STICKLEY AUDI & CO.

FINE FURNITURE SINCE 1900

Process Improvement at Drawer Assembly Cell

SCM 755 Lean Six Sigma

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Acknowledgement

We would like to thank our professor, Gary La Point, for setting up this projecting and allowing us to experience how to implement the LSS principles we learned in class in a real manufacturing environment. His expertise and assistance were invaluable for this project.

We would also like to thank Rich Croft, Mark Woody, and Paul Puelo for giving us their time and resources to complete this project. It was very encouraging to have people in the factory who were actively supporting the project and assisting us with every phase of the project.

This project has been an incredible learning experience and will be something that we will remember for years to come.

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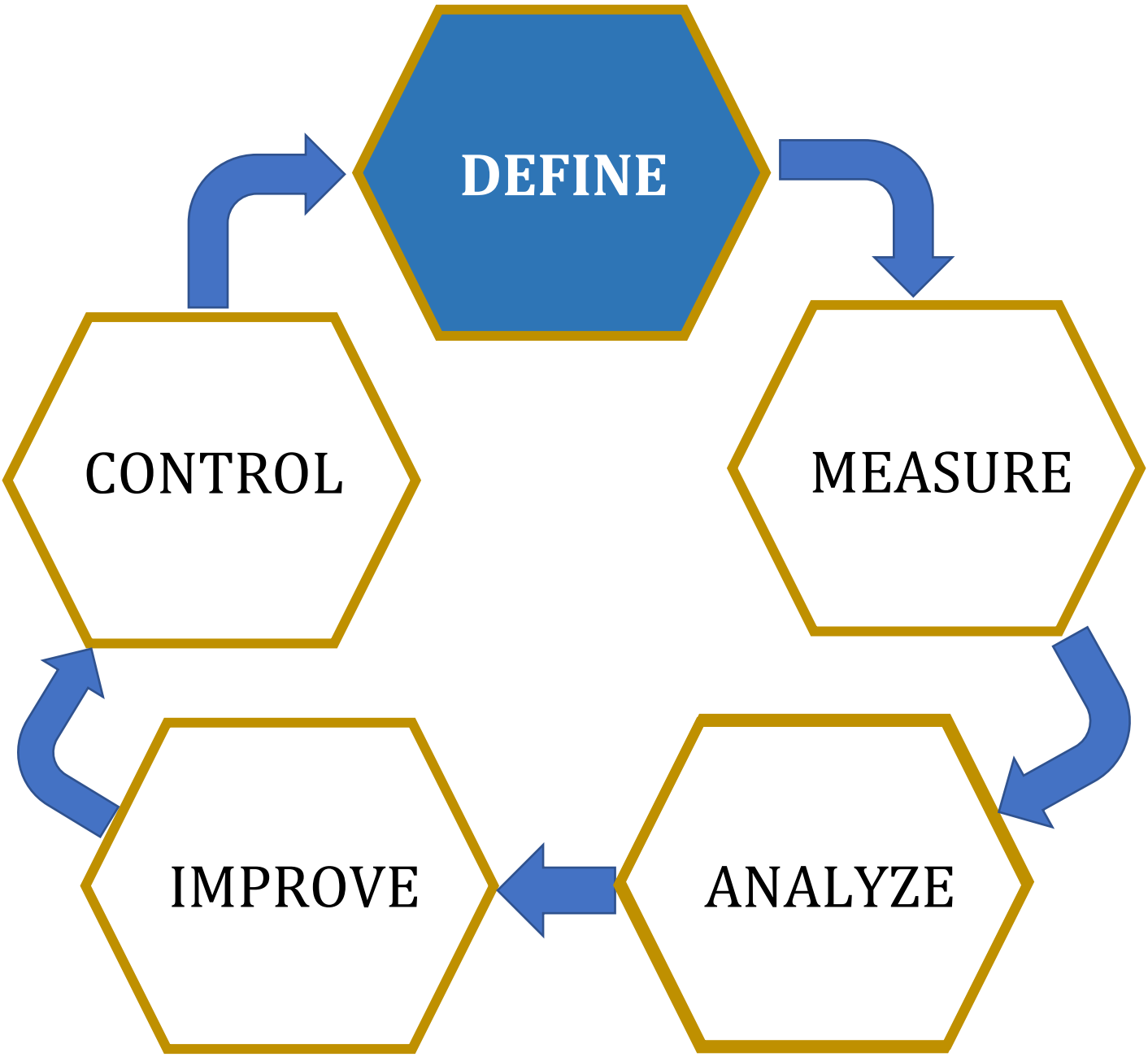
Executive Summary

Stickley is a manufacturer of fine furniture based in Upstate New York. Their main production facility is in Manlius NY, although they do have other production facilities across the world, including one in Vietnam. Their furniture consists of high-end pieces that are made to be kept for decades.

Our project is focused on the drawer cell, which feeds drawers into the Cabinet cell. There are instances where the drawer cell is not as productive as it should be, resulting in the cabinet cell not getting enough drawers to place into the cabinet when they need them. This goal of this project is to find the reason for this issue and proposed potential solutions to the problem. We also aim to use Arena, program made by Rockwell Automation, to simulate the drawer production process and derive improvement from our simulation.

When our improvements are implemented, we hope to increase the production of the drawer cell by 15% and introduce a cost savings to the drawer cell. Our solutions also may be able to be adapted to other cells in the factory as well, increasing efficiency and reducing cost all over the factory.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Background Information

In the drawer cell, the output per person is significantly lower than what is expected. To compensate, drawers are being produced a shift in advance. This project aims to understand why the output is lower than expected and determine a method to allow drawer and cabinet production to occur simultaneously, or at the very least, allow drawer production to occur later than one shift in advance.

The Drawer Cell feeds drawers to the Cabinet Cell. In any situation where a cabinet needs drawers (some items built in the cabinet area do not have drawers, like nightstands) the cabinet area is reliant on the drawer cell to complete the construction of a cabinet. Fitting the drawers into a cabinet is a long process, so any delays in drawer production delays the final completion of a cabinet.

The drawer cell consists of several machines, all of which must be operated by workers. At most, there are 2 workers in the drawer cell. There are instances where there could be 1 worker, and if there are no cabinets in production that have drawers, there may be no workers in this cell.

Project Charter

The project charter is a document that is created at the beginning of a Lean Six Sigma project. Its goal is to define the scope of the project, the key members, and stakeholders of the project, detail any needs and constraints, and proposes deadlines for all expected deliverables.

Project Mission: Stickley is a maker of high-end furniture based in Manlius, NY. They have been making this furniture for over 100 years. This project involves understand the flow of the drawer cell and minimize waste along points in the drawer cell production. FIFO is the desired end goal of this project.

Problem Statement: In the drawer cell, the output per person is significantly lower than what is expected. To compensate, drawers are being produced a shift in advance.

Business Case: Drawer production can slow down the cabinet making process, which means that order cycle time is taking longer than it should. Increasing the efficiency of drawer assemblies by at least 15% can increase overall throughput.

Goals and Metrics: Increase the output per person by 15%. Decrease time spent on non-value-added activities.

Deliverables: Provide an improved process flow and improved efficiency for the drawer assembly area.

Project Scope: The scope is focused on the assembly of drawers and the retrieval of drawer parts and items that assist in drawer production. No other parts of the factory are in scope.

Team Members:

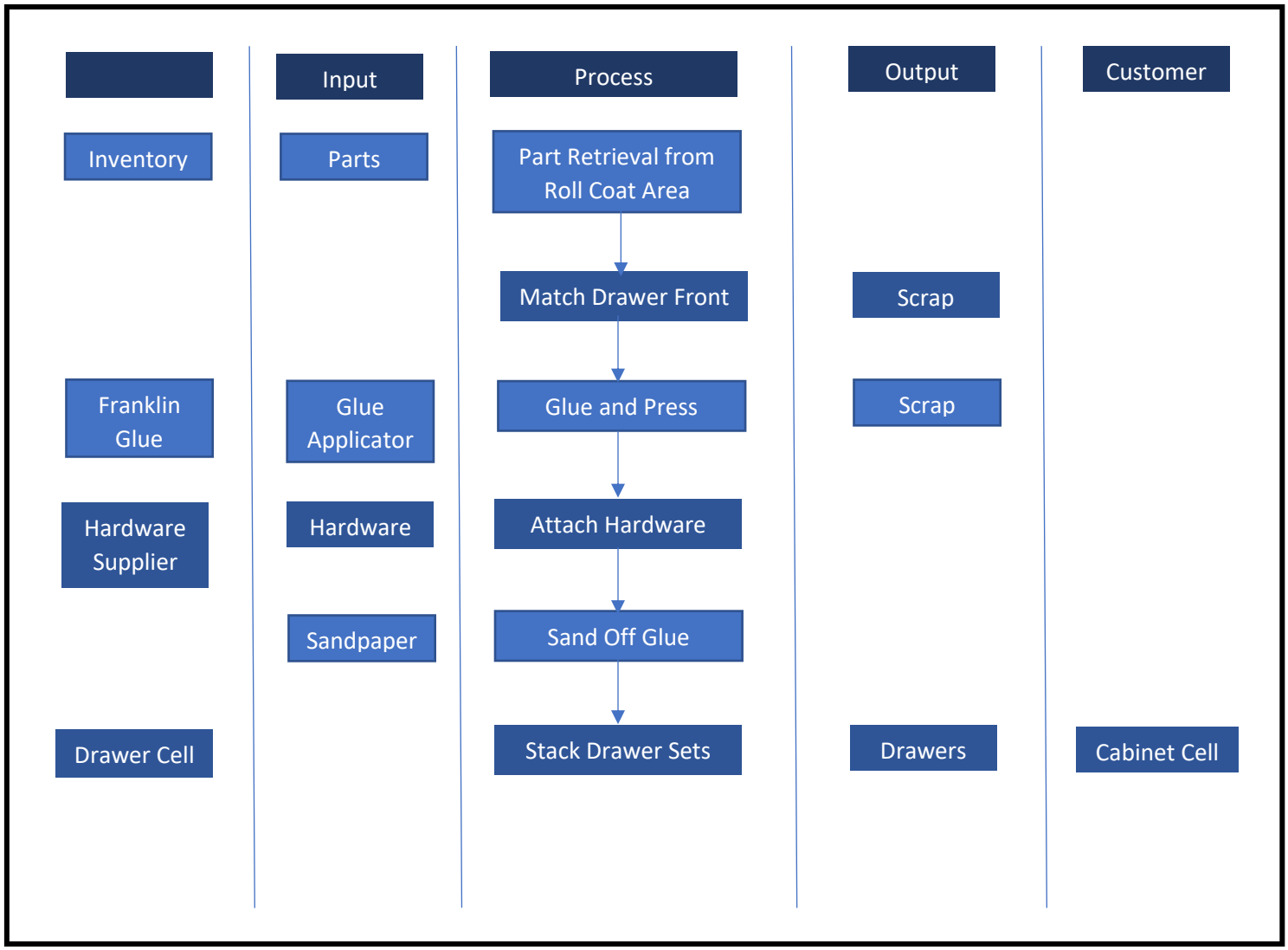
Syracuse University: Philip Toro, Manas Engineer, Rahul Kotian and Saket Sharma

Stickley Audi & Co.: Mark Woody and Rich Croft

Communication Plan

Date: 5/12/2022	Communication Plan				
Stakeholder Name	**Method of Communication (email updates, invite to tollgate, phone call, send slides)**	**Purpose of Communication (why & what)**	**Team member responsible (or sponsor)**	**Frequency of Communication (dates)**	**Notes**
Paul Puelo	Email updates, invite to tollgate	Status/Updates	Manas Engineer, Philip	Weekly updates and progress reports	Participate in progress reports
Mark Woody	Email updates and phone calls, invite to tollgate, Face to Face	Information, action	Manas Engineer, Philip	Weekly and as needed	Participate in weekly meetings
Rich Croft	Email updates and phone calls, invite to tollgate, Face to Face	Information, action	Manas Engineer, Philip	Weekly and as needed	Participate in weekly meetings
Saket Sharma	Email updates and phone calls, invite to tollgate	Buy-in, information, action	Rahul, Saket	As Needed	Participate in all events
Philip Toro	Email updates and phone calls, invite to tollgate	Buy-in, information, action	Rahul, Saket	As Needed	Participate in all events
Rahul Kotian	Email updates and phone calls, invite to tollgate	Buy-in, information, action	Rahul, Saket	As Needed	Participate in all events
Manas Engineer	Email updates and phone calls, invite to tollgate	Buy-in, information, action	Rahul, Saket	As Needed	Participate in all events

SIPOC Diagram



Description of the Current Process

1. *Order Generated:* Once the cabinet order is scheduled, the supervisor goes down to the drawer cell and hands the workers an order sheet. This will detail the drawers that they will be building, as well as the number of drawers that they will be building. It is important to note that drawers are built in sets. Each set of drawers corresponds to a single cabinet. For example, if there is a cabinet with 10 drawers, a set of drawers would refer to the 10 drawers that go into that cabinet.
2. *Parts Retrieval:* After the order sheet is handed to the drawer cell workers, they go to a designated area where the drawer parts are kept. This designated is the roll coat area, which houses the Roll Coat Machine. This coats the wood that is going to be used in products in a protective coating. The roll coat operator places drawer parts on carts and writes the Job Number that they correspond to on the cart. The drawer cell workers walk to this area of the factory and find all the carts (there could be more than one per order) labeled with the Job Number that matches the one on the sheet. Once they find the carts with the correct job numbers, the roll the carts back to the drawer cell.

Figure 1: Roll Carts in Roll Coat Area

3. *Assembly:* The parts are then retrieved, and the drawers are assembled. This includes 4 main processes: Matching, Assembly/Gluing, Attaching Hardware, and Sanding. Matching refers to workers matching the fronts of drawers with others that have similar grain patterns. Stickley ensures that all the drawers in a cabinet have similar wood grain patterns to maintain a consistent and high-quality appearance. Once the drawer fronts are matched, the drawer is glued and pressed using the device below:

Figure 2: 1 of 2 Presses in Drawer Cell

4. *Hardware Attachment*: After the drawer is pressed, the hardware attached. The term "Hardware" refers to metal slides that are attached to certain drawers – not all drawers have this hardware, and in that case, this step is skipped completely. Once the drawers are fully assembled, the drawers are sanded using this belt sander:

5. *Sanding Drawers:* The sanding process is done to ensure there is no excess dried glue visible on the drawers once they are complete.

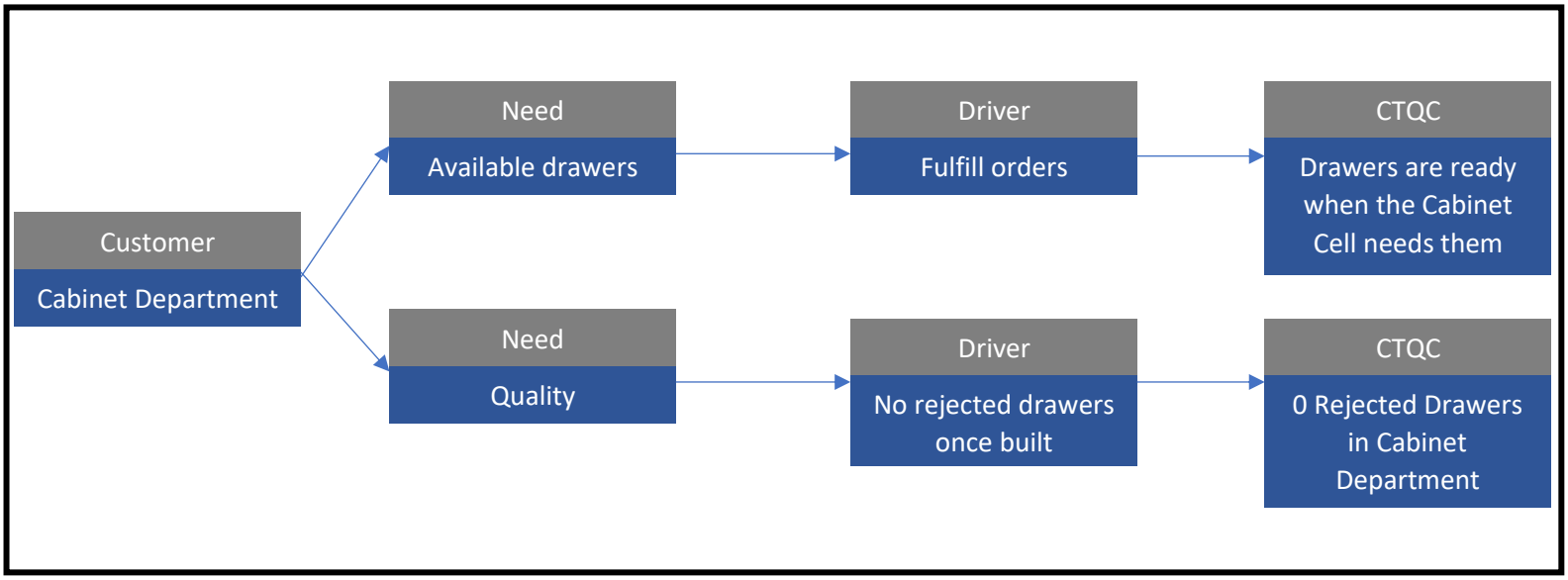
Figure 3: Sanding Belt

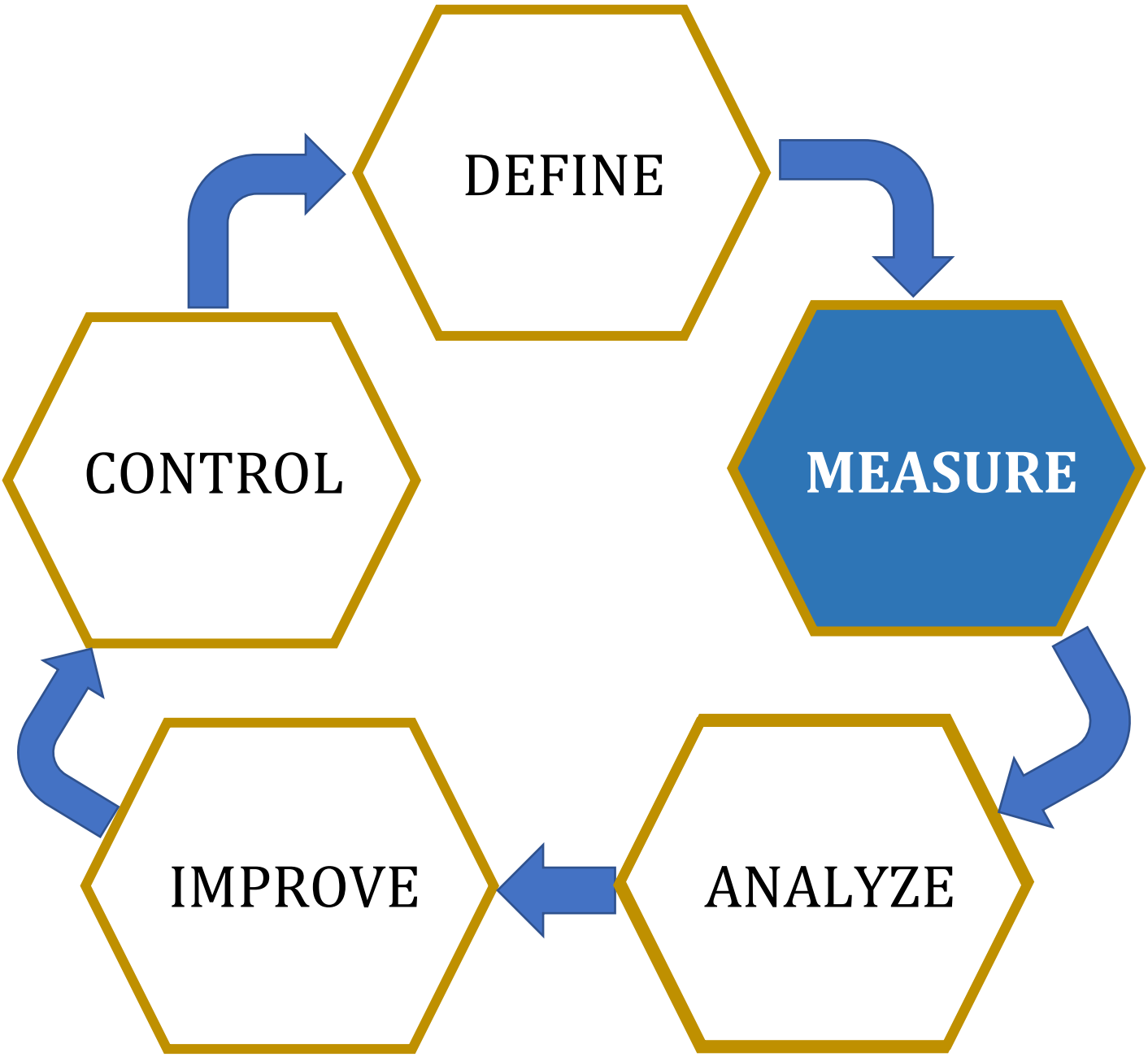
6. *Finished Drawers Stacked:* Once the drawers are finished, they are placed on a pallet and moved to a staging area for the cabinet cell to obtain and begin the fit process when are ready.

Figure 3: Completed Drawers on Pallet

Critical to Quality Characteristics (CTQC)

Critical to quality characteristics help project team members determine what is important to the customer. In the case of this project, the customer is the Cabinet Department, as they are the ones who directly receive the drawers from the drawer cell. We have determined that the needs from the cabinet department are availability of the drawers when they begin the fit process on a cabinet, and that the drawers that are available are of acceptable quality, lest they need rework (which would delay the fit process. The drivers for the needs mentioned are fulfilling orders and no rejected drawers once the drawers are assembled.

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Process Flow Diagram

Step	Inputs	Process	Outputs
1	1. Drawer Order	Order Handed to Drawer Assembly Person by Supervisor	
2a	1. Drawer Order	Walks to roll coat area to search for carts of drawer parts	Drawer parts on carts
2b	1. Drawer Order	Walks to roll coat area to search for carts of drawer parts	Drawer parts on carts
3a		Decision Point: Does the number on the cart match the order number? If YES, go to 4a and if NO, go to 2c	
2c	1. Drawer Order	Consult Supervisor	
4a	1. Drawer Order 2. Parts on cart	Bring cart(s) to assembly area	Drawer parts on carts
5a	1. Drawer Parts	Match drawer fronts	Matched drawer front sets
6		Decision Point: Are all drawer fronts acceptable? If YES, go to 7a and if NO, go to 5b	
5b		Decision Point: Can it be reworked? If YES, go to 5c and if NO, go to 5e	
5c	1. Drawer Parts	Rework the part	Reworked Part
5d	1. Reworked Drawer Front	Match drawer fronts	Matched drawer front sets
5e	1. Drawer Parts	Scrap the part	
7a	1. Matched Fronts 2. Drawer parts	Stack parts in sets	All parts matched and stacked

8		Decision Point: Is there glue? If YES, go to step 8a and if NO, go to step 8b	
8a	1. Glue bottle 2. Drawer parts 3. Hydraulic Press	Place drawer front into press	Semi assembly of drawer
8b	1. Glue Bottle	Retrieve glue from finishing area	Glue filled bottle
8c		Conduct step 8a	
9a		Decision Point: Are all drawer sides acceptable? If YES, go to 10a and if NO, go to 9b	
9b		Decision Point: Can it be reworked? If YES, go to 9c and if NO, go to 9e	
9c	1. Drawer Parts	Rework the part	Reworked Part
9d	1. Reworked Drawer Sides 2. Matched Fronts 3. Hydraulic Press 4. Glue	Apply glue on dovetail joints and insert in press	Drawer sides ready to fit
9e	1. Drawer Parts	Scrap the part	
10a	1. Matched Fronts 2. Drawer sides 3. Hydraulic Press 4. Glue	Apply glue on dovetail joints and insert in press	Semi assembly of drawer
11a		Decision Point: Is drawer bottom acceptable? If YES, go to 12a and if NO, go to 11b	
11b		Decision Point: Can it be reworked? If YES, go to 11c and if NO, go to 11e	
11c	1. Drawer Parts	Rework the part	Reworked Part

11d	1. Reworked Drawer Bottom	Insert drawer bottom	Semi assembly of drawer
11e	1. Drawer Parts	Scrap the part	
12a	1. Matched Fronts 2. Drawer sides 3. Hydraulic Press	Insert drawer bottom	Semi assembly of drawer
13a		Decision Point: Is drawer back acceptable? If YES, go to 14a and if NO, go to 13b	
13b		Decision Point: Can it be reworked? If YES, go to 13c and if NO, go to 13e	
13c	1. Drawer Parts	Rework the part	Reworked Part
13d	1. Reworked Drawer Back 2. Hydraulic Press 3. Glue	Apply glue on back and insert in press	Semi assembled drawer
13e	1. Drawer Parts	Scrap the part	
14a	1. Drawer sides 2. Hydraulic Press 3. Glue	Apply glue on back and insert in press	Semi assembled drawer
15a		Decision Point: Is the hardware being attached at the Assembly Area? If YES, go to 15b and if NO go to 15c	
15b	1. Glued Drawer 2. Hardware	Attach guide or hardware	Completely assembled drawer
15c	1. Glued Drawer	Send parts to other area for hardware attachment	Completely assembled drawer
16a		Decision Point: Are there pallets? If YES, go to 16b and if NO, go to 16c	
16b	1. Assembled Drawers is sets	Stack on pallets	Sets of assembled drawers resting

16c		Retrieve pallets	Pallets in assembly area
16d	1. Assembled Drawers in sets	Stack on retrieved pallets	Sets of assembled drawer sets
17a	1. Drawer sets on pallets	Push the pallets with drawer sets to sanding area	Set moved to new location
18a	1. Assembled Drawers 2. Sanding Belt	Sand assembled drawers	Finished drawers
18b		Decision Point: Does sanding belt need to be replaced? If YES, go to 18c and if NO, go to 18e	
18c	1. Sanding Belt	Replace the belt on the machine	New sanding belt on machine
18d		Conduct step 18a	
18e	1. Finished Drawers	Stack in sets on a pallet	Finished drawers ready to be fitted
19	1. Blow dryer	Clean off Sanding machine	Clean workstation
20	1. Finished drawers on pallets	Push to staging area for fitment in cabinets	

Issues During Process Prior to Measurement

1. Roll Cart Retrieval -

Currently, the Roll Carts in the Roll Coat Area are labeled only with a Job Number. This means that when a drawer cell worker goes to obtain a Cart, they must find the cart with that Job Number. However, there are instances where the parts for a job can span over multiple carts. There is no indication on the order sheet how many carts the workers need to look for, so it is possible for a drawer cell worker to not collect every cart that they need to create the drawers. They usually end up realizing this later on in the build process and have to halt the production of drawers and collect the missing cart/carts. Also, it is possible that some parts are in inventory and not on the carts. If this is the case, and the drawer workers are not aware of this, they must halt the drawer process and talk to inventory in order find the missing parts.

2. Glue Retrieval -

The assembly of drawers requires glue to be applied to the dovetail joints on the sides of the drawers. The glue is stored in old gallon water bottles. When the glue in these bottle runs out, workers have to walk to the glue storage area (which is about a 3-minute walk) and fill up this gallon jug and bring it back to the drawer area. This also halts the drawer assembly process.

3. Pallet Retrieval –

As mentioned above, assembled drawers are place on pallets with wheels and are moved around the drawer cell. These pallets are essential for drawer construction as they allow the finished drawers to be moved to a staging area where the cabinet assembly workers can move them to the cabinet cell to be fit into cabinets. When the drawer cell does not have enough of these pallets, workers must walk around the factory and find pallets that are not in use. There is no dedicated area for these pallets, rather, workers just must look for pallets wherever they can find them.

Figure 4: Location of Drawer Cell vs Glue and Parts Locations

4. Drawer Build Schedule VS Cabinet Build Schedule -

For the overall Cabinet Assembly process, drawer fit into the cabinets are the bottleneck. This means that there needs to be a constant supply of the correct drawers into the cabinet cell to avoid holding up the entire cabinet build process. Because of the issues facing the drawer cell, supervisors aim to being drawer production one shift in advance of the drawer fit. This leads to 2 problems. One is an excess of completed drawers left on the factory floor, and the other is excess drawer scrap. Since drawers are built in advance, any issue in cabinet production (i.e., cabinets taken off the production list) means that drawers that are already assembled will be scrapped. These drawers are usually not returned into inventory due to the wood aging and the overall fragility of the drawers.

5. Inefficient Use of Space -

Within the drawer cell are several stacks of unused parts. These parts have been left over from other builds and were not returned to inventory. These parts do not have much value, so storing them and retrieving them for the next drawer build is more expensive than just cutting new parts. Currently, drawer cell workers use these parts as spares if one of the parts on the roll carts fails. This does not happen often, and even if there is a part failure, these extra parts might not be one that corresponds to the drawers that they are currently building. There are 367 different drawers that are assembled, and while there may some part overlap, it is unlikely that these extra parts will always be useful in event of a failure.

6. Potentially Outdated Metrics -

Currently, efficiency is measured by the drawer cell using a set of standard timings. However, there is the potential that these standard timings are not representative of the actual process, as certain activities (such as sanding) always result in a low efficiency for the worker. The time is also not allocated to each task, so if a worker builds and sands in one shift, there is no indication of how long they built or sanded, just how long their shift was.

Data Collection Plan

Performance Measure	Data Location	Method of Collection	When to collect	Unit of measure	Type of data	Family of measure
Numbers of orders received	Supervisor	Order Sheet	1st Shift 2nd shift	Number of orders	Count	Productivity
Drawer part search duration	Inventory	Video Collection	When order received	Time	Ratio Data	Productivity
Drawer hardware search duration	Inventory	Video Collection	When order received	Time	Ratio Data	Productivity
Number of cart errors	Inventory	Performance sheet	On order completion	Number of errors	Count	Quality
Duration of match	Drawer Assembly	Performance sheet	On shift completion	Time	Ratio Data	Productivity
Drawer part quality	Drawer Assembly	Performance sheet	On shift completion	Number of failed parts	Count	Quality
Drawer part rework	Drawer Assembly	Performance sheet	On shift completion	Number of reworked parts	Count	Productivity
Drawer part Scrap	Drawer Assembly	Performance sheet	On shift completion	Scrap Parts	Count	Quality

Number of glue collections	Drawer Assembly	Performance sheet	On shift completion	Number of trips	Count	Productivity
Duration of glue collections	Drawer Assembly	Video Collection	On visit completion	Time	Ratio Data	Productivity
Duration build	Drawer Assembly	Performance sheet	On shift completion	Time	Ratio Data	Productivity
Number of pallet collections	Drawer Assembly	Performance sheet	On shift completion	Number of trips	Count	Productivity
Duration of pallet collections	Drawer Assembly	Video Collection	On visit completion	Time	Ratio Data	Productivity
Sanding Belt Replacements	Drawer Assembly	Performance sheet	On shift completion	Number of replacements	Count	Productivity
Duration of sanding belt replacement	Drawer Assembly	Video Collection	On visit completion	Time	Ratio Data	Productivity
Duration of sanding	Drawer Assembly	Performance sheet	On shift completion	Time	Ratio Data	Productivity
Drawer scrap	Drawer Assembly	Performance sheet	On shift completion	Number of drawers scraped	Count	Quality
Duration of cleaning sanding machine	Drawer Assembly	Video Collection	On visit completion	Time	Ratio Data	Productivity

To collect the data, two methods were used. The first is a time sheet that was to be filled out by the drawer cell workers and the other was a 360-degree camera. The camera was used to get very specific timings (such as the duration of sanding 1 drawer) that the team did not want workers to time themselves, as it would be very disruptive to the building experience. The time sheet is demonstrated below. In the event that the time sheet and the camera caught 2 of the same events at once, such as a recording of someone sanding and someone filling out their time sheet and mentioning that they sanded, the camera timings take precedence over the time sheets.

The camera was placed at the Drawer Cell on 3/21. It remained there until 4/1. The camera was placed in a location that would allow for a view of the whole drawer cell. Since there was not always drawer activity in the drawer cell, the camera was turned on by one of the team members at Stickley when they knew drawer activity was occurring. Once the camera was turned on, it remained on until the SD card ran out space. This occurred about every 24 hours, so a team member would swap SD cards every morning to ensure that the camera was ready to record.

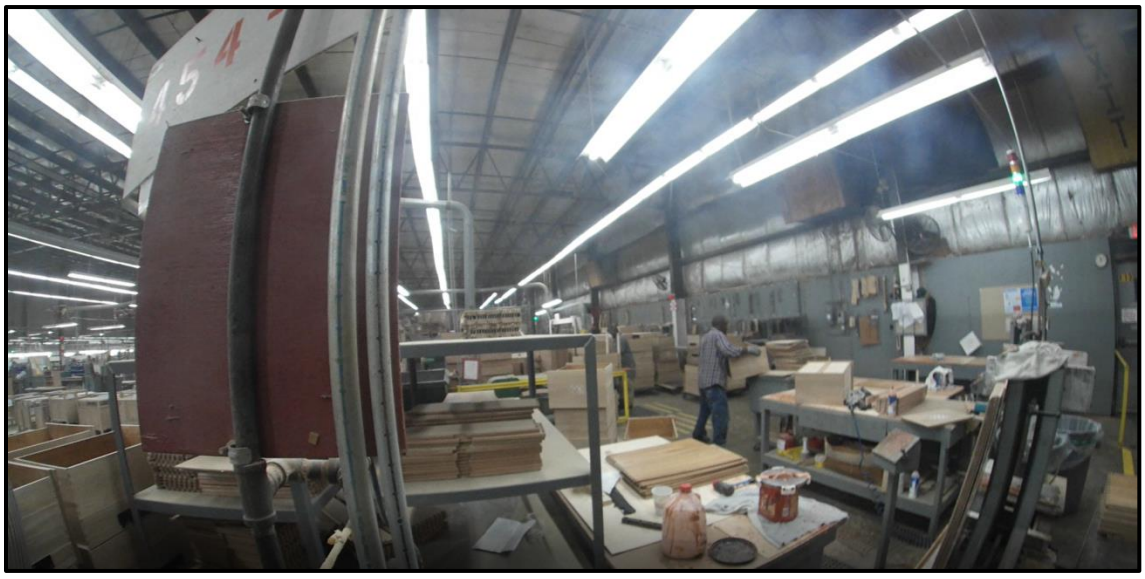


Figure 5: Image demonstrating the view of the camera

An example of the time sheet designed by the team, to be filled out with details regarding each shift and each operator is given below. This was filled daily by each operator.

Date:	Name:	Shift (Circle One) Day / Night

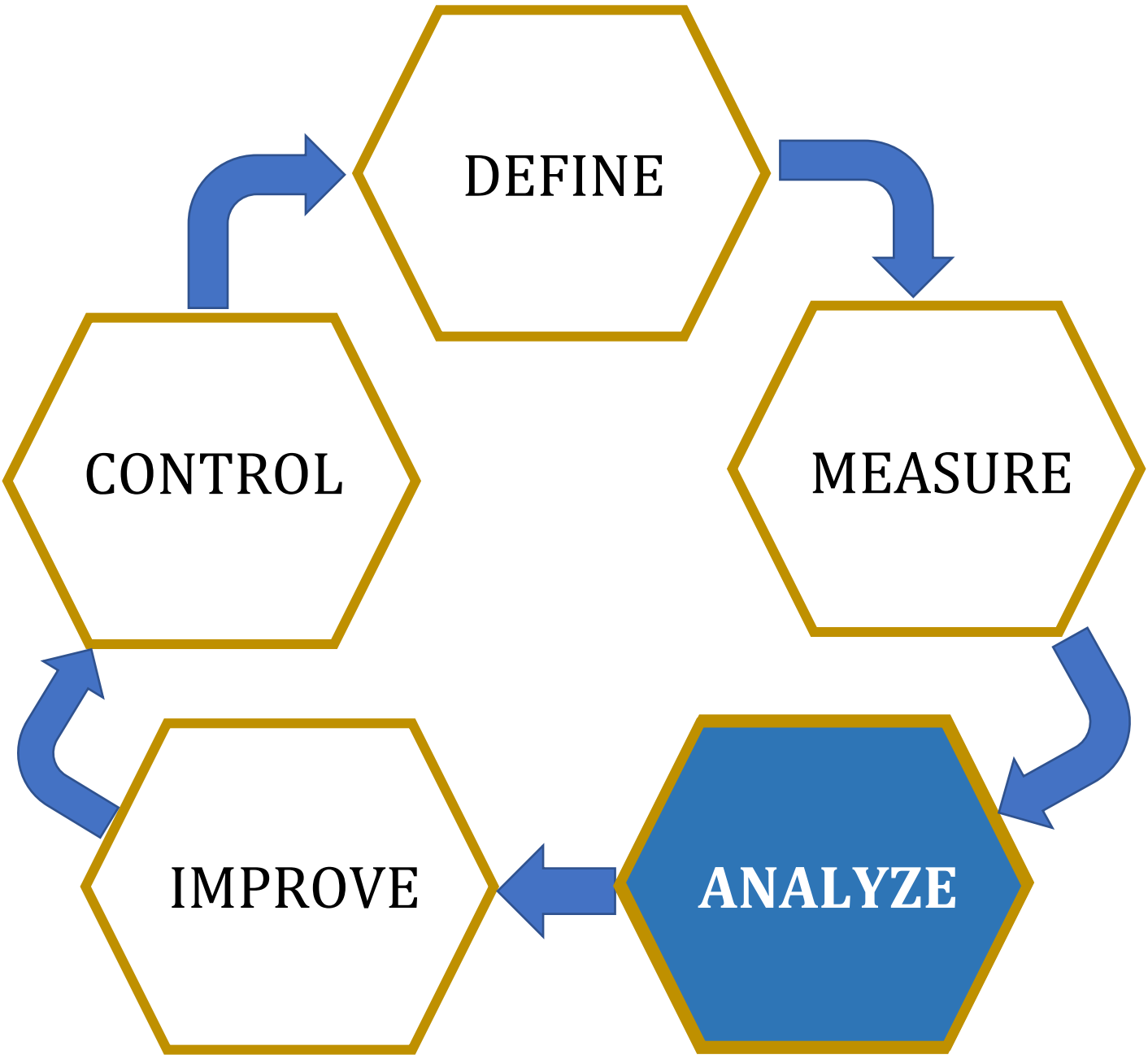
Number of Cart Errors (the number of times a cart was not labeled correctly, or you could not find a cart)		
	# Of Hours:	# Of Drawers
How many hours did you spend matching? How many Drawers did you match?		
	# Of Hours:	# Of Drawers
How many hours did you spend building? How many drawers did you build?		
	# Of Hours:	# Of Drawers
How many hours did you spend Sanding? How many drawers did you Sand?		
How many drawer parts did you have to scrap or send off to be reworked?		
How many drawer parts did you have to rework yourself/How many parts were difficult to use in assembly?		

How many completed drawers did you have to scrap?	
How many times did you have to leave the workstation to collect glue?	
How many times did you have to leave the workstation to collect pallets?	
How many times did you have to replace the sanding belt?	

Limitations of Measurement Methods

Although the camera was able to observe far more than the team was able to in person, there were still some limitations to the methods that were used to capture all the data.

1. Lack of Historical Data - Stickley has over 376 different kinds of drawers that they can produce. Despite filming for over a week, we were only able to film a few different types of drawers. Since there is no relevant historical data, this means that we are limited to what we observed. This should not matter much, as the construction process is the same for most drawers, however it does mean that there may be certain types of drawers that have a slightly different build process than what we observed.
2. Lack of Drawer Cell Activity - There may be instances where the drawer cell is completely inactive while an order of cabinets with no drawers are being built. This occurred more than once during our measurement process and meant that we were unable to collect any data during those periods.
3. Focus on NVA Time -After creating our process flow diagram and thinking about the issues that were listed on page 16, the team decided that one of our focuses would be to investigate Non-Value-Added Time (NVA).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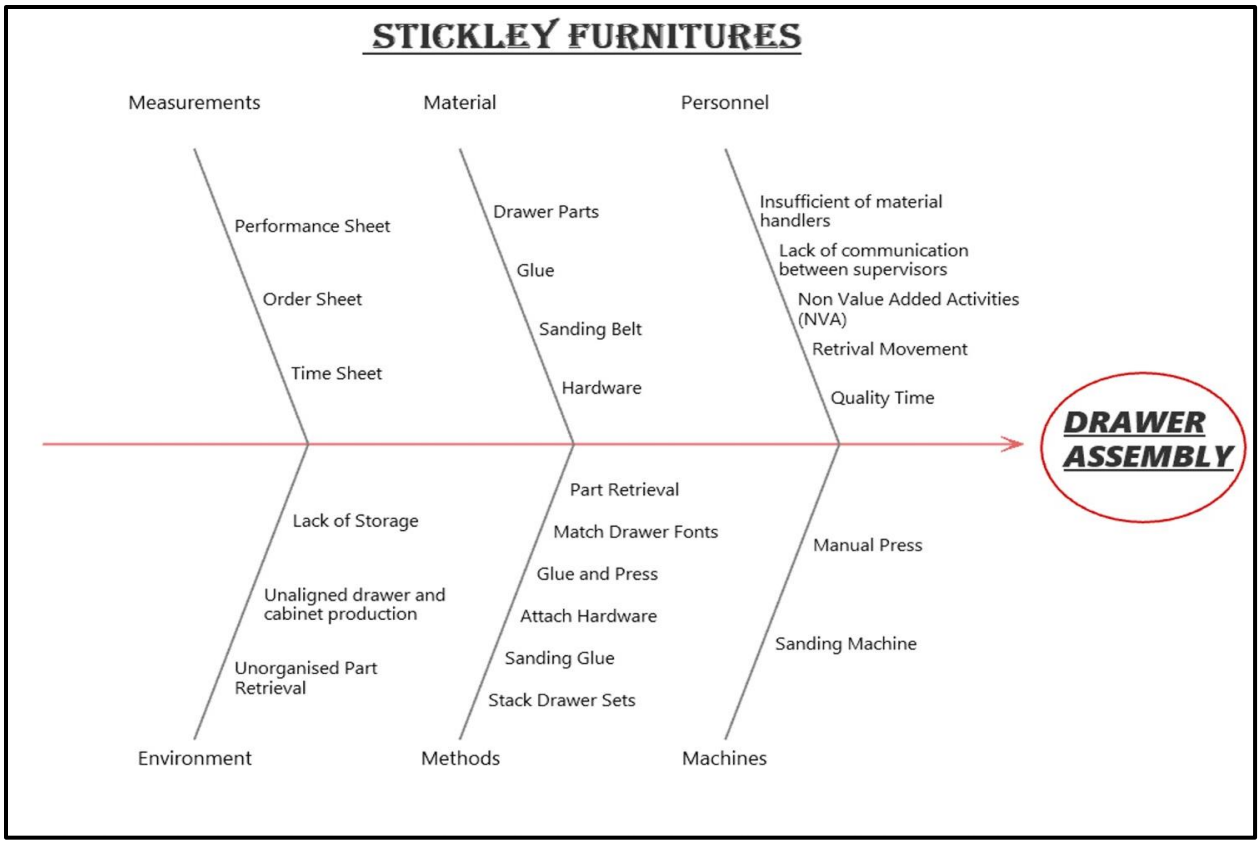
Fishbone Diagram (Ishikawa Chart)



Fishbone diagrams help us understand and identify root causes in our process, and helps the team put our thoughts properly. Therefore, a fishbone diagram was critical to analyze what could be and were the pain points in the drawer assembly process. Identified were the following three points –

- Lack of communication between supervisors – The supervisors would have verbal communication between shifts, else no communication. This practice would not shed light on the issues at hand or the issues that are imminent on the shop floor.
- Part Retrieval – As observed previously, the fetching of drawer parts is a major pain point due to the ambiguity of the placement of the parts.
- Unaligned drawer and cabinet production – As discussed, since the drawers are built a shift prior to the building of the cabinets, therefore, there is a high chance of wastage of drawers in terms of labor, material, and input costs.

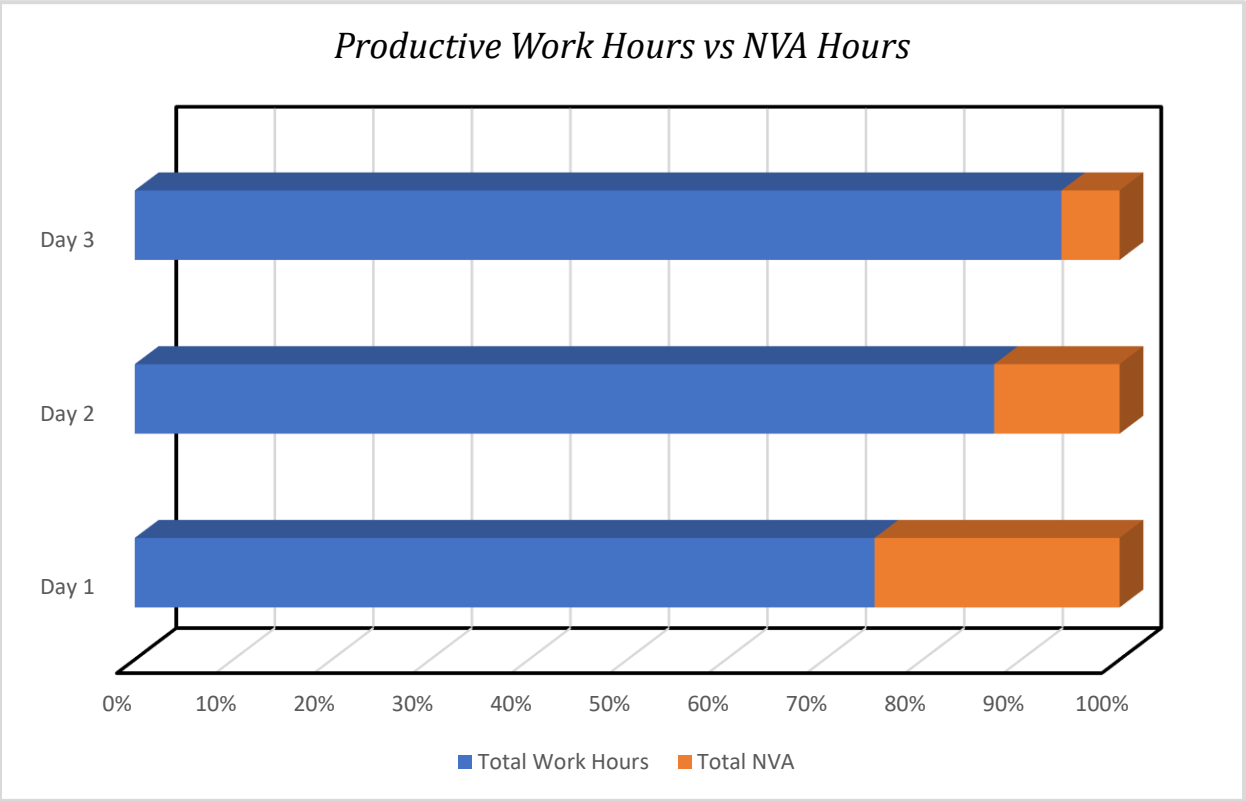
Observations from Video Data

Once we collected all the video, the next step was to rewatch the video and measure the timings for each of the processes on the data collection sheet, as well as note down any NVA activities. Below is a sample of what we collected.

Date	Stamp S	Start	Stamp E	End	Total	Size	File
21-Mar	1:29	01:29	4:31	04:31	03:02	Small	_0023
21-Mar	5:56	05:56	8:47	08:47	02:51	Small	_0023
21-Mar	9:12	09:12	11:18	11:18	02:06	Small	_0023
21-Mar	0:03	00:03	2:07	02:07	02:04	Small	_0024
21-Mar	2:45	02:45	6:37	06:37	03:52	Small	_0024
21-Mar	6:59	06:59	9:31	09:31	02:32	Small	_0024
21-Mar	10:21	10:21	13:05	13:05	02:44	Small	_0025
21-Mar	1:51	01:51	4:44	04:44	02:53	Small	_0026
21-Mar	5:29	05:29	8:15	08:15	02:46	Small	_0026
21-Mar	8:26	08:26	13:10	13:10	04:44	Small	_0026
21-Mar	1:46	01:46	4:30	04:30	02:44	Small	_0027
21-Mar	4:35	04:35	8:45	08:45	04:10	Small	_0027
21-Mar	8:51	08:51	12:04	12:04	03:13	Small	_0027
21-Mar	0:36	00:36	3:36	03:36	03:00	Small	_0028
21-Mar	3:41	03:41	6:46	06:46	03:05	Small	_0028
21-Mar	0:43	00:43	3:37	03:37	02:54	Small	_0036
21-Mar	6:18	06:18	9:15	09:15	02:57	Small	_0039
31-Mar	6:48	06:48	12:30	12:30	05:42	Large	_0498
31-Mar	1:19	01:19	6:25	06:25	05:06	Large	_0499
31-Mar	6:42	06:42	12:20	12:20	05:38	Large	_0499
31-Mar	15:30	15:30	19:57	19:57	04:27	Large	_0499
31-Mar	3:44	03:44	9:44	09:44	06:00	Large	_0500
31-Mar	10:18	10:18	18:12	18:12	07:54	Large	_0500
31-Mar	6:44	06:44	15:22	39:22	32:38	Large	_507
1-Apr	0:25	00:25	1:51	01:51	01:26	Small	_552
1-Apr	2:18	02:18	3:38	03:38	01:20	Small	_552
1-Apr	3:44	03:44	5:11	05:11	01:27	Small	_552
1-Apr	5:23	05:23	6:40	06:40	01:17	Small	_552
1-Apr	2:30	02:30	4:15	04:15	01:45	Small	_553
1-Apr	4:27	04:27	5:43	05:43	01:16	Small	_553
1-Apr	5:52	05:52	7:13	07:13	01:21	Small	_553
1-Apr	8:49	08:49	10:06	10:06	01:17	Small	_553

Figure 6: Sample of Video Data Collection

Productive Work Hours vs Non-Value-Added Hours

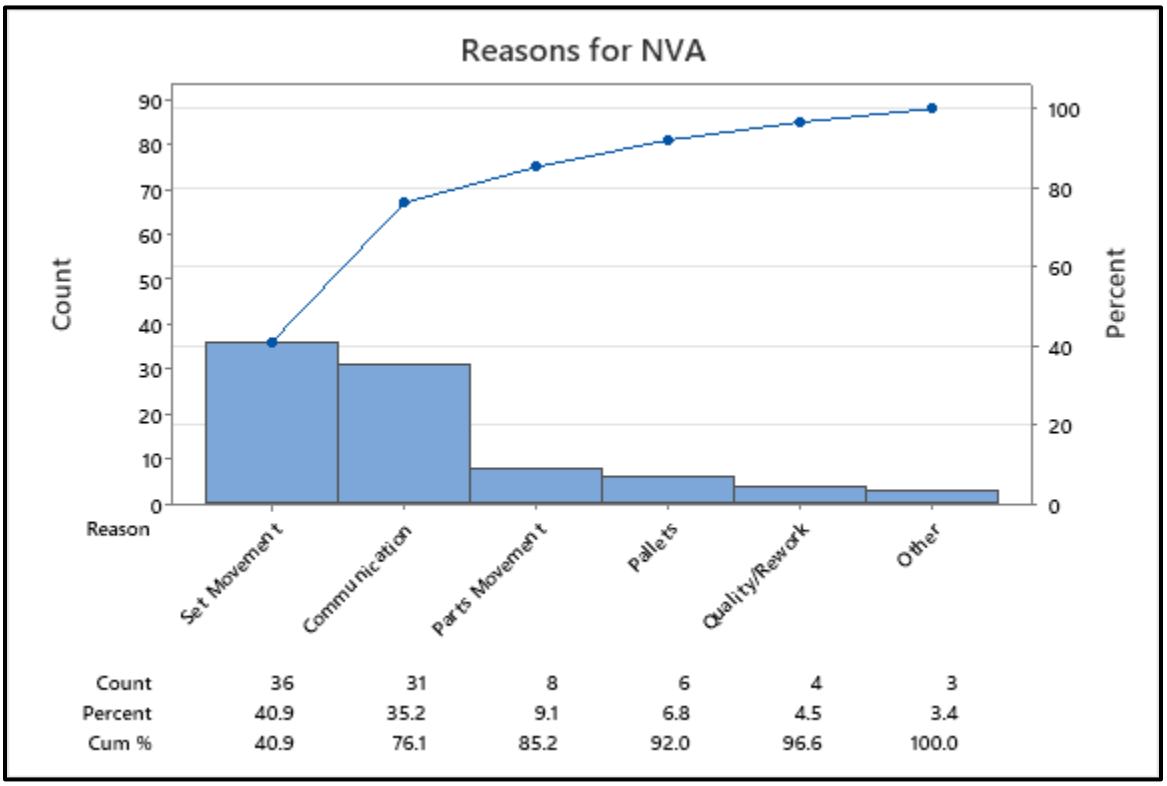


This graph displays total hours worker against total NVA over 3 different days when data was collected. These days (March 21, March 23, and March 29) were selected because we had the most data for these days, both in terms of time sheets and footage. The average NVA over these 3 days was about 18.2%.

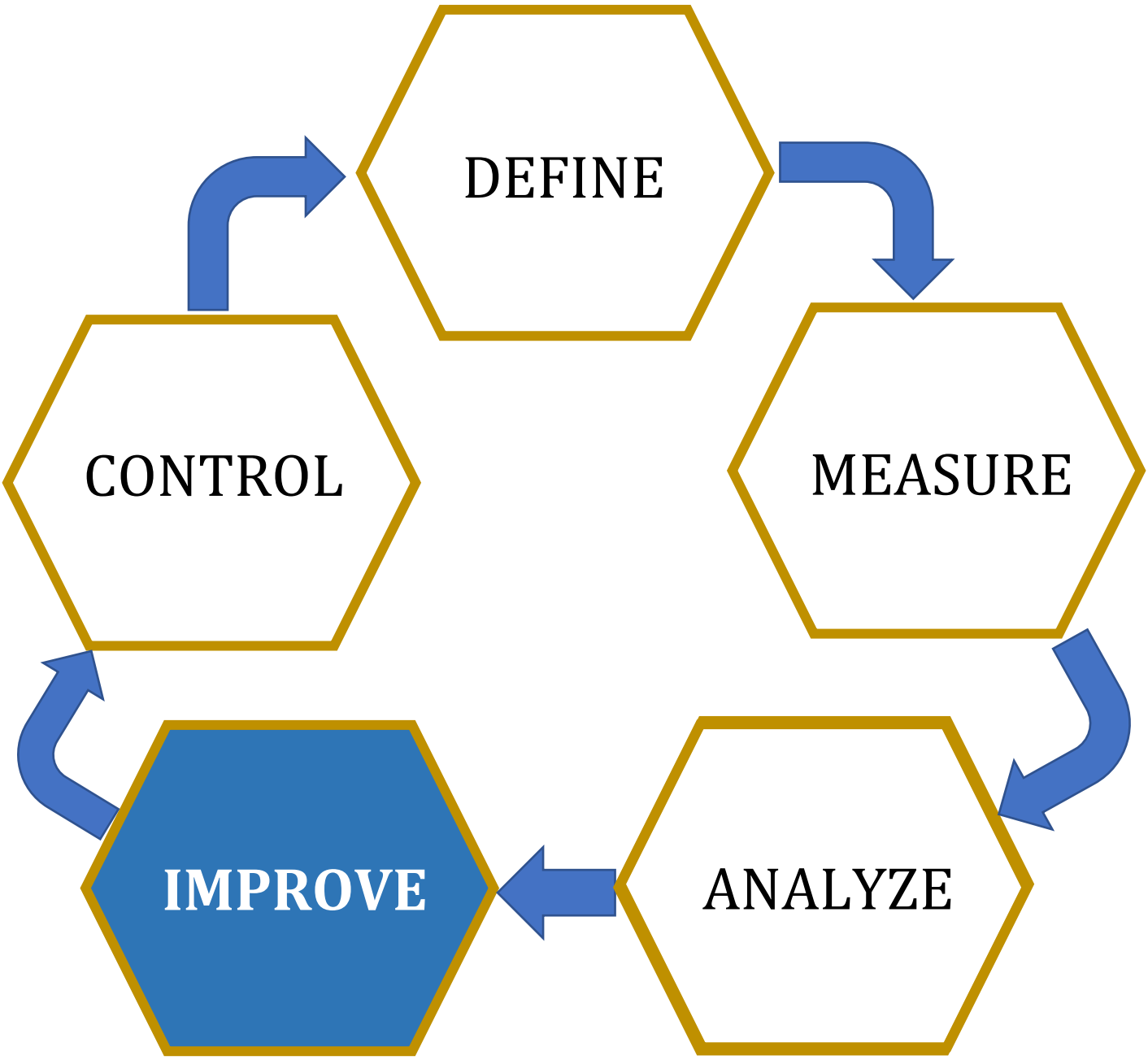
Taking that that percentage into account, NVA costs the Stickley Drawer Cell about $38000 dollars per year, assuming a worker salary of $30/hour.

Workdays per year	Shift Time	Average Number of Workers Day and Night	Worker Salary	Percent of time as NVA	Total Cost of NVA
223	10.5	3	30$/hour	18.20%	$38,353.77

Pareto Analysis



This pareto analysis lists the reasons for NVA that we observed, along with the frequency and overall percentage. Set movement, which is defined as any time a worker must stop working to move a pallet full of drawers around the work cell, is the most frequent. Communication, which is defined as a worker leaving the work cell to speak to a worker from another cell or to a supervisor, is the second most frequent. Parts movement refers to the workers leaving to get parts from the roll coat area or moving parts from the roll carts around the drawer cell. Pallets refers to the worker going to have to retrieve pallets that are mean to hold the completed drawers.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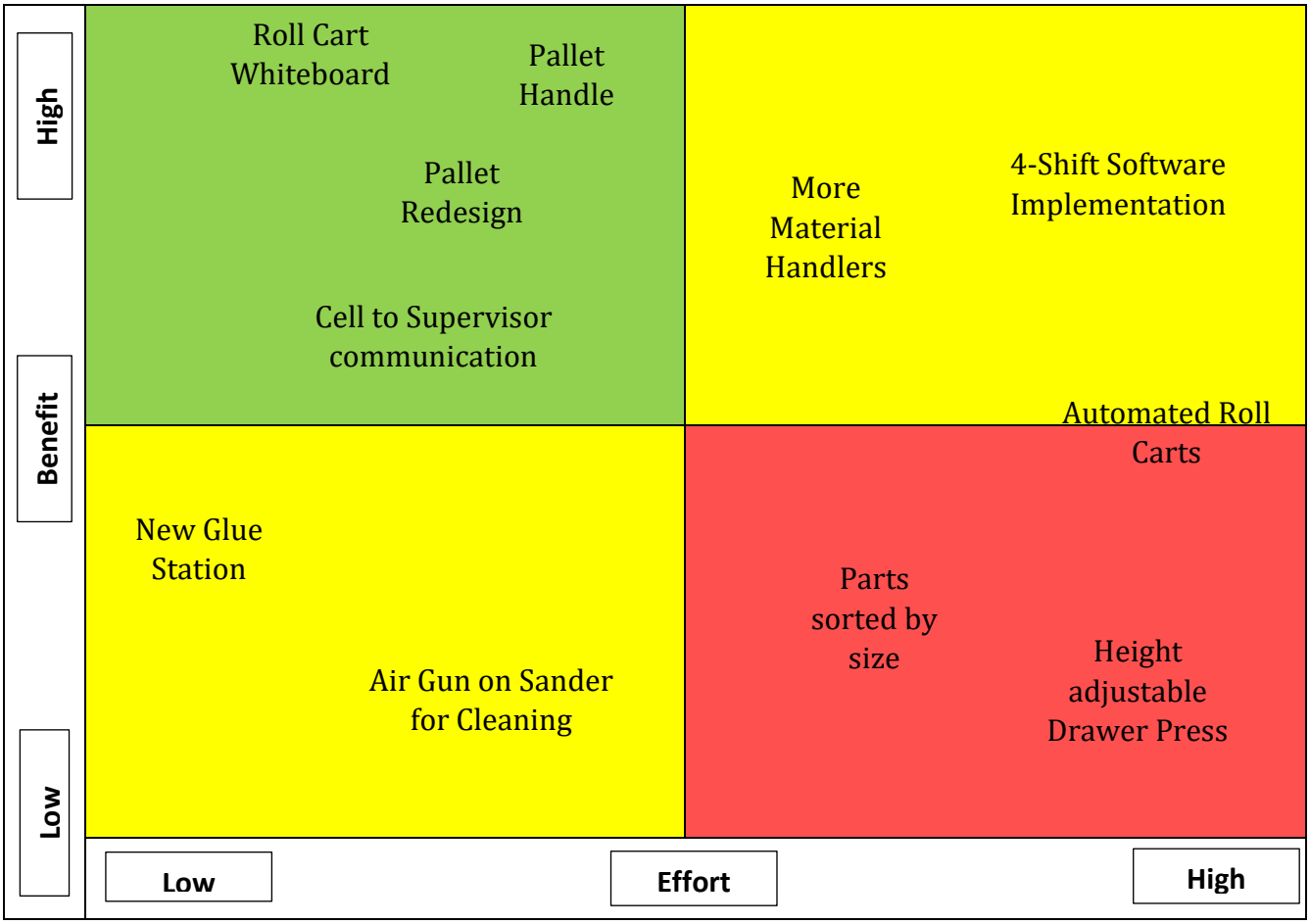
Brainstorming



In total we had about 50 ideas, these ideas above represent our most cohesive ones.

Potential and Implemented Solutions

Once the processes were measured, analyzed and the pain points were identified, we conducted a brainstorming session as discussed above, through which we were able to identify the pain points and shortlist a group of realistic implementable solutions as listed below –

- Pallet Handles –

Handles fashioned with a mouth in the front which latches on to the pallet, allowing easy maneuvering of the pallet without the parts toppling off. This simple solution reduces the chance of damaging the drawers and effectively doubles the movement speed.

- Cart Labeling System & Tracking Board –

We labeled 26 available carts used for stacking work orders at the roll coat area, a whiteboard is used to note that which cart is the job ID stacked. It also has a provision for notifying operator if some parts of the given job ID are not in any carts but is in the inventory shelves.

- Additional Glue Station, with bigger bottles –

Given that the drawer assembly area is a prolific user of glue as compared to the rest of the departments in the factory, a glue station should be installed near the drawer assembly area, potentially near the exit door. This, in concert with the bigger bottles to carry glue, would make sure that the operators do not venture outside their station for long.

- Walkie-Talkies for Cell to Supervisor Communication –

Currently, the communication between the floor and the supervisor is via a signal installed in every cell, chances are the supervisor would not be able to notice the signal when started else, would be in another cell when it happens, this forces operators seldom to venture out to find the supervisor, causing huge downtime. A simple walkie-talkie between the cell and the supervisor will eliminate this issue.

- Shift to Shift Communication Sheet –

As discussed above in the fishbone diagram, there is an evident lack of communication between the two supervisors, which can be eliminated by a communication sheet for each shift.

- Revised time sheet –

Upon implementing the time sheets as discussed in measure phase, we noticed that the operators seldom get confused between the number of sets or number of drawers, therefore, we revised the time sheet to implement more clarity in data collection.

- New Performance Efficiency Sheet –

The metrics that are in use by the team are not efficient and are baselined with outdated timings for processes. Instead, a new performance sheet, which is more detailed and automated is implemented with new standard times for all processes.

- Reducing Excess Parts Stack for more space –

Excess scrap parts for drawers are kept near the emergency exit gangway, these are non-value parts that take up valuable space, therefore, a rack can be installed in place which will hold 10 scrap parts of each type, in case an operator needs to a spare part, therefore freeing up a lot of space where the finished drawers stacked on the pallets can be stored.

- Establish a Pallet Collection Area –

Currently, all operators, wander the shop floor in search of empty, not-in-use pallets to stack the finished drawers, multiple dedicated pallet collection areas can be tape-marked for all not-in-use pallets, therefore, eliminating the operator's need to venture aimlessly across the floor.

Arena Simulation

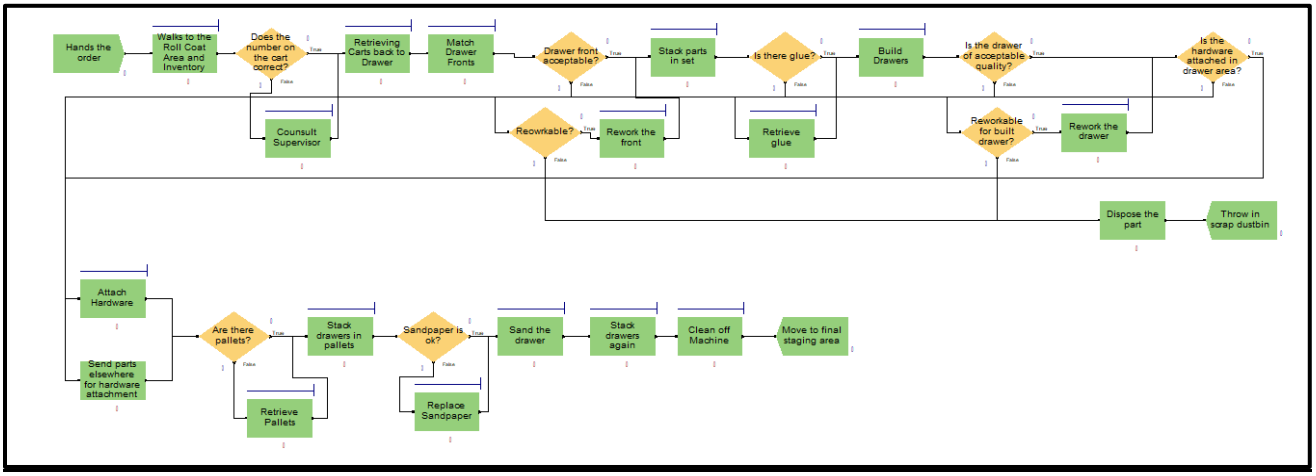


Figure 6: Detailed Arena Flowchart of the existing process

One of the improvements, we brainstormed and wanted more detail was the number of workers in the drawer assembly cell per shift to increase the process efficiency and expedite our processes. In order to study the different combinations and permutations, the team decided to test with the Arena Simulation software, developed by Rockwell Automation, that is specifically developed to study the different variations in a process and point the best variation. In our study, the variation was the number of operators in a given shift for the drawer assembly cell.

Unfortunately, the simulation did not give any satisfying result and point towards a solid variation to increase our productivity, also, we faced multiple issues with the software, which kept crashing and thus demotivating the team further to not include results from the Arena simulation.

It was a good try and was a definite exposure to the team, wherein we were able to find a software, learn it and try implementing new tools to achieve our project goal.

New Time Sheet

Date:	Name:	Shift (Circle One) Day /Night	Job Number (If all same number, write in this box)
Number of Cart Errors (the number of times a cart was not labed correctly, or you could not find a cart)			
		Hours:	Drawers/Sets
How many hours did you spend **Matching**? How many Drawers did you **Match**?			
		Hours:	Drawers/Sets
How many hours did you spend **Building**? How many drawers did you **Build**?			
		Hours:	Drawers/Sets
How many hours did you spend **Attaching Hardware**? How many drawers did you **Attach Hardware** to?			
		Hours:	Drawers/Sets
How many hours did you spend **Sanding**? How many **drawers did you Sand**?			
How many drawer parts did you have to scrap or send off to be reworked?			
How many drawer parts did you have to rework yourself/How many parts were difficult to use in assembly?			
How many completed drawers did you have to scrap?			
How many time did you have to leave the workstation to collect glue?			
How many time did you have to leave the workstation to collect pallets?			
How many times did you have to replace the sanding belt?			

This time sheet is an updated version of the time sheet we used during the measurement phase. It new includes the job number for each task, and it also allows workers to differentiate between sets and individual drawers, so fewer mistakes are made with the number of drawers per task.

New Process Efficiency Sheet

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Process Efficiency

Task	Standard time (mins)	Actual Process Time (hours)	Actual Process Time (mins)	Standard Number of Drawers	Actual Number of Drawers	Actual Per Drawer Time	Efficiency
Sand	1.5	6.5	390	260	90	4.333333333	35%
Match	3.7	1	60	16.21621622	15	4	93%
Hardware	3.5	0.68	40.8	11.65714286	12	3.4	103%
Build	3	9.6	576	192	109	5.28440367	57%

This new process efficiency sheet works in conjunction with the new time sheet that we proposed above. It includes new standard timings, and allows for the allocation of time per task, so more accurate efficiencies can be calculated.

Supervisor Communication Sheet

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Shift Communication Sheet					
Date		*Shift*		*Supervisor Name*	
Status of WIP					
Issues During the Shift					
Major Problems for Focus					
Supervisor Signature					

This proposed sheet allows supervisors to document

Quantifying Improvements

We implemented multiple improvements to the drawer assembly cell, two of which were to solve the highest contributors to the non-value-added time, therefore wasted time, they were labelling all carts in concert with a tracking whiteboard to assist in the parts retrieval, and wooden handles fashioned for the pallet, so they are easier to move.

- Labeling carts and installing a tracking whiteboard – The whiteboard that we implemented is in the roll coat area. It, combined with a label for every roll cart, allows for the roll coat operator to list each exact cart that the parts for a specific job are on. The whiteboard also allows for inventory to indicate if there are any parts located in inventory. This implemented solution reduces the per cart retrieval time by 7 minutes per cart. In addition, this whiteboard eliminates any confusion about missing carts or parts in inventory. In the past, these issues took anywhere from 30 to 60 minutes to solve.

- Pallet Handle – Currently, workers would stack completed drawers on pallets and push them around using their foot. This was a slow process, and there are no handles on the pallets, and they must be slow to ensure that no drawers were damaged during movement. The movement of pallets was one of the biggest contributors to NVA. We have implemented pallet handles that can be attached to pallets to assist in moving the pallets around the workspace. This cut down the movement time of each pallet by half, from about 1 minute to 30 seconds. This also reduces the chance for a drawer to be dropped and damaged during movement.

Future Improvements

- Redesign of pallets to be drawer specific –

The pallets are not custom built for carrying the drawers currently. The overall design could be changed to make it specifically for holding drawers – holding the bottom drawers in place so the piles are more stable as they are moved around

- Hire more material handlers –

All the improvements that we have suggested are focused on reducing NVA, however an even larger reduction could occur if more material handlers were hired that could retrieve pallets, carts, and glue for the drawer cell workers, ensuring that they do have to leave their cell

- Time study of drawer and cabinet production –

Since the scope of our project was restricted to the drawer cell alone, we concentrated our efforts on monitoring the drawer cell. To establish FIFO between the drawer cell and cabinet cell, a time study would need to be completed on the cabinet cell as well. This could reduce NVA time there as well and would allow supervisors to confidently schedule drawer production and cabinet production to be simultaneous. This would reduce the WIP, and drawers lost to scrap.

- Establish a communication system between the cells using a whiteboard –

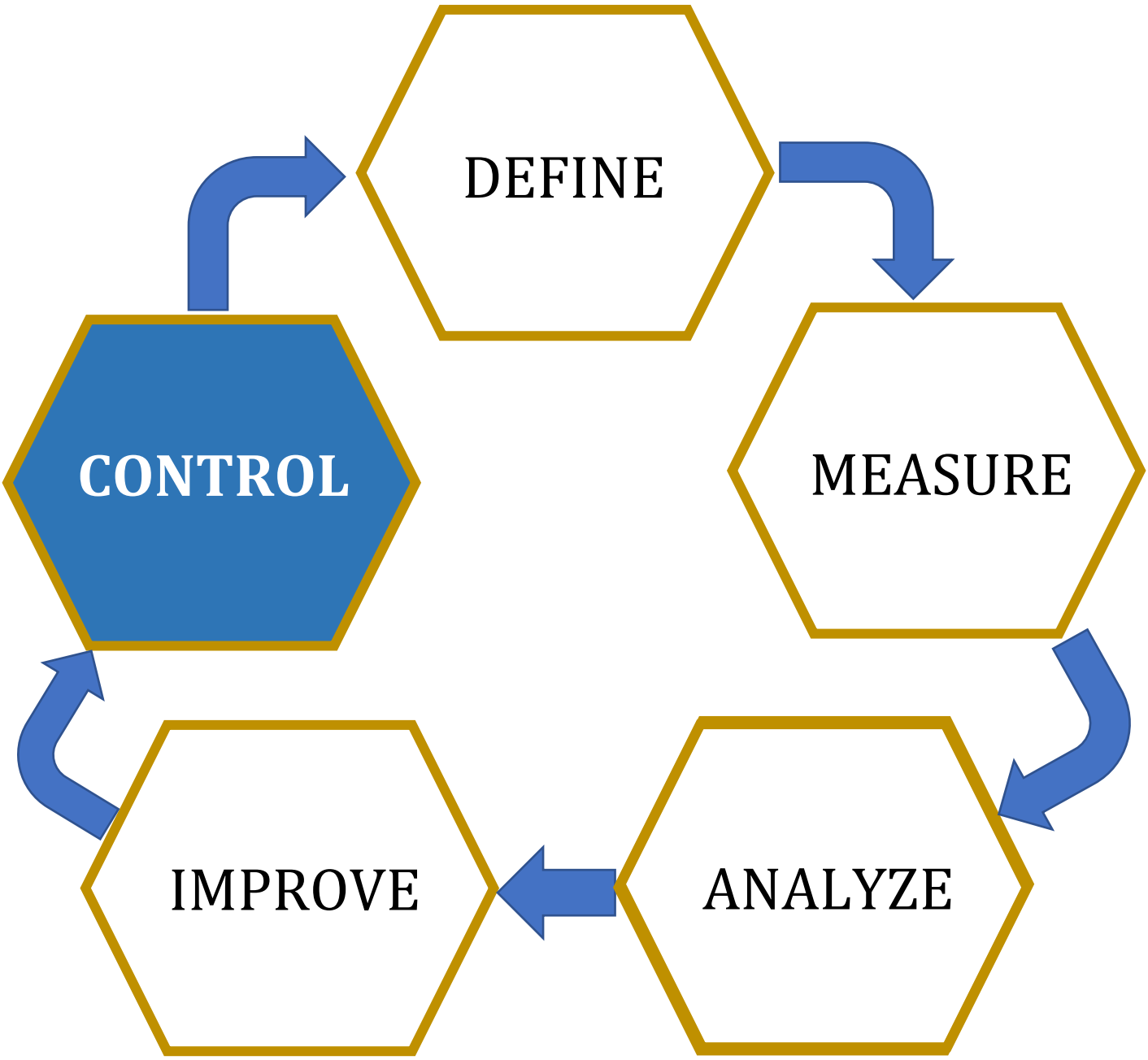
If drawers and cabinets are built simultaneously then having a form of communication between the 2 cells would allow for worker to adjust what they are building in real time.

- Implement Four-Shift software into each production cell for even better communication and tracking –

The company is currently making use of Four Shift software to track the progress of the activities done by the workers. If this were implemented in the cabinet and drawer cells, workers could track exactly what is being built and the progress of an order, along with understand what issues are occurring on the floor

- Apply what we have learned to other parts of the factory –

The various concepts of Lean Six Sigma could be applied to not just the drawer department but also to other departments in the company.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Control Plan

Control Plan				
Process being Measured	***Measurement Method***	***Frequency of Data Collection***	***Who will collect***	***Reaction Plan***
Part Retrieval from roll coat area	Manual Time Measurement	Weekly	Shift Supervisor	Operators need to be re-trained regarding whiteboard system
Set movement to staging area	Manual Time Measurement		Shift Supervisor	Operators need to be re-trained regarding pallet handles and its usage
Attaching Hardware Duration per set	Time Sheet	Daily	Operator	Attention from supervisor
Match Duration per set	Time Sheet		Operator	Attention from supervisor
Build Duration per set	Time Sheet		Operator	Attention from supervisor
Sand Duration per set	Time Sheet		Operator	Attention from supervisor
Number of Reworks	Time Sheet		Operator	Attention from supervisor and higher management needed
Number of drawer scrap	Time Sheet		Operator	Attention from supervisor and higher management needed
Number of glue collections	Time Sheet		Operator	Attention from supervisor
Number of pallet collections	Time Sheet		Operator	Attention from supervisor

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- Sorting –

The excess materials on the side of the drawer cell should be reduced. These parts may be useful in the event of a part failure, however there is no need for the amount there is now. A shelf should be installed in that location to store excess parts, and no more than 10 of each part should be on those shelves. If the number of a single part exceeds 10, it should be scrapped or moved back to inventory, which ever is more cost effective.

- Straightening –

The new pallet handles are quite large and can take up a lot of space if not stored correctly. There should be a dedicated space for the pallet handle, so workers do have to find it. The removal of the excess parts should also allow more space for storing completed drawers, so they are out of the way of the drawer cell workers when they are assembling drawers.

- Shining –

Currently, part of the sanding process is cleaning it off between each set. This is something that should be continued and emphasized as part of the assembly process.

- Standardizing –

Workers should adhere to a standard set of practices that are consistent. The assembly process of a drawer should not vary from worker to worker. The control plan should be followed.

- Sustaining –

Once our solutions have been implemented and proven to work, they should be maintained and monitored at regular intervals. Any new policy that is introduced should be followed.