MEEM 5655 (Spring 2020)

Lean Manufacturing Project Report

Team number 02

Improvement of Paper Car Manufacturing Process Using Lean Tools

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We would like to express our gratitude for giving us the opportunity to accomplish a project on 'Improvement of Paper Car Manufacturing Process Using Lean Tools'. We would especially like to thank our course instructor Dr. Radheshyam Tewari for providing us all the guidance and support whenever required. His invaluable comments, ongoing encouraging and enormous motivation which has helped us optimize our efforts in all stages of the project. Our implementation of processes such as reduction of lead times, cycle times, work standardization, error proofing, kaizen, 5S and various other lean tools were done all because of his teachings and we were successfully able complete our project in our course of MEEM 5655.

Abstract

In lean manufacturing the most crucial part is minimizing waste and increasing productivity by maximizing the utilization of resources. This type of manufacturing is possible by following some basic principles and with the help of lean tools. The most important key principles in lean manufacturing are to identify the value of the customer and the finished product, map the value stream, create a continuous flow, establish a pull system and eliminate quality issues to seek perfection. This project is based on implementing various tools and techniques for improving a car manufacturing process. The main goal of this project was to reduce the cycle time, lead time, work in progress inventory and increase the operator utilization by reducing the operator movement from different stations, by modifying the plant layout or by balancing the assembly line. There was a total of three runs performed and each subsequent trail run has some improvements in the value stream to increase the efficiency of the overall plant. Tools and techniques that were used for this project were implementation of 5S, Value Stream Mapping, Work Standardization, Poka-Yoke (error proofing), Cellular Layout, Kaizen improvements and the use of Kanban (pull) system. By using the above methodologies, it was observed that we were successfully able to balance the assembly line of the factory, have a production rate of finished cars according to the required demand from the customer, reduce the number of operators and by having better utilization of the operators.

Problem Statement

The problem stated was to have a balanced production line in a manufacturing factory to supply a constant demand of 125 cars to the customer per week. The manufacturing production firm consists of a total of 11 different processes. The raw material for the production factory was supplied by Amazon per week. The raw material for the firm consists of the colored A4 size papers, scissors, tape, punching machine and some decorating materials like sketch pens. The requirement of the customer was to have 25 cars which were divided into 5 groups of different colors every day. For the first run it was assumed that every project member must be considered as an operator, so the total of 11 different steps were distributed to six operators. The goal of the project was to improve the car manufacturing process by using the lean tools and techniques. At the end of each run, there were certain norms to ensure the quality of the finished products. For the second run, we made sure that the target takt time is half the cycle time of the slowest process in the entire manufacturing assembly line while for the third run the target takt time is as small as half the cycle time of the fastest process in the assembly line. By improving the process throughout the runs in the project we also set the seal on not changing any of the car design and dimensions and the decoration details. The production planning and control department receives a 30-day forecast from the customer electronically.

Figure 1 Project Model Car

Lean tools and Techniques implemented in the trials

5s - This tool is the base of a visual factory. All the 5S tools contribute towards the foundation of the visual factory. As the name suggests this tool consists of five elements namely Sort (Seiri), Straighten/Stabilize (Seiton), Shine (Seiso), Systematize (Seiketsu), Sustain (Shitsuke).

The Sort (Seiri) step is about sorting through all the items in a targeted area. This step also includes the elimination of the unwanted items that might be present hence reducing the number of items at the workstation.

In the straight (Seiton) step we organized and made place for each and everything and placed the required things in their respective place. Address signboards were made for every equipment used.

The shine (Seiso) step eliminated all the debris, dust that was present at the workstation. We thought of methods to control the accumulation of the debris while making the cars.

The fourth part of the 5S strategy was Systematize (Seiketsu) this step about following the Sort, Straighten and step thoroughly. We standardized all the processes that were set in the previous steps such that we could easily find out the presence of any abnormalities present.

The last step is Sustain (Shitsuke) is all about maintaining and sustaining the above process and following them on a regular basis and we made it a habit to follow all the rules.

Value stream Mapping - We analyzed all the production flow considering both value-added and nonvalue-added activities of the process flow and the material flow as well. This tool helped us immensely in understanding the flow and information flow as the product goes through various processes in the process.

7 types of wastes (Muda) - For the improvement of the processes we needed to eliminate the different types of wastes that are present in the process. The different types of wastes can be categorized as follows

Transportation - The process of transportation is a non-value-added activity hence not paid for by the customers hence must be made as minimum as possible. For this we made the distance between the workstation as small as possible. Hence reducing the transportation time in the process.

Inventory - unnecessary inventory at a workstation is basically a result of overproduction times and imbalanced process. The excess inventory results in increasing the lead time of the process.

Motion - The unnecessary motions that an operator makes to complete a process increases the time required for completing the job. For reducing this time all the processes were made ergonomic considering that the operator can work more efficiently.

Waiting - this another kind of waste that needs to be eliminated from the process. This typically refers to the stagnant state of the product hence increasing the time required for a process.

Overproduction - unnecessarily producing the part without the need of it. We increased the coordination between the co-workers so that there is no excessive production.

Over processing - This Is basically the useless efforts taken to improve the product.

Defects - these kinds of wastes usually directly impact the production time. These wastes are a result of Quality defects, improper parts being fit etc. these might result in reworking of the product or even scrapping the whole part if needed which might cost a lot to the enterprise.

Poka-Yoke - This basically refers to ‘Error proofing’ in a process. We made some Poka-Yoke devices which helped us prevent and resolve some defects that were rising during the production process, hence reducing the need of quality inspection after the process.

Work Standardization - This is a key element in making the process more efficient. This refers to repeating a set of methods again and again while following a standard. This leads to a more organized process and also makes it easier to spot the areas of improvement in the process.

Cellular layout - This type of layout is when all the workstations are grouped together according to the process requirements. This type of layout helps us in improving the processing times, lowering the material handling, reduction of inventory which directly help us in reducing the cost.

Kaizen - This is a tool which tells about continuously improving the process. The idea of continuous improvement is about how small incremental improvements in the process over a period can lead to major improvements to the process in the long run.

Trial 1

Objective

For trial 1 we need to stimulate the paper car manufacturing company as per the given guidelines and the process flow which will help us to draw the Value stream Map for the current state. Using this map, we can find out the total lead time and the cycle time for operations and the total cycle time for a unit Car. Drawing the current state map will also pinpoint the place in the flow for improvement which in turn will reduce the lead time for the Future State Map.

Simulation

According to the information provided for the 1st run we setup the manufacturing layout as a straight line with each operator handling the assigned tasked. The company used to receive a weekly raw material from the supplier AMAZON as per the production control demand. The customer demanded in total of 25 high quality cars of 5 colors (Lunar Blue, Solar Yellow, Terra Green, Cosmic Orange and Fireball Fuchsia) daily with distribution of 5 cars of each color for which the customer used to send a 30-day demand forecast to meet his needs.

Operations

1. **Template**: Draw a T-shaped template with dimensions 1x6 inches vertical and 1x8 inches horizontal.
2. **Cut**: Cut this T-shaped Template using scissors.
3. **Fold**: Fold the template into a box shape having 3 sides.
4. **Tape**: In this operation join the three sides of the box in a car like shape using tape such that it should have a rounded roof.
5. **Wheels**: cut 4 1inch circles from the cardboard which will be used as wheel.
6. **Decorate**: stick the headlights and the windshield and the decals and decorate the car to make it more realistic.
7. **Punch:** punch holes for the axle assemble of the car at the marked location.
8. **Wheel 1 & 2 assembly:** join the wheel 1 and 2 with the toothpicks of the required length as front wheel assembly.
9. **Wheel 3 & 4 assembly:** Assemble the rear wheel assembly using wheel 3 and 4 and toothpick through the punched holes.

The above mentioned 9 operations were distributed among 6 operators(members) and the first run was carried out. The Work distribution as per the process flow was as follows:

Operator 1: Template and Cut

Operator 2: Fold and Tape

Operator 3: Wheels

Operator 4: Decorate

Operator 5: Punch and Wheel 1 & 2 assembly

Operator 6: Wheel 3 & 4 assembly

Processing time calculation for first run is given below with lead time, cycle time, inventory turns, and operators count for each operation.

Table 1 Processing Time for 1st Run

Process	Cycle time	QC Time	Total Cycle Time	Total Time	Lead time (Days)	Operators
Template	128	21	149	242	4.46	1
Cut	78	15	93			
Fold	42	5	47	178	6.07	1
Tape	126	5	131			
Wheels 1	360	10	370	370	2.92	1
Decorate	580	60	640	640	1.67	1
Punch	85	10	95	185	5.84	1
Wheels 2	80	10	90			
Wheels 3	80	10	90	180	6	1
Wheels 4	80	10	90			
Inventory					7	
			Total	1795	33.96	6
			Total Inventory Turns		7	

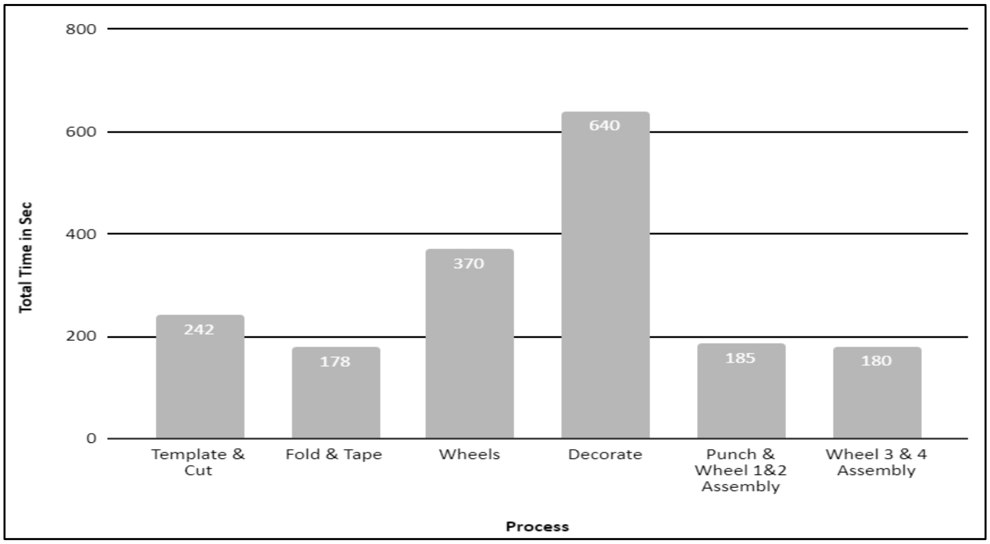


Figure 2 Cycle Time Plot for 1st Run

Sample Calculation

Some Assumptions

Type of system = **push type**

No. of hours per shift = 8 hours with paid break of 30 mins

Therefore,

$$\textbf{Available time} = 7.5 \times 60 \times 60 = \textbf{27000 sec}$$

$$\textbf{Takt Time} = \frac{\text{Total avaliable time Per Shift(sec)}}{\text{demand per day}} = \frac{27000}{25} = \textbf{1080 sec/car}$$

Lead time calculation for **1st operation**

$$\textbf{Lead Time} = \frac{\text{Availble time per day}/\text{cycle time for an operation}}{\text{Demand per day}} = \frac{27000}{242 \times 25}$$

$$= \mathbf{4.46\ days}$$

Value Stream mapping

The main objective of VSM is to present streamlined detailed visualization of the all the steps in work process. It helps in understanding the flow of the material and the information from raw material to the finished good sequentially. Plotting the VSM help to avoid the pilling up of inventory and the elimination of 7 types of waste including the lead time which matters the most. It also helps to understand the cycle time, changeover time, machine efficiency for every step and the takt time i.e., the required time for each product to be manufactured to meet the customer demands.

After doing the as-is run in the straight-line layout with six operators in a push type fashion we understood that we need to meet the demand of 25 cars every day with takt time of 1080 sec for each car. To meet the uncertainties in the delivery of raw material by the supplier we kept an inventory of 7 days at start of the process. The customer demanded a daily shipment of 25 cars by train to meet such demand we made the daily priority list which the production planning would provide to each station separately. After demonstrating 1st run and making the actual paper according to our layout we found out the cycle time for each process which are mentioned in the table above. Time for quality check at each process was allotted to keep in check the quality of the product. On the bases of the total cycle time for each process and the demand we found out the lead times between each process. The VSM below depicts all the times and the process flow.

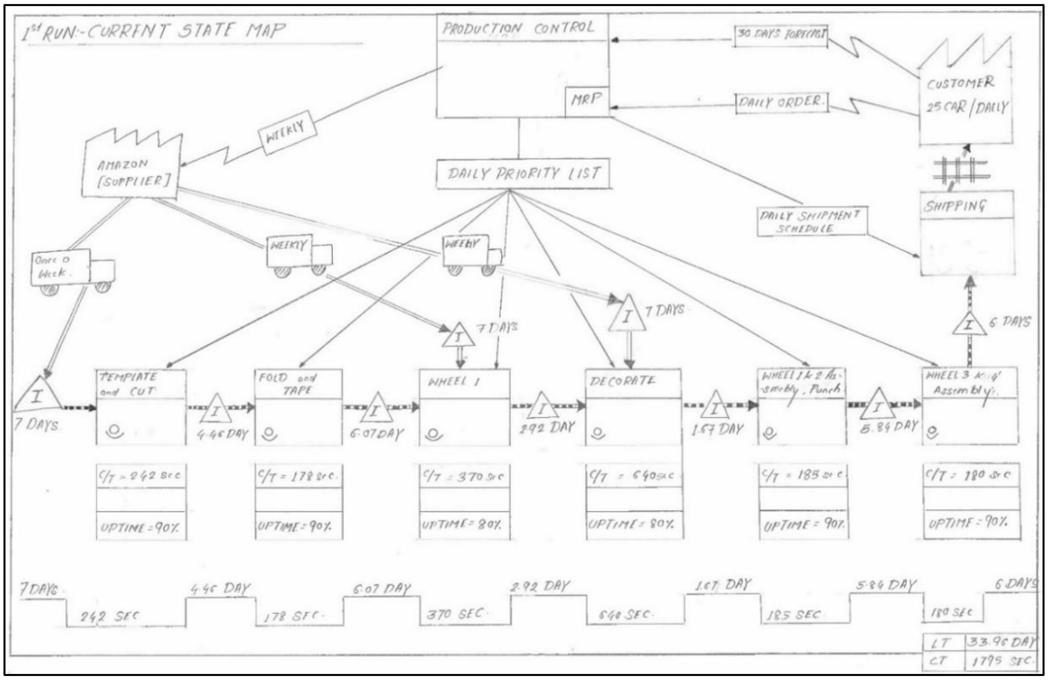


Figure 3 Current State Map for 1st Run

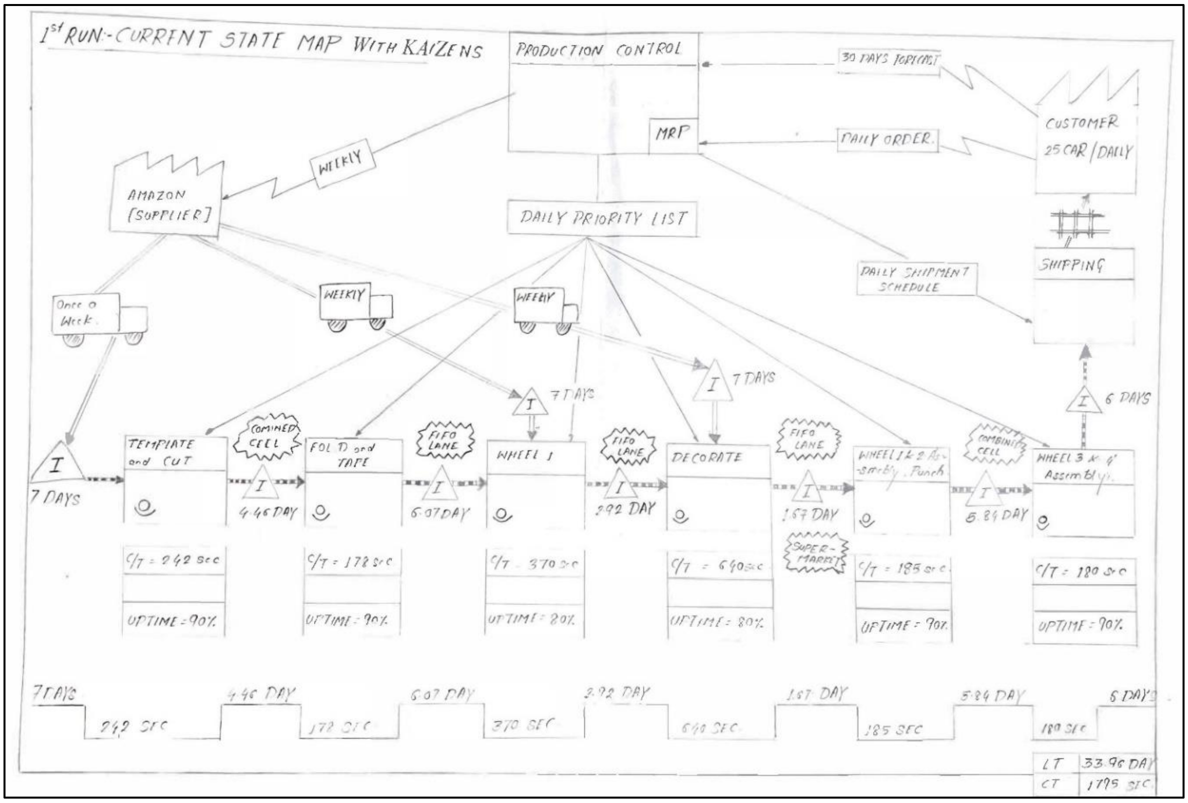


Figure 4 Current State Map for 1st Run with Kaizens

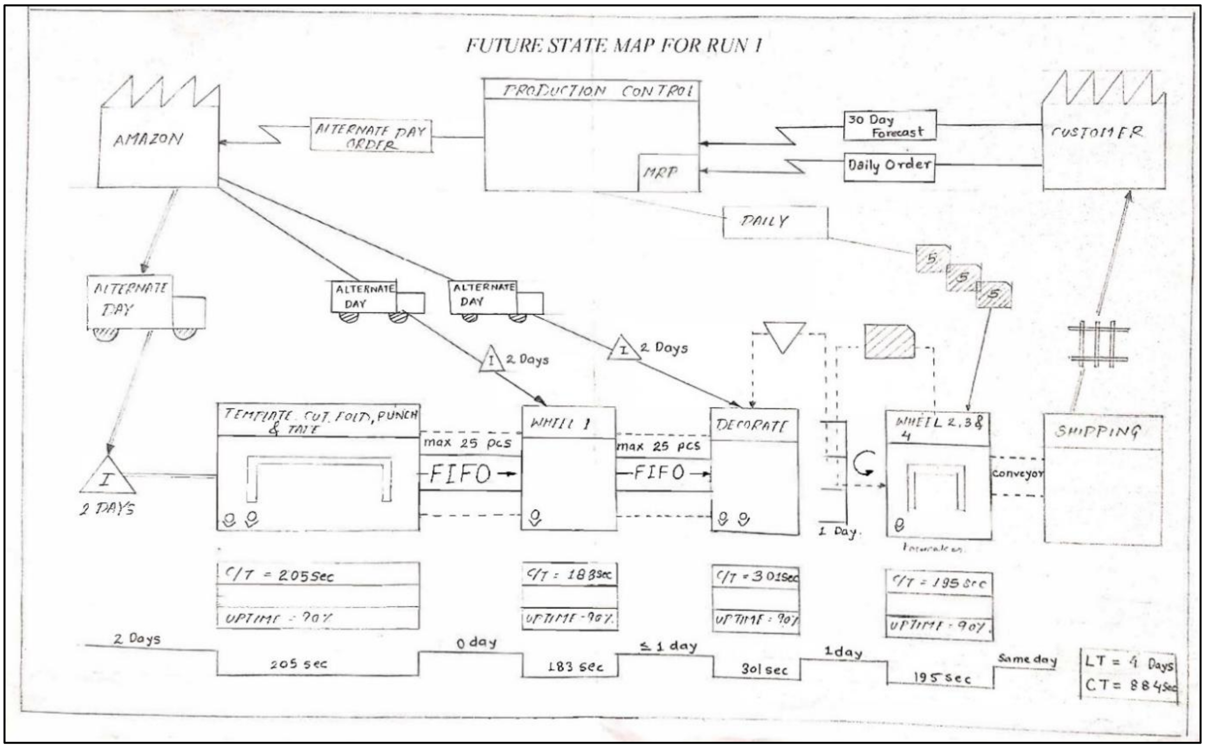
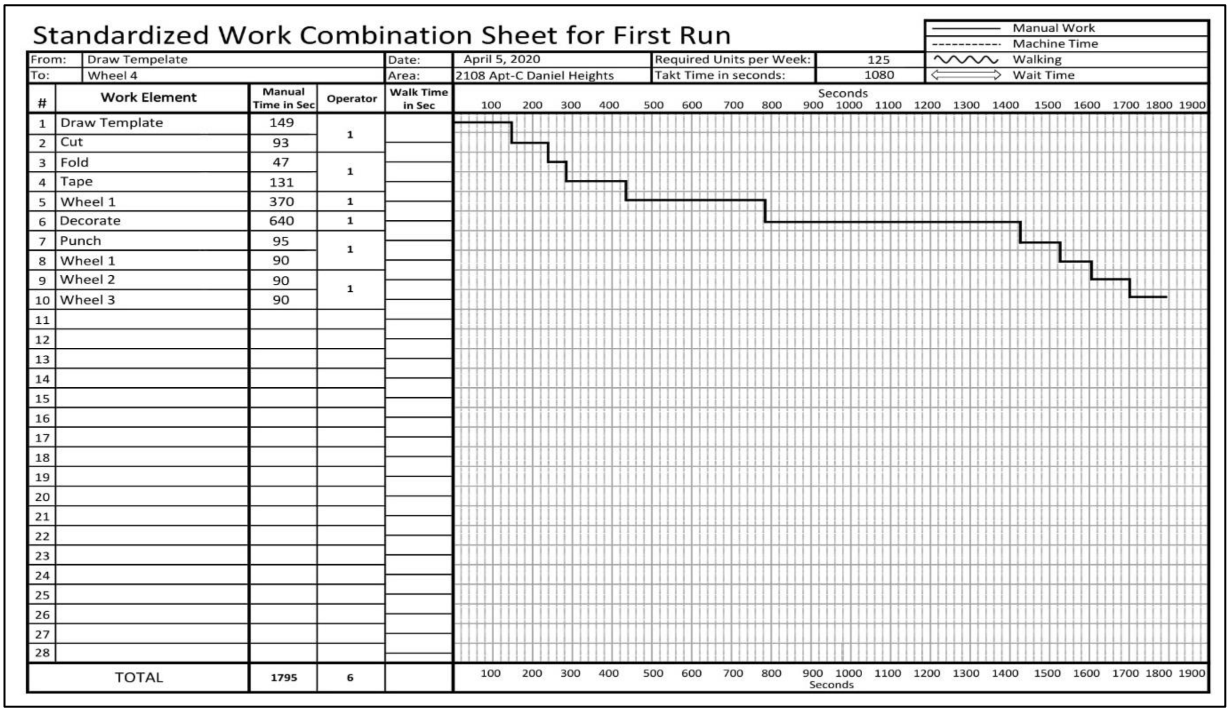


Figure 5 Future State Map for 1st Run

Standardized work combination sheet



Standardized Work Combination Sheet for First Run

From:	Draw Tempelate	Date:	April 5, 2020	Required Units per Week:	125
To:	Wheel 4	Area:	2108 Apt-C Daniel Heights	Takt Time in seconds:	1080

#	Work Element	Manual Time in Sec	Operator	Walk Time in Sec
1	Draw Template	149	1	
2	Cut	93		
3	Fold	47	1	
4	Tape	131		
5	Wheel 1	370	1	
6	Decorate	640	1	
7	Punch	95	1	
8	Wheel 1	90		
9	Wheel 2	90	1	
10	Wheel 3	90		
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
TOTAL		1795	6	

Figure 6 Standardized Work Combination Sheet for 1st Run

Standardized work combination sheet provides the total time taken by all operators to manufacture a single paper car. It is represented by a series of thick lines in the stepwise pattern. The time shown include the cycle time and the quality control time and the time required to move to product forward in the process. As the processes as set in a close vicinity of one another there is no handling time between the process. From the above chart we can notice that the decoration process is the most time consuming with the time of 640 sec in the overall process and the cut process is the fastest with the time of 93 sec.

Trial 2

As we discussed in previous trial, basic run of car manufacturing was processed with six operators performing specific amount of task at each workstation separately. After calculating lead time, cycle time, inventory, and takt time we found some room for improvement in order to reduce lead time and inventory. We have implemented following improvements for our trial 2:

Improvements

1) We have clubbed template, cut, fold, tape, and punch in our second run which is performed by 2 operators. We are using T-shaped template as shown in figure 7 below which has punching locations at measured locations as per distance between two wheels of car.

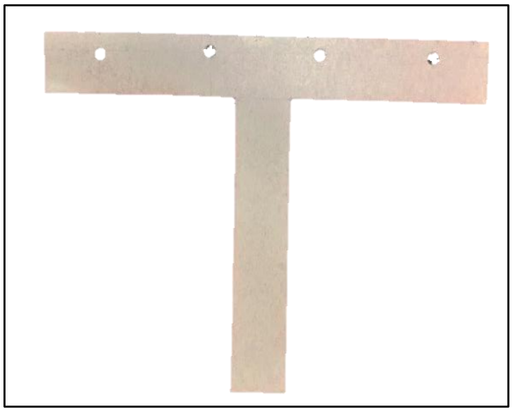


Figure 7 T-Shaped Template with Punching

2) The operation wheel 2, 3, and 4 is combined and one operator is appointed for this task.
3) The cycle time of operation one is greater than operation two every part is consumed as per first in first out basis hence, FIFO line is used between operation station one and two.
4) We have also implemented FIFO line between operation 2 and 3 which is justified below, In this case inventory of 0.19 day is building as per calculation below:

$$\frac{(301\times125)-(183\times125)}{301} = \frac{14750}{301} = 49.0033$$

As inventory buildup gradually between operation 2 and 3, with minimum inventory of 0 and maximum inventory of 49 thus we must take average,

$$\frac{49.0033}{2} = 24.50$$

Therefore, we can have FIFO line with maximum capacity up 25 pieces between operation 2 and 3.

$$\frac{24.50}{125} = 0.19 \text{ days} \approx \leq 1$$

5) Another improvement in our second run was placing supermarket between operation 3 and 4 which is easily justifiable from cycle time of these two operations. Operation 3 has total cycle time of 301 sec whereas operation 4 has 195 sec, thus it’s good to have supermarket with 1-day inventory.

Above mentioned five improvements were distributed among 6 operators and second run was carried out. The work distribution for this run was as follows:

Operator 1 & 2: Template, Cut, Fold, Tape, Punch

Operator 3: Wheel 1

Operator 4 & 5: Decorate

Operate 6: Wheel 2, 3, and 4

Processing time calculation for first run is given below with lead time, cycle time, inventory turns, and operators count for each operation.

Table 2 Processing Time for 2nd Run

Process	**Cycle time**	**QC Time**	**Total Cycle Time**	**Lead time (Days)**	**Operators**
Template	170	35	205	0	2
Cut					
Fold					
Tape					
Punch					
Wheels 1	163	20	183	0	1
Decorate	271	30	301	≤1	2
Wheels 2	180	15	195	≤1	1
Wheels 3					
Wheels 4					
Inventory				2	
		Total	884	4	6
		Total Inventory Turns		60	

If we compare total cycle times of second run with first, we can say that due to uneven distribution of workers the operator who was performing decoration must work for more time than rest of the workers. Hence, we decided to allot two workers for that operation in this run. We can justify same for first operation as well. After running second run we observed following change in lead time, cycle time and takt time:

Takt time: As per project guidelines, we must take takt equal to the half of highest cycle time from our first run. From our first run we can observe that 640 is the highest time for operation decorate. Hence takt time of 320 seconds is target for second run. If we observe above table, we can note that no operation has cycle time more than 320 seconds. According to project guidelines, half of lowest cycle time which is 183 seconds for wheel 1 operation would be target for next run.

Inventory: In second run, as production is going on first in first out basis most of the inventory has reduced. Also due to the clubbing of processes like template, cut, fold, tape, punch inventory in those two operations eliminated. Between operation 3 and 4 we are placing supermarket in which withdrawal Kanban is used which further reduced our inventory.

Lead time: Due to implementation of various improvements mentioned above, Lead time for second run reduced from 33.96 to 4 days. Total inventory turns is also significantly changed from 7 to 60.

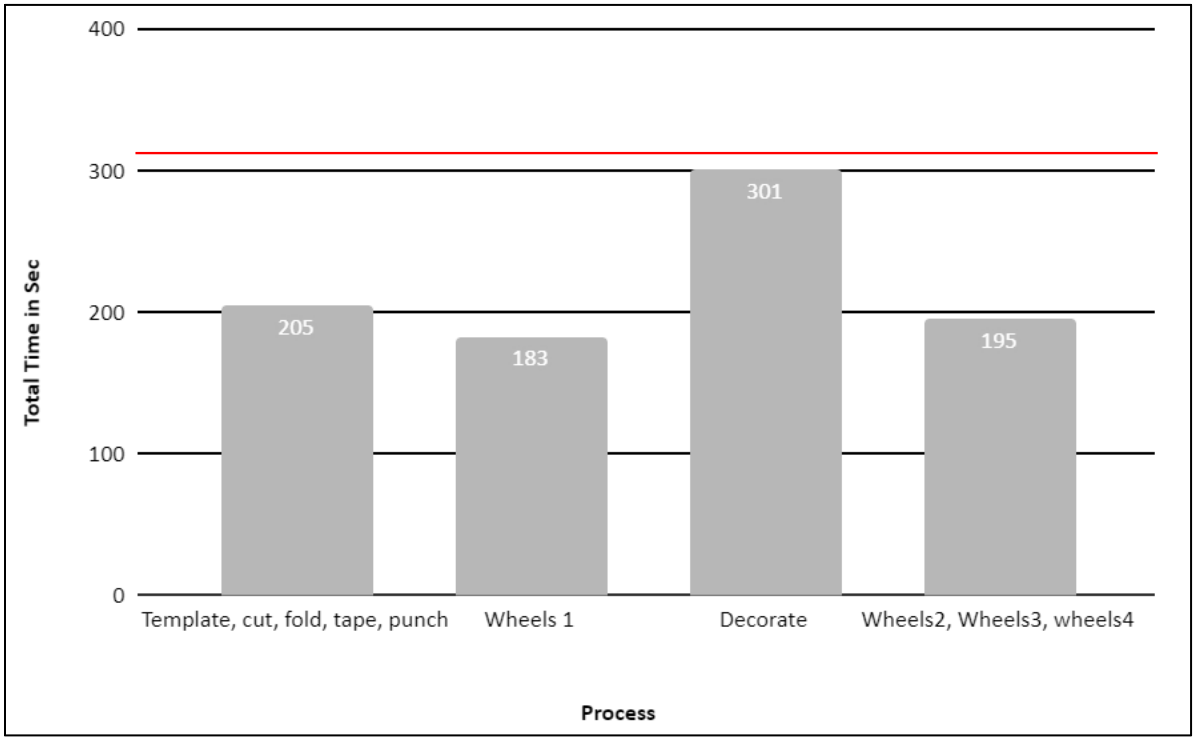


Figure 8 Cycle Time Plot for 2nd Run

Value Stream Mapping

In our second run due to the application of various improvement justified above lead time is we noticed significant change in lead and cycle time. At operation 4 we can notice that wheel 2,3, and 4 is clubbed together where Kanban schedules are arriving in batch of 5. Also because of the supermarket it's easy to cope with sudden surge in demand from customers. As we know pacemaker process is generally most downstream operation in any facility from where you can manage all the upstream processes in that value stream, hence we have decided to make our operation 4 i.e. wheel 2, 3, and 4 as our pacemaker process.

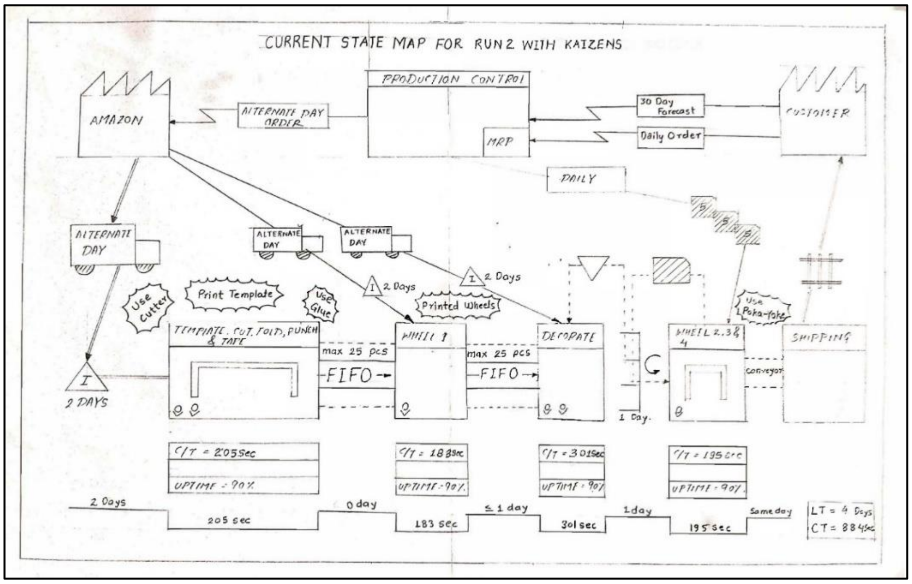


Figure 9 Current State Map for 2nd Run with Kaizens

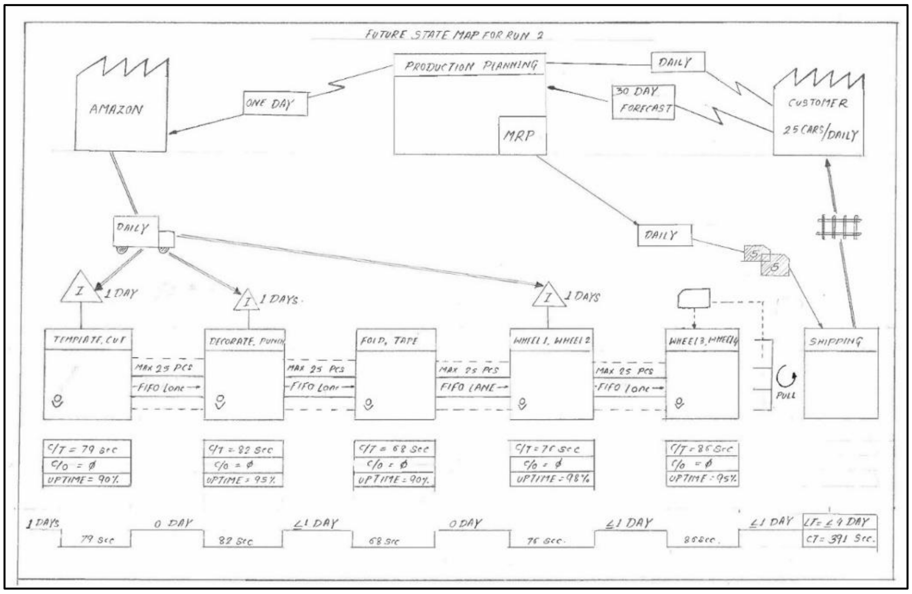
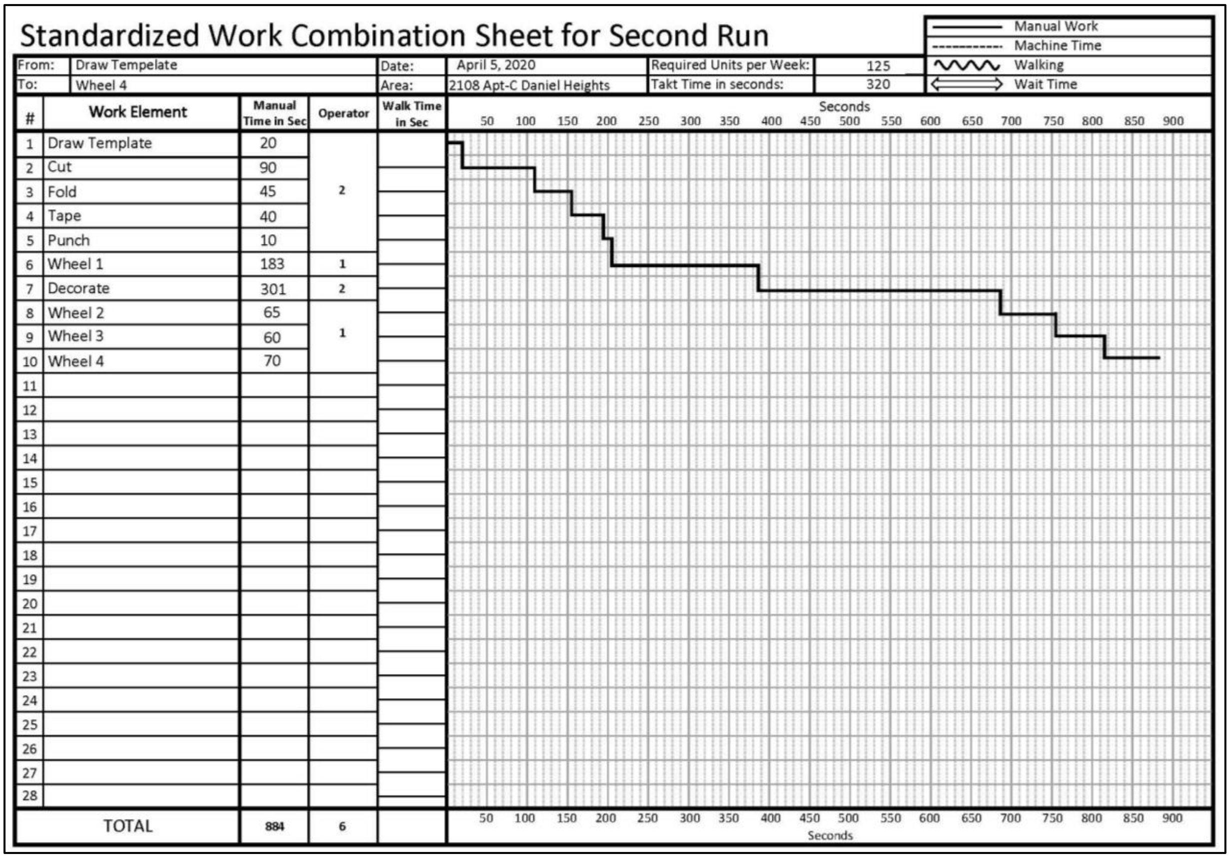


Figure 10 Future State Map for 2nd Run

Standardized work combination sheet

As we know we have combined first two operation along with punching operation in our second run, the revised time distribution can be seen in standardized work combination sheet. From chart shown below we can notice that the decoration process is the most time consuming with the time of 301 seconds in the overall processes and the punch process is the fastest with the time of 10 seconds.



Standardized Work Combination Sheet for Second Run

From: Draw Tempelate
To: Wheel 4
Date: April 5, 2020
Area: 2108 Apt-C Daniel Heights
Required Units per Week: 125
Takt Time in seconds: 320

#	Work Element	Manual Time in Sec	Operator	Walk Time in Sec
1	Draw Template	20	2	
2	Cut	90		
3	Fold	45		
4	Tape	40		
5	Punch	10		
6	Wheel 1	183	1	
7	Decorate	301	2	
8	Wheel 2	65	1	
9	Wheel 3	60		
10	Wheel 4	70		
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
TOTAL		884	6	

Figure 11 Standardized Work Combination Sheet for 2nd Run

Trial 3

In the second run we have achieved a good improvement in the total cycle time and lead time as well as individual cycle times are below the takt time. Thus, the load was distributed properly to the operators. For the third we must assume that the target time could be as small as half the fastest process of second run. Thus, we decided to take the target time half of fastest process which was the Wheels 1 process. So, our target takt time is 91.5 sec.

Improvements

To bring the individual process cycle time below the target takt time we brainstormed various ideas and selected few ideas for improvement and implemented them. The following improvements were done in the third run:

1. Instead of using a templet to draw the T-shape, we have decided to get a raw material with the design on the raw material paper itself as shown in figure 12. We have two T-shapes in on the one paper and thus reducing waste and space required to store the inventory.

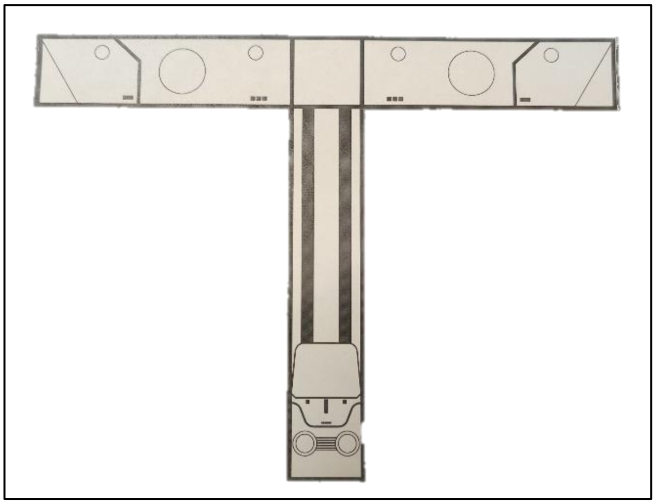


Figure 12 Template Print

2. We have also included location for punch, windshield, decal and headlights. Thus, standardizing the process and reducing the time required for sticking it in exact location.
3. Performing the decorate step before the fold and tape step. This provides ease for sticking the windshield, decal and headlight on the car and significantly reducing the time required for the decorate operation.

4. For cutting in the Template and Wheels1 process we used cutter instead of scissor which reduced the operation time and increase quality of cut.
5. For the tape process we used glue instead of tape.
6. We error-proofed the cutting of toothpick operation in the wheels 2 process by making a jig that will only allow the required length of toothpick to slide in and the excess is trimmed as shown in figure 13. This reduce the time required for marking every toothpick.

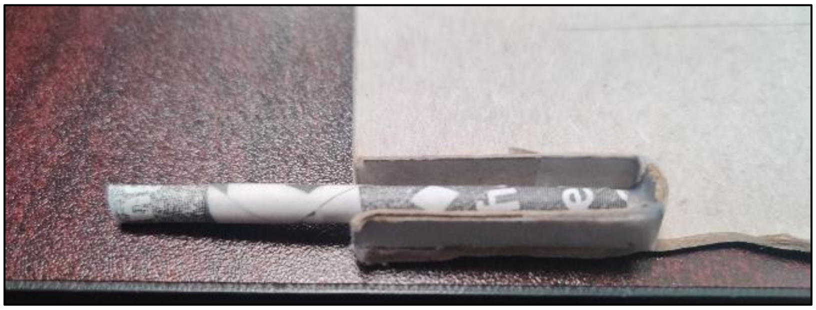


Figure 13 Poka-Yoke for Wheel Axel

Cycle Time and Line Balancing

All these improvements reduce the individual cycle time of the process by significant amount. The cycle time are shown in the table 3. The table is in different color scheme which shows which processes are combined. The Template-Cut, Decorate-Punch, Fold-Tape, Wheels1- Wheels 2, and Wheels 3-Wheels 4 are combined having of total 5 operating stations with five operators, one at each station. Thus, the total number of operators is five. We have reduced the number of operators from 6 to 5. The layout used is a U-shaped layout as it provides benefits such as improved communication and visual management and reduces non-value adding activities. The lead times are also shown in the table 3. Where the upline process is fast than the downline process, an inventory will build up gradually and where the upline process is slow than the downline process there will be no inventory and the downline process will consume all the parts built by the upline process. Thus, there will be an inventory built between station 1 and station 2, station 3 and station 4, and station 4 and station 5.

Table 3 Processing Time for 3rd Run

Process	Cycle time	QC Time	Total Cycle Time	Lead time (Days)	Operators
Template	69	10	79	0	1
Cut					
Decorate	72	10	82	≤1	1
Punch					
Fold	58	10	68	0	1
Tape					
Wheels 1	66	10	76	≤1	1
Wheels 2					
Wheels 3	76	10	86	≤1	1
Wheels 4					
Inventory				1	
		Total	391	≤4	5
		Total Inventory Turns		60	

Thus, we have calculated the inventory as shown below:

For station 1 and station 2 -

$$\frac{(82\times125)-(79\times125)}{82} = \frac{375}{82} = 4.57$$

As inventory buildup gradually with minimum inventory of 0 and maximum inventory of 4.57. Thus, taking average,

$$\frac{4.57}{2} = 2.28$$

To find the inventory in days,

$$\frac{2.28}{125} = 0.018 \text{ days} \approx \leq 1$$

Similarly, we can do for all the stations where inventory is built up. The table also shows the total inventory turns which is 60 days. Also, from the cycle time chart we can see that the individual process cycle time is below the target time of 91.5 sec. Also, we can see that the work is balanced between the operators as shown in figure 14. The operator at the station 3 (Fold-Tape process) is underutilized. We can further improve the process and reduce the number of operators.

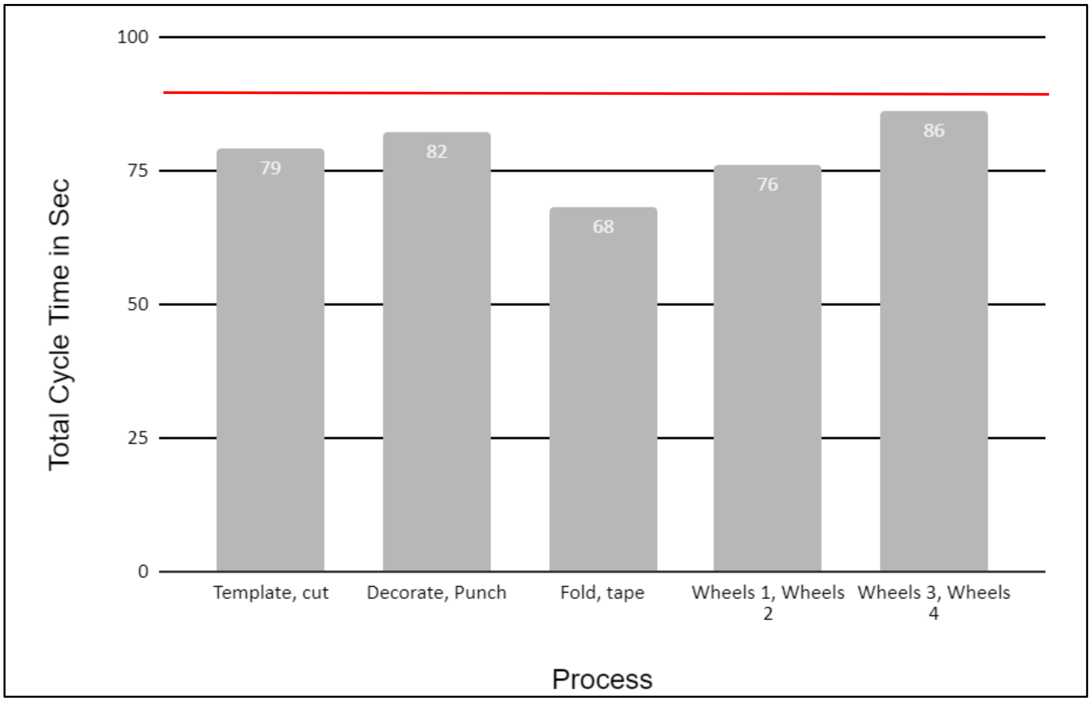


Figure 14 Cycle Time Plot for 3rd Run

Operator 1: Template and Cut

Operator 2: Decorate and Punch

Operator 3: Fold and Tape

Operator 4: Wheels 1 and Wheel 2

Operator 5: Wheels 3 and Wheels 4

For the improvements we have decided to set the target time to be 50% of the fastest process in the third run. Thus, the target time for further improvement is 34 sec.

Value Stream Mapping

From the value stream map below we can see that the production planning department is sending daily order to the supplier (Amazon) and the supplier is also delivering the order daily. We are taking the benefit of the Amazons one day delivery scheme. This has reduced the raw material inventory lead time. Then we have implemented FIFO line between all the stations. As we have different color cars and there is not much difference in the cycle time, implementing FIFO line was the best choice. There is some work in process inventory built up, but that inventory is negligible and can be easily handled by the FIFO line of capacity 25 parts. We have implemented a supermarket between the last station and the shipping department and the daily order from the

MRP is sent to the shipping. This way the shipping will create a pull of the daily requirement and a production Kanban will be sent to the station 5 and the parts that are replenished will be produced.

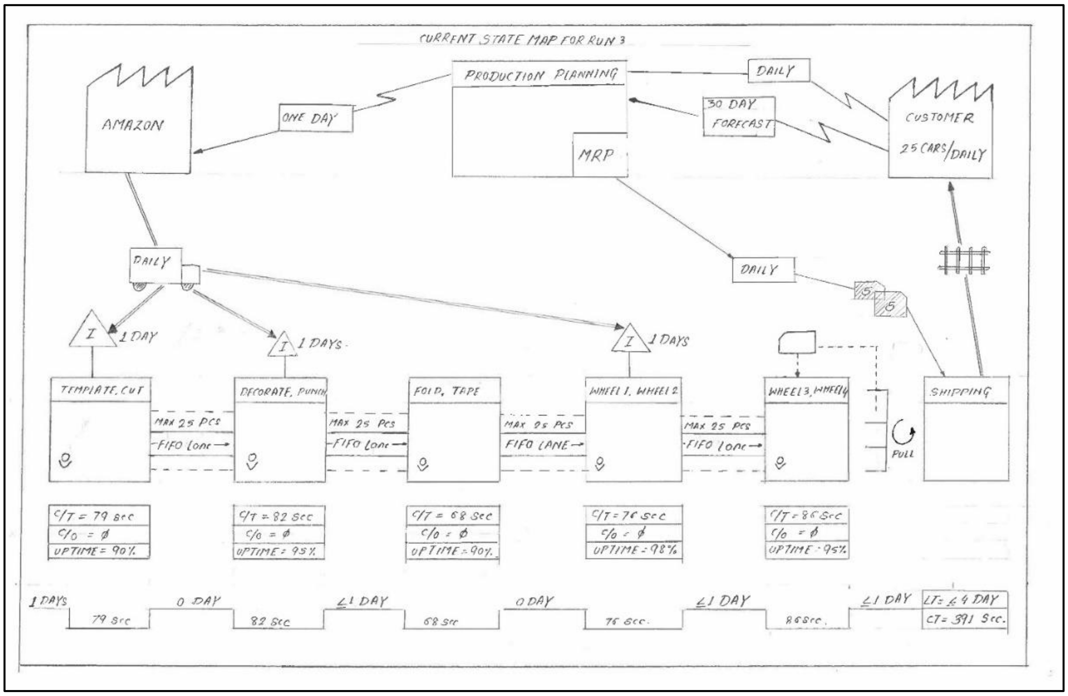


Figure 15 Current State Map for 3rd Run

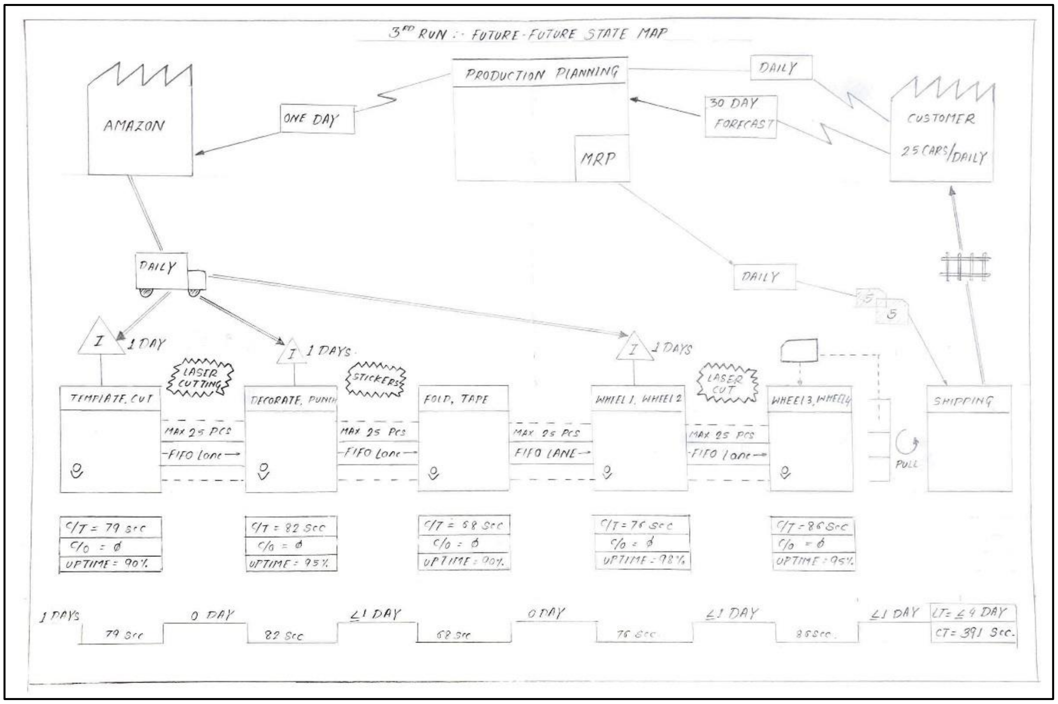
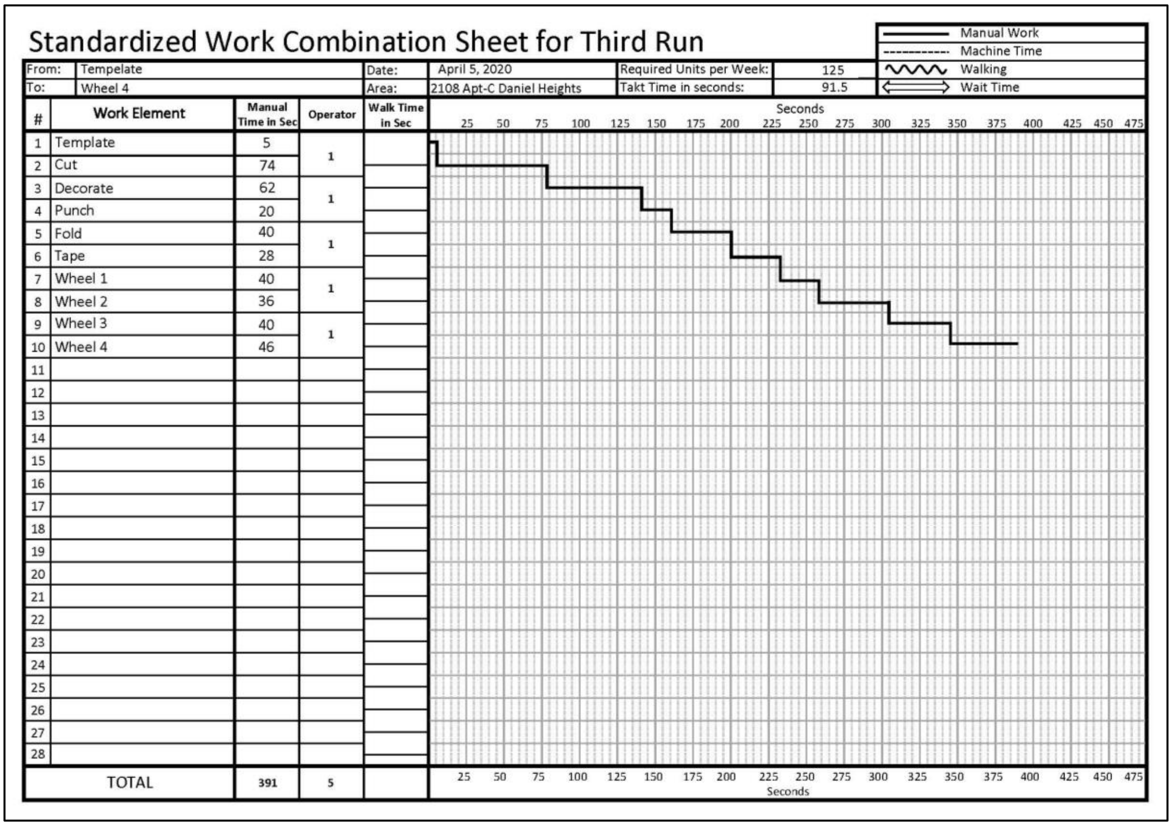


Figure 16 Future State Map for 3rd Run with Kaizens

Standardized Work Combination Sheet

From the standardized work combination sheet, we can see the time required for each process. The time required for cut process is the longest which is 74 sec and for the decorate process it is 62 sec. So, we can further improve these processes to reduce the cycle time.



Standardized Work Combination Sheet for Third Run

From:	Tempelate	Date:	April 5, 2020	Required Units per Week:	125
To:	Wheel 4	Area:	2108 Apt-C Daniel Heights	Takt Time in seconds:	91.5

#	Work Element	Manual Time in Sec	Operator	Walk Time in Sec
1	Template	5	1	
2	Cut	74		
3	Decorate	62	1	
4	Punch	20		
5	Fold	40	1	
6	Tape	28		
7	Wheel 1	40	1	
8	Wheel 2	36		
9	Wheel 3	40	1	
10	Wheel 4	46		
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
TOTAL		391	5	

Figure 17 Standardized Work Combination Sheet for 3rd Run

Conclusion

We successfully completed 3 runs of paper car manufacturing process and we were successful in the implementation of lean tools like 5S, Workspace organization, Work Standardization, Line Balancing, Value Stream Mapping, Poka Yoke, Continuous flow (FIFO Lane) which helped us in reducing Inventory, Cycle time, Lead Time and Defect Rate.

We were able to attain a lowest cycle time of 391 secs with 5 operators, also we implemented the U-Shaped Cell line for our assembly. For our last run we targeted a takt time of 91.5 sec and we were able to bring down the time required by each operator and station below it. We also decided that we would be having a supermarket before the shipping department and when the schedule is sent to the shipping department and the delivery of cars is made it will create a pull in the upstream processes.

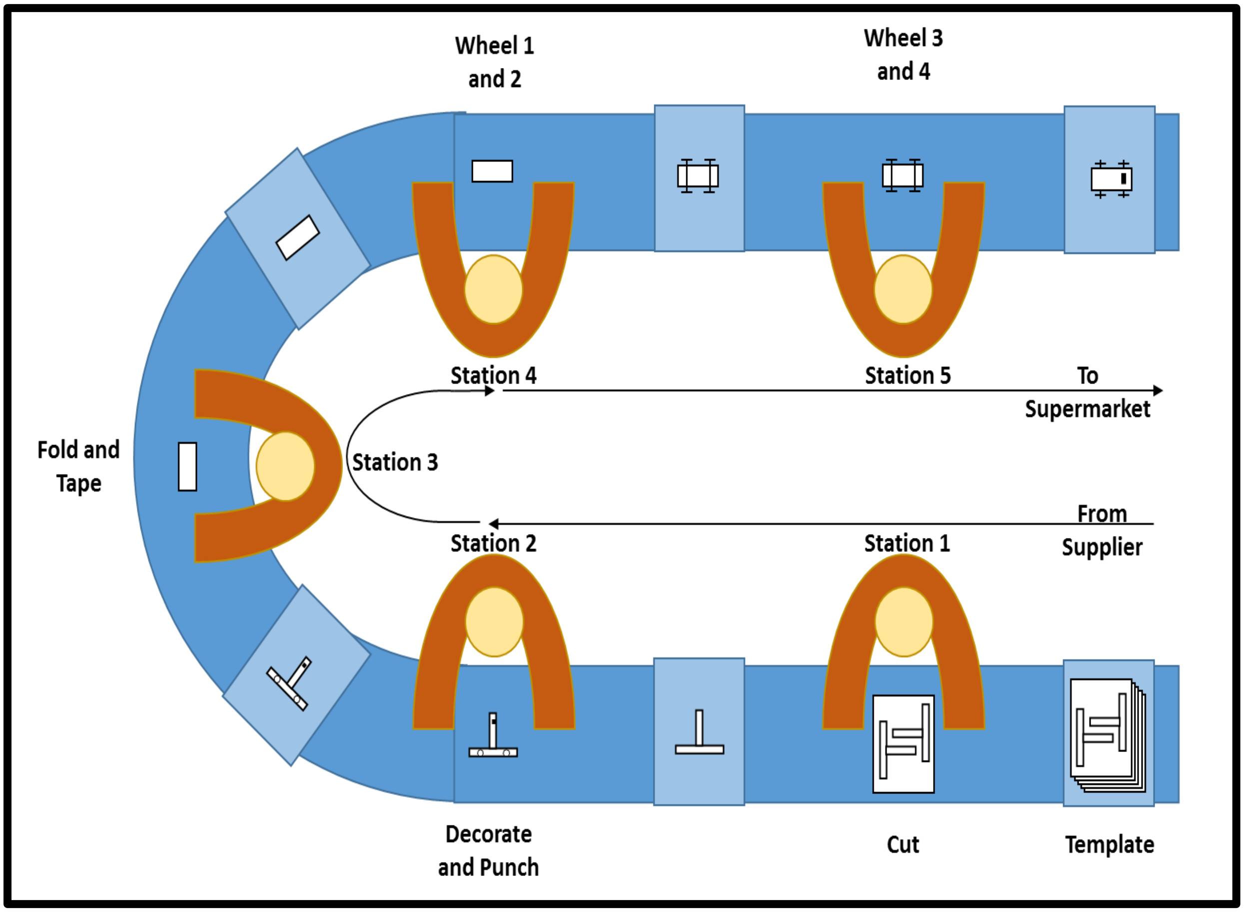
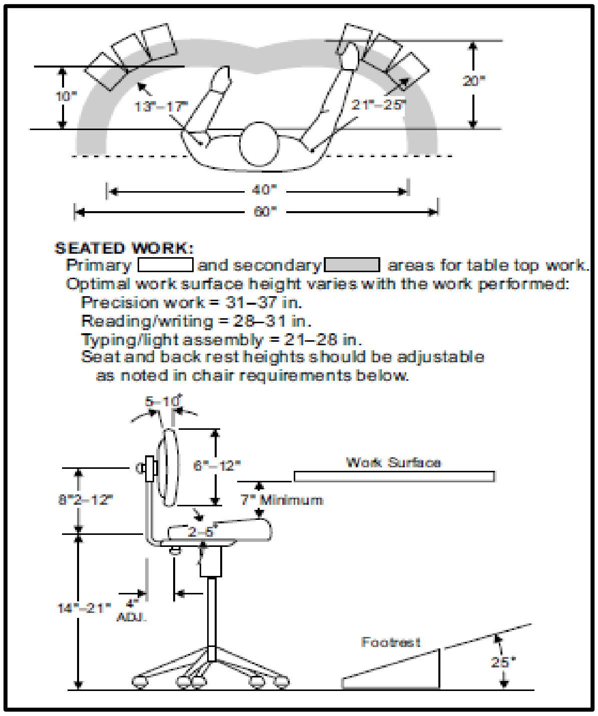


Figure 18 U-Shaped Layout

We have also considered the ergonomic for designing the workstation for the seated work. The following standards were adapted according to the UAW-GM [1990] (Madison Heights, Michigan: Center for Health & Safety).

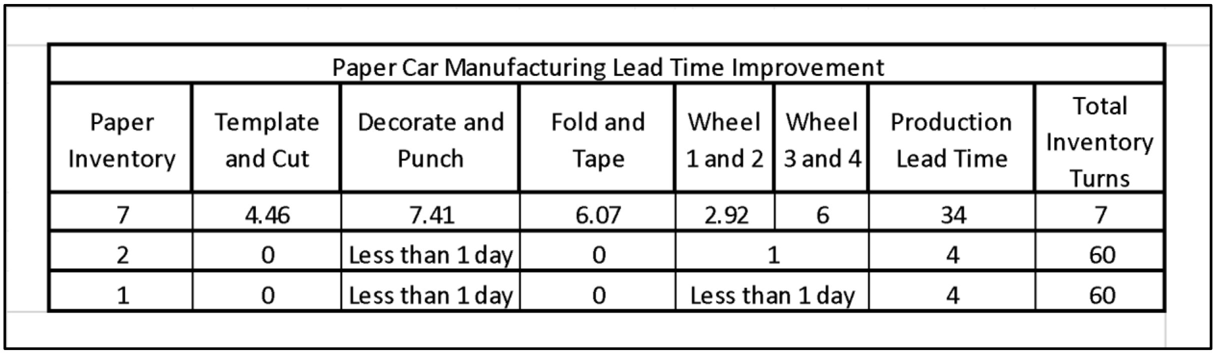


SEATED WORK:
Primary ☐ and secondary ▨ areas for table top work.
Optimal work surface height varies with the work performed:
Precision work = 31–37 in.
Reading/writing = 28–31 in.
Typing/light assembly = 21–28 in.
Seat and back rest heights should be adjustable as noted in chair requirements below.

Figure 19 Ergonomic Consideration [2]

We also considered the safety aspect during the manufacturing of the Paper car like we used proper precautions while using paper cutter.

Table 4 Paper Car Manufacturing Lead Time Improvement



Paper Car Manufacturing Lead Time Improvement							
Paper Inventory	Template and Cut	Decorate and Punch	Fold and Tape	Wheel 1 and 2	Wheel 3 and 4	Production Lead Time	Total Inventory Turns
7	4.46	7.41	6.07	2.92	6	34	7
2	0	Less than 1 day	0	1		4	60
1	0	Less than 1 day	0	Less than 1 day		4	60

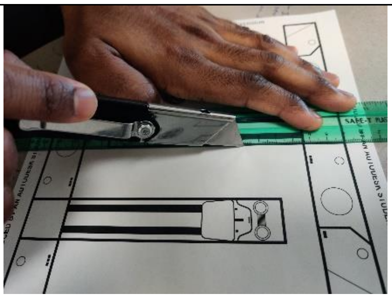
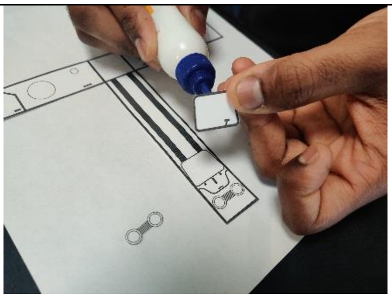
References

[1] M. Rother and J. Shook, Learning to see: value-stream mapping to create value and eliminate muda ; a lean tool kit method and workbook. Cambridge, MA: The Lean Enterprise Institute, 2009.

[2] L. Cohen, *Elements of ergonomics programs: a primer based on workplace evaluations of musculoskeletal disorders*. Cincinnati, OH: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 1997.

Appendix

Table 5 Paper Car Manufacturing Process Steps of Final Run

Station No.	Process	Photo
1	Template, Cut	
2	Decorate, Punch	 
3	Fold, Tape	

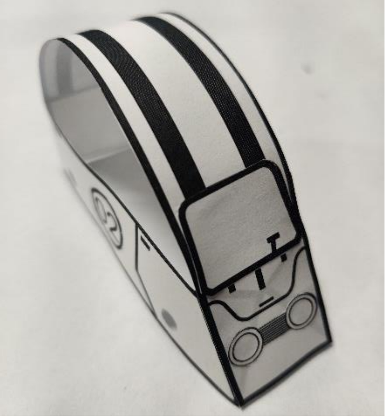
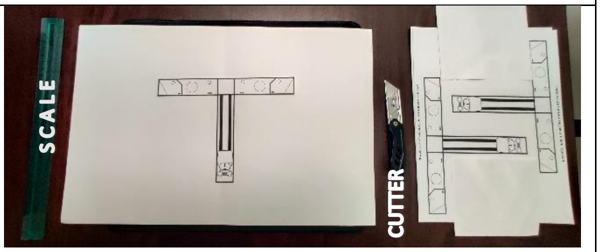
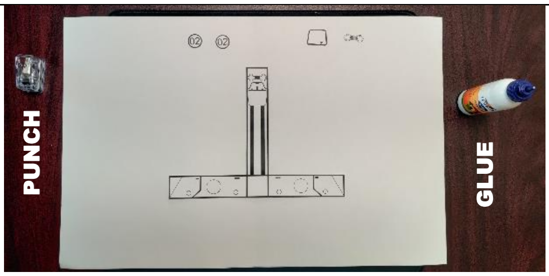
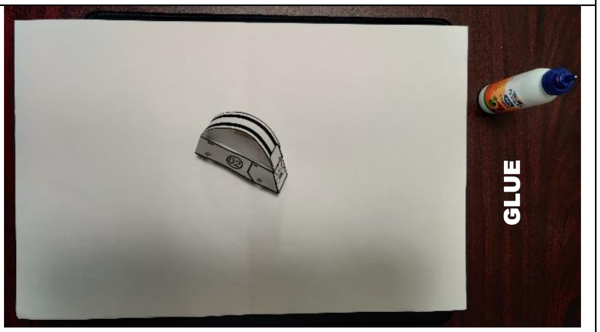
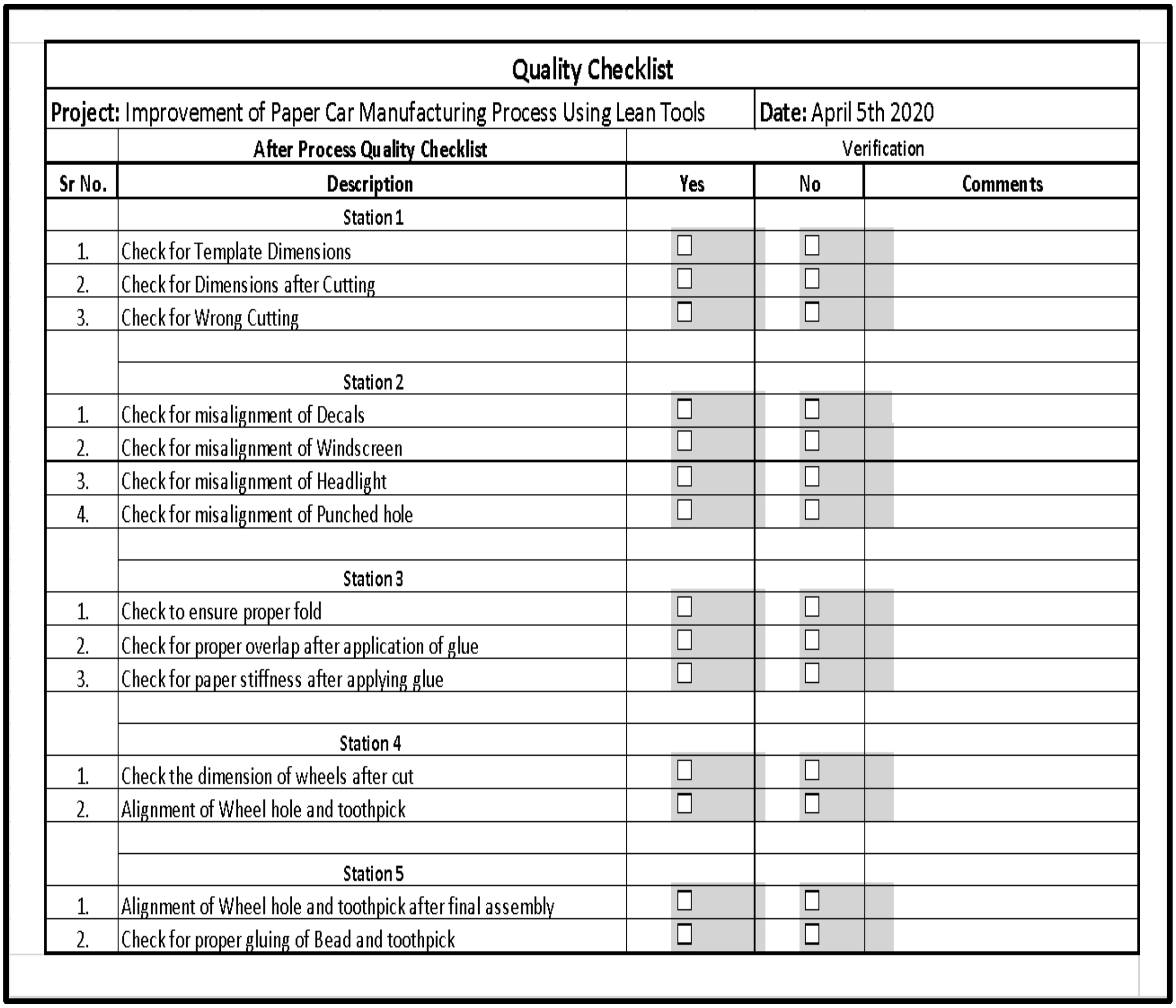
		
4	Wheels 1, Wheels 2	
5	Wheels 3, Wheels 4	

Table 6 Paper Car Manufacturing Process Final Workstations

Station No.	Process	Photo
1	Template, Cut	
2	Decorate, Punch	
3	Fold, Tape	
4	Wheels1, Wheels 2	

5	Wheels 3, Wheels 4	  

Table 7 Quality Checklist



Quality Checklist

Project: Improvement of Paper Car Manufacturing Process Using Lean Tools **Date:** April 5th 2020

	After Process Quality Checklist	Verification		
Sr No.	**Description**	**Yes**	**No**	**Comments**
	Station 1			
1.	Check for Template Dimensions	☐	☐	
2.	Check for Dimensions after Cutting	☐	☐	
3.	Check for Wrong Cutting	☐	☐	
	Station 2			
1.	Check for misalignment of Decals	☐	☐	
2.	Check for misalignment of Windscreen	☐	☐	
3.	Check for misalignment of Headlight	☐	☐	
4.	Check for misalignment of Punched hole	☐	☐	
	Station 3			
1.	Check to ensure proper fold	☐	☐	
2.	Check for proper overlap after application of glue	☐	☐	
3.	Check for paper stiffness after applying glue	☐	☐	
	Station 4			
1.	Check the dimension of wheels after cut	☐	☐	
2.	Alignment of Wheel hole and toothpick	☐	☐	
	Station 5			
1.	Alignment of Wheel hole and toothpick after final assembly	☐	☐	
2.	Check for proper gluing of Bead and toothpick	☐	☐	