Production Sequencing in a Fifth Wheel Industry: Case Study

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***Abstract*—Fifth wheel is a type of hitch mounted in the bed of a truck. Fifth wheel coupling provides the link between a trailer and the towing truck. Lean methodology is applied to handle production sequencing at fifth wheel industry. Due to high variation of final products and non-constant demand, there is no specific methodology to determine the quantity of production and its order. This results into overproduction and high number of inventory between welding and assembly, and also finished product. We propose a sequencing algorithm between painting and welding area that helps to reduce inventory and movements between welding and assembly. An evaluation is made on the feasibility of coordinating welding production and painting of parts in sequence. The simulation of current and future state indicates shorter lead time and lower work in process.**

Keywords—Fifth wheel; sequencing; variation; production plan

I. INTRODUCTION

Fifth wheel is a horseshoe-shaped coupling device located on rear end of the towing vehicle. The fifth wheel coupling provides the link between a trailer and the towing truck, leading trailer. The surface of the trailer rotates against the surface of the fixed fifth wheel which does not rotate. An analysis was performed for the operations at the JOST International facility in Greeneville, Tennessee. JOST has been manufacturing fifth wheel coupling devices to the heavy duty truck and trailer industries since 1956 and they began manufacturing for the North America market at their Greeneville, Tennessee facility since 2000.

The objective of this analysis is to propose a sequencing algorithm between painting and welding area that helps to reducing inventory and movements between welding and assembly. We made an evaluation on the feasibility of coordinating welding production and painting of parts in sequence.

Due to high variation of final products and non-constant demand, there is no specific methodology to determine the quantity of production and its order. This results into overproduction and high number of inventory between welding and assembly, and also finished product. Also, the concern for safety in an area as critical as the automobile industry may outweigh the economic benefits of using recycled equipment [2]. Sawhney et al. studied the effect of variation at different stations of a manufacturing process [3]. Liability is of equal concern as the remanufacturing companies are generally smaller in scale than the original equipment manufacturers (OEMs) and may not be able to absorb the financial setback from recalls [2]. We found a lack in welding production and painting of parts which may be due to the variation of demand that forces to produce every day and not in optimum quantities, consequently resulting in unnecessary inventory. The relationship that keeps painting and welding area is vital for the company as both are coordinated and aware of the needs of the other area.

At present the painting area has a work pace that allows being always on time with their deliveries but has no production plan, which has often complicated their job.

On the other hand the welding area has a production plan but it doesn´t have a sequence that permits to know in which order the pieces has to be made.

There is an opportunity to simplify the work and achieve reduction in inventory and movements. Like any project is subjected to limitations that make its execution more complex, variability, flexibility and restrictions in production were main issues.

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II. LAYOUT

Current State

The manufacturing process of fifth wheel involves three main steps as shown below.

Fig. 1: Current Process

Welding

All the families are made in this line, except the fifth wheel. They are welded before sending for painting. There is a greater opportunity of improvement in this area since most of the time the workers produce every day with a production plan but without a sequence.

Painting

This line has a good flow but is necessary to identify which products are most important as they present closer due date. The unique restriction is that the fifth wheel should enter first because the other products need a special treatment.

Assembly

All parts are assembled together to form fifth wheel.

Current Layout

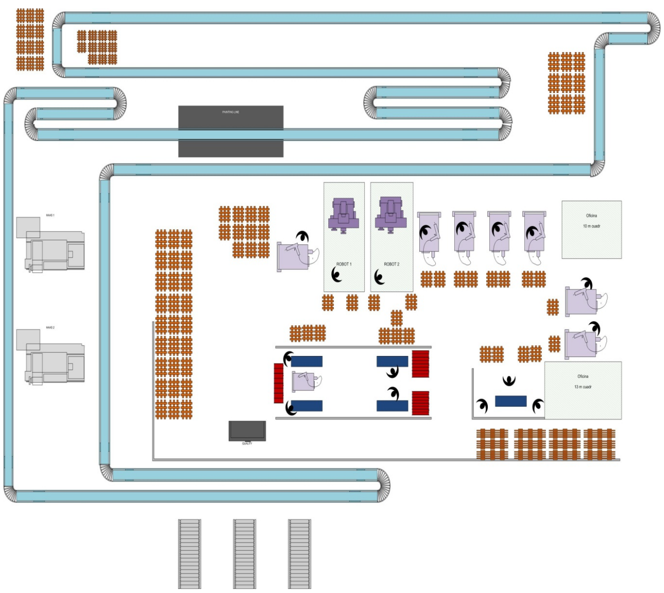

Fig. 2. Current Layout

The second step was to identify the involvement of products in this area and the amount of production. The following graphics was used for this study. We considered four families products: Mounts, Inboards, Outboards and 5th wheel, based on the sales of (July 2011-June 2012).

Table I: One Year Sale of Products

Model	Demand	Percentage	Aggregate
5th Wheel	23852	44.18%	44.18%
Mount	15433	28.59%	72.77%
Outboards	12743	23.60%	96.37%
Inboards	1960	3.63%	100.00%
Total	53988		

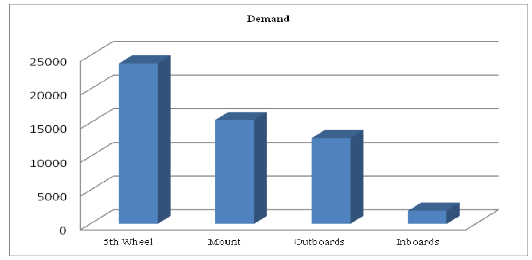

Fig. 3 Demand of Products

The focus is only on the 80% of each family product following the Pareto principle since the product families present a lot of variation.

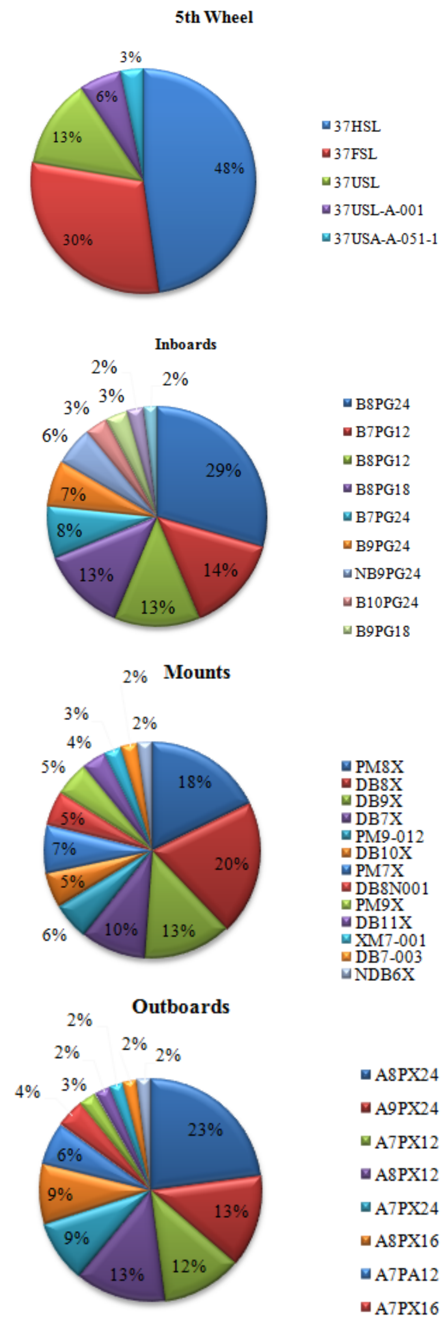

Fig. 4: Product Families

Above pie chart represents the percentage of each product models within 5th wheel, inboards, mounts, and outboards. The analysis helped to reduce the variation in the families and focus only on the bestselling products. The current production system is based on the due date; the research is to illustrate sequencing of production with above information.

III. Methodology

Sequencing

It is the establishment of priority in orders in different workplaces to meet scheduled delivery dates with the least amount of resources and inventories. Atuahene et al. used a similar method with the application of queuing theory for their analysis [4]. Lozano et al. have applied sequencing the batches of glass parts at different machines in an automotive glass facility [5]. People have been using sequencing in cellular manufacturing [6]. Optimization technique such as ant colony optimization has been used for the sequencing of jobs and machines [7].

Some aspects to consider:

- The pattern of arrivals
- The number and variety of machines
- The number and type of workers
- The workflow patterns in the workshop
- The objectives of evaluating alternative sequencing rules

In a production plan, we applied four patterns to sequence the process:

- FCFS: first come, first send
- SPT: shortest processing time
- EDD: earliest due date
- CR: critical ratio

General production plan (this plan was used to exemplify all the process) is shown in table below:

TABLE II. GENERAL PRODUCTION PLAN

SEQ	Order No.	Part No.	Quantity	Due Date
1	2096215	37USA-A051-2R	2	18/07/2012
2	2096213	37USL-A8PX24	1	18/07/2012
3	2096229	36NSL-A7PX12	6	19/07/2012
4	2096393	37USA-A-051-1	1	19/07/2012
5	2096603	37USLN-A8PX24	1	19/07/2012
6	2096230	36NSL-A7PX24	1	23/07/2012
7	2096231	36NSL-A8PX12	2	23/07/2012
8	2096232	37USA-A-001	15	23/07/2012
9	2096403	37USA-A-002	5	23/07/2012
10	2096609	37USL-A-008	1	23/07/2012
11	2096407	37USL-A8PX24	2	23/07/2012

FCFS: first come, first send

"Program the work in accordance with the orders received"

The logic in this method is sorting all the orders according to the order number they appear (ascending), and then we can do the first come to be the first send. Next we need to know the finish time for all the jobs, assuming that a_n are all jobs (a_1, a_2, $a_3 \ldots a_n$), and the process time is t_n, t_1 is the time for job a_1, t_2 for a_2, t_n for a_n, so the finish time for the job a_1 is t_1, $a_2=a_1+t_2$, $a_n=an\text{-}_1+t_n$.

Then we calculate the delay as the following function, if (finish time<due date, 0, finish time - due date). We need to calculate the mean flow time, average tardiness and the number of tardy jobs.

Mean flow time = finish time/total jobs.

Average tardiness = sum of all the tardiness/total jobs.

Number of tardy jobs = count jobs if tardiness is greater than 0.

TABLE III. PRODUCTION PLAN

Order No.	Part No.	Process Time	Due Date
2	37USL-A8PX24	1.42	5.00
1	37USA-A051-2R	2.25	5.00
3	36NSL-A7PX12	4.5	6.00
6	36NSL-A7PX24	0.96	10.00
7	36NSL-A8PX12	1.67	10.00
8	37USA-A-001	11.88	10.00
4	37USA-A-051-1	0.83	6.00
9	37USA-A-002	4.38	10.00
11	37USL-A8PX24	2.83	10.00
5	37USLN-A8PX24	1.33	6.00
10	37USL-A-008	0.79	10.00

TABLE IV. PRODUCTION PLAN AS PER FCFS

FCFS Method			
Order No.	*Finish Time*	*Due Date*	*Delay*
2	1.42	5	0
1	3.67	5	0
3	8.17	6	2.17
6	9.13	10	0
7	10.79	10	0.79
8	22.67	10	12.67
4	23.5	6	17.5
9	27.88	10	17.88
11	30.71	10	20.71
5	32.04	6	26.04
10	32.83	10	22.83
11	202.79		120.58

The process time of order no. 2 is least and so this order is sent out first. Order 10 has the longest processing time and is processed at the end. Mean flow time which is the average finish time and average delays are listed below.

TABLE V. RESULTS OF FCFS METHOD

Mean Flow Time	18.44
Delay Average	10.96
# Delays	8

SPT: shortest processing time

"Program the work with the shortest processing time" Although the total time to complete multiple jobs is independent of the sequence, the average cycle time is minimized by processing jobs according to their processing times, starting with the shortest processing time first under this rule. The congestion in a factory can be reduced by processing shorter jobs first so that they will not block jobs with the longer processing time.

We need to program the jobs starting the job with minimum process time and the last one with the longest processing time. We calculated the tardiness with the same function of excel (if (finish time<due date, 0, finish time - due date)). Mean flow time, average of tardiness and the number of tardy jobs are listed under results.

TABLE VI. PRODUCTION PLAN

Order No.	Part No.	Process Time	Due Date
10	37USL-A-008	0.79	10.00
4	37USA-A-051-1	0.83	6.00
6	36NSL-A7PX24	0.96	10.00
5	37USLN-A8PX24	1.33	6.00
2	37USL-A8PX24	1.42	5.00
7	36NSL-A8PX12	1.67	10.00
1	37USA-A051-2R	2.25	5.00
11	37USL-A8PX24	2.83	10.00
9	37USA-A-002	4.38	10.00
3	36NSL-A7PX12	4.50	6.00
8	37USA-A-001	11.88	10.00

TABLE VII. PRODUCTION PLAN AS PER SPT

SPT Method				
Order No.	*Process Time*	*Finish Time*	*Due Date*	*Delay*
10	0.79	0.79	10	0.00
4	0.83	1.63	6	0.00
6	0.96	2.58	10	0.00
5	1.33	3.92	6	0.00
2	1.42	5.33	5	0.33
7	1.67	7	10	0.00
1	2.25	9.25	5	4.25
11	2.83	12.08	10	2.08
9	4.38	16.46	10	6.46
3	4.5	20.96	6	14.96
8	11.88	32.83	10	22.83
11		112.83		50.92

The process time of order no. 10 is least and is processed first and order no. 8 is processed at the end. Mean flow time is the average of finish time.

TABLE VIII. RESULTS OF SPT

Mean Flow Time	10.26
Delay Average	4.63
# Delays	6

EDD: earliest due date

"Program the first works with the nearest deadline" The maximum lateness of any job can be minimized by ordering the jobs according to their due dates, with the earliest due date first and the latest due date last. All the jobs will be completed on time if it is possible. We need to calculate the same variables (completion time, tardiness) as in FCFS and SPT.

TABLE IX. PRODUCTION PLAN

Order No.	Part No.	Process Time	Due Date
1	37USA-A051-2R	2.25	5.00
2	37USL-A8PX24	1.42	5.00
3	36NSL-A7PX12	4.50	6.00
4	37USA-A-051-1	0.83	6.00
5	37USLN-A8PX24	1.33	6.00
6	36NSL-A7PX24	0.96	10.00
7	36NSL-A8PX12	1.67	10.00
8	37USA-A-001	11.88	10.00
9	37USA-A-002	4.38	10.00
10	37USL-A-008	0.79	10.00
11	37USL-A8PX24	2.83	10.00

TABLE X. PRODUCTION PLAN AS PER EDD

EDD Method				
Order No.	*Due Time*	*Process Time*	*Finish Time*	*Delay*
1	5	2.25	2.25	0.00
2	5	1.42	3.67	0.00
3	6	4.5	8.17	2.17
4	6	0.83	9	3.00
5	6	1.33	10.33	4.33
6	10	0.96	11.29	1.29
7	10	1.67	12.96	2.96
8	10	11.88	24.83	14.83
9	10	4.38	29.21	19.21
10	10	0.79	30	20.00
11	10	2.83	32.83	22.83
11			174.54	90.63

In this method, orders are prioritized according to their due dates i.e. order with shortest due date is processed first.

TABLE XI. RESULTS OF EDD

Mean Flow Time	15.87
Delay Average	8.24
# Delays	9

The average finish time is 15.87 days and delay is 8.24 days.

CR: critical ratio

The critical ratio is: submission deadline - current date / time of processing. Program works in order considering the shorter of the CR.

The model starts with a current or present time = 0. Current time updates after each selection by adding scheduled process time to current time. IF CR = 1, implies there is just enough time; CR > 1 implies more than enough time and CR < 1 implies not enough time.

TABLE XII. CALCULATION OF CR

Present Time	0.00				
Order No.	**Part No.**	**Process Time**	**Due Date**	**CR**	
2	37USL-A8PX24	1.42	5.00	3.53	A
1	37USA-A051-2R	2.25	5.00	2.22	B
3	36NSL-A7PX12	4.5	6.00	1.33	C
6	36NSL-A7PX24	0.96	10.00	10.43	D
7	36NSL-A8PX12	1.67	10.00	6	E
8	37USA-A-001	11.88	10.00	0.84	F
4	37USA-A-051-1	0.83	6.00	7.2	G
9	37USA-A-002	4.38	10.00	2.29	H
11	37USL-A8PX24	2.83	10.00	3.53	I
5	37USLN-A8PX24	1.33	6.00	4.5	J
10	37USL-A-008	0.79	10.00	12.63	K
			Min Value	**0.84**	
			Order No.	**F**	

CR for order no. 2 is due date (5) divided by process time (1.42) results 3.53. All other CR is estimated in a similar manner.

Present Time	11.88				
Order No.	**Part No.**	**Process Time**	**Due Date**	**CR**	
2	37USL-A8PX24	1.42	-6.88	-4.86	A
1	37USA-A051-2R	2.25	-6.88	-3.06	B
3	36NSL-A7PX12	4.50	-5.88	-1.31	C
6	36NSL-A7PX24	0.96	-1.88	-1.96	D
7	36NSL-A8PX12	1.67	-1.88	-1.13	E
4	37USA-A-051-1	0.83	-5.88	-7.06	G
9	37USA-A-002	4.38	-1.88	-0.43	H
11	37USL-A8PX24	2.83	-1.88	-0.66	I
5	37USLN-A8PX24	1.33	-5.88	-4.41	J
10	37USL-A-008	0.79	-1.88	-2.37	K
			Min Value	**-7.06**	
			Order No.	**G**	

We can see in above table that at time 11.88, the due date for order 2 will be 5-11 = -6.88. Order G has the highest CR.

Present Time	12.71				
Order No.	**Part No.**	**Process Time**	**Due Date**	**CR**	
2	37USL-A8PX24	1.42	-7.71	-5.44	A
1	37USA-A051-2R	2.25	-7.71	-3.43	B
3	36NSL-A7PX12	4.5	-6.71	-1.49	C
6	36NSL-A7PX24	0.96	-2.71	-2.83	D
7	36NSL-A8PX12	1.67	-2.71	-1.63	E
9	37USA-A-002	4.38	-2.71	-0.62	H
11	37USL-A8PX24	2.83	-2.71	-0.96	I
5	37USLN-A8PX24	1.33	-6.71	-5.04	J
10	37USL-A-008	0.79	-2.71	-3.43	K
Min Value				**-5.44**	
Order No.				**A**	

Present Time	14.13				
Order No.	**Part No.**	**Process Time**	**Due Date**	**CR**	
1	37USA-A051-2R	2.25	-9.13	-4.06	B
3	36NSL-A7PX12	4.50	-8.13	-1.81	C
6	36NSL-A7PX24	0.96	-4.13	-4.31	D
7	36NSL-A8PX12	1.67	-4.13	-2.48	E
9	37USA-A-002	4.38	-4.13	-0.94	H
11	37USL-A8PX24	2.83	-4.13	-1.46	I
5	37USLN-A8PX24	1.33	-8.13	-6.1	J
10	37USL-A-008	0.79	-4.13	-5.22	K
			Min Value	**-6.10**	
			Order No.	**J**	

Present Time	23.96				
Order No.	**Part No.**	**Process Time**	**Due Date**	**CR**	
3	36NSL-A7PX12	4.50	-17.96	-3.99	C
9	37USA-A-002	4.38	-13.96	-3.19	H
			Min Value	**-3.99**	

Order No.	C

Present Time	28.46			
Order No.	Part No.	Process Time	Due Date	CR
9	37USA-A-002	4.38	-4.13	-0.94
			Min Value	-4.22
			Order No.	H

H

CR Method					
Order No.	***Due Time***	***Process Time***	***Finish Time***	***Due Date***	***Delay***
8	5	11.88	11.88	10.00	1.88
4	5	0.83	12.71	6.00	6.71
2	6	1.42	14.13	5.00	9.13
5	6	1.33	15.46	6.00	9.46
10	6	0.79	16.25	10.00	6.25
6	10	0.96	17.21	10.00	7.21
1	10	2.25	19.46	5.00	14.46
7	10	1.67	21.13	10.00	11.13
11	10	2.83	23.96	10.00	13.96
3	10	4.5	28.46	6.00	22.46
9	10	4.38	32.83	10.00	22.83
11			213.46		125.46

Mean Flow Time	19.41
Delay Average	11.41
# Delays	11

TABLE XIII. RESULTS OF SEQUENCING METHODS

Method	Mean Flow Time	Delay Avg.	# Delays
FCFS	18.44	10.96	8
SPT	10.26	4.63	6
EDD	15.87	8.24	9
CR	19.41	11.41	11

Above table lists number of delays for four different methods. CR represents the highest number of delays and lowest for the FCFS method. SPT provides the least number of delays in above case. Depending on what is more important for the company the decision could be taken.

Simulation

ProModel software [8] was used to run simulation for both current and future state. The lead time for future state is reduced to 2898 min from 3031 min. Work in process is reduced to 86.72% from 92.52% and the utilization increases from 6.96% to 11.59%.

Benefits

The benefits of a sequence production or scheduling are the reduction of WIP, cycle times and movements.
Reducing cycle times can achieve following:

- The lead time to the customer can be shortened.
- We can maintain flexibility in our process trying to change jobs that are planned to start next.
- Quality can be improved by short queues in the system.
- We can make better forecasts since the reduction of cycle times can shorten the forecast horizon.

Future Layout

Some changes can be made in the current layout:

Make to stock: All the parts that have more demand
Make to order: All other products that are required frequently

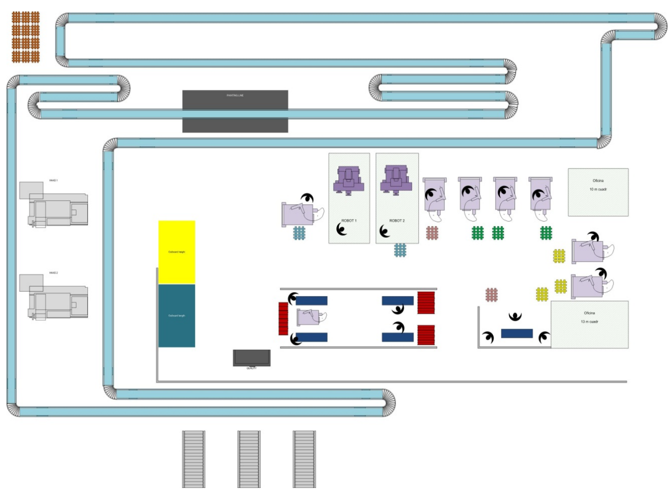

Fig. 5: Future Layout

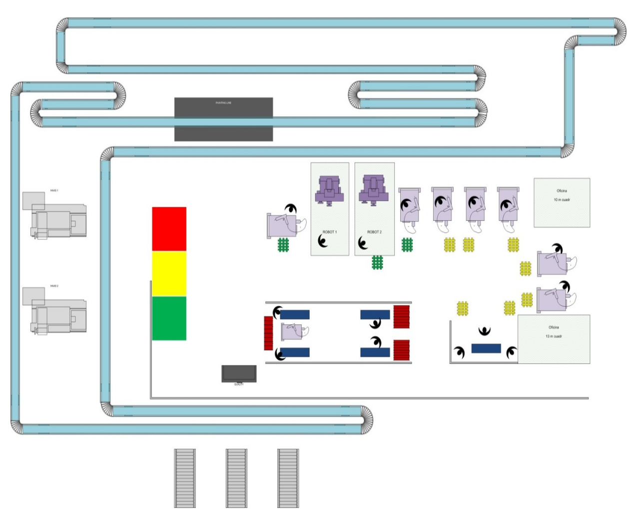

Fig. 6. Future Layout with Color Coding for Job Priority

Based on the delivery date of products, we can prioritize the products created with colors as shown in figure 6:
Red- highest priority
Yellow- medium priority
Green- low priority

By making some adjustments in the layout, output of the system can be increased as shown in simulation results.

IV. CONCLUSIONS AND DISCUSSIONS

5's methodology is needed for any improvement; the result of this methodology is measured both in productivity and staff satisfaction. The application of this technique has a long-term impact. The 5´s implementation can be one of the first steps of change towards continuous improvement.

In addition to short-term results the order of all the material in process and finished product inventory would be more controlled and the proper use of the racks instead of putting the material in the hallway.

The best time to apply this methodology is through Kaizen (continuous improvement) which involves all employees of the company, from workers to CEO, to find areas of opportunity, rearrangement of layout, cleanliness and general improvements.

Fig. 7. 5S
(Source: http://www.epa.gov)

Forecasting to Production Control

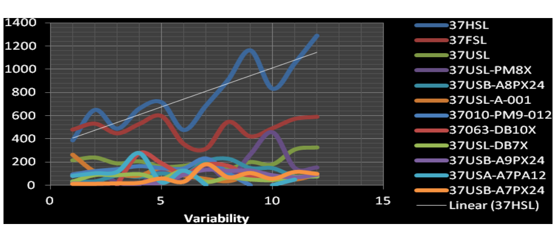

Fig. 7: Forecasting of Sales of Different Models

A good forecasting system can get the daily amount needed to produce; it could be difficult but is a good implementation option. Exponential smoothing method is used in this case for the forecasting of sales.

Kanban

Kanban provides a number of benefits.

- Reduce inventory and product obsolescence
- Reduces waste and scrap
- Provides flexibility in production
- Reduces total cost

Kanban is a type of lean tool that can be a useful because of the degree of variability that occurs in the company. Integration of lean and green methods was found to be synergistically beneficial [9]. Lee has shown that Kanban controlling and scheduling can minimize the total production cost by approximately 30% [10]. Monden and later Huang et al. showed that the Kanban system controls the work in process (WIP) of each workstation or production stage [11-12]. Kanban method should be used as shown below, making necessary modifications to work in the best way.

TABLE XIV. KANBAN METHOD

Type				Per day	5 days volume	Lot size	Lot size rev 1	Basket size		# of kanbans			
INBOARDS	Height (lime)	7"	B7P(SK77240-07)	1.69	8.45	20	20	10	0.845	1			
		8"	B8P(SK77240-08)	3.52	17.60	20	20	10	1.76	2			
		9"	B9P(SK77240-09)	0.76	3.80	20	20	10	0.38	1	B7P	406	1.69
		10"	B10P(SK77240-10)	0.21	1.05	20	5	5	0.21	1	B8P	845	3.52
		9" NT	P77201-09 no tilt 9" /NB9P	0.37	1.85	20	20	10	0.185	1	B9P	183	0.76
											B10P	51	0.21
	Length (lt orange)	12"	SK77275-12	1.73	8.65	30	30	14	0.61786	1	NB9P	89	0.37
		18"	SK77275-18	1.18	5.90	30	30	14	0.42143	1	G12	415	1.73
		24"	SK77275-24	3.41	17.05	30	30	14	1.21786	2	G18	283	1.18
		36"	SK77275-36	0.24	1.20	20	10	10	0.12	1	G24	818	3.41
		48"	SK77275-48		0	20	5	6	0	0	G36	58	0.24
					0								
OUTBOARDS	Height (yellow)	7"	A7P(SK77001-07)	13.56	67.80	35	30	10	6.78	7	A7	3254	13.56
		8"	A8P(SK77001-08)	20.35	101.75	35	20	10	10.175	11	A8	4885	20.35
		8" NT	NA8P(SK77082-08)		0.00	20	10	10	0	0	A9	2306	9.61
		9"	A9P(SK77001-09)	9.61	48.05	35	20	10	4.805	5	PX12	3451	14.38
		9" NT	NA9P(SK77082-09)		0.00	20	10	10	0	0	PX16	1599	6.66
		10"	A10P(SK77001-10)		0.00	10	5	5	0	0	PX24	4724	19.68
		11"	A11P(SK77001-11)		0.00	10	5	5	0	0	PX36	458	1.91
					0						PX48	213	0.89
	Length (turquoise)	12"	SK77037-12	14.38	71.90	50	30	10	7.19	8			
		16"	SK77037-16	6.66	33.30	50	15	10	3.33	4			
		24"	SK77037-24	19.68	98.40	50	45	10	9.84	10			

The goal of Kanban is to make positive change to optimize the flow of work flow through the system. By looking at the Kanban as in table above, we can understand how the workflow currently functions and how we can improve it by making the correct adjustments.

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