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Resource Level Estimation Under Probabilistic Demand Environment

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Introduction

Industry 3.0 is characterized by high product volume, product variety and short delivery time. With mass customization on the rise, the ability to quickly react to response in changing customer demands, or market conditions is crucial to the competitiveness of industries.

This study is focused on formulating the best manufacturing design for meeting variable product demand for a fashion jewelry manufacturing company based on historical demand data collected across distribution centers using data analysis tools.

- 10 products of interest to the manufacturer were collected and analyzed on basis of their production processes.
- Resource availably, reliability and efficiency are considered in determining the actual capacity required.
- Resource levels (number of machines) were estimated, and design alternatives were considered.
- Viability of meeting demand was simulated to corroborate the optimal design.

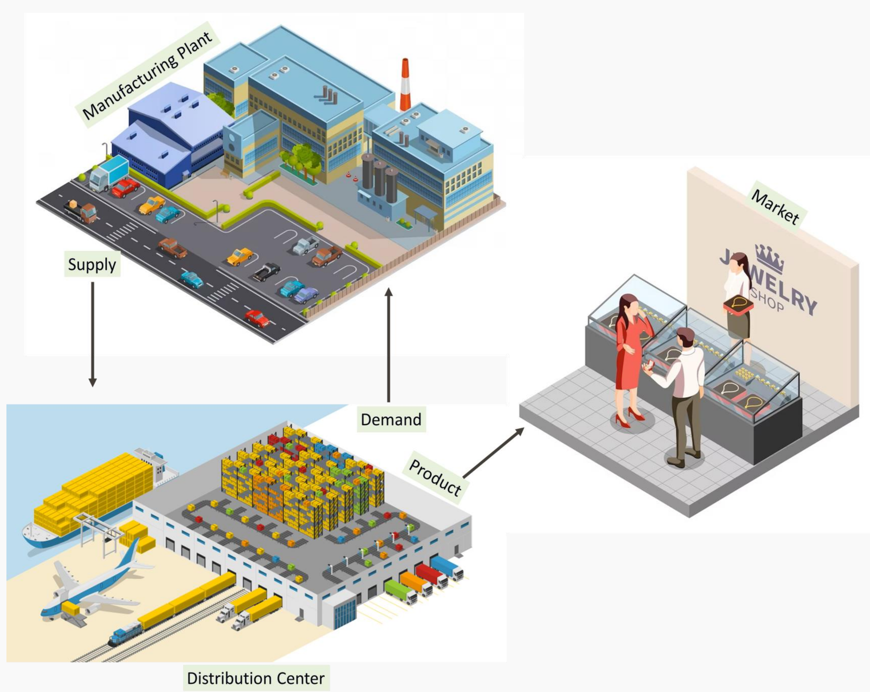

Figure 1: Supply chain network

Methodology

Step 1
- Gathering data
- Data wrangling
- Computing annual demand
- Finding demand probability

Step 2
- Identify resources
- Process time estimation
- Resource capacity for flow shop
- Resource capacity for job shop

Step 3
- Simulation of optimal design

Step 4
- Results and discussion

R, jupyter, ggplot2, Simio

Equations

$$\text{Resource Level} \rightarrow CR \rightarrow \begin{cases} \sum_{i=1}^{N} D_i T_i \rightarrow \beta = \dfrac{\sum_{i=1}^{N} D_i \times T_i}{C \times \eta \times \lambda \times S} \\ D_i BT_i \rightarrow \theta = \dfrac{D_i \times BT_i}{C \times \eta \times \lambda \times S} \end{cases}$$

Annotations

CR	Capacity required (hours)
D_i	Demand for product i (annual)
T_i	Processing time product i (hours)
BT_i	Bottleneck processing time for product i (hours)
C	Capacity available for machines (annually)
η	Machine reliability
λ	System efficiency
θ	Number of machines considering flow shop
β	Number of machines considering job shop

Assumptions

i. Machines efficiency and reliability is estimated 90%.
ii. Continuous processing with insignificant waiting/transfer time.
iii. One shift per a day (8 hours/shift), 50 weeks per a year.
iv. Capacity available per year is 2000 hours.

Data tables

Product	Demand	Probability
P-1	7524	0.114
P-2	1400	0.021
P-3	5800	0.088
P-4	1900	0.029
P-5	11700	0.177
P-6	9700	0.147
P-7	8190	0.124
P-8	4600	0.070
P-9	1110	0.017
P-10	14000	0.212

Table 1: Products annual demand and their probability.

Operation Number	Operation	Machine Number
1	Finding	M1
2	Deburring	M2
3	Casting	M3
4	Degating	M4
5	Tumbling	M5
6	Buffing	M6
7	Chain Platting	M7
8	Manual Platting	M8
9	Barrel Platting	M9
10	Dying	M10
11	Carding	M11
12	Packaging	M12

Table 2: Operations/machines in the system studied.

Product	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	BN	CR	θ
P-1	0.1	0.6	0	0	1.2	0	0	0	0	0	0.4	0.7	1.2	9029	6
P-2	0.3	0.7	0	0	0	0	0	1	0	0	0.2	0.4	1	1400	1
P-3	0.5	0.9	0.3	0.85	1.4	1.1	1.6	1.4	0	0	0	0	1.6	9280	6
P-4	0.2	0.6	0.1	0.7	1.5	0.5	1.1	0.8	0	0	0	0	1.5	2850	2
P-5	0.1	0.3	0.2	0.9	0	1.3	0.8	0.6	0	0	0	0	1.3	15210	9
P-6	0.3	0.8	0	0	1	0	0	0	0	0	0.5	0.9	1	9700	6
P-7	0	0	0	0.6	1.4	0	0	0	1	0.3	0.5	0	1.4	11466	7
P-8	0	0	0	1	1.2	0	0	0	0.7	0.2	0.4	0	1.2	5520	3
P-9	0	0	0	0.7	0	0	0	0	0.4	0.1	0.5	0	0.7	777	1
P-10	0.3	0.8	0	0	1	0	0	0	0	0	0.2	0.8	1	14000	9
Exp. D	12732	34324	4270	27081	60685	22540	20730	18060	11854	3488	17430	25757			
β	8	21	3	17	37	14	13	11	7	2	11	16			

Table 3: Product process and capacity estimation.

Simulation

- 10 products were modeled proportionally from a data table.
- Products were routed to appropriate nodes based on processing steps outlined in Table-3.
- OptQuest selected the scenario with an exponential arrival time with mean of 5hrs and number of entities per arrival 3 for maximum throughput.
- Simulation was run for 24 hours.
- Sample path for P-1 and P-7 shown in Figure 1.

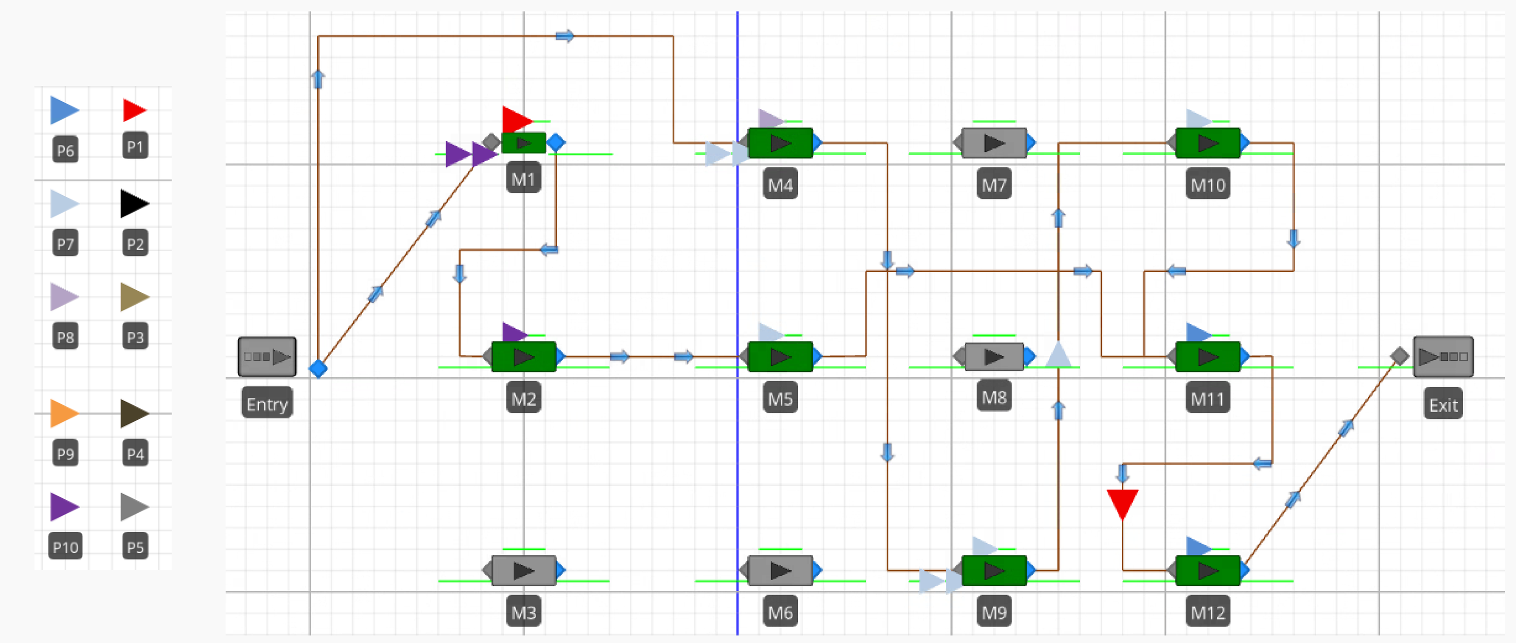

Figure 2: Job floor simulation run

Results

- Based on the simulation runs, considering flowshop perspective of an individual product, bottleneck machine with the highest processing time determines the throughput of each production line. Consequently, high average WIP for the finished product is resulted as shown in Figure 3.
- Considering jobshop perspective where each product has a different route in the system, less average WIP is obtained for each machine department as shown in Figure 4. This proves the validity of the model for a jobshop.
- On average, based on simulation results in Figure 5, the machine units utilized are closer to the ones calculated in Table 3.

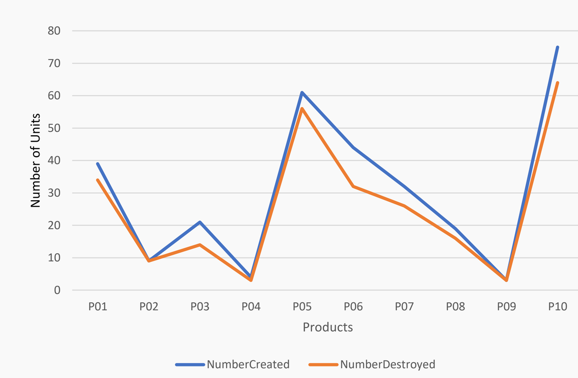

Figure 3: Product throughput

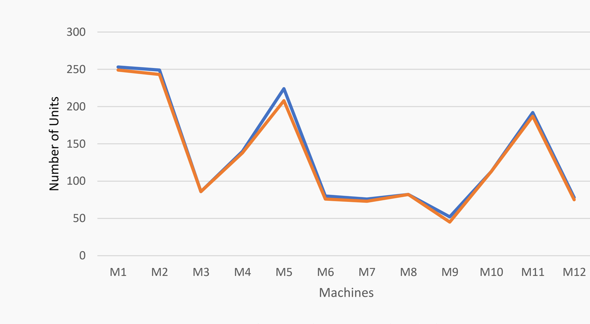

Figure 4: Machine throughput

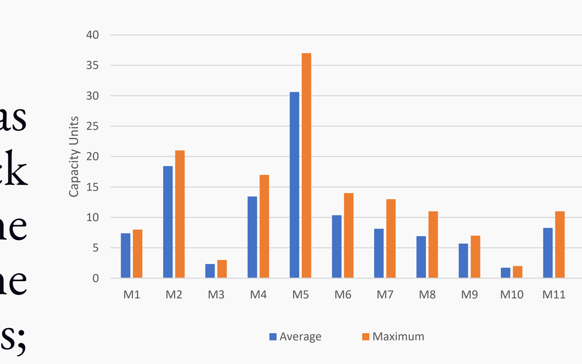

Figure 5: Capacity analysis

Conclusion

The process layout/job shop design as calculated was selected for reduced WIP in the system. The bottleneck issue in the flowshop perspective dictates the throughput of each line; however, the impact of the bottleneck can be minimized by duplicating machines; however, this is not a cost-effective method.

This study is significant in calculating the number of machines considering the flowshop and jobshop perspectives. To meet the demand for all products, jobshop perspective requires more machines. Generally, this study helps decision makers in such industry to minimize the investment cost which will help them compete well in their market.

References

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