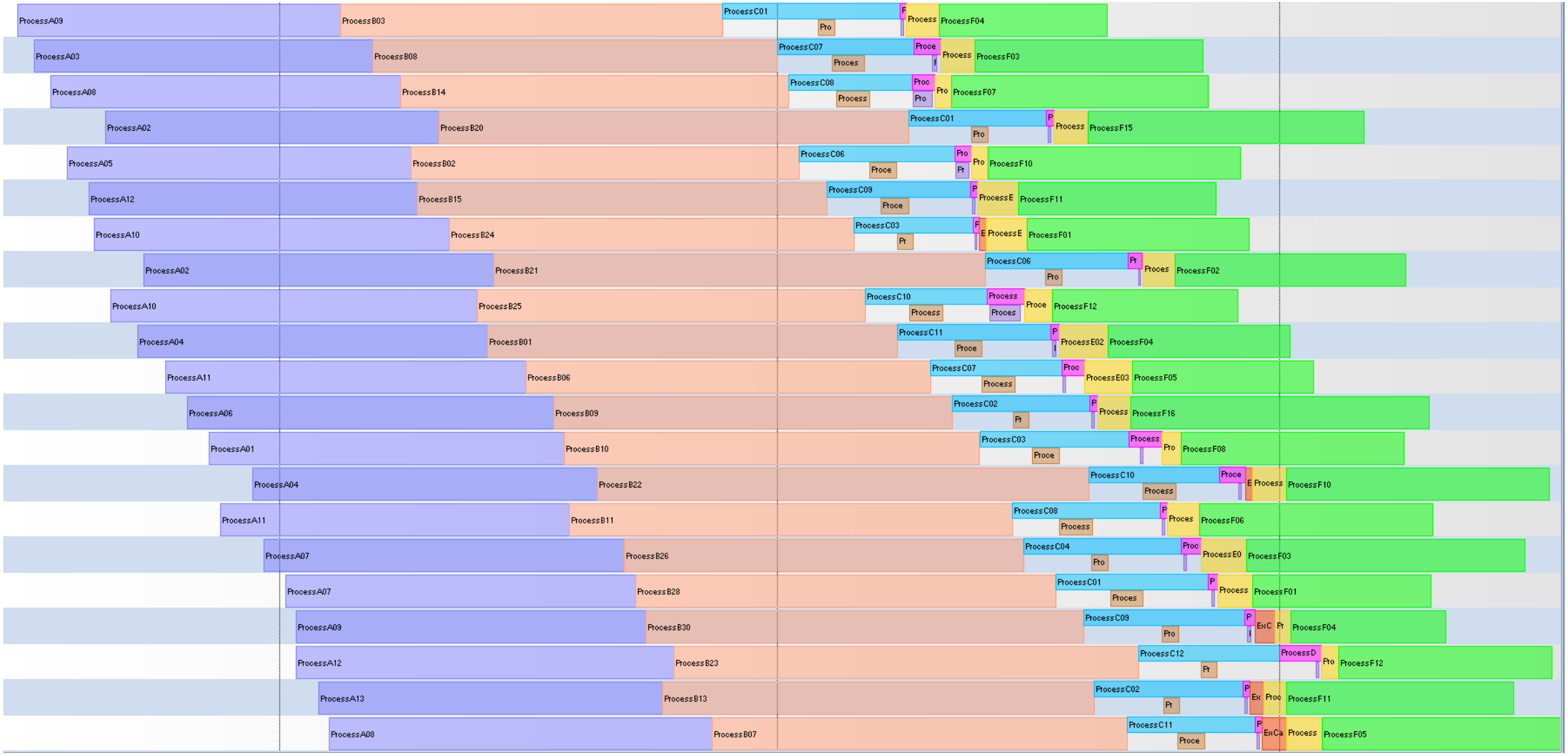
Potential Impact at Perfection:

Variable #37 = 5 Days savings
Variable #33 = 3 Days savings
Variable #25 = 2 Days savings
Variable #2 = 1 Days savings

Variables Correlation Heat Map



SIMIO GANTT CHART OF DETAILED SCHEDULE



*DATA IS NOTIONAL

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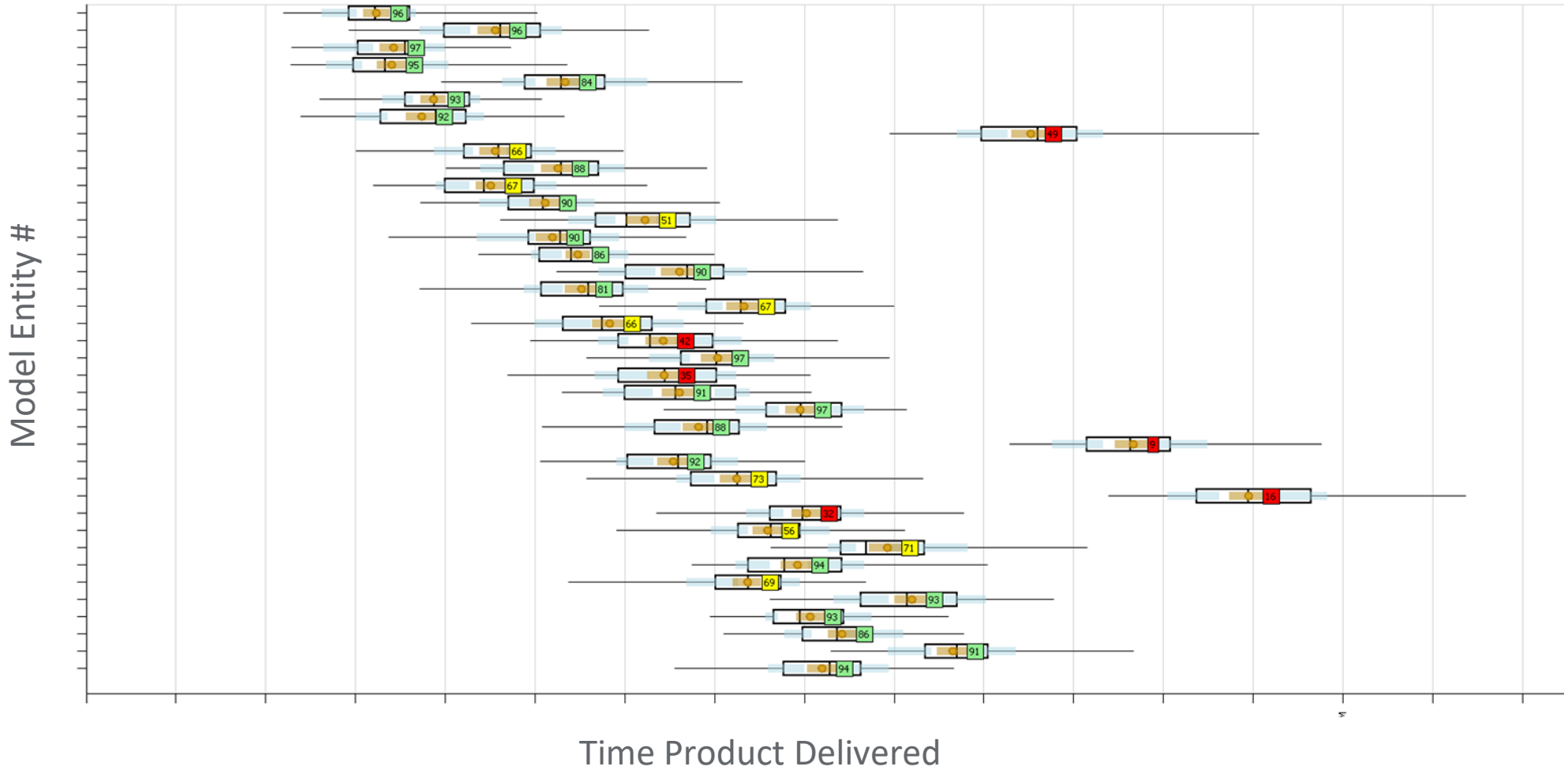
BOX-WHISKER VIEW OF DELIVERY TIMELINE FROM SIMIO

Projected Deliveries Timeframe



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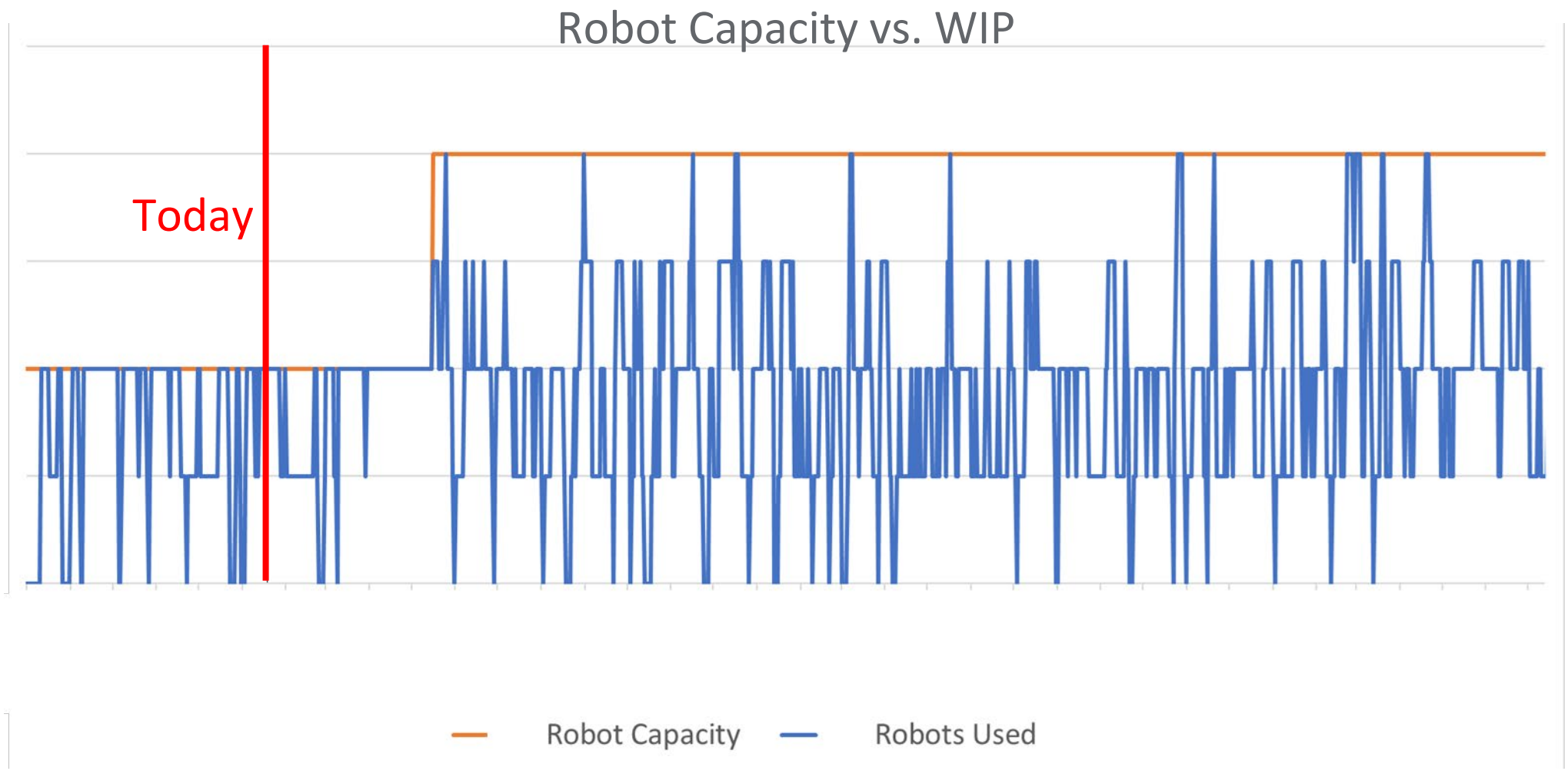
ROBOT CAPACITY UTILIZATION FORECAST



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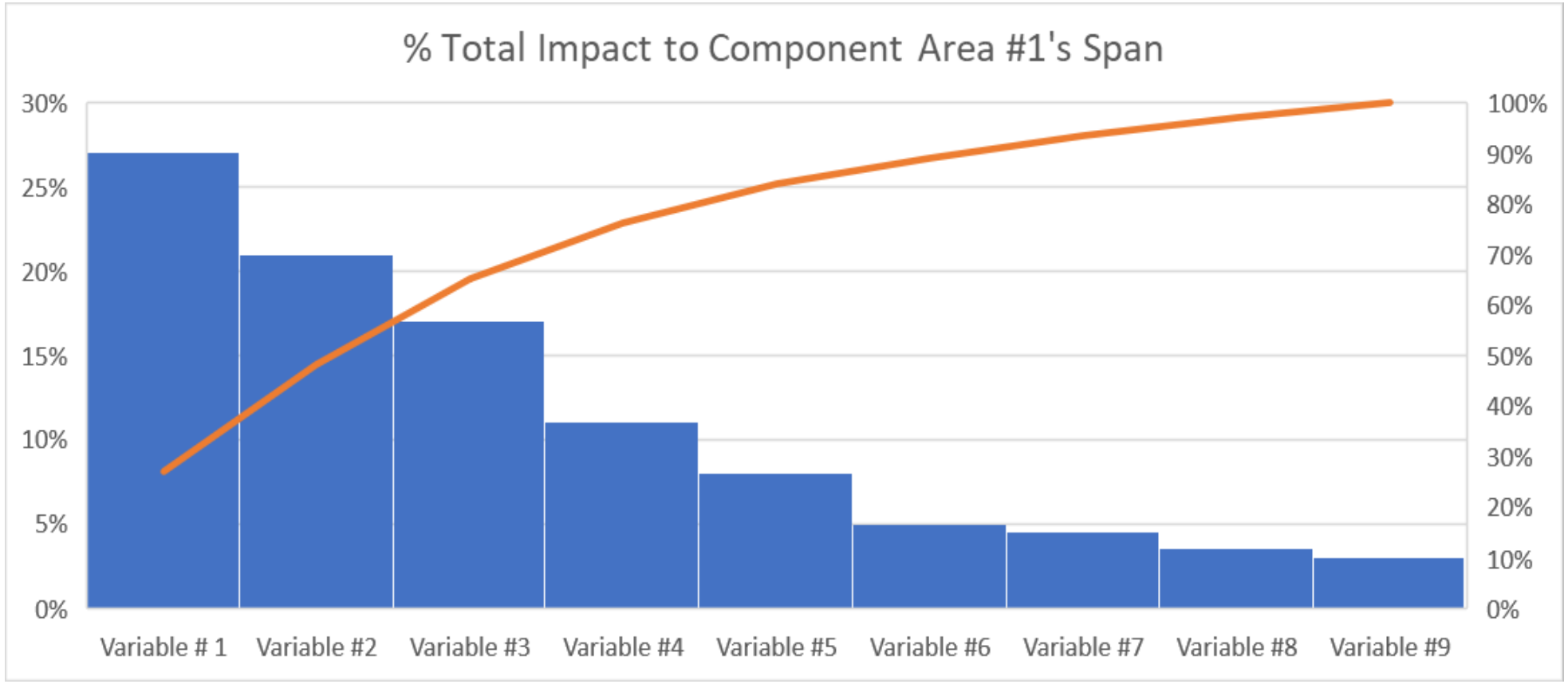
PARETO OF VARIABLE IMPACT TO FINAL SPAN



Neural Network will auto-rank impact variables to Span Output.

*DATA IS NOTIONAL

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QUESTIONS?

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