HOW TO IDENTIFY AND IMPROVE DYNAMIC BOTTLENECKS TO INCREASE THROUGHPUT, CAPACITY, AND REVENUE

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What is a dynamic bottleneck in manufacturing?

Dynamic bottlenecks are in most discrete manufacturing plants, and many leaders are unaware of the dynamic bottlenecks in their plants. Some leaders have never heard of the term “dynamic bottlenecks” because they are complex to solve and challenging to see in most discrete manufacturing processes. The only time dynamic bottlenecks are not in a discrete manufacturing plant is when the plant has all product lines balanced, such as automotive assembly lines, or the manufacturing plant has only one product on each process line. Therefore, most discrete manufacturing plants have dynamic bottlenecks, and management does not know what and where they are in their plant. Let us start by defining a bottleneck: It is the longest-timed operation in the manufacturing process sequence to complete the finished product from the receiving to the shipping dock. The term bottleneck comes from the hourglass, where the narrow neck of the hourglass determined the sand's flow rate for one hour, as shown in Figure 1. In manufacturing, the bottleneck operation is the pace of the entire production line. This means that if a manufacturing process has a two-hour bottleneck operation, that process running at a steady stake will produce a product at the end of the line every two hours. **The bottleneck operation is the pace of any manufacturing process**. That is why knowing where the bottlenecks are in your plant is extremely important to increasing throughput, capacity, and revenue.

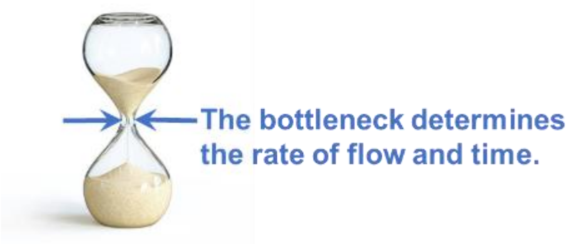
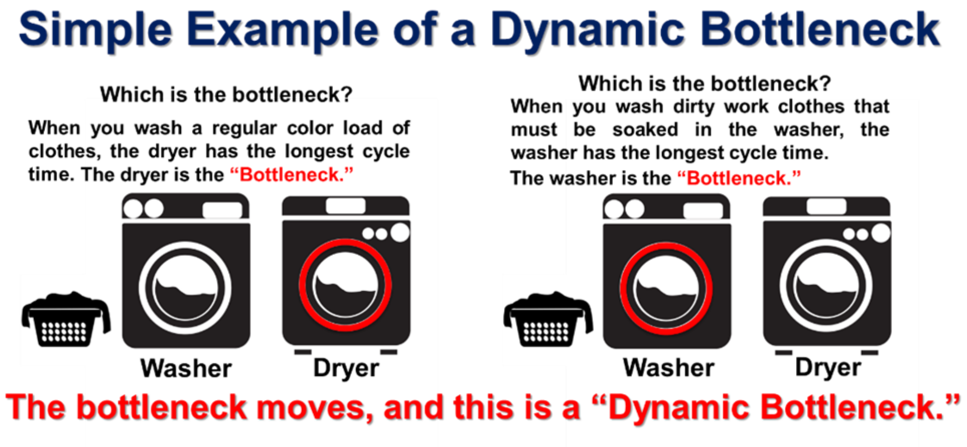


Figure 1 – An hourglass showing the narrow neck determines the flow rate for one hour

Dynamic bottlenecks are moving bottlenecks within the manufacturing process and are extremely difficult to identify. Let us use washing clothes as a simple example of a dynamic bottleneck. When you wash a regular load of white or colored clothes, the dryer has the longest operation time. Therefore, it is the bottleneck. However, soaking dirty work clothes in the washer is the longest-timed operation, and the bottleneck has moved to the washer, creating a dynamic bottleneck. Depending on what you wash and dry, the washer or dryer can be the bottleneck, as shown in Figure 2. It is the same in manufacturing. Depending on which product is going through the process, the bottleneck moves based on the product configuration and material, but it is much more complicated to determine. If you Google “dynamic bottlenecks in manufacturing,” you will find a few research papers on the subject that are so complex to read that you must have a master's degree in engineering to understand them. ***The Managing Method for Dynamic Bottlenecks (MMDB) is a simple, systematic method of identifying and determining the critical bottlenecks in a discrete manufacturing process by providing a prioritization list to increase throughput, capacity, and revenue.*** The MMDB utilizes the Theory of Constraints and Lean Six Sigma methodology.



Simple Example of a Dynamic Bottleneck

Which is the bottleneck?

When you wash a regular color load of clothes, the dryer has the longest cycle time. The dryer is the "Bottleneck."

Which is the bottleneck?

When you wash dirty work clothes that must be soaked in the washer, the washer has the longest cycle time. The washer is the "Bottleneck."

The bottleneck moves, and this is a "Dynamic Bottleneck."

Figure 2 – A simple example of a dynamic bottleneck

Understanding the "Essence of Manufacturing" with Group Technology

The essence of manufacturing is used when designing a Lean manufacturing process. The essence of manufacturing is made up of two primary drivers and a secondary driver of the operational process. The two primary drivers are 1.) material and 2.) configuration. The material is the raw material used in the product, such as steel, plastic, wool, etc. The design, shape, dimensions, and tolerance in the engineering drawings or sketches are the configuration. The secondary driver is the annual customers' demand quantity for the next twelve months. The primary drivers determine the group technology that forms cellular manufacturing and reduces the number of dynamic bottlenecks in the plant. The primary and secondary drivers are not applicable when using 3D printing. Let us use a simple illustration in Figure 3 to understand better how the primary drivers determine the group technology to form a manufacturing cell.

Figure 3 – This is a 3D sketch of a finished product

- Using Figure 3 – What machines could you use to produce this steel product?
  - Manual Lathe
  - CNC Lathe
- Using Figure 3 – If the part was plastic, what machines could you use to produce this part?
  - Manual Lathe
  - CNC Lathe
  - Injection Molding
  - Compression Molding
- Using Figure 3 – What machines would you use to produce this plastic part with an annual demand of 500 units?
  - Manual Lathe – To be cost-effective and make a profit.
- Using Figure 3 – What machines would you use to produce this plastic part with an annual demand of 2 million units?
  - Injection Molding – To be cost-effective and make a profit.

Let us move forward to group technology for cellular manufacturing to minimize the plant's dynamic bottlenecks. How would you group these parts in Figure 4? XYZ's group technology is based on the primary drivers of material and configuration. Figure 5 shows the correct grouping for the Aluminum Cylindrical Stopper Cell and Steel Block Stopper Cell.

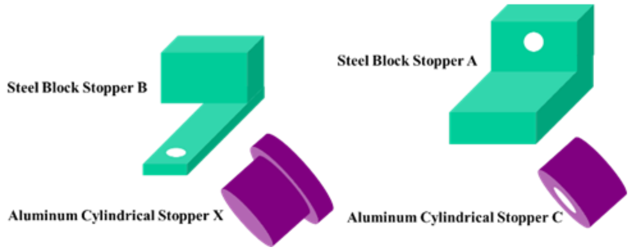


Figure 4 – Stoppers produced at XYZ Job Shop

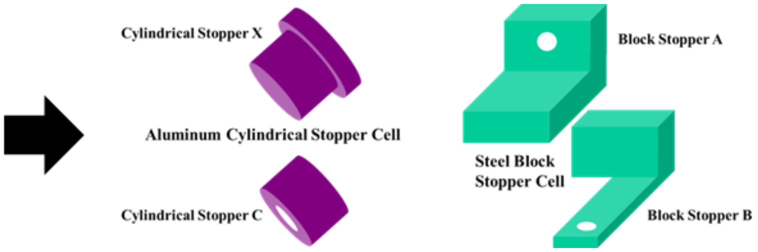


Figure 5 – Group Technology at XYZ Job Shop

Figure 6 shows the layout of the Steel Block Stopper Cell. Figure 7 illustrates the Steel Block product flow, and Figure 8 displays the operator flow. Many companies implementing Lean have completed this step and can skip it in the MMDB process.

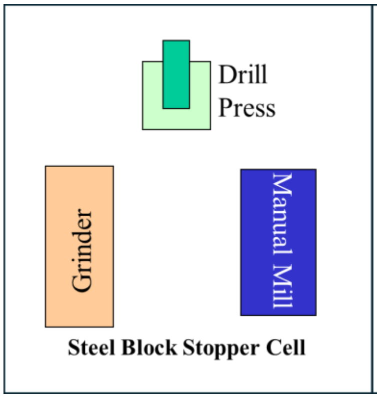


Figure 6 – SBS Cell

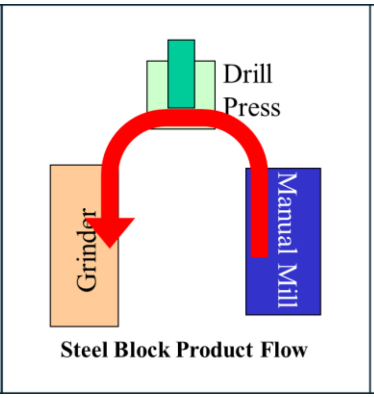


Figure 7 – Product Flow

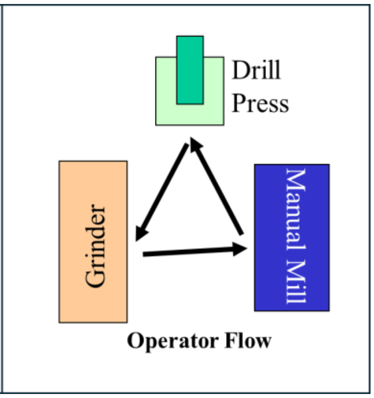
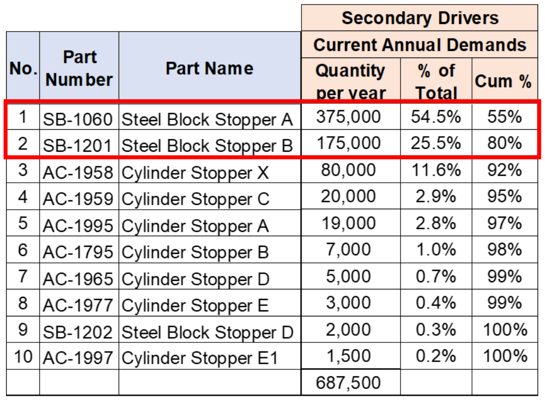


Figure 8 – Operator Flow

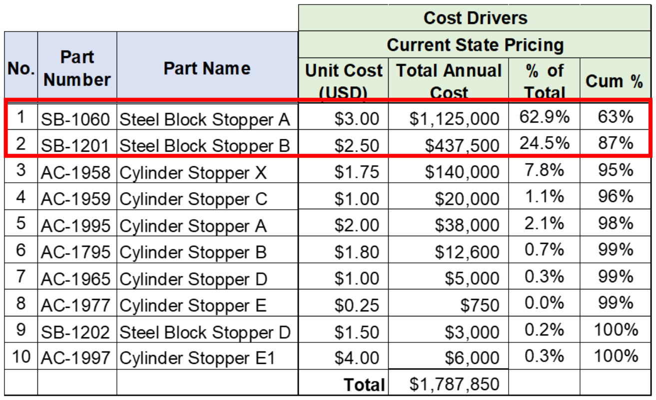
Determining the Vital Few Products in Production and Cost

The next step in the MMDB is to list all finished products with their customer's demands for the next twelve months. Take that customer's demand list and conduct a Pareto Analysis based on the orders for the next twelve months. The results will provide the top 80% or vital few finished goods products produced in the plant over the next twelve months, as shown in Spreadsheet 9. Accounting must supply the unit cost data for each finished product to conduct a Pareto Analysis based on annual costs, as illustrated in Spreadsheet 10. The Annual Costs Pareto Analysis is essential because a plant can produce more low-cost products than high-cost products, and this analysis ensures that the higher-cost products are evaluated. For example, if a plant was manufacturing nails, nuts, bolts, and screws. Nails can be the highest demand, but bolts would be the highest cost. Now, we know which products will generate the most activities and expenses in the plant over the next twelve months.



			Secondary Drivers		
			Current Annual Demands		
No.	Part Number	Part Name	Quantity per year	% of Total	Cum %
1	SB-1060	Steel Block Stopper A	375,000	54.5%	55%
2	SB-1201	Steel Block Stopper B	175,000	25.5%	80%
3	AC-1958	Cylinder Stopper X	80,000	11.6%	92%
4	AC-1959	Cylinder Stopper C	20,000	2.9%	95%
5	AC-1995	Cylinder Stopper A	19,000	2.8%	97%
6	AC-1795	Cylinder Stopper B	7,000	1.0%	98%
7	AC-1965	Cylinder Stopper D	5,000	0.7%	99%
8	AC-1977	Cylinder Stopper E	3,000	0.4%	99%
9	SB-1202	Steel Block Stopper D	2,000	0.3%	100%
10	AC-1997	Cylinder Stopper E1	1,500	0.2%	100%
			687,500		

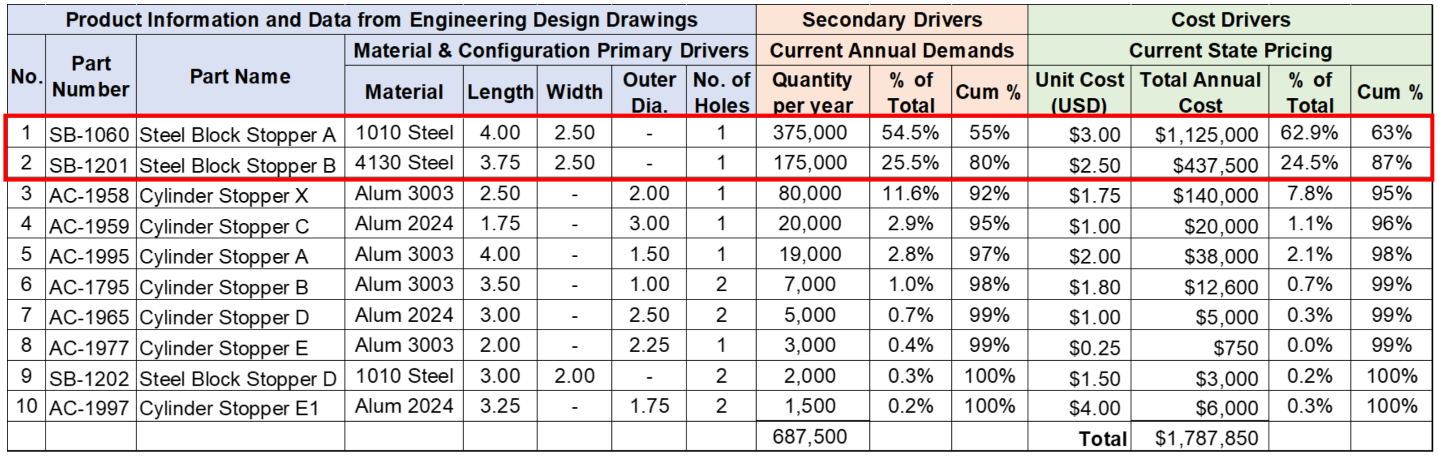
Spreadsheet 9 – Current Demands Pareto Analysis



			Cost Drivers			
			Current State Pricing			
No.	Part Number	Part Name	Unit Cost (USD)	Total Annual Cost	% of Total	Cum %
1	SB-1060	Steel Block Stopper A	$3.00	$1,125,000	62.9%	63%
2	SB-1201	Steel Block Stopper B	$2.50	$437,500	24.5%	87%
3	AC-1958	Cylinder Stopper X	$1.75	$140,000	7.8%	95%
4	AC-1959	Cylinder Stopper C	$1.00	$20,000	1.1%	96%
5	AC-1995	Cylinder Stopper A	$2.00	$38,000	2.1%	98%
6	AC-1795	Cylinder Stopper B	$1.80	$12,600	0.7%	99%
7	AC-1965	Cylinder Stopper D	$1.00	$5,000	0.3%	99%
8	AC-1977	Cylinder Stopper E	$0.25	$750	0.0%	99%
9	SB-1202	Steel Block Stopper D	$1.50	$3,000	0.2%	100%
10	AC-1997	Cylinder Stopper E1	$4.00	$6,000	0.3%	100%
			Total	$1,787,850		

Spreadsheet 10 – Annual Costs Pareto Analysis

The material and configuration primary drivers must be added to the list. The configuration drivers are based on characteristics that require a different machine or operation, such as length, width, outer diameter, and number of holes noted in Spreadsheet 11.

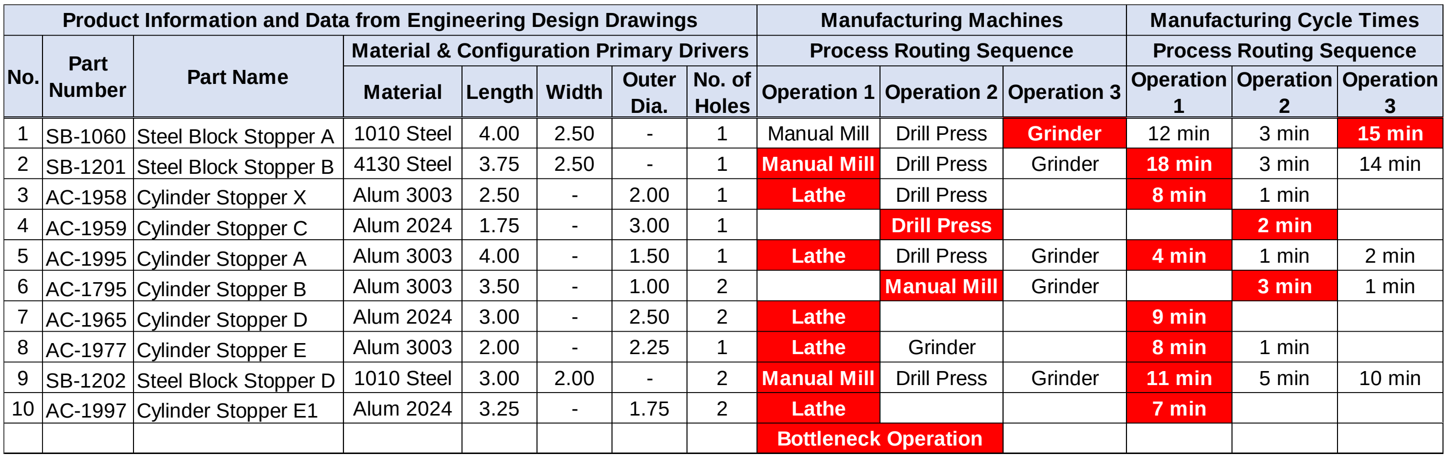


Product Information and Data from Engineering Design Drawings								Secondary Drivers			Cost Drivers			
			Material & Configuration Primary Drivers					Current Annual Demands			Current State Pricing			
No.	Part Number	Part Name	Material	Length	Width	Outer Dia.	No. of Holes	Quantity per year	% of Total	Cum %	Unit Cost (USD)	Total Annual Cost	% of Total	Cum %
1	SB-1060	Steel Block Stopper A	1010 Steel	4.00	2.50	-	1	375,000	54.5%	55%	$3.00	$1,125,000	62.9%	63%
2	SB-1201	Steel Block Stopper B	4130 Steel	3.75	2.50	-	1	175,000	25.5%	80%	$2.50	$437,500	24.5%	87%
3	AC-1958	Cylinder Stopper X	Alum 3003	2.50	-	2.00	1	80,000	11.6%	92%	$1.75	$140,000	7.8%	95%
4	AC-1959	Cylinder Stopper C	Alum 2024	1.75	-	3.00	1	20,000	2.9%	95%	$1.00	$20,000	1.1%	96%
5	AC-1995	Cylinder Stopper A	Alum 3003	4.00	-	1.50	1	19,000	2.8%	97%	$2.00	$38,000	2.1%	98%
6	AC-1795	Cylinder Stopper B	Alum 3003	3.50	-	1.00	2	7,000	1.0%	98%	$1.80	$12,600	0.7%	99%
7	AC-1965	Cylinder Stopper D	Alum 2024	3.00	-	2.50	2	5,000	0.7%	99%	$1.00	$5,000	0.3%	99%
8	AC-1977	Cylinder Stopper E	Alum 3003	2.00	-	2.25	1	3,000	0.4%	99%	$0.25	$750	0.0%	99%
9	SB-1202	Steel Block Stopper D	1010 Steel	3.00	2.00	-	2	2,000	0.3%	100%	$1.50	$3,000	0.2%	100%
10	AC-1997	Cylinder Stopper E1	Alum 2024	3.25	-	1.75	2	1,500	0.2%	100%	$4.00	$6,000	0.3%	100%
								687,500			Total	$1,787,850		

Figure 11 – The Top 80% of the Annual Production Demands and Costs Chart

How to Identify Dynamic Bottlenecks

To identify the dynamic bottlenecks, input the machines and cycle times in the process sequence in the spreadsheet from the manufacturing process routing information, as shown in Spreadsheet 12. The Dynamic Bottlenecks Prioritization for Lean Six Sigma Improvements List shows in detail all the bottlenecks in the plants and the critical ones at the top. This list provides the best perspective for maximizing throughput, capacity, and labor. The theory of constraints teaches us that to maximize throughput, we must manage the bottleneck (Herbie). Therefore, placing 5S signage with the part number on each bottleneck machine will let everyone in the plant know when and where the bottleneck is when running production. Lean Six Sigma Black and Green Belts can focus on reducing the cycle times at the top bottlenecks to improve the throughput and capacity of the entire plant. This is the most important reason for identifying the dynamic bottlenecks. When cycle times are reduced on machines before the bottleneck, more inventory is created in front of the bottleneck, and there are no throughput improvements. Reducing cycle times on machines after the bottleneck does not improve throughput, which is why improving the bottleneck is critical. When employees are absent and there is a labor shortage, management can ensure that the bottlenecks are running with the workers there. Management must cross-train employees on the bottleneck machines, so as many as required to provide cover at all times during production. Management must ensure that the bottleneck machines are adequately maintained with preventive and predictive maintenance. All these improvements, with others not mentioned in this article, can increase the cash flow and revenue for the company. The list can indicate that some products can be misrouted in production. For example, in Spreadsheet 12, part number AC-1795 Cylinder Stopper was put in the Cylinder Stopper Cell, and every time it went through the plant, the Cylinder Cell operators had to get a deviation request approved to run it on the manual mill in the Block Stopper Cell. Further investigation determined that AC-1795 is a purchase cylinder that should be put in the Block Stopper Cell, eliminating the wasted time getting approvals.

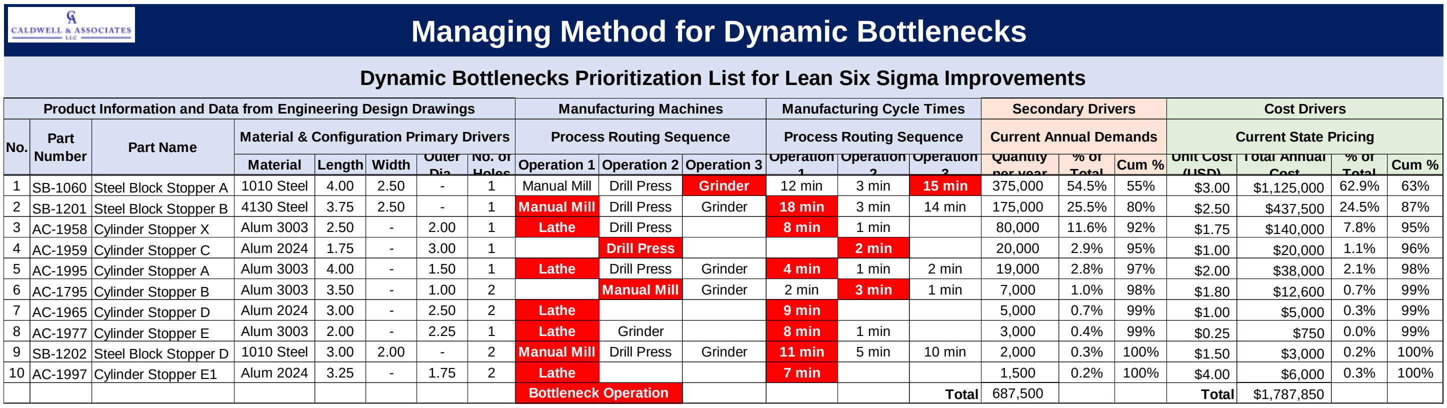


Product Information and Data from Engineering Design Drawings								Manufacturing Machines			Manufacturing Cycle Times		
No.	Part Number	Part Name	Material & Configuration Primary Drivers					Process Routing Sequence			Process Routing Sequence		
			Material	Length	Width	Outer Dia.	No. of Holes	Operation 1	Operation 2	Operation 3	Operation 1	Operation 2	Operation 3
1	SB-1060	Steel Block Stopper A	1010 Steel	4.00	2.50	-	1	Manual Mill	Drill Press	**Grinder**	12 min	3 min	**15 min**
2	SB-1201	Steel Block Stopper B	4130 Steel	3.75	2.50	-	1	**Manual Mill**	Drill Press	Grinder	**18 min**	3 min	14 min
3	AC-1958	Cylinder Stopper X	Alum 3003	2.50	-	2.00	1	**Lathe**	Drill Press		**8 min**	1 min	
4	AC-1959	Cylinder Stopper C	Alum 2024	1.75	-	3.00	1		**Drill Press**			**2 min**	
5	AC-1995	Cylinder Stopper A	Alum 3003	4.00	-	1.50	1	**Lathe**	Drill Press	Grinder	**4 min**	1 min	2 min
6	AC-1795	Cylinder Stopper B	Alum 3003	3.50	-	1.00	2		**Manual Mill**	Grinder		**3 min**	1 min
7	AC-1965	Cylinder Stopper D	Alum 2024	3.00	-	2.50	2	**Lathe**			**9 min**		
8	AC-1977	Cylinder Stopper E	Alum 3003	2.00	-	2.25	1	**Lathe**	Grinder		**8 min**	1 min	
9	SB-1202	Steel Block Stopper D	1010 Steel	3.00	2.00	-	2	**Manual Mill**	Drill Press	Grinder	**11 min**	5 min	10 min
10	AC-1997	Cylinder Stopper E1	Alum 2024	3.25	-	1.75	2	**Lathe**			**7 min**		
								Bottleneck Operation					

Spreadsheet 12 – Dynamic Bottlenecks Prioritization for Lean Six Sigma Improvements List

Conclusion

In conclusion, the MMDB is a simple, systematic method of identifying and determining the critical bottlenecks in a discrete manufacturing process by providing a prioritization list to increase throughput, capacity, and revenue, as shown in Spreadsheet 13. This spreadsheet gives management insight into operating their plant more efficiently and effectively than currently. It is a spreadsheet that should be updated annually or when significant changes in the production process occur.



Managing Method for Dynamic Bottlenecks

Dynamic Bottlenecks Prioritization List for Lean Six Sigma Improvements

Product Information and Data from Engineering Design Drawings								Manufacturing Machines			Manufacturing Cycle Times			Secondary Drivers			Cost Drivers			
No.	Part Number	Part Name	Material & Configuration Primary Drivers					Process Routing Sequence			Process Routing Sequence			Current Annual Demands			Current State Pricing			
			Material	Length	Width	Outer Dia.	No. of Holes	Operation 1	Operation 2	Operation 3	Operation 1	Operation 2	Operation 3	Quantity per year	% of Total	Cum %	Unit Cost (USD)	Total Annual Cost	% of Total	Cum %
1	SB-1060	Steel Block Stopper A	1010 Steel	4.00	2.50	-	1	Manual Mill	Drill Press	**Grinder**	12 min	3 min	**15 min**	375,000	54.5%	55%	$3.00	$1,125,000	62.9%	63%
2	SB-1201	Steel Block Stopper B	4130 Steel	3.75	2.50	-	1	**Manual Mill**	Drill Press	Grinder	**18 min**	3 min	14 min	175,000	25.5%	80%	$2.50	$437,500	24.5%	87%
3	AC-1958	Cylinder Stopper X	Alum 3003	2.50	-	2.00	1	**Lathe**	Drill Press		**8 min**	1 min		80,000	11.6%	92%	$1.75	$140,000	7.8%	95%
4	AC-1959	Cylinder Stopper C	Alum 2024	1.75	-	3.00	1		**Drill Press**			**2 min**		20,000	2.9%	95%	$1.00	$20,000	1.1%	96%
5	AC-1995	Cylinder Stopper A	Alum 3003	4.00	-	1.50	1	**Lathe**	Drill Press	Grinder	**4 min**	1 min	2 min	19,000	2.8%	97%	$2.00	$38,000	2.1%	98%
6	AC-1795	Cylinder Stopper B	Alum 3003	3.50	-	1.00	2		**Manual Mill**	Grinder	2 min	**3 min**	1 min	7,000	1.0%	98%	$1.80	$12,600	0.7%	99%
7	AC-1965	Cylinder Stopper D	Alum 2024	3.00	-	2.50	2	**Lathe**			**9 min**			5,000	0.7%	99%	$1.00	$5,000	0.3%	99%
8	AC-1977	Cylinder Stopper E	Alum 3003	2.00	-	2.25	1	**Lathe**	Grinder		**8 min**	1 min		3,000	0.4%	99%	$0.25	$750	0.0%	99%
9	SB-1202	Steel Block Stopper D	1010 Steel	3.00	2.00	-	2	**Manual Mill**	Drill Press	Grinder	**11 min**	5 min	10 min	2,000	0.3%	100%	$1.50	$3,000	0.2%	100%
10	AC-1997	Cylinder Stopper E1	Alum 2024	3.25	-	1.75	2	**Lathe**			**7 min**			1,500	0.2%	100%	$4.00	$6,000	0.3%	100%
								Bottleneck Operation					**Total**	687,500			**Total**	$1,787,850		

Spreadsheet 13 – Dynamic Bottlenecks Prioritization List for Lean Six Sigma Improvements – Complete

After the Dynamic Bottlenecks Prioritization List for Lean Six Sigma Improvements is complete. The MMDB's initial action steps are to do the following:

1. Place 5S signage with the part number on each vital few bottleneck machines
2. Assign Lean Six Sigma Black Belts and Lean Six Sigma Green Belts projects to reduce the cycle times at the vital few bottlenecks
3. During absenteeism, management can ensure that the vital few bottlenecks are running with the workers there
4. Make sure that the vital few bottleneck machines are serviced with preventive and predictive maintenance
5. Re-route products to improve flow and reduce the number of bottlenecks, like the example: *AC-1795 Cylinder Stopper B purchased – needs re-routing to Block Cell to eliminate "Work Around"*

Below are some of the benefits of the ***Managing Method for Dynamic Bottlenecks***:

1. Daily improved throughput and productivity
2. Reduce production costs
3. Increase cash flow and revenue
4. Better understanding of the overall manufacturing process in the plant
5. Improved employees' morale by letting them know where they can impact their performance positively

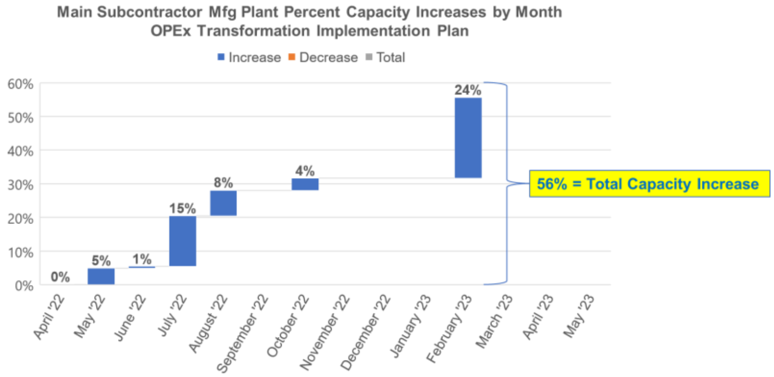
Case Study – 2022 Fortune 500 Chemical Company Plant Capacity Increase Request

In December 2021, a Fortune 500 chemical company requested a capacity increase utilizing Lean Six Sigma methodology for Operational Excellence (OpEx) at a critical contract supplier plant in Ashland, VA. The contract supplier is the main supplier of the chemical company's Home Wrap products. Therefore, the chemical company hired Caldwell & Associates to partner with the contract supplier's leadership team to perform an OpEx Assessment Phase 1 in 40 days that delivered the following:

1. Caldwell & Associates discovered a dynamic bottleneck in a vital product line, which is the key to increasing the contract supplier plant's throughput and capacity.
2. Identified critical bottleneck downtime issues that impacted throughput and capacity.
3. Identified Lean Six Sigma Training needs with customized workshops.
4. Determined several potential short-term Lean Six Sigma improvements to solve the worst-case operation problem in the plant. The contract supplier's general manager determined the worst-case problem in the plant.
5. Determined several potential long-term Lean Six Sigma improvements to increase throughput and capacity at the critical dynamic bottleneck operations in the contract supplier's plant.

On March 8, 2022, the chemical company rehired Caldwell & Associates to develop an Operational Excellence Transformation Plan Phase 2 to increase the plant capacity at their key contract supplier in 160 days. Here is a summary of the following deliverables:

1. Provided customized Lean Six Sigma Workshops that utilized problems from the contract supplier's plant. For example, a Lean Six Sigma Set Up Reduction Workshop using videos from the contract supplier's critical bottleneck operation. This approach helped contract suppliers' employees learn better while solving their problems.
2. Implemented some short-term Lean Six Sigma improvements to increase capacity.
3. Caldwell & Associates provided the chemical company's upper management with an Operational Excellence Transformation Implementation Plan to increase the contract supplier's plant capacity by 56%, as shown in Graph 14. The graph below is a waterfall chart showing the month-by-month capacity increases from the implementation plan:



Graph 14 – Main Subcontractor Manufacturing Plant Percentage Capacity Increases by Month