INDUSTRIAL & SYSTEMS ENGINEERING
TEXAS A&M UNIVERSITY

ISEN 645

Lean Thinking and Lean Manufacturing

ASIS Analysis and TOBE Recommendations for Best Flow Line Production System

Submitted By:

Prakhar Bajpai	926008033
Saksham Agrawal	427009319
Atul Srivastava	527005075
Smith Kenedy Shah	227008337

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We would like to thank Dr. Michael Graul for providing us an opportunity to work on this project. We are highly indebted to him for his guidance and constant supervision throughout the course of this project.

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We are also thankful to Best Flow Line Material planner Mrs. Beth Faichtinger for taking out time from her busy schedule and segregating Production plan data required for our project.

EXECUTIVE SUMMARY

This report provides an analysis of the current production flow at Best Flow Line Equipment, Houston. Best Flow Line Equipment is a manufacturer of pumping products (pipes, valves, fittings and pressure pumps). The products manufactured at Best Flow can be divided into 8 different product families. These families belong to 5 major production flow paradigms – MTO (Make to Order), MTS (Make to Stock), ATO (Assemble to Order), ETO (Engineer to Order) and PTO (Procure to Order). This report discusses the top 3 product families – Swivels, Plug valves and Pup joints – that contribute to more than 60% of the revenue. The main focus is on these three product families in this report.

Over the past one year, the main issues at Best flow have been the ever-rising inventory levels, ineffective space utilization and poor adherence to delivery schedules. These numbers have been tabulated below:

Inventory	**$14 Million**
On-time delivery	**58%**
Space Utilization	**45%**

Table 1: Best Flow Line in numbers

Tools used for analysis in this report include IDEF0, IDEF3, VSM, Spaghetti diagram and Shop floor Value Heat map. After laying down the ASIS details, this report uses the 8 TOBE flow design principles along with 8 cell design steps to draw a future state VSM and a rough shop floor layout for the improved production flow. Recommendations discussed in this report for some of the major areas of weaknesses include:

- Switching to the Make-to-order flow paradigm, especially for the products with less customization and high sales volumes.
- Reducing the changeover times by using the SMED methodology.
- Reducing batch size and thus improving the EPEI run values.
- Establishing a Kanban-induced pull system
- Changing layout from a scattered structure to a U-shaped structure.

This report also provides a Cost-benefit analysis of all the recommended improvements in the process flow and layout. A temporal analysis of the Cost and benefits shows that the cumulative benefits exceed the cumulative cost after 7-8 years.

Moreover, because of limited information about the SOP of the process activities, re-engineering these activities for TOBE cell design is out of scope of this report. We have limited our scope to layout changes and specific kaizens aimed at eliminating wastes in the TOBE design.

ABOUT BEST FLOW LINE EQUIPMENT

'When you change the way you look at manufacturing, the way you manufacture will change.'
(Best Flow Tagline)

Best Flow Line Equipment has served the oil and gas industry for over 40 years. In 1968, at the peak of US oil production, Best Flow Line emerged from Houston offering the highest quality rig equipment at the time. Since then, they've been continuously innovating to meet their clients ever-changing needs. Best Flow continues to supply the petroleum industry with a large selection of equipment for fracturing, acidizing, cementing, well servicing, well testing and drilling requirements.

At present, Best Flow operations run at three different locations – Houston, Forth Worth and Odessa. The Best Flow plant at Houston is a 75,000 square foot flow iron manufacturing and warehouse facility, is centrally located to support the oil and gas industry.

Best Flow is a supplier to the domestic and international oil and gas markets, providing the industry with highly engineered and quality products. Their goal is to provide you, the customer, with the highest level of service, commercial value and technical expertise available in today's oil and gas landscape.

Following are some of the products that Best Flow manufactures:

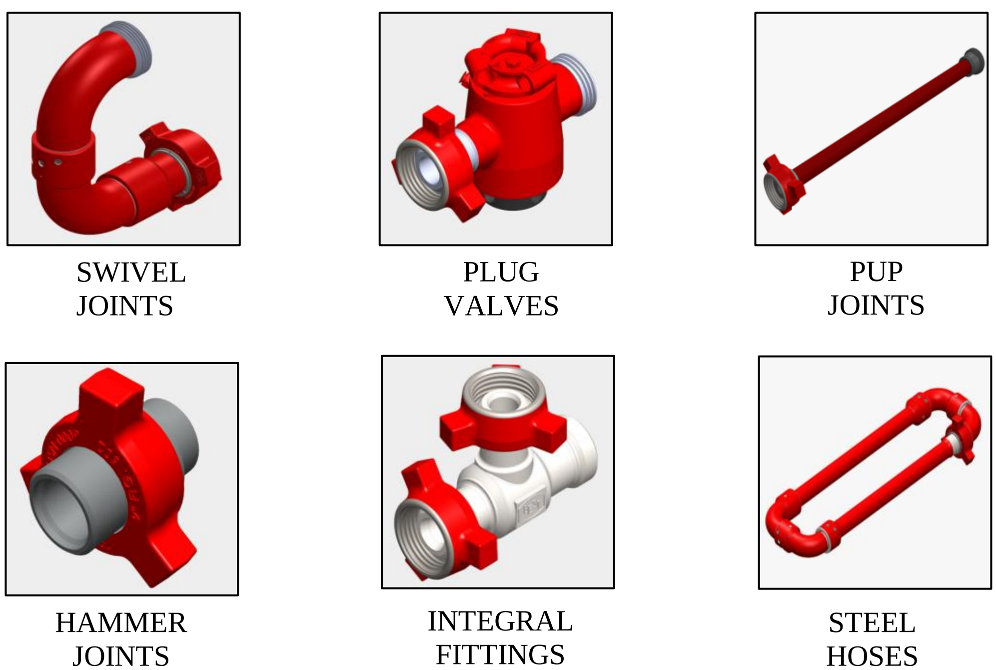

Fig. 1: Top products at Best Flow

INTRODUCTION: A PRELIMINARY LOOK AT THE PROBLEM STATEMENT

Best Flow Line Equipment produces all of its products in batches. Producing in batches makes sense for products that are customized and need special attention, but batch production is a prevalent practice even for the high-demand regular products like swivels. This leads to huge buffers between each stage of operation. Aisles and spaces around the work station are filled with unfinished products waiting to be processed. These unfinished products keep piling over time. This not only lead to processing delays but also spoils the 5S aspirations of the workplace.

As discussed later, Best Flow needs to maintain some kind of inventory for incoming raw materials, especially because of a lead time, that is as high as 16 weeks. Even for such a lead time, an inventory worth $14 Million is exceptionally high. All the efforts made in the recent past to monitor the buying patterns of the buyers have failed miserably. The buyers buy in excess when there is a surplus at the supplier end. There is no benchmark set to control the bought quantity. Some sort of a monitoring system like DBM (Dynamic Buffer management) or a safety stock would help the organization's cause. These have been discussed in the TOBE analysis section of this report.

The value-adding areas (where the production activities take place) on the Best Flow shop floor are scattered in patches and roughly occupy only 40-45% of the entire area. This issue has been captured conspicuously in a shop floor heat map and a Spaghetti diagram in later sections. In the TOBE analysis, a more compact U-shaped cell has been recommended, which not only offers a higher space utilization but also eliminates many NVA activities, especially in the logistics department.

ASIS ANALYSIS

1. IDEF0 DIAGRAM

Purpose: The purpose of this IDEF0 model is to capture all the categorized sets of transformative activities involved in the production process of Swivel 1' joints manufactured in Best Flow Line Equipments Pvt. Ltd. This model will be used as a baseline to plan change management activities in the future.

Context: This model encapsulates on a broad scale, the resources and the subsequent production and planning required to process a customer's order of flow line equipments until its dispatch from the factory. Any activity pertaining to the upstream supply chain (at supplier's end) and the know-how of the on-line manufacturing processes are beyond the scope of this model.

Viewpoint: The viewpoint of this model is of a Production manager who wishes to have an outlook of production process of Best Flow line equipment.

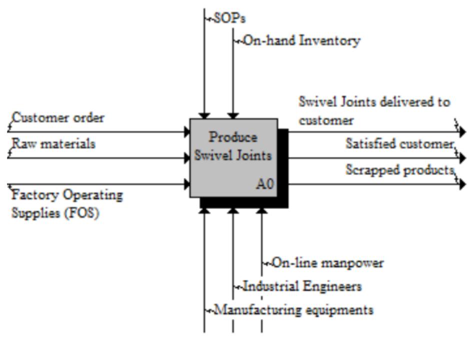

Fig.2(a): IDEF0 Parent diagram

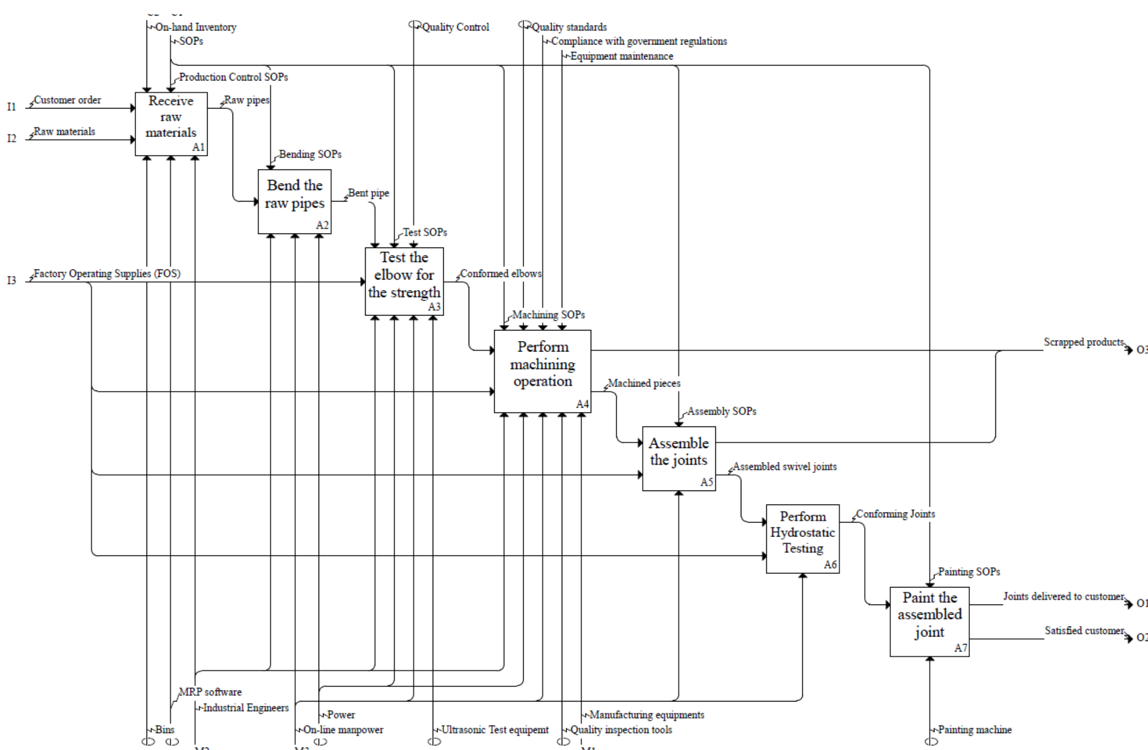

Fig.2(b): IDEF0 Parent diagram

2. IDEF3 DIAGRAM

Purpose: The purpose of this IDEF3 design is to lay down all the processes involved in the production and manufacturing of swivel joints.

Context: This diagram encompasses all the processes involved in the production and order processing of Swivel joints at Best Flow Line Equipment. Processes involved in other products have not been included in this model.

Viewpoint: The viewpoint of this diagram is of a production manager who wishes to see the detailed process design involved in the production of swivel joints

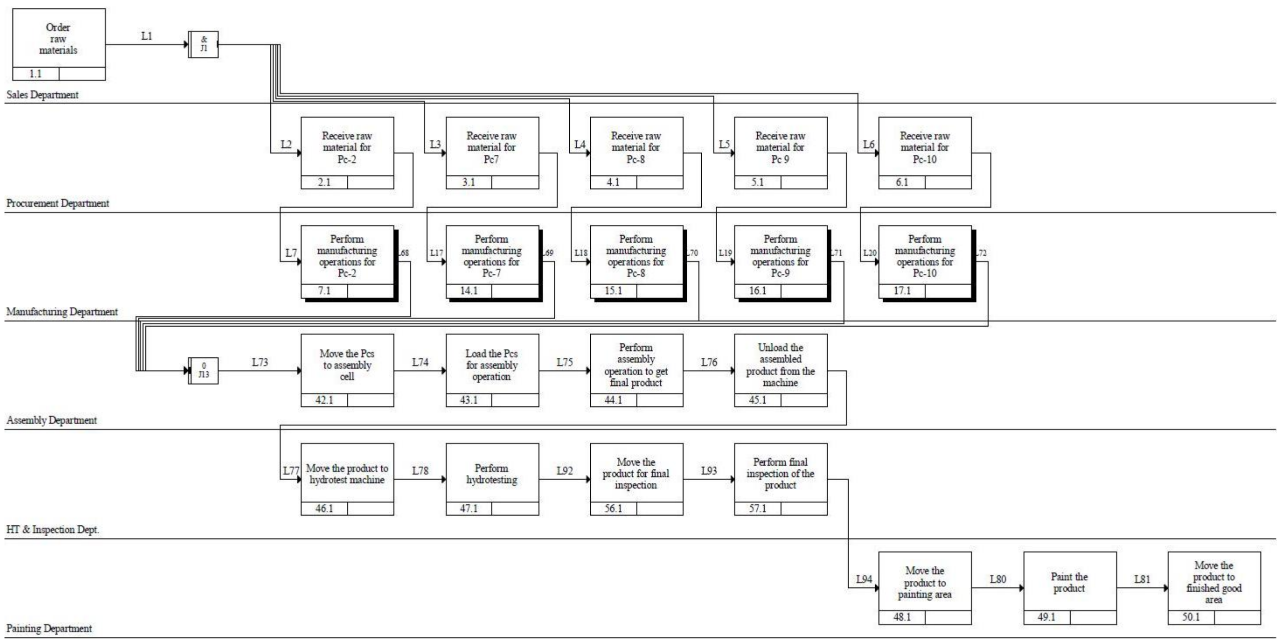

Fig. 3: Swimlane – IDEF3 diagram of Best Flow PS

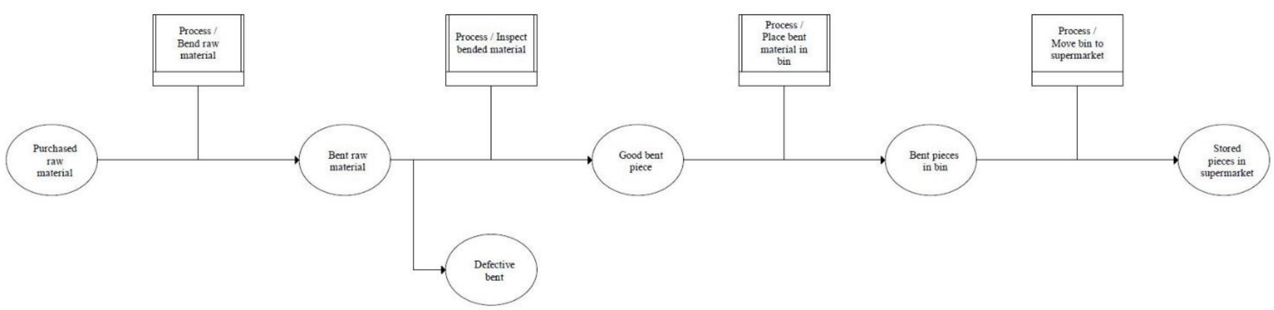

Fig. 4: OSTN for Bending process

3. Current Value Stream Mapping

The main operations involved in the production of a swivel are as shown below:

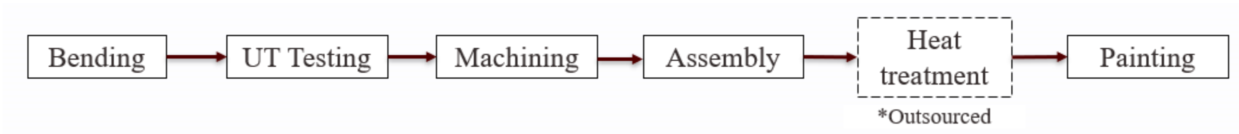

Fig.5: Process flow

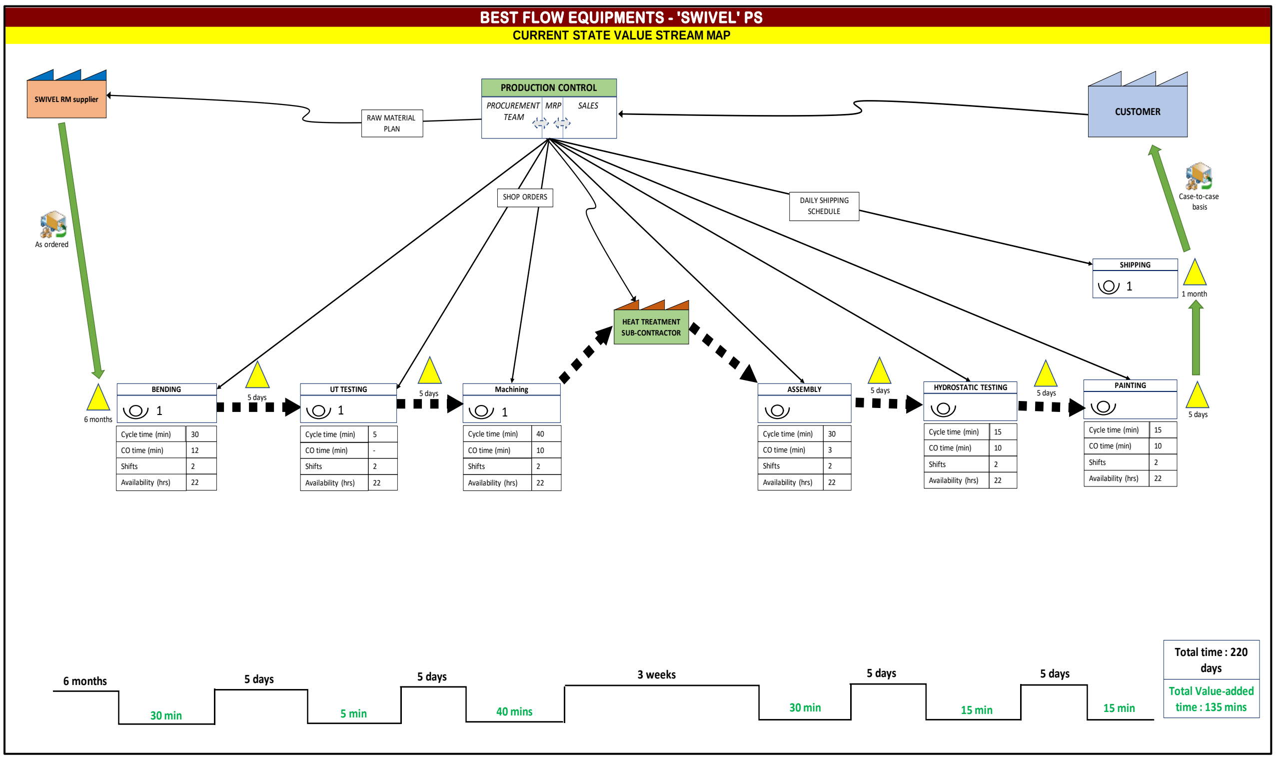

Fig.6: Current State Value Stream Map

Observations:

- Changeover times for some of the processes like Assembly are as high as 30 minutes.
- An inventory of 6 months is maintained at the upstream warehouse.
- There is no fixed pattern for buying of raw materials and dispatch of finished goods.
- Production in batches leads to buffer of 5 days between each stage.
- Lead time for heat treatment process is 3 weeks.
- Value-added ratio is only 0.0004.

4. Spaghetti Diagram

Using the spaghetti diagram, we have tracked the movement and the distance travelled by all the products - Swivel joint, Plug valve and Pup joint - through the process.

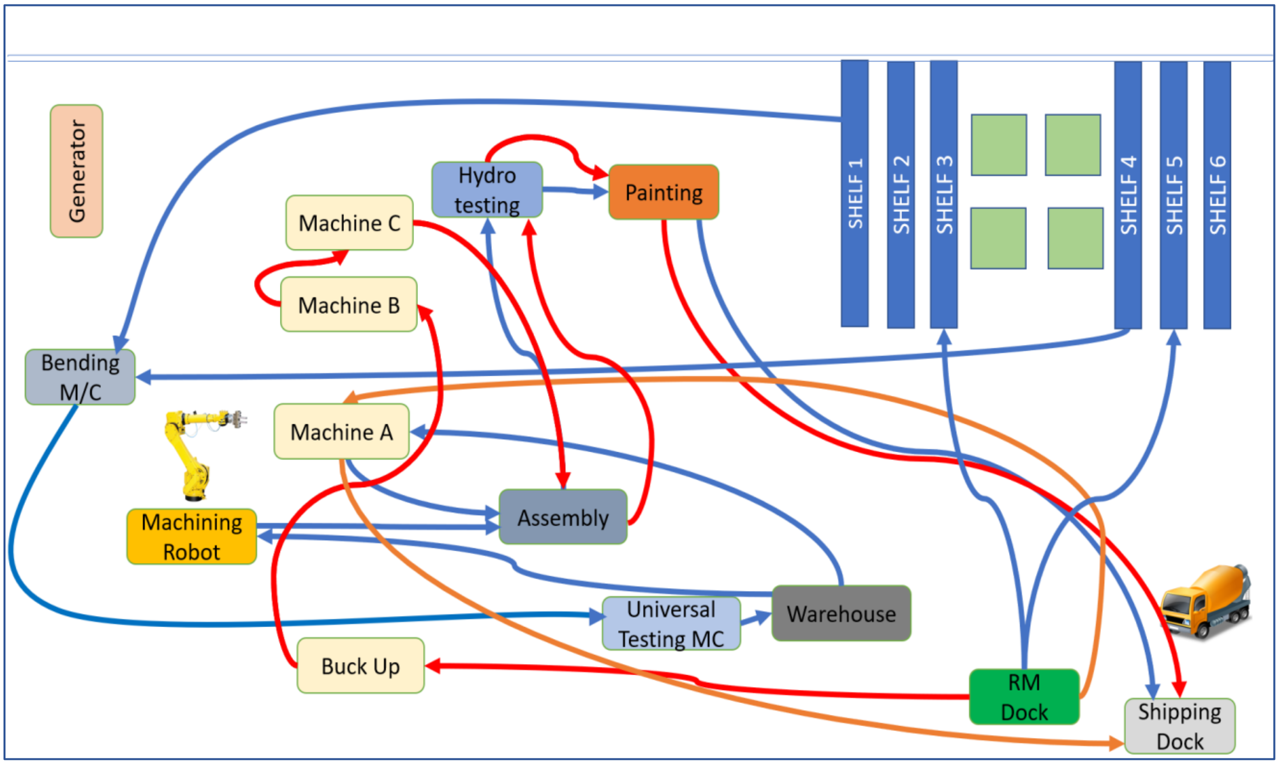

Fig.7: Spaghetti Diagram of Shop floor

Representation	Part	Distance
(blue line)	Swivel	2454 ft
(red line)	Pup joint	2033 ft
(yellow line)	Plug valve	1005 ft

Table 2: Distance travelled by parts on shop floor

Observations:

- Identified wasted motions by calculating the distance travelled by each product.
- Complex product flow on the shop floor.
- Ineffective utilization of space
- More handling, less resource allocation and weak communication between workers

5. Shop Floor Heat Map

We have used the Heat map as a visualization tool which clearly depicts the value added and non-value-added activities in a floor shop.

The red region below indicates a hot area, meaning value added activities are being performed there whereas the green region shows the region where non-value-added activities are performed. The red regions are scattered throughout the plant in patches, which indicates the difficulty in monitoring these areas in an efficient way.

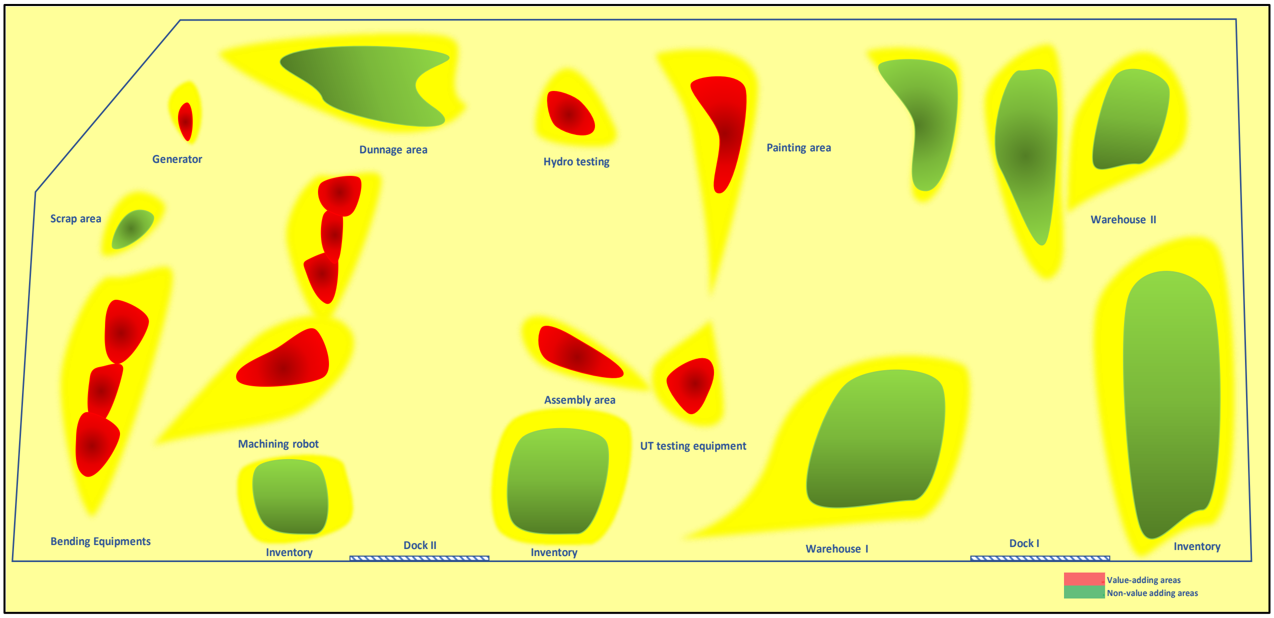

Fig.8: Shop floor Value heat map

Observations:

- Inefficient space utilization, roughly 45% indicating that 45% of the space contributes to the revenue
- Identified the areas with non-value-added activities

TOBE ANALYSIS

In the TOBE analysis of the Best Flow Production system, 8 design steps are followed to arrive at a future Value Stream map with all the recommended kaizens to eliminate the specific issues identified in the flow. Later, 8 cell design principles have been used to design a TOBE shop floor layout.

1. Application of 8 design steps

STEP 1: Takt time calculation

Average monthly demand of Swivels = 500 units
Number of production days = 25
Number of shifts in each production day = 2
Total number of production hours in each shift = 7 hour
Total number of production hours in a day = 2*7 = 14 hour
Total operating time in a month = Number of production days * Number of operating hours in a day
= 25*14 hours = 350 hours = 350*60 minutes = 21,000 minutes
Takt time = Total operating time in a month/Customer demand over a month
= 21,000 minutes / 500 units = **42 minutes**

STEP 2: Supermarket or Direct to shipping

In a “Make to order” business paradigm with high demand irregularities, keeping a supermarket at the End-of-line (EOL) will lead to excess inventory and product obsolescence, which can handicap Best Flow’s ability to ‘react’ positively to an order (whose stock doesn’t exist in the EOL supermarket). Hence, we recommend that Best Flow should opt for a Direct-to-shipping strategy to avoid excess inventory accumulation. We would, however, install supermarkets upstream.

STEP 3: Making the flow continuous

All the processes involved in the manufacturing of swivels along with their cycle times are tabulated below:

Process	Number of operators	Cycle time (min)	Takt time (min)	Planned cycle time (min) (95%*takt)	Utilization (%)
Bending	1	30	42	40	75
UT test	1	5	42	40	12.5
Machining	1	40	42	40	100
Assembly	1	30	42	40	75
Hydrostatic Testing	1	15	42	40	37.50
Painting	1	15	42	40	37.50

Table 3: ASIS Cycle times values

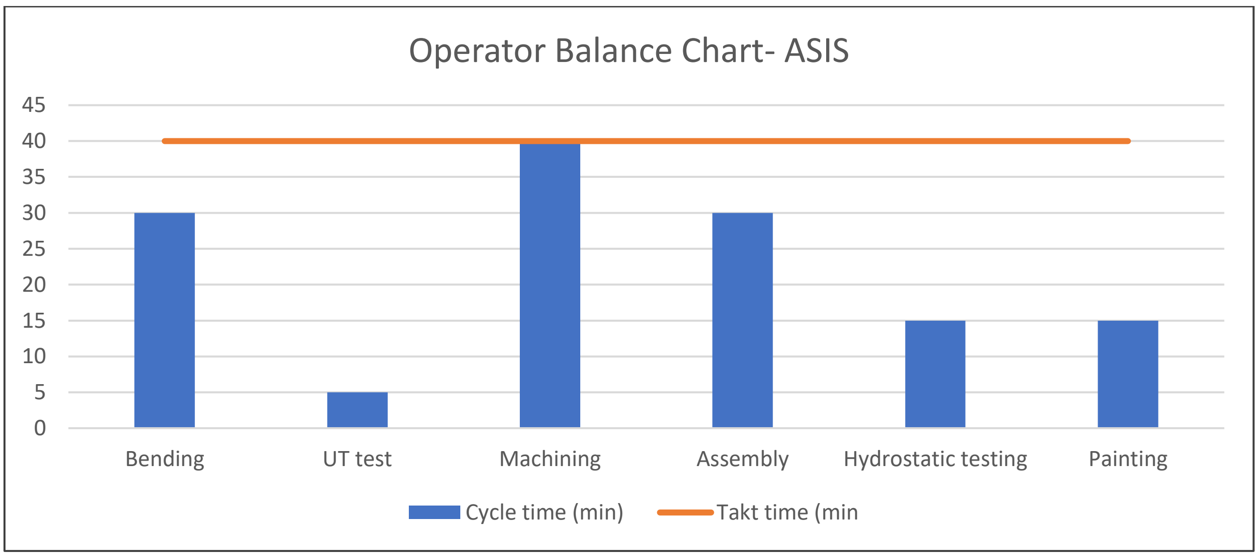

Fig.9: ASIS Operator Balance Chart

Observations:

- We observe that Bending and UT testing have cycle times of 30 minutes and 5 minutes respectively. These operations can be clubbed together because UT testing is basically an inspection of the bent products. Clubbing these together also ensures that we don't exceed the planned cycle time (which we have assumed to be 95% of the takt. Hence, Best Flow can keep them in a continuous flow and eliminate any kind of buffer/inventory between them.
- The cycle time of machining process is 40 minutes which is equal to the planned cycle time and hence any changes or clubbing is not possible here. Moreover, Machining and assembly are two different operations. Hence, it's better that they stay in two different cells to avoid an extra requirement of multi-skilled workers, who have a valid skillset in machining as well as assembly operation.
- It could be argued that Assembly is an underutilized operation here because of the 10 min gap between its cycle time (30 mins) and the planned cycle time (40 mins). But, assembly has a high

changeover time of 30 minutes. So, trying to increase its utilization might backfire because of its reduced availability for production.

- Best Flow needs to apply the SMED methodology to reduce all the changeover times to at least 10 minutes.

We can see that there are 6 operators in ASIS layout. However, the utilization is very low at few work centers like UT and hydrostatic testing, and painting. So, we will try to establish a continuous flow by clubbing some of these operations to increase utilization and eliminate intermediate buffers.

Minimum number of workers= ∑cycle time/number of work centers

In the TOBE layout, total task time= 135 min

No of operators = Total task time/Takt time = 135/42 = 4

Process	Number of operators	Cycle time (min)	Planned Cycle Time (min)	Utilization (%)
Bending + UT test	1	35	40	87.50
Machining	1	30	40	100.0
Assembly	1	30	40	75.00
Hydro. Test +Painting	1	30	40	75.00

Table 4: TOBE Cycle times values

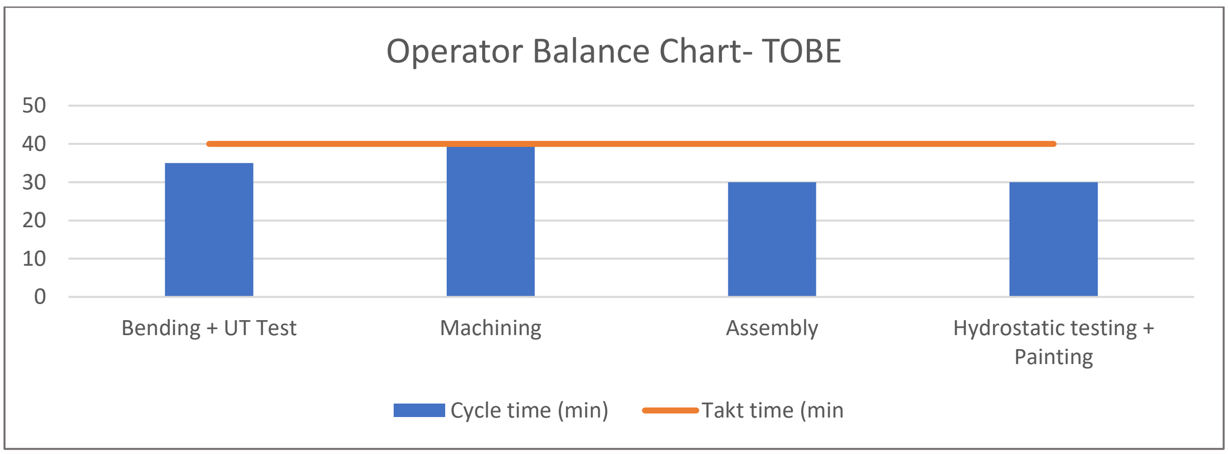

Fig.10: TOBE Operator Balance chart

We can observe that utilization improves significantly in the TOBE layout. In addition, the number of operators in TOBE layout is 4, which is smaller than the ASIS layout causing the significant savings in the recurring costs.

STEP 4: Location of Supermarket

As discussed in the Current Value Stream Mapping section, there is no fixed pattern of delivery of the raw materials. Add to this the high lead time of 16 weeks and it almost seems reasonable to maintain a large inventory (of roughly 6 months). If Best Flow requests and negotiates with the suppliers to dispatch a truck every fortnight, an inventory of a month (including safety stock) will be enough.

We can install a supermarket in front of the Bending operation and fix the supplier dispatch rate to once a fortnight. Raw materials are supplied to the bending work stations from these supermarkets in bins. Once a bin is used, a withdrawal Kanban card is sent back to the supermarket signaling the requirement of another bin. A Kanban post is placed near the two supermarkets to store all the Kanban cards.

Moreover, to reap better returns from the supplier, Best Flow can opt for a more symbiotic relationship with the suppliers. This is to say that Best Flow can include the suppliers themselves as a part of their Kanban scheduling system. As the raw materials are consumed at the supermarket, an e-kanban production card can be generated online (in place of an actual Kanban card) and can be sent back to the suppliers. This would act as a signal to the supplier to replenish the supermarket with new raw materials. This would obviously leverage the relationship between Best Flow and its raw material supplier. One has to really convince these suppliers that this is a win-win situation for both Best Flow and them. A fair argument would be that a well-sorted Kanban scheduling system with Best Flow would help the suppliers focus on their other customers too. Similarly, we can have supermarkets for machined swivels, which would then pull from the preceding workstations using production kanbans.

STEP 5: Pacemaker placement

It is generally recommended that the pacemaker process be near the final stages of operation, which would be the Assembly stage in this case. This would also assist the Production control in monitoring the volumes dispatched to the succeeding painting operation, which is an external process and hence not under the direct control of the PC department. In fact, we have argued later that this outsourced be brought in-house to avoid the delay of 3 weeks. Best Flow is currently working on this, as we prepare this report.

The Production Control can directly send its orders and schedules to the Assembly production cell, making it the pacemaker. This intuitively makes sense too, since almost half of our product processing happens in this cell. It would be more convenient for the PC department to have a better control over the entire system by focusing on the cell.

STEP 6: Leveling the production mix at the pacemaker process

We have used a Model mixing and scheduling tool (that leverages Hamel's equations) to level the production mix here. All the formulae used in the following tables have been discussed in the appendix. The demands of each of the three products are as shown below:

Monthly Demand Data												Annual Demand	Levelled Volume
Models	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Swivel	550	542	442	556	498	621	600	542	586	592	498	6027	502
Plug valve	232	278	237	247	295	275	312	210	256	232	292	2866	239
Pup joint	131	102	102	76	176	109	192	142	123	102	100	1355	113

Table 5(a): Demand Levelling

Using C_h equations, we get the production ratio of Swivels, Plug valves and Pup joints as 9:4:2.

TIME DATA		DEMAND DATA				C_h calculations				
Models	Annual demand	Daily demand	Takt time (mins)	Calculated Prod Ratio	x2	x3	x4	x5	Selected Prod Ratio	Quantity on card
Swivel	6,027	20	41.8	4.4	8.9	13.3	17.8	22.2	9	2
Plug valve	2,866	10	87.9	2.1	4.2	6.3	8.5	10.6	4	2
Pup joint	1,355	5	186.0	1.0	2.0	3.0	4.0	5.0	2	2

Table 5(b): C_h Calculations

The following table shows the adjustment in the C_h values by either taking away or adding Kanban cards after a certain number of cycles:

			C_h adjustment						
Models	1 Card every X cycles	2 Card every X cycles	3 Card every X cycles	4 Card every X cycles	5 Card every X cycles	Selected X cycles	Selected X cycles (~)	No of cards	Cards Removed/ Added
Swivel	-9.6	-19.2	-28.8	-38.4	-48.0	-48.0	-48	5	REMOVED
Plug valve	4.3	8.7	13.0	17.4	21.7	13.0	13	3	ADDED
Pup joint	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 5(c): C_h Adjustment

The EPEI (Every Part Every Interval) calculations for the three major product families are as tabulated below:

TIME DATA			EPEI RUN CALCULATIONS					
Models	Changeover time (mins)	Process time (mins)	Daily demand	Daily run time (mins)	Available time	Days to complete one sequence (EPEI)	Daily demand * EPEI	EPEI run
Swivel	40	135	20	2712.2	398.4	0.26	5.3	5
Plug valve	33	80	10	764.3			2.5	3
Pup joint	32	72	5	325.2			1.2	1

Table 5(d): EPEI Run Calculations

Based on the above calculations, a Heijunka box can be setup on the production floor, as shown below:

Swivel	X		X		X		X		X
Plug valve		X		X		X			
Pup joint								X	

Fig. 11: Heijunka box

STEP 7: Pitch Calculation

At every process a material handler must bring the number of items needed i.e. Kanban to the pacemaker process and forward it to the finished goods area. The total time taken for this activity is called pitch. Assuming a minimum pack-out quantity of 5 in one carton box, we get:

Parts	Takt (mins)	Pitch (mins)
Swivel	42	209.1
Plug valve	88	439.6
Pup joint	186	929.9

Table 6: Pitch Values

Where, Pitch= Takt time*Minimum Pack-out quantity

STEP 8: Process Improvements

S. No.	Issues identified	Type of waste	Recommended kaizen/improvement
1	Single section for raw material and shipping docks	Waiting	Separate sections for RM & shipping dock
2	Long distance from RM section to bending work center	Transport	Bending work center to be installed closer to RM section
3	Large amount of inventory accumulating	Inventory	1. Forecasting customer requirements 2. New U-shaped cell to be constructed
4	Late delivery of products	Waiting	Adherence to production scheule
5	Ineffective space utilization	Wasted resource, Motion	1.New U-shaped cell design 2. Use of conveyor belt for material transport
6	Ineffective operator utilization	Wasted skill	Number of operators to be reduced by task engineering
7	No display for production plan and defects	-	Install online display monitors for display
8	Wrong swivel feeding to machining robot	Defect	Poka yoke to be implemented
9	Long lead time for outsourcing heat treatment	Waiting	Separate heat treatment facility installed closer to the plant
10	Issues identified	Type of waste	Recommended kaizen/improvement
11	Single section for raw material and shipping docks	Waiting	Separate sections for RM & shipping dock
12	Customer complaints about the defects	Defect	Weekly CSI (Customer Satisfaction Index) Initiative to be conducted

Table 7: Issues Identified and Recommended kaizens

2. Application of 8 cell design steps

STEP 1: Calculation of Takt Time

Takt time = 42 minutes (as calculated earlier)

STEP 2: Identification of planned Cycle-Time

We assumed that 95% of takt time is used in the production, i.e., the planned cycle time is 0.95* takt time.
Planned CT = 0.95* Takt time
= 0.95*42
= 40 minutes

STEP 3: Analysis of the activities for reengineering to the single piece flow

Although drawing an entire flow process chart is out of scope of this project, we can still observe that the major transformative activities are Bending, Machining, Assembly and Painting. Additionally, there are ultrasonic testing and hydrostatic testing processes which are done after bending and assembly respectively for measuring the strength.

The cycle time for the above-mentioned activities (for Swivel joints) are follows:

S. No.	Activity	Cycle time (minutes)
1	Bending	30
2	Ultrasonic Testing	5
3	Machining	40
4	Assembly	30
5	Hydrostatic Testing	15
6	Painting	15

Table 8: Cycle time values

STEP 4: Reengineering of the cell layout and activities

The following is the ASIS layout of the shop floor. We can observe that there is a lot of movement of material and hence there is an elongated throughput time and delayed delivery.

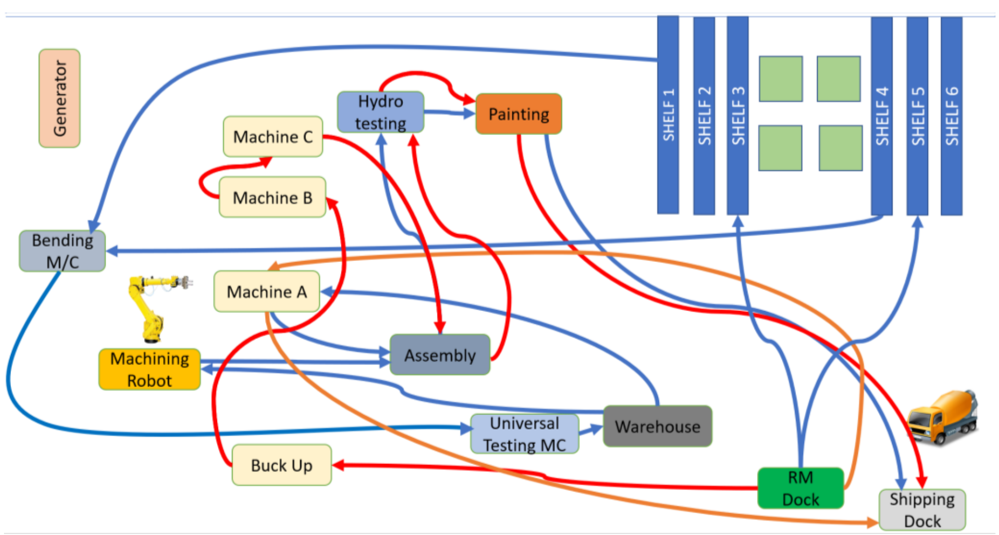

Fig. 12: Rough ASIS layout

To reengineer the cell layout, it is important to bring all the machines closer to each other and create a smooth flow of material on the shop floor. Additionally, the raw material and shipping dock needs to be separated so that there is no confusion of placing the raw materials and finished goods.

We redesigned the layout as follows:

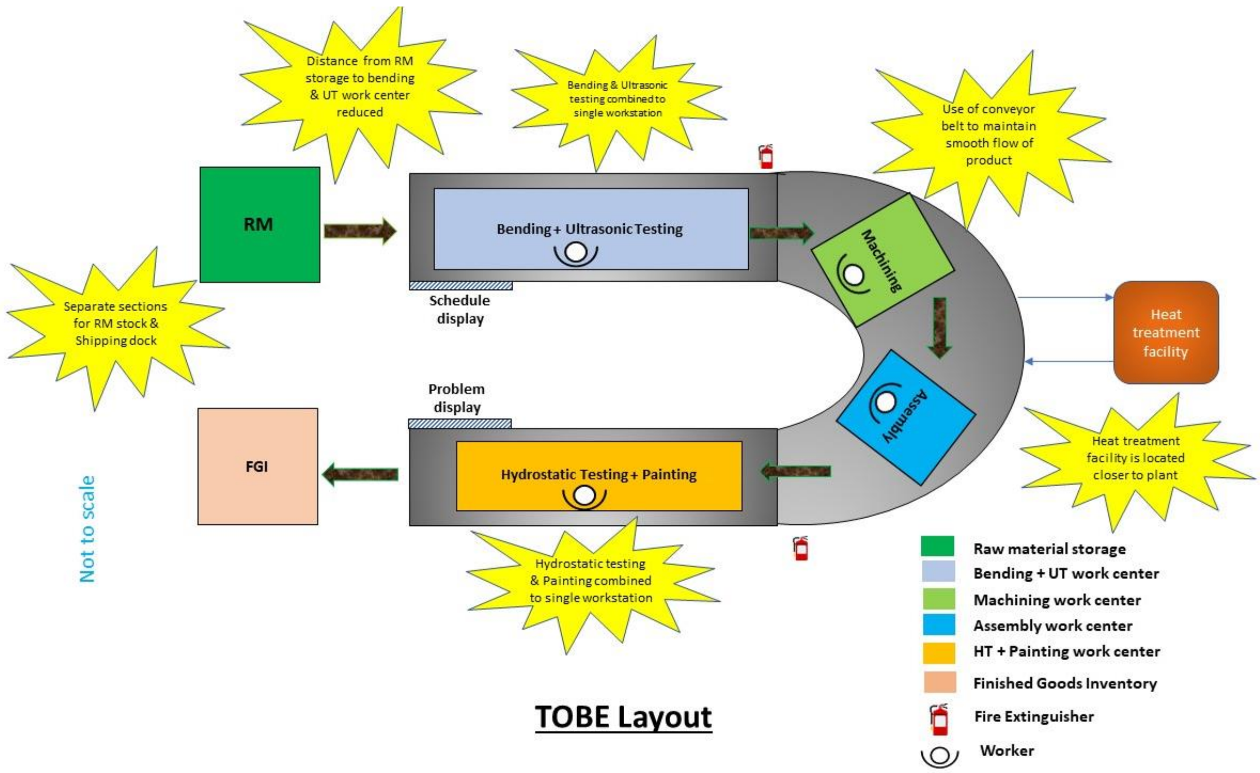

Fig.13: TOBE Layout

We have created the U-shaped layout where all the machines are placed. Additionally, bending and ultrasonic testing machines are combined in a single work center. Similarly, hydrostatic testing and painting stations are also combined in a single work center.

STEP 5: Calculation of minimum number of operators

As calculated in the earlier 'Application of 8 design steps' section -

- ASIS layout

Process	Number of operators	Cycle time (min)	Planned cycle time (min)	Utilization (%)
Bending	1	30	40	75
UT test	1	5	40	30.30
Machining	1	40	40	60.61
Assembly	1	30	40	66.67
Hydrostatic Testing	1	15	40	37.50
Painting	1	15	40	37.50

Table 9: ASIS Utilization values

We can see that there are 6 operators in ASIS layout. However, the utilization is very low.

- TOBE layout

Process	Number of operators	Cycle time (min)	Planned Cycle Time (min)	Utilization (%)
Bending + UT test	1	35	40	87.50
Machining	1	30	40	100.0
Assembly	1	30	40	75.00
Hydro. Test +Painting	1	30	40	75.00

Table 10: TOBE Utilization values

The total number of operators in the TOBE layout is 4.

STEP 6: Operator Balance Chart

- ASIS layout

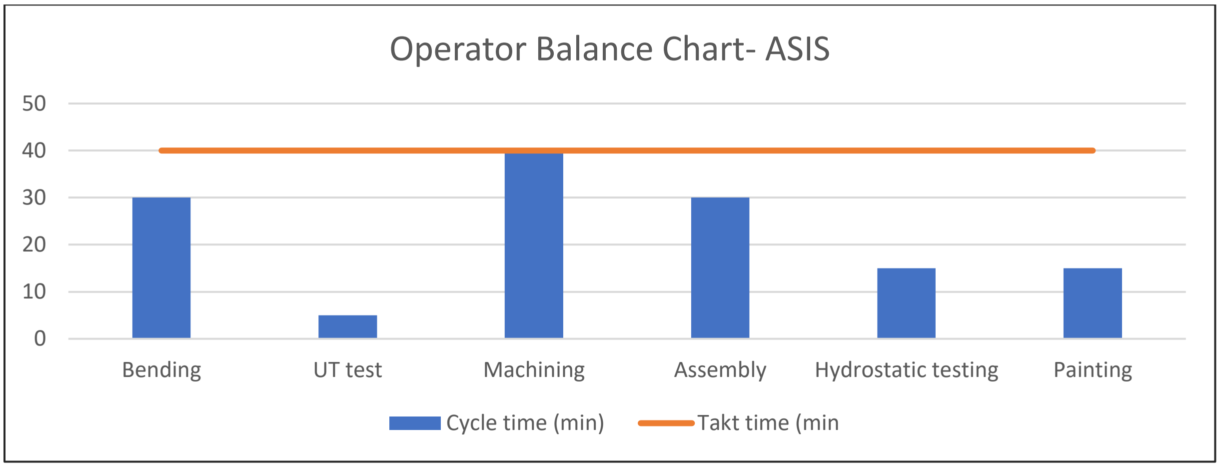

Fig.14: ASIS Operator Balance Chart

- TOBE layout

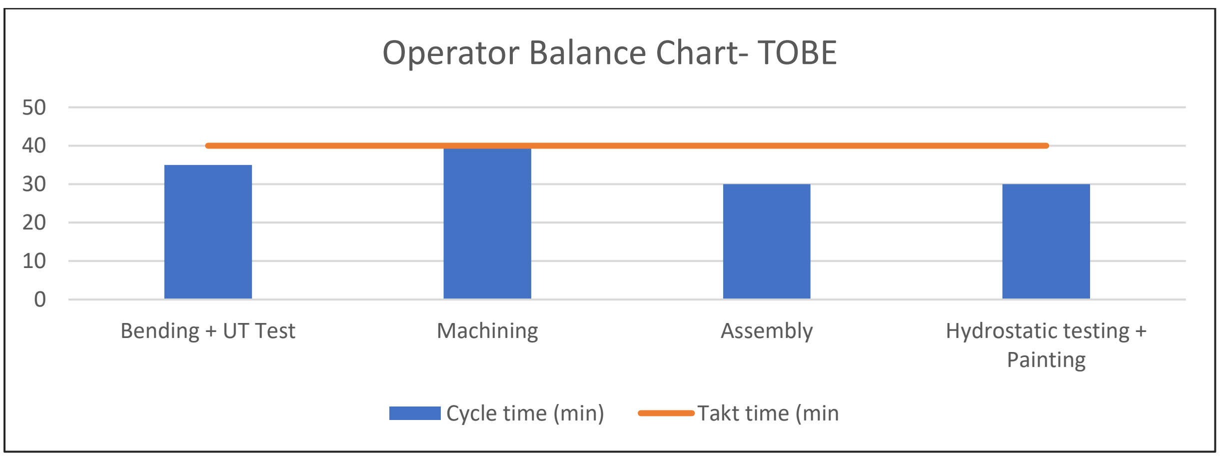

Fig.15: TOBE Operator Balance Chart

We can observe that utilization improves significantly in the TOBE layout. In addition, the number of operators in TOBE layout is 4, which is smaller than the ASIS layout causing the significant savings in the recurring costs.

STEP 7: Work station specification

We haven't changed or reengineered any activities pertaining to the individual operations while clubbing them. So, the individual SOPs (Standard Operating Procedure) are still the same as those of the ASIS layout.

STEP 8: Implementation of plan and schedule

Looping makes our action plan easier as we can distribute personnel according to their expertise across the loops and carry out all the engineering actions/kaizens required to achieve the future state. Following are the loops in the Value stream map:

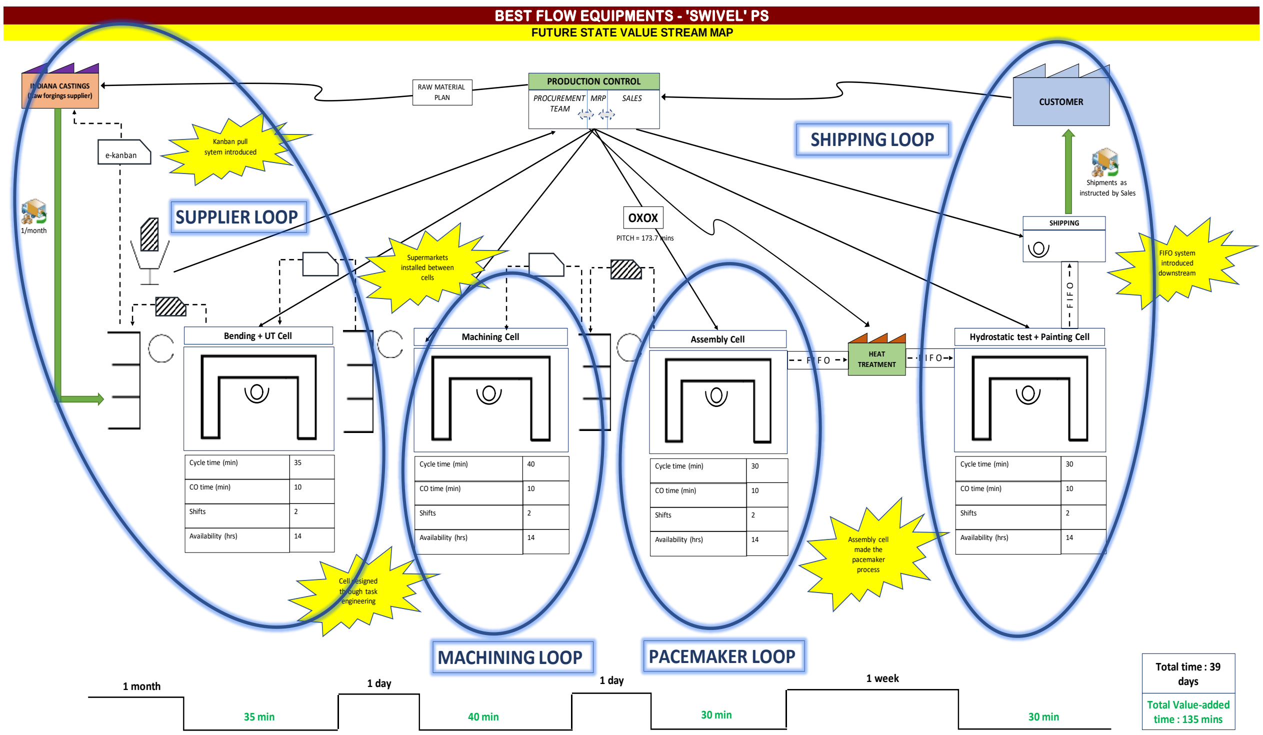

Fig.16: Loops identified in VSM

The four loops identified are:

- Supplier loop
- Machining loop
- Pacemaker loop
- Shipping loop

To develop an effective implementation plan and timeline, we have created a GANTT chart. The purpose of having the chart is to try and make things clearer and simpler for the people that are involved in the project. All the activities mentioned in the Gantt chart have to be performed in a chronological order, as shown in the chart.

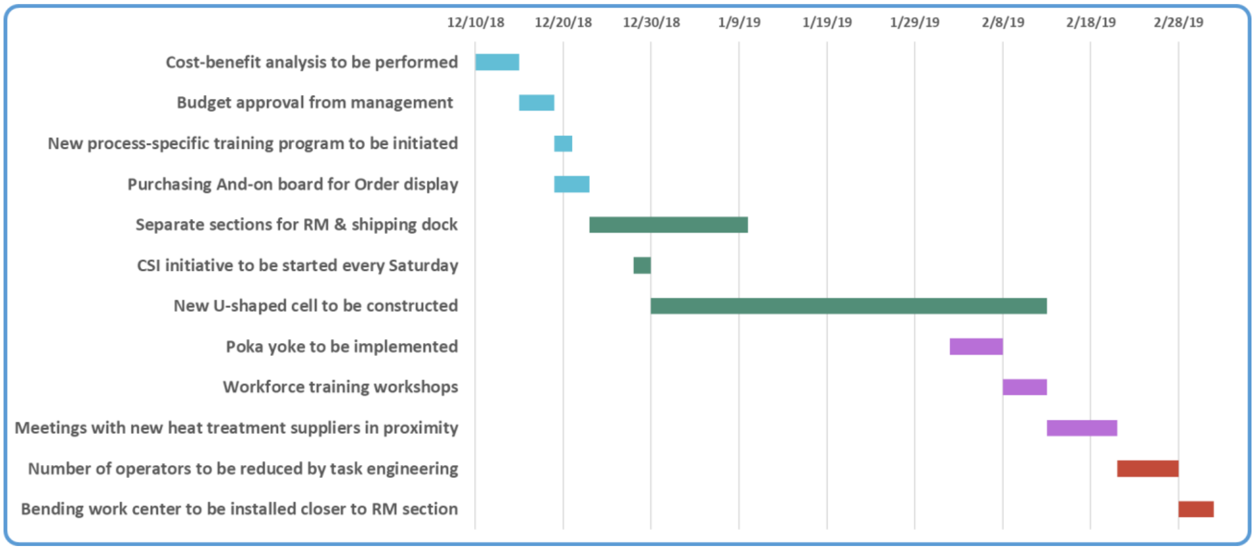

Fig.17: Gantt Chart

The implementation plan begins with generating a cost-benefit analysis of adopting the new layout and ends when all the work centers are installed as in TOBE layout.

According to the implementation plan, it will take approximately 110 days to adopt the new U-shaped layout on the shop floor.

3. FUTURE VALUE STREAM MAP

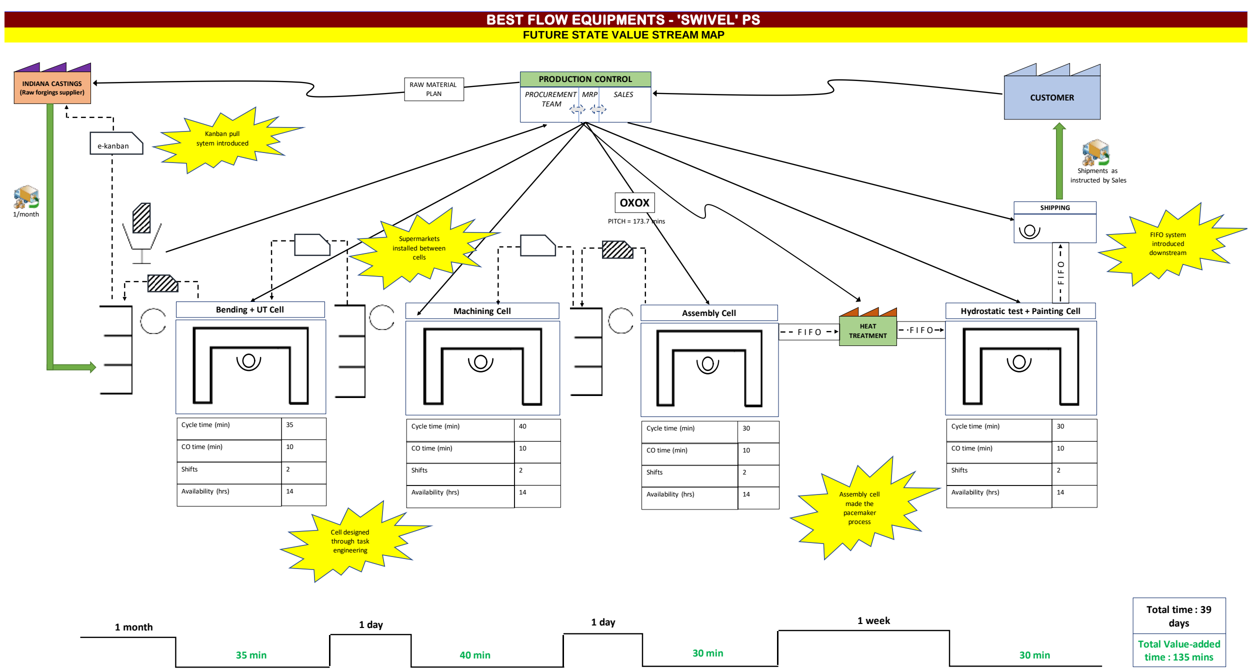

Fig.18: Future Value Stream Map

All the above-mentioned changes in the TOBE analysis have been incorporated in the Future State Value Mapping.

RECOMMENDATIONS

All the recommended kaizens and improvements have been tabulated in the 8^{th} step of the 8 design steps. Here, we will discuss some of the other suggestions that we recommend for lean production flow at Best Flow.

We have the demand data of Swivels for the past 11 months. ‘Procure to forecast’ can be one efficient way to tackle the variability of demand in the future. Assuming a normal distribution of demand, we have calculated an Order Quantity value, inclusive of safety stock at 95% service level. The value comes out to be **2260 – I**, where ’I’ is the inventory level at the time of ordering. The time period between two orders has been assumed to be one fortnight i.e. 15 days. The formulae used for this calculation has been discussed in the Appendix.

Best Flow is currently looking to move to a new facility. We recommend that a U-shaped conveyor belt system be installed in the new facility. This would conserve space as well as ensure an easier monitoring by the management. Electronic line stoppage signals and And-on systems could further automate the production system and make monitoring even easier. A morale boost to the workers is always a given during such improvements.

COST-BENEFIT ANALYSIS

After having researched similar projects carried out in the past, we have created a Costs vs Benefits table:

Cost-Benefit Analysis						
U- Cell Layout for Manufacturing Swivel Joints						
Quantitative Costs	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Non-Recurring Costs						
New layout cost	$ 150,000.00					$ 150,000.00
Display Monitor Board	$ 1,200.00					$ 1,200.00
Furniture and fixtures	$ 5,000.00					$ 5,000.00
Planning (upon approval)	$ 10,000.00					$ 10,000.00
Contract negotiations	$ 1,000.00					$ 1,000.00
Labour	$ 40,000.00					$ 40,000.00
Training of employees (pre-implementation)	$ 20,000.00					$ 20,000.00
Transition costs (parallel systems)	$ 10,000.00					$ 10,000.00
Post implementation reviews						$ -
Total Non-Recurring Costs	$ 237,200.00	$ -	$ -	$ -	$ -	$ 237,200.00
Recurring Costs						
Conveyor Belt	$ 5,000.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 5,800.00
Software maintenance and upgrades	$ 1,000.00	$ 100.00	$ 100.00	$ 100.00	$ 100.00	$ 1,400.00
Robots for machining	$ 90,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 130,000.00
In house heat treatment facility (65 MT)	$ 40,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 48,000.00
Office leases	$ 80,000.00	$ 80,000.00	$ 80,000.00	$ 80,000.00	$ 80,000.00	$ 400,000.00
Total Recurring Costs	$ 216,000.00	$ 92,300.00	$ 92,300.00	$ 92,300.00	$ 92,300.00	$ 585,200.00
Total Costs	$ 453,200.00	$ 92,300.00	$ 92,300.00	$ 92,300.00	$ 92,300.00	$ 822,400.00
Cost Savings						
Savings from structural changes	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 100,000.00
Material Movement Savings	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 50,000.00
Reduced staffing cost (incl. overtime)	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 500,000.00
Total Cost Savings	$ 130,000.00	$ 130,000.00	$ 130,000.00	$ 130,000.00	$ 130,000.00	$ 650,000.00
Cost Avoidance						
Factory supplies savings	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 2,500.00
						$ -
Total Cost Avoidance	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 2,500.00
Total Benefits	$ 130,500.00	$ 130,500.00	$ 130,500.00	$ 130,500.00	$ 130,500.00	$ 652,500.00

Table 11: Cost-Benefit Analysis

The following curve represents the break-even point after which we can expect a positive ROI (Return On Investment) from this project.

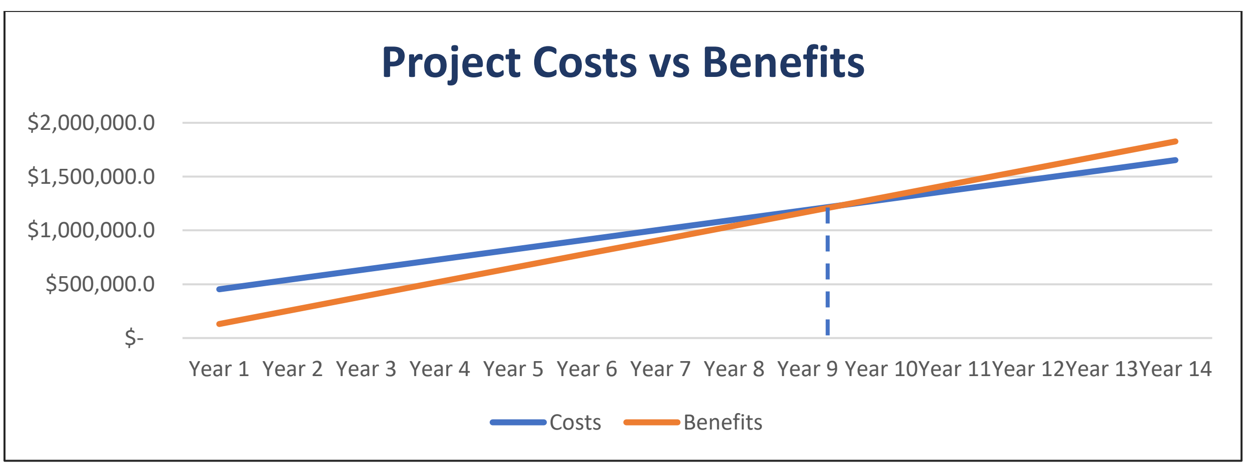

Fig.19: Project Cost vs Benefits

CONCLUSION

The ASIS numbers of Best Flow show that they hold an inventory of $14 Million at the moment. After the implementation of all the TOBE recommendations and the Future State Value flow, we expect this number to decrease by at least 50%. Moreover, with the new U-shaped layout, the space utilization of the new shop floor will also go up. With the new Kanban-induced pull system, we also expect the on-time delivery numbers to boost up.

The total non-value adding time (including lead time and intermediate buffers) in the ASIS state is a whopping 220 days. We have managed to bring it down by 82% to 39 days. We have also illustrated that the operator and equipment utilization would improve at 95% of the takt.

Alongside all the aforementioned numbers, the way to go in the future would be to implement 6-sigma to eliminate the underlying variability in the system.

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GLOSSARY

Cells—The layout of machines of different types performing different operations in a tight sequence, typically in a U-shape, to permit single-piece flow and flexible deployment of human effort by means of multi-machine working. Contrast with process villages.

Changeover—The installation of a new type of tool in a metal working machine, a different paint in a painting system, a new plastic resin and a new mold in an injection molding machine, new software in a computer, and so on. The term applies whenever a production device is assigned to perform a different operation.

Cycle time—The time required to complete one cycle of an operation. If cycle time for every operation in a complete process can be reduced to equal takt time, products can be made in single-piece flow.

EPEI- Every Part Every Interval, also known as EPEI represents the frequency that different parts are produced, or services provided within a fixed repeating schedule. This fixed repeating schedule is often graphically portrayed, for training purposes and as a scheduling visual control, as a wheel, with the different products represented by alphas (A, B, C…) and the wheel indexed clockwise to follow the intended sequence.

Heijunka—The creation of a "level schedule" by sequencing orders in a repetitive pattern and smoothing the day-to-day variations in total orders to correspond to longer-term demand. For example, if customers during a week order 200 of Product A, 200 of Product B, and 400 of Product C in batches of 200, 200, and 400 respectively, level scheduling would sequence these products to run in the progression A, C, B, C, A, C, B, C, A, C . . . . Similarly, if customer orders totaling 1,000 products per week arrive in batches of 200 products on day one, 400 on day two, zero on day three, 100 on day four, and 100 on day five, the level schedule would produce 100 per day, and in the sequence A, C, A, B . . . . Some type of level scheduling is unavoidable at every producer, mass or lean, unless the firm and all of its suppliers have infinite capacity and zero changeover times. However, lean producers tend to create excess capacity over time as they free up resources and to work steadily at reducing changeover times so the short-term discrepancy between the heijunka schedule and actual demand is steadily minimized, aided by level selling.

IDEF0-Integrated Computer Aided Manufacturing, is a function modeling methodology for describing manufacturing functions, which offers a functional modeling language for the analysis, development, reengineering, and integration of information systems; business processes; or software engineering analysis.

IDEF3- or Integrated Definition for Process Description Capture Method is a business process modelling method complementary to IDEF0. The IDEF3 method is a scenario-driven process flow description capture method intended to capture the knowledge about how a particular system works. The IDEF3 method provides modes to represent both.

Just-in-Time—A system for producing and delivering the right items at the right time in the right amounts. Just-in-Time approaches just-ontime when upstream activities occur minutes or seconds before downstream activities, so single-piece flow is possible. The key elements of Just-in-Time are flow, pull, standard work (with standard in-process inventories), and takt time.

Kaizen—Continuous, incremental improvement of an activity to create more value with less muda. Also called point kaizen and process kaizen.

Kanban—A small card attached to boxes of parts that regulates pull in the Toyota Production System by signaling upstream production and delivery.

Lead time—The total time a customer must wait to receive a product after placing an order. When a scheduling and production system are running at or below capacity, lead time and throughput time are the same. When demand exceeds the capacity of a system, there is additional waiting time before the start of scheduling and production, and lead time exceeds throughput time. See throughput time.

Poka-yoke—A mistake-proofing device or procedure to prevent a defect during order-taking or manufacture. An order-taking example is a screen for order input developed from traditional ordering patterns that questions orders falling outside the pattern. The suspect orders are then examined, often leading to discovery of inputting errors or buying based on misinformation. A manufacturing example is a set of photocells in parts containers along an assembly fine to prevent components from progressing to the next stage with missing parts. The poka-yoke in this case is designed to stop the movement of the component to the next station if the light beam has not been broken by the operator's hand in each bin Containing a part for the product under assembly at that moment. A poka-yoke is sometimes also called a baka-yok.

Process—A series of individual operations required to create a design, completed order, or product.

Processing time—The time a product is being worked on in designer production and the time an order is being processed. Typically, processing time is a small fraction of throughput time and lead time.

Pull—A system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need. The opposite of push. See also kanban.

Single Minute Exchange of Dies (SMED)—A series of techniques pioneered by Shigeo Shingo for changeovers of production machinery in less than ten minutes. One-touch setup is the term applied when changeovers require less than a minute. Obviously, the long-term objective is always zero setup**,** in which changeovers are instantaneous and do not interfere in any way with continuous flow.

Single-piece flow—A situation in which products proceed, one complete product at a time, through various operations in design, order-taking, and production, without interruptions, backflows, or scrap. Contrast with batch-and-queue.

Spaghetti chart—A map of the path taken by a specific product as it travels down the value stream in a mass-production organization, so-called because the product's route typically looks like a plate of spaghetti.

SOP—A standard operating procedure also called as SOP is a set of step-by-step instructions compiled by an organization to help workers carry out complex routine operations. Sops aim to achieve efficiency, quality output and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations.

Takt time—sets the pace of production to match the rate of customer demand and becomes the heartbeat of any lean system. In other words, it is the available production time divided by the rate of customer demand. For example, if customers demand 240 widgets per day and the factory operates 480 minutes per day, takt time is two minutes; if customers want two new products designed per month, takt time is two weeks.

Throughput time—The time required for a product to proceed from concept to launch, order to delivery, or raw materials into the hands of the customer. This includes both processing and queue time. Contrast with processing time and lead time.

Value—A capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.

Value stream—The specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer.

Value stream mapping—Identification of all the specific activities occurring along a value stream for a product or product family.

Level-Loading Heijunka Cycle—Heijunka, also known as level-loading, production-leveling or production-smoothing, is a foundational element of the Toyota Production System. Successful heijunka reduces lead time, inventory, and worker physical and psychological stress that can accompany fluctuating workloads. Some prerequisites include quick changeovers, capable processes, standardized work (or at least defined work content), good visual management, and a solid understanding of customer demand – volume, mix, and variation, see separate demand segmentation graph post.

A. $R_p = D_p$ /lowest D_p

Where,
R_p= Production Ratio
D_p= Demand Period

B. $C_h\ adj = \frac{1}{R_p\ multiple - selected\ R_p} \times C$

Where,
C_h= the specific C_h interval
R_p= Production Ratio

Calculation of minimum number of operators:

Minimum number of workers= ∑cycle time/number of work centers

Safety Stock and Order Quantity(Q) Calculations:

Assuming that the demand is normally distributed,

$$Q = \bar{d}(t_b + L) + Z\sigma_d\sqrt{t_b + L} - I$$

where:

$\bar{d}$ = average demand rate
t_b = the fixed time between orders
L = lead time
σ_d = standard deviation of demand
$Z\sigma_d\sqrt{t_b + L}$ = safety stock
I = inventory in stock

Best Flow PS IDEF0 Model Checklist:

S. No	Checkpoints	Description	Yes	No
1	3-6 rule	All child diagrams must have at least 3 and at max 6 boxes.	☑	☐
2	Minimum ICOM rule	Each box must have at least one control and one output and at max 6 ICOMs of each type.	☑	☐
3	V/P/C rule	Each diagram should comply with the Viewpoint, Purpose and Context of the PS.	☑	☐
4	Active verb use for activities	Only an active verb should be used inside the box for activities; gerunds should be avoided.	☑	☐
5	Noun phrased labels for ICOMs	All the labels for ICOMs must be nouns.	☑	☐
6	Communication to the reader	1. Does our model enhance domain expert's understanding of the process?	☑	☐
		2. Is the model coherent to an outsider?	☑	☐
7	Completeness	Are all labels, descriptions, purpose, viewpoint, arrows and boxes present in the model?	☑	☐
8	Conciseness	Similar activities have been merged and not mentioned separately; decomposition is avoided.	☑	☐
9	Element Description	Each element in the model must have a description.	☑	☐
10	Coupling evaluation rule	If the total number of entities is greater than 4 times the number of boxes, the model has high coupling. This should be avoided.	☑	☐
11	Clarity and consistency	Tunneling and bundling of similar concepts should be incorporated to maintain clarity and consistency in the PS model.	☑	☐
12	High cohesion	Better the binding and inter-relatedness, higher the cohesion. It's recommended that the output of an activity be the control of another activity. Such models are self-managing.	☑	☐
13	Hierarchy in diagrams	Parent diagram should be followed by the child diagrams. There should be a smooth flow of activities from left top to right bottom.	☑	☐

Best Flow PS IDEF3 Model Checklist:

S. No	Checkpoints	Description	Yes	No
1	Compliance with 8 design principles	Process design must comply with the 8 design principles.	☑	☐
2	V/P/C rule	The IDEF3 model should comply with the Viewpoint, Purpose and Context of the PS.	☑	☐
3	Active verb use for processes	Only an active verb should be used inside the box for process label; gerunds should be avoided.	☑	☐
4	Noun phrased labels for object state	Object states in OSTN diagrams should be labelled with a noun (or a noun preceded by an adjective/past participle)	☑	☐
5	Clarity and consistency	Proper use of Fan-in and Fan-out junctions, and Referents should be incorporated to maintain clarity and consistency in the process design.	☑	☐
6	Completeness	Are all labels, descriptions, purpose, viewpoint, required OSTNs and elaboration present in the model?	☑	☐
7	Communication to the reader	1. Does our IDEF3 process design enhance domain expert's understanding of the process?	☑	☐
		2. Is the model coherent to an outsider?	☑	☐
8	Elaboration documentation	Each UOB must have a filled elaboration form that provides the defining characterization of the process. Objects, Constraints and Description fields must be filled for each process.	☑	☐
9	Hierarchy in diagrams	There should be a smooth flow of processes from left to right in a process design. Parent processes should be decomposed to the child diagrams if required, in which case they appear in a window below the parent diagrams.	☑	☐
10	Identification of therbligs	All the 17 therbligs should be identified and leveraged while describing the elements of a task (especially at lower levels).	☑	☐
11	Decomposition	For a clearer understanding of the processes, one should go a level deeper and decompose parent processes into child processes.	☑	☐
12	Swim lanes	Swim lanes must be used to represent job sharing and responsibilities in the process design. They could be horizontal or vertical.	☑	☐

Instructions to use Model Mixing and Scheduling tool:

S.No.	INSTRUCTIONS TO USE THIS MIXED MODEL LEVEL SCHEDULING TOOL
1	Enter Models and their Monthly Demand (in descending order i.e. model with highest demand on top) in the 'DEMAND DATA' sheet.
2	Enter data as asked in the green cells in the 'Ch CALCULATIONS' sheet
3	Enter data as asked in the green cells in the 'EPEI CALCULATIONS' sheet
4	Once the aforementioned data is entered, all the calculations are done automatically. The final deliverables of this tool are :
	(i) Production ratios (Model mix) of models
	(ii) Quantity on card
	(iii) Number of cycles after which cards are removed or added to the heijunka box
	(iv) Number of cards to be removed or added to the heijunka box
	(v) EPEI run for each model
	(vi) Heijunka box pitch
S.No.	THINGS TO BE DONE MANUALLY
1	Making the heijunka scheduling box
2	Placing the kanban cards in the pigeon boxes
NOTE :	Every green cell requires a value to be entered in that cell.