

A modern rooftop patio area with a grey brick wall in the background. The patio features several tables and chairs, some of which are metal folding chairs. There are also some plants and trees, including a small tree in a planter. The overall atmosphere is clean and contemporary.

Optimized Material Flow of Woodshop Through Layout Redesign

Project Team

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Minor: Biological Science



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Major: Industrial Engineering
Minor: Supply Chain
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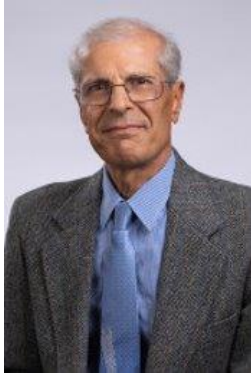


Madison Wegner

Major: Industrial Engineering
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Academic and Industry Advisors



Dr. Azim Houshyar

Academic Advisor



Dr. Bob White

Academic Advisor



**Professor Dana
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Academic Advisor



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Industry Advisor –
Manufacturing
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Sponsor Background

- Industry leader in high-design site furniture
- Located in Kalamazoo, MI and over 50 years in business
- Metal, wood, HDPE, and concrete site furniture
- High mix-low volume production

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Woodshop Specific Background

- **45 Wood Products**
 - > 120 Product Variations
- **10+ Wood Species**
- **Boards Matched with Order in Assembly**
 - **Palisade – Exception**



Moulder
Chopsaw 1 & 2

CNC 2

Sanding Table

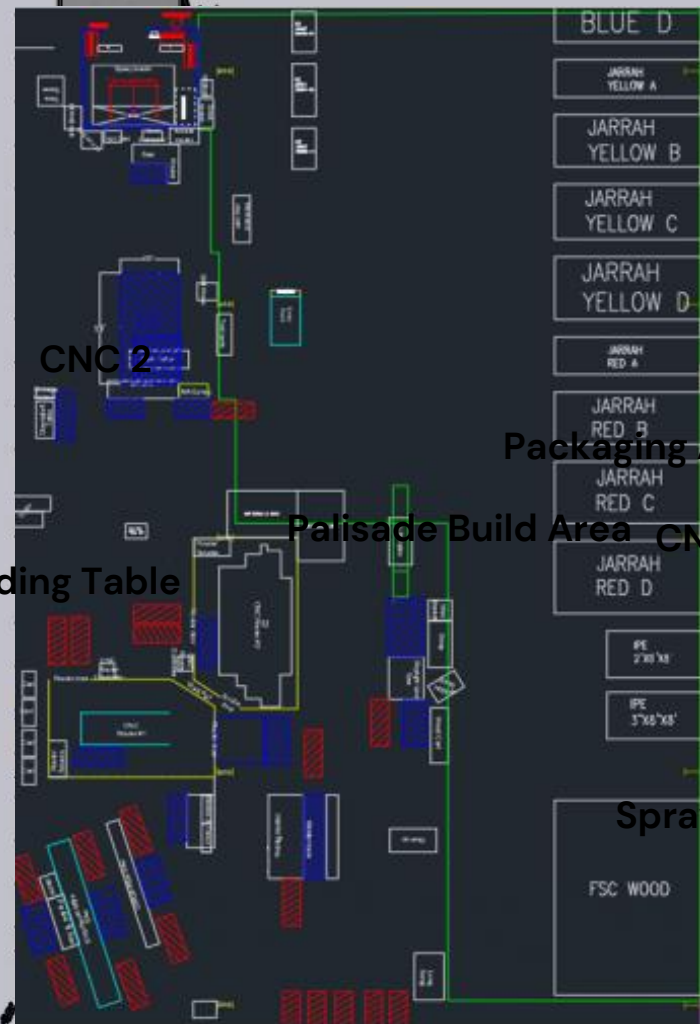
Palisade Build Area

Packaging Area

CNC 1

Mortise & Tennon
Finished Product
Spray Booth

Straight Line Saw



Defining The Problem

1

Space Usage

2

Flow of Material

3

Worker Movement

4

Unknown Utilizations

Project Goal

To increase machine and worker utilization, minimize worker movement, improve travel paths, increase throughput, and create a concise flow of material.



Considerable Factors

Design Criteria

- Eliminate Backtracking
- Physical Flow
- Concise Process

Constraints

- Staff Levels
- Machine Movement
Cost
- Amount of Inventory

A modern wooden bench with a black metal frame is shown in a close-up, low-angle shot. The bench is made of light-colored wood slats and is set against a concrete wall. A black rectangular box is superimposed over the center of the image, containing the text "Data Analysis" in white, bold, sans-serif font. The background shows a paved area with a pattern of light and dark gray tiles.

Data Analysis

Movement Diagram

CNC Area

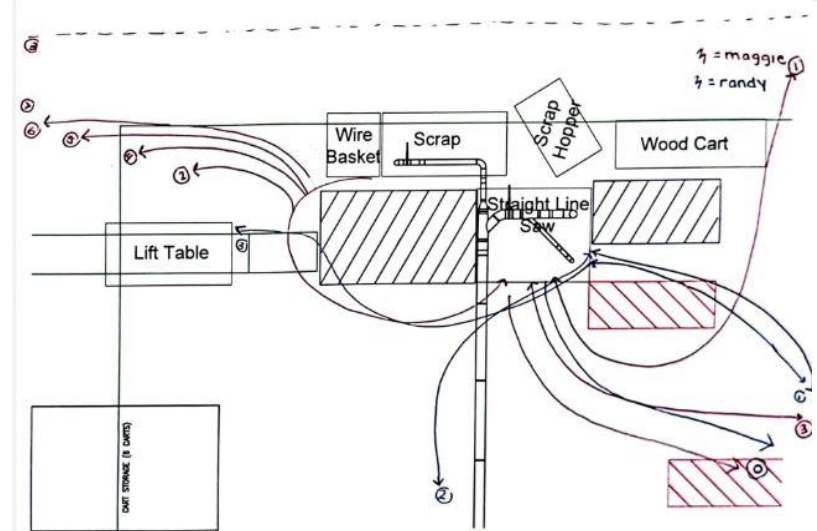
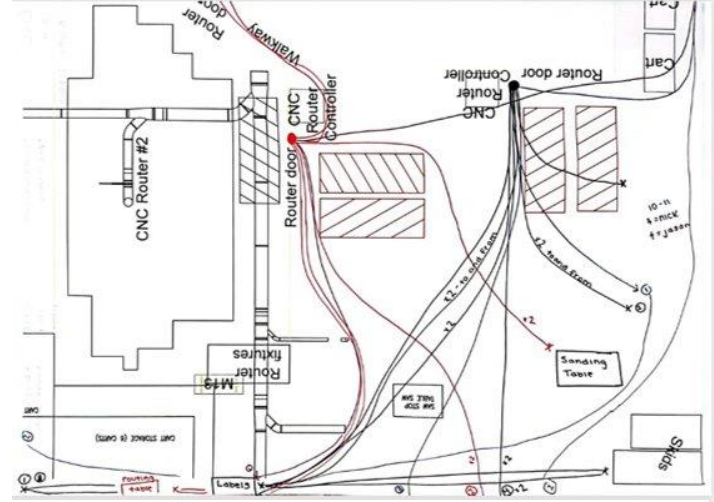
Problem: Excessive movement of workers

Important Locations: CNC computer, label printing computer, chop saws

Straight Line Saw Area

Problem: Imbalance of work

Important Locations: Forklift, moulder queue



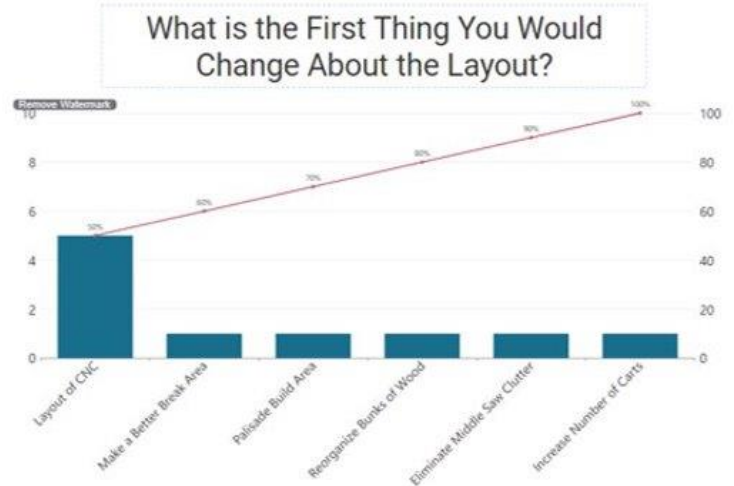
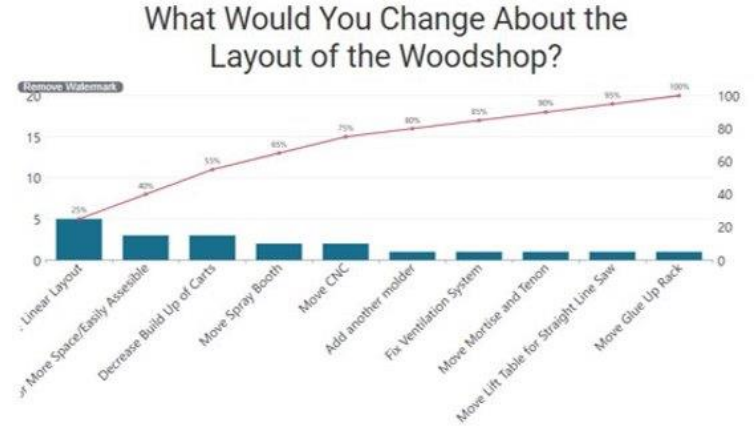
Stakeholder Interviews

Question 1: What would you change about the layout of the woodshop?

Conclusion: Linear layout preferred; accessibility

Question 2: What is the first thing you would change about the layout [of the woodshop]?

Conclusion: CNC layout could be impactful



Utilization Study

- 155 Observations
- 90% Confidence Level
- 6.5% Margin of Error

Operator Study

Operator	Utilization Study
CNC 1 Operator	63.58%
Straight Line Operator 1	56.79%
Chop Saw 1 Operator	56.17%
Moulder Operator	54.32%
CNC 2 Operator	54.32%
Straight Line Operator 2	43.83%
Middle Area Operator 1	37.65%
Large Sanding Table Operator	32.64%
Chop Saw 2 Operator	28.40%
Palisade Operator 2	10.49%
Middle Area Operator 2	3.70%
Spray Booth Operator	0.00%

Machine Study

Location	Utilization Study
CNC 2	51.97%
Moulder	49.34%
CNC 1	48.03%
Straight Line Saw	41.45%
Middle Area	39.47%
Chop Saw 1	36.84%
Chop Saw 2	36.18%
Large Sanding Table	30.26%
Palisade Build Area	24.34%
Moritise and Tenon	19.08%
Spray Booth	0.00%

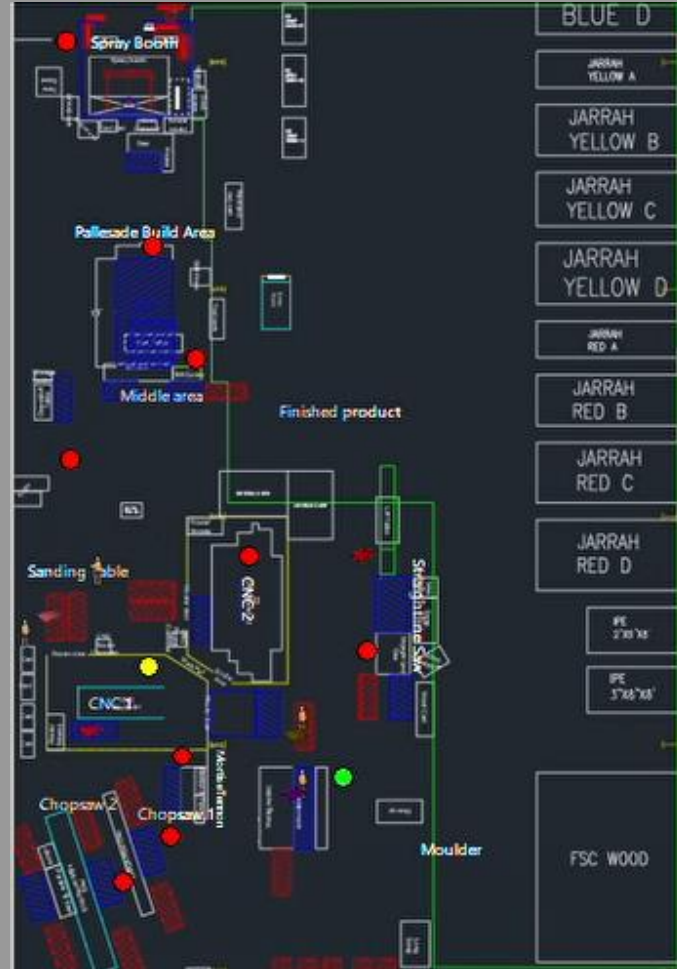
ProModel Simulation

Goal:

Replicate Actual Operation,
Superimpose Layouts and
Track Improvements to
Data

Information Used

- CAD Layout
- 2022 Sales Data
- Product Routing Times
- Woodshop Operator Time Studies



Statistical Analysis

Model verified through ANOVA analysis comparing utilization study and current layout simulation

Straightline Saw					
Level	Current Layout	Move Only CNC's	Layout Variation 1	Layout Variation 2	Layout Variation 3
Replication 1	48.17	38.70	93.08	64.44	90.44
Replication 2	47.66	74.77	93.18	86.20	91.60
Replication 3	43.54	36.50	93.55	89.62	92.26

Example of ProModel Utilization
Results Comparing Layouts

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
2 - 1	4.20	3.39	(-5.22, 13.61)	1.24	0.729
3 - 1	38.28	3.39	(28.87, 47.69)	11.30	0.000
4 - 1	30.58	3.39	(21.17, 39.99)	9.03	0.000
5 - 1	38.79	3.39	(29.38, 48.20)	11.45	0.000
3 - 2	34.09	3.39	(24.67, 43.50)	10.06	0.000
4 - 2	26.39	3.39	(16.97, 35.80)	7.79	0.000
5 - 2	34.59	3.39	(25.18, 44.01)	10.21	0.000
4 - 3	-7.70	3.39	(-17.11, 1.71)	-2.27	0.163
5 - 3	0.51	3.39	(-8.90, 9.92)	0.15	1.000
5 - 4	8.21	3.39	(-1.20, 17.62)	2.42	0.118

Individual confidence level = 99.34%

Using Confidence Intervals to
Determine Layout Hierarchy

The image shows an outdoor public space, likely a waterfront park or plaza. In the foreground, there are several concrete picnic tables and wooden benches arranged on a paved surface. In the background, the Manhattan Bridge is visible, spanning a body of water. The bridge's steel structure and suspension cables are prominent. The sky is clear and blue. A large black rectangular box is overlaid in the center of the image, containing the text "Layout Proposals" in white. A thin white rectangular box is also visible, framing a portion of the bridge and the sky in the background.

Layout Proposals



Short-Term Layout Proposal

Dedicated Cart Storage



Cart Overflow Locations:

Moulder Queue, Chop Saw Queue, and CNC Queue

Solution:

Create dedicated cart storage locations using floor tape

Cost:

\$60.99/Roll – 7 rolls recommended

Total Cost: \$445.87

Color-Coded Cone System



Goal: Reduce changeovers on CNC; reduce worker movement through visual ergonomic cues

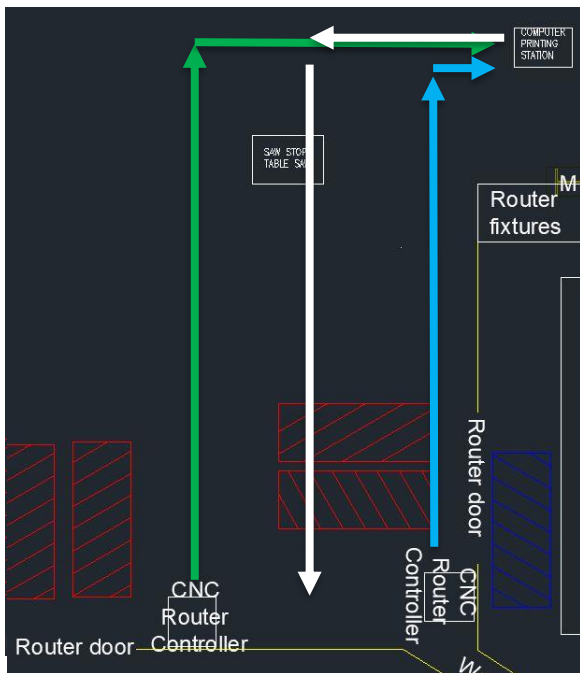
Solution: Color-Coded Cone System

Cost: Previously purchased cones

Retraining operator – 1 hour

Computer Station Relocation

Solution: Decrease workload of computer printing station
 Move location of computer printing station



2023 Daily Pallet Tags Printed: 56 per day

Steps Taken to Pallet Tag Printing Computer

	Current Layout
CNC 1	1008
CNC 2	572

Total Cost to Implement:
 $\$31.20 \times 1.5 \text{ hours} = \47



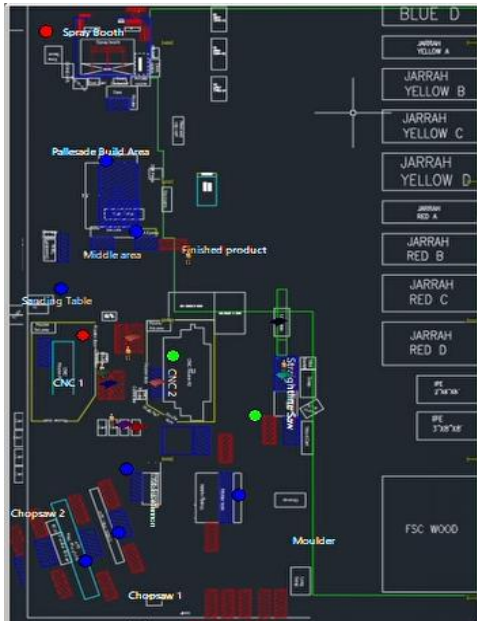
Mid-Term Layout Proposal

Layout Idea Generation Picking the Best Model

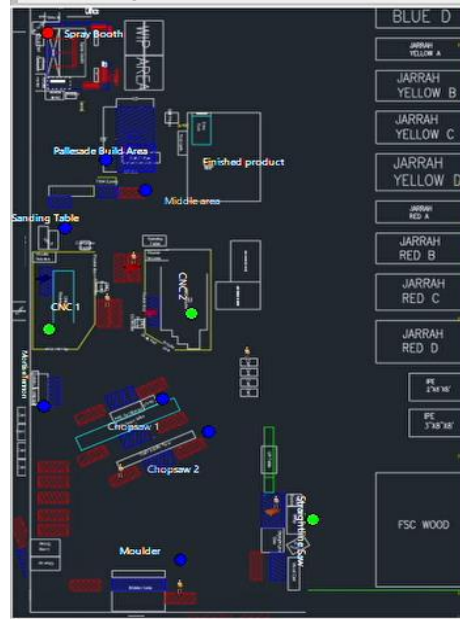
- VIP Planopt Optimization Software
 - Space Constraints
 - Flow of Material
- Considerable factors
 - Significantly different data
 - Improved Total throughput
 - Improved utilization
 - Cost

Simulating Mid-Term Models

Move Only CNC's



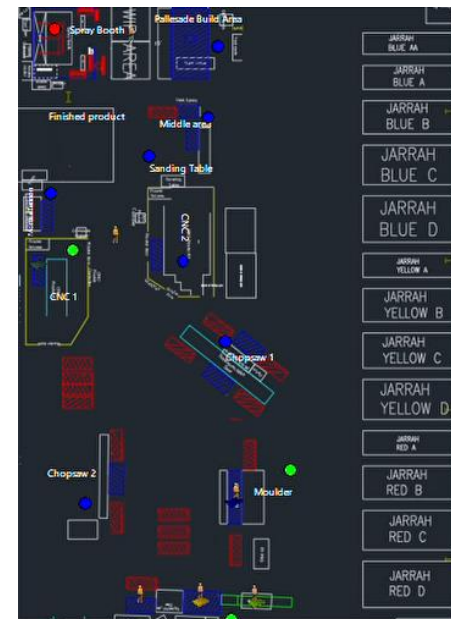
Layout Variation 1



Layout Variation 2



Layout Variation 3



Data Analysis for Layout Selection

Layout Variation 1

Machine	Move Only CNC's	Layout Variation 1	Layout Variation 2	Layout Variation 3
Cost per Unit (\$)		Product	# of Units	Final Cost (\$)
124 Straight Line Saw	4.196	38.281	30.5815	38.281
124 Moulder	1.342	33.0335	22.978	371
65 Chop Saw 1	0.8785	6.2165	12.395	325
99 Chop Saw 2	0.9095	7.195	13.635	60
45 Mortise and Tenon	-0.0075	0.19	2.708	6.184
30 CNC 1	0.0205	2.8105	-1.0095	0.0345
334 CNC 2	1.6995	13.6275	10.9975	30
158 Middle Area	7.2495	30.7735	17.6335	3.953
190 Palisade Build Area	3.2585	0.1165	3.7865	9.1565
17 Spray Booth	3.295	0.064	4.1755	23.601
22 Sanding Table	4.5647	6.4	4.5647	1.4745
				-1.983
				3.997

Total Cost \$ 2,321

Utilization Differences – Current Layout
Simulation and Proposed Layout Simulations

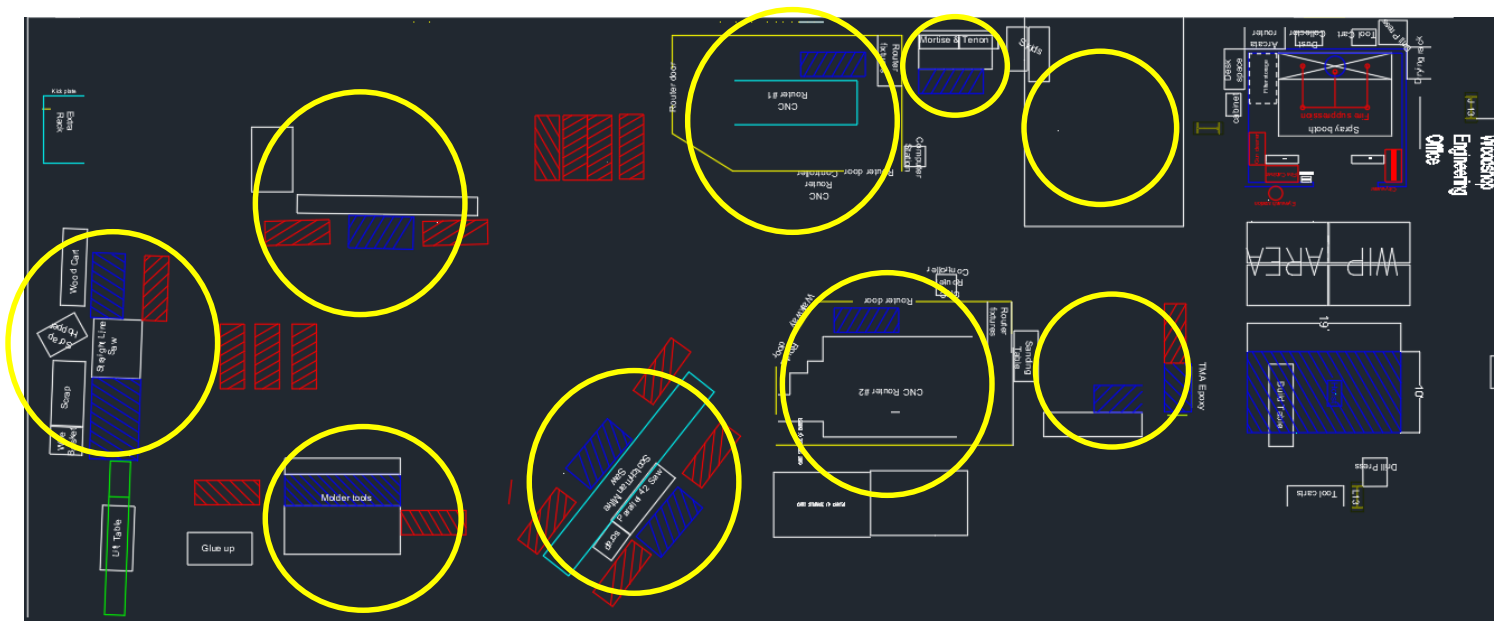
Layout Variation 3

Location	First	Second	Third	Weights
Straightline Saw	5	5	4	First = 1
Moulder	3	5	4	Second = 0.5
Chop Saw 1	4	5	5	Third = 0.15
Chop Saw 2	4	5	5	
Mortise and Tenon	4	3	5	
CNC 1	5	3	4	
CNC 2	5	3	4	
Middle Area	5	3	4	
Palisade Build Area	5	3	4	
Spray Booth	5	3	4	
Sanding Table	5	3	4	

	Weighted Average Scoring Table				Total Cost \$
Current Layout	0	0.5	0	0.5	1,029
Move Only CNC's	0	0	0.15	0.15	
Layout Variation 1	2	5	0.6	7.6	
Layout Variation 2	5	1	0.75	6.75	
Layout Variation 3	4	2	1.05	7.05	

ANOVA Analysis Weighted Average
Comparison Table

Final-Mid Term Layout



Layout Design: Layout Variation 3

Improvements: Increased monthly throughput average of 114 units (13% increase)

Identified Benefits: Funnel flow, separate cart storage locations

Associated Costs:

- Additional Ductwork – \$1,030
- Maintenance Costs – 6 weeks



Long-Term Layout Proposal

Key Differences

Long-term proposal aimed towards new facility

- Minimal space constraints
- No current ductwork limitations
- Additional machines

Data Analysis for Layout Selection

Tukey Simultaneous Tests for Differences of Means

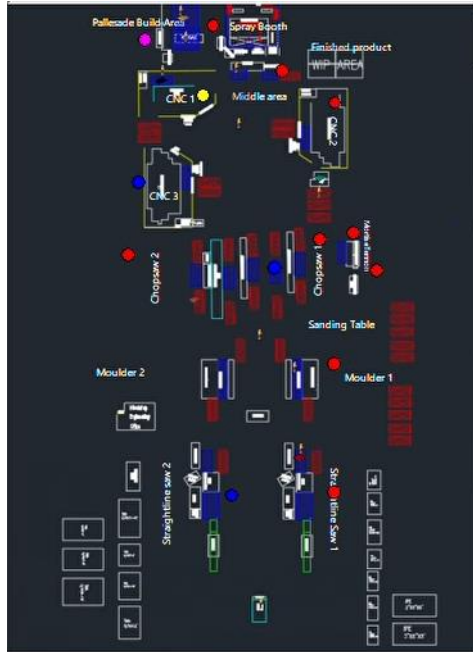
Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
2 - 1	30.89	3.34	(22.10, 39.68)	9.25	0.000
3 - 1	44.85	3.34	(36.06, 53.63)	13.43	0.000
4 - 1	52.04	3.34	(43.26, 60.83)	15.58	0.000
3 - 2	13.96	3.34	(5.17, 22.74)	4.18	0.000
4 - 2	21.15	3.34	(12.36, 29.94)	6.33	0.000
4 - 3	7.20	3.34	(-1.59, 15.98)	2.15	0.146

Individual confidence level = 98.97%

Layout	Machine Score	Worker Score	Weighted Score Total
Layout Variation 1	1.6	0	1.6
Layout Variation 2	9.3	7.2	16.5
Layout Variation 3	8.75	12.3	21.05
Layout Variation 4	10.45	10.6	21.05

Simulating Layout Models

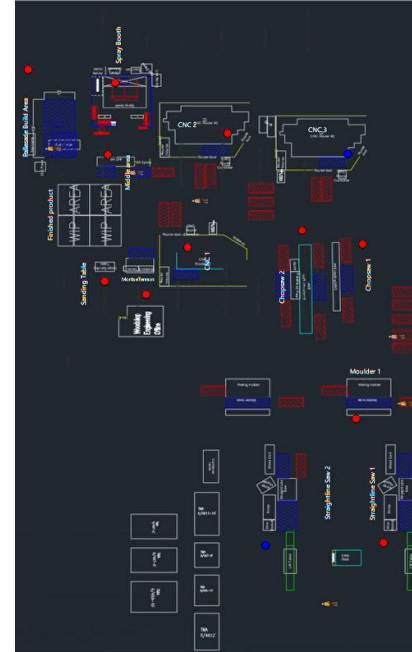
Full Linear Layout
(Multiple Machines)



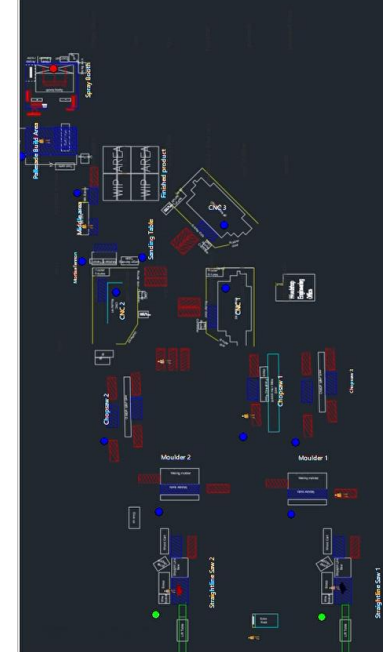
Full Linear Layout



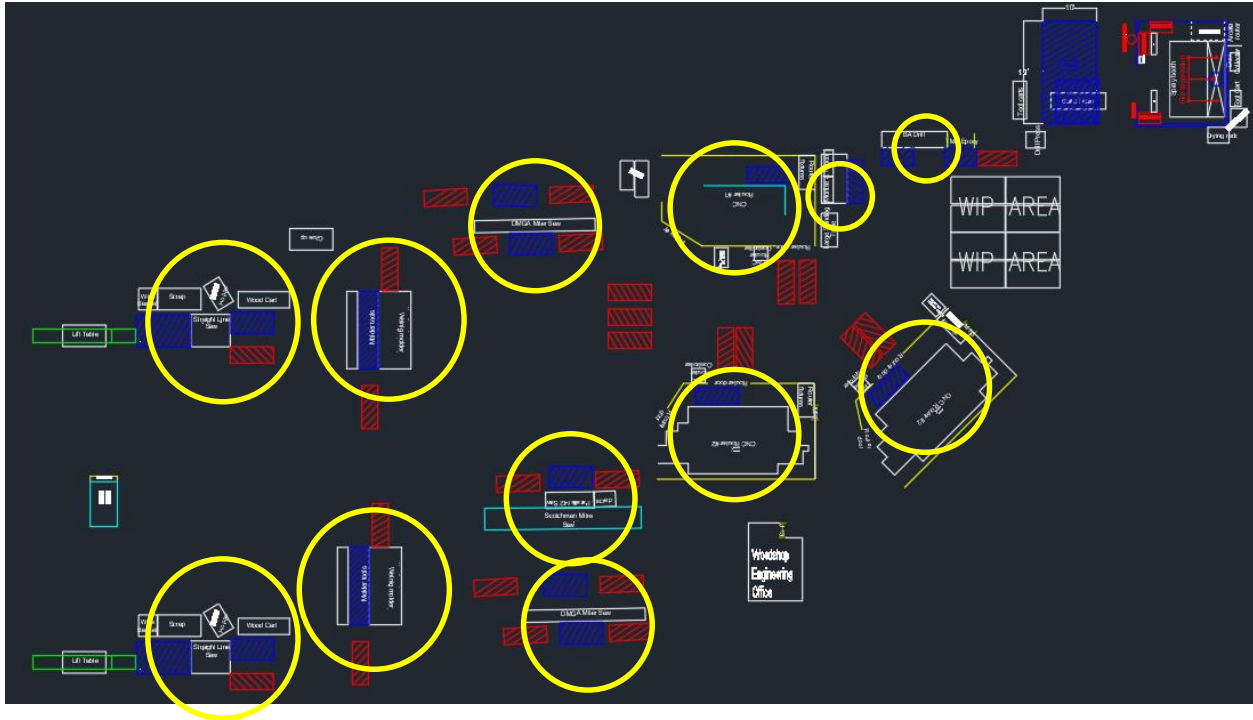
L-shaped



Diagonal Shape



Final Long-Term Layout



Additional Machines

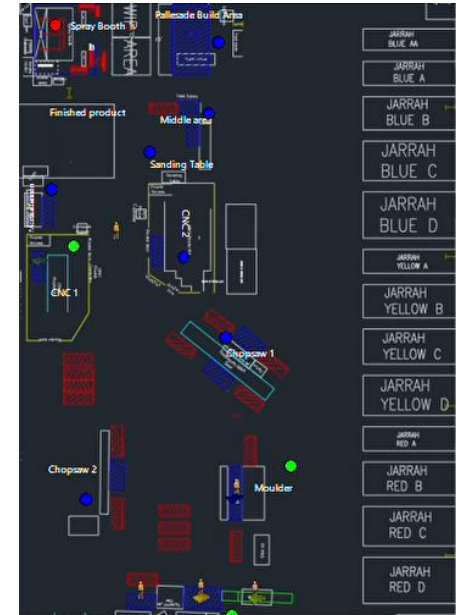
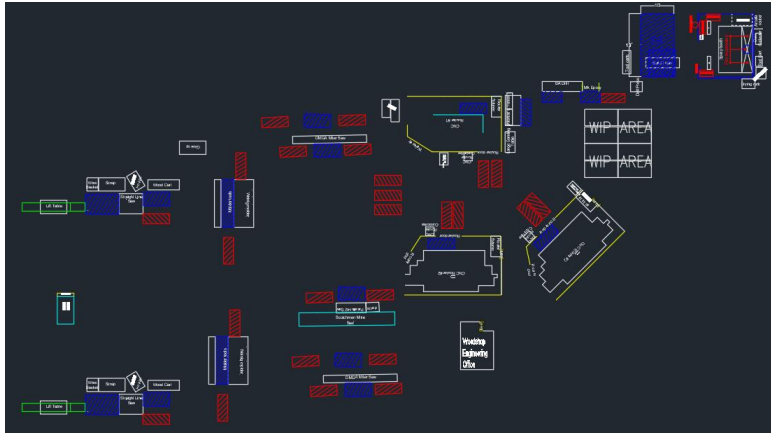
- 2nd Straight Line Saw
- 2nd Moulder
- 3rd Chop Saw
- 3rd CNC

Layout Design: Diagonal Move

Identified Benefits: Highest Monthly Throughput of 1,785 Units (101% increase from current layout)

Deliverables to Sponsor

- Final CAD Layouts for Mid- and Long-Term Recommendations
- ProModel Simulation for Final Mid- and Long-Term Layout Recommendations
- Ductwork Cost Analysis Worksheet
- All Other Layouts and ProModel Simulation Upon Request



Thank You!

A special thank you to:

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