INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Maximizing Profitability through Productivity Improvement using Theory of Constraints and Simulation: A Case Study

R. Rahul Ramakrishnan
Assistant Manager, Jindal Steel & Power Ltd. Raigarh, India
Randhir Kumar
Assistant Manager, Jindal Steel & Power Ltd. Raigarh, India
Karunesh Brahmpurya
M.Tech (I.E&M), Indian School of Mines, Dhanbad, Jharkhand, India

***Abstract**:*
Maximizing profitability is the primary goal of all business ventures. Without profitability the business will not survive in the long run. Improvement in Productivity always indicate step towards optimum utilization of resources and to be competitive in this Global market.
This case study is about improving production of a Cut-to-length unit of an integrated steel Industry. In this case study, we have applied theory of Constraints and identified the system constraints that are responsible for low production. Identification of Constraints has been done through Process mapping & Line Balancing of Defined system. For Process mapping, time study has been conducted to establish the standard time for elemental activities of cutting & related processes which are represented through Gantt chart. By analyzing Gantt chart, the activities which are of critical path and have potential for improvement are identified. We have suggested and implemented ideas using resource allocation, re-engineering and waste minimization which has resulted in increase in overall production capacity. We have also validated our suggestion and results using simulation through macro programming on Microsoft Excel 2010. The case study has given an opportunity to the Management to utilize optimum nos. of the resources with higher productivity and keep other resources as standby, resulting in the saving of manpower and other operating cost.
This case study will give an insight for developing an approach of Re-engineering & Resource planning which will results in better productivity and cost reduction.

***Keywords**: Process Mapping, Line Balancing, Gantt, Re-engineering, Simulation, Productivity*

1. Introduction

In current Competitive market and growing customers demand, every business organization tends to expand their business, thus in the process of expansion various resources and infrastructure are required. For those resources and infrastructure capital is required. The required capital for that expansion can be obtained from the market as a loan or can be invested from within the organization. Investment from the organization is safe and easy as compared to market loan. The strength of organization to invest the money in new or expansion project comes from the profit it earns form the existing infrastructure. Every company tries to increase its profit. The profit can be increased by improving the productivity of the organization. In this, we have shown how we have increased the productivity of the system by various tools and techniques like theory of constraints, reengineering, time study, simulation etc.
The productivity can be increased by two ways, either by decreasing the service cost on the input or by increasing the price of output. We can't increase the price of products, only we can decrease the inputs cost. The input costs can be decreased by various measures. We can decrease the service cost by reducing the operating expenses, reducing the amount of waste generated and by increasing the output of the system. Thus by increasing the productivity as stated above we can increase the profitability.
This is a case study of a cut to length unit of a steel plant where plates are being cut to various length and width from the rolled coils. The CTL consists of 3 units whose combined capacity is 40000 TPM out of which unit 1 & 2 are of 5000 TPM each and 3rd unit is of 30000TPM. But due to system constraints, we are not being able to achieve the full capacity of the CTL units. The existing maximum production in a month from CTL-3 is 20000 MT and combined production of CTL-1 & 2 are 10000 MT, that means the CTL units is

operating at only almost 50% of its capacity. This inefficient Productivity of the CTL unit leads to inadequate customer service level, which leads to commercial failure of an operating system.

In this case study, we have suggested the operating strategy of the 3 units of the CTL as per the variation in demands of plates from the market. With the current market demand we have stopped the operation of the 1st & 2nd units of CTL, since the 3rd unit is sufficient enough to fulfill the marked demand. The profitability of the CTL unit is increased by minimizing the waste and optimistic use of the other input of the unit. The detail study is discussed thereafter.

There are several critical factors within the operating system, which affects the productivity and hampers the overall profit of the system. The various factors which we have considered are –

- Cost: In our case study, we have minimized the various service costs by reengineering, Man Power planning, Waste Reduction and minimizing the Mill running time.
- Quality: Several changes that are applied to the production line improve the quality of the plates and reduce the wasted generation from the system.
- Speed: If bottlenecks in the system are removed, that will result in decrease the production time per coil and increase in overall production. Thus production capacity of the CTL unit increases.
- Flexibility: Reengineering of the system enables us to adopt with the frequent change in the dimension of the coil introduced, without delaying the production.
- Dependability: Automation of system leads to elimination of various manual errors in the system. Thus with automation the dependability of the system increases.

2. Existing Scenario

From last few years, we are getting more and more demand for the thinner section plates from the domestic as well as the foreign markets. Due to Increase in demand, timely dispatch of material became a challenge for us because of slow production rate due to constraints with the production line. This led to the Bank guarantee losses which were of a great impact on the profits of the company. Moreover, a bad reputation of the company was on line if this trend continued.

Average production of CTL was 17000 MT per month while installed capacity was around 40000 MT per month as per technology supplier. Our demand per months was around 30000 MT per month. Since existing production and installed capacity had huge gap, we were unable to meet our customer demands on time. This was leading loss of our customer faith on our firm. Therefore, our management was concerned to increase the production level and meet customer demands on time. The layout of CTL 3 unit is shown in figure 1.

3. Methodology

First, the constraint which slows the production rate has to be identified and improved. We used the Theory of constraints approach in phases to find the constraints and attack accordingly. In theory of constraints, there are five steps involved for improvements.

- Step 1: System's constraints identification: We used process mappings, Time study, Gantt chart and critical path method to identify the critical constraints.
- Step 2: Decision making about how to attack the problem: We used Brainstorming, resource planning, re-engineering and waste reduction to increase the production, quality and profits.
- Step 3: Aligning the system to the decision: We used line balancing and simulation to check the system so that utilization is maximum, and its long-term benefits.
- Step 4: Elevation of the constraints
- We monitored changes phase wise and increased productivity, yield and profits.
- Step 5: If any shift in constraints, start again from Step 1: Once the Constraints influence was obsolete, new constraints were identified and the same process is repeated again.

4. Data Analysis and Results

The average Monthly production of the last 2 years of all the three Cut-To-Length units (CTL-1, 2 & 3) is approx. 17000 TPM (Tons per Month) against the rated capacity of 40000 TPM. The average productions of these three CTL units are showing that we are not fully utilizing their rated capacity. The Production trend of CTL units is shown in Figure 2. From trend line, we concluded that the maximum production achieved is approx. 30000 Tons in a month which is less than the defined capacity of 30000 MT per month of CTL-3 itself. It indicates that we can cater the existing thinner plate demand with CTL-3 only, i.e. Production through CTL-1 & 2 is not required. The improvement in the production was a result of solving the constraints of highest priority with the help of theory of constraints and validating it with simulations.

4.1. Capacity Assessment of CTL 3

Now question arises, how much production we can achieve through CTL-3 for our product mix demand? To define the capacity of CTL-3 as per our product mix of thin plates, time study of all the elemental activities have been done to establish standard time and use this data as input of a real time simulation model for CTL-3 Process. Raw Material for CTL is rolled coil from Plate Mill of various thicknesses. Coil Specifications are shown in Table 1.

Capacity of CTL for different coil specification is computed below:
Let us suppose
Pi = Average Monthly Production Capacity of CTL for Coil Thickness 'i' mm
A = Available Working Minute per Day (1200 Min.)
C_i = Critical Process/Cycle Time per coil of 'I' mm thick plate in CTL
W = Average Coil Weight (18 Tonnes)
D = Nos. of working Days in Month (30 Days)
Then
Pi = (A/C_i)*W*D ………… (1)
Avg. Monthly Capacity of CTL-3 = Weighted Average (Pi) ....………. (2)
Time Study for each thickness has been done to establish critical process /Cycle time for a particular size (thickness) coil considering all activities from coil feeding to removal of packed product. The production will depend upon the processing time of the Sub process which takes maximum time for particular size (thickness) coil. For each thickness, processing time in minute for each sub process and average monthly production capacity calculation is shown in Table 2 with existing practices, considering allocation of equal production minute per month for each thickness indicated in Table 1, Average monthly production capacity of CTL -3 for all thicknesses is approx. 18500 Tonnes.

4.2. Capacity Enhancement of CTL-3
Once we are aware of the target, theory of constraints is applied for the process improvement.

4.2.1. Phase 1
Step 1: The most critical activity in Cut-to-Length process obtained. For improvement in average monthly production capacity of CTL -3, we have to reduce the existing cycle time of 'Cutting of a coil'. The following elemental activities are identified in the process of 'cutting a coil':
- Time for Coil feeding up to Flying Shear
- Time taken between Coil cutting & Movement of CTL plate to Inspection area
- Inspection Time of each CTL Plate
- ID Marking time on CTL Plate
- Scrap Removal Time
- Time for Movement of each CTL plate packet to Chain conveyor
- Movement of plates from chain conveyors to evacuation point

Gantt chart was used to find the Total cycle time for cutting one Coil (Product 1) is shown in Figure 3. The figure shows all elemental activities of cycle time for cutting one coil are in series and part of critical path. Cutting time of a Coil is the bottleneck in the process, which hampers the overall production.
Existing Man-Day distribution at CTL-3 is 39men (i.e. 13+13+13) men in 3 shifts.
Step 2: To reduce the timing of these critical activities, following suggestions was been given and implemented.
- Against existing deployment of 1-man for Manual ID marking, 2-men should be deployed.
- Against existing deployment of 1-men for Stenciling, Cold Punch, color Coding & Sticker pasting, 2-men should be deployed.
- Against existing deployment of no dedicated man, 1-dedicated Manpower for PO-3 control pulpit.

These changes will increase the total man power from 39 men to 48 men (i.e. 16+16+16) in 3 shifts and will reduce the cycle time by approximately 15%.
Step 3: line balancing was done to check the flow of the production rate. It turned out to be fair enough.
Step 4: The changes in the manpower increased the production rate after implementation of Phase-1, the average Production capacity will increase to around 22000 TPM from existing 18000 TPM. Still the line could not achieve the target.
Step 5: The process had to be repeated as the same constrains remains critical in the process which hampers production. So we start off with the Step 1 again.

4.2.2. Phase 2: Re-engineering
Step 1: The critical constraint remains the same i.e. cutting time for a coil. More study was done again to verify whether it is true that cutting time remains critical. In order to increase the production time study was done and there are following observation from Gantt chart shown in figure 4.
- Manual ID marking is interrupting between the cutting process of Coil and it has also increased the manpower requirement after implementation of phase 1.
- While introduction of Coil, CTL remains Idle the whole time when tail end of the coil leaves the mandrel and moves until Flying Shear.

Step 2: Brainstorming was done for solutions to overcome this problem. An idea to change the philosophy of CTL was proposed and implemented. This change enabled that next coil to be introduced parallel to the previous. Question arises now:
- What will happen if both the coils or of different thickness?

- What happens if there is any mismatch?

Re-engineering was the option that was chosen to overcome the problem. The following modifications were done.

- Manual ID marking to be replaced by Automatic ID marking.
- Two photocells were installed on the line to ensure safety of the machine and logic was incorporated to maintain gap between the two coils.

Step 3: line balancing was done to check the flow of the production rate. There was no any problem encountered.
Step 4: The process was studied for a long time with the help of simulations. The real time simulation model were made on MS-Excel with the help of macros to find out the production level possible with our suggestions for phase-1 & Phase-2 and compare it with existing system. Graph of simulated production for Phase-1, Phase-2 & Existing System is shown in Figure 5.
After implementing phase 2, the average Production capacity had increased up to around 30000 TPM. Calculation for average monthly production capacity after implementation of phase-2 using equation (2) is shown in Table-3. This means the target is achieved with operation of only CTL 3.
These changes have decrease the total manpower from 48 men to 42 men and will reduce the cycle time by approximately 42% with respect to existing cycle time. Proposed Man-Day Distribution for CTL-3 was 42 men (i.e. 14+14+14) in 3 working shifts.
Step 5: As the constraint switches in some cases to the strapping machine, we analyze again to attack the evacuation area.

4.2.3. Phase 3: Automatic Evacuation

Step 1: Work study was done for the P03 Pulpit to evacuation area. There was a lot of manual work, which increases the working time and the mistakes were high which led to breakage to evacuation chain.
Step 2: Sensors were installed at the start as well as the end of the evacuation chains & rolls, so that the movement of the metal is detected and tracking is produced in the Human Machine Interface (HMI). Logic sequences were created so that the motor starts and stop automatically with reference to metal detected.
Step 3: This reduced the movement of the person in the evacuation area of the CTL line and concentrate more on the production line. A click button was provided at main pulpit so that the operator can start the evacuation looking at the cameras provided.
Step 4: The Breakdown due to the chain breaks was nil and the evacuation happens automatically this reduced the manpower to 39 men (13+13+13) in 3 shifts.
Step 5: The delays and the excess manpower is reduced. The scope of improvement in the production is now not the critical constraint. However, the non-conformance of the customer's material hampers the company's profits. To further increase profit, steps of theory of constraints were repeated.

4.2.4. Phase 4: Yield Improvement through Diversion Reduction

Step 1: Our yield was only about 96% of the total coil input, that means we are wasting about 4% of the coil which is a great loss for the company. Therefore, we had to minimize the waste in order to increase the yield for the profitability. The diversions from the prime materials were the main source in the reduced yield. So it had to be minimized.
Step 2: An existing camera was shifted to the top the leveler so that a clear view of the processing material can be viewed. This view enabled the operator to adjust the backup rolls to achieve the desired flatness. This also made sure the portion with non-conformance is properly cut so that the wastage is minimized.
Step 3: There is no scope of any other changes in the system except this. A special training was given to the operators for effective operation.
Step 4: The diversions due to wavy, camber, buckling and crossbow were reduced significantly.
Step 5: The target put forth by the management was almost achieved. The results were promising as shown in Figure 6
As there is always a scope of improvement in the system, the theory of constrains can be used any number of times for improvement. As of now we have achieved our target. Therefore, once the target is revised, steps of Theory of constraints will be repeated again and again to fulfill the increasing needs.

5. Results

- **Production capacity Improvement**: Our average production of CTL-3 has improved to around 30000 MT per month. This resulted to match our rated capacity 40000 MT per month.
- **Optimum Facility Operation:** Our demand is varying around 30000 MT per month. After improvement, we can produce 30000 MT per month with operation of CTL 3 only. Therefore, our management has decided to operate only CTL 3 and operation of CTL 1&2 will be postponed until further increase in demand.
- **Labor Productivity Improvement**: Decision for operation of only CTL 3 for target production has increased our labor production productivity 769.2 MT/ Man-day from 195.4 MT/ Man-day which approximately 3.9 times of previous.
- **Yield Improvement:** Decrease in diversion resulted in yield improvement which means we can produce more tonnage with same input.
- **Profit Clocked**: These all improvements have shown the way to earn Rs. 47.3 Crores more profit against Rs. 0.4 Crores investment.

6. Conclusion

Productivity improvement is a wide, vague, and challenging task. It is often very troublesome and undesirable for an organization if the system is not operating with full capacity. In our case study, we have shown the stages of how we have improved the productivity of a Cut to length unit using various productivity improvement techniques like Theory of Constraints, process mapping, line balancing, Reengineering etc. Using these tools effectively we have achieved our target production with less number of facilities. It was the result of these improvements, the profitability of the Cut to Length unit also maximizes.

Sl	Description	UOM	Product-1	Product-2	Product-3	Product-4
1	Thickness of Coil	(mm)	6	9	12	15
2	width of Coil	(mm)	1500	2500	2500	2500
3	Coil weight	(Tonnes)	15	18	19	20
4	Coil Length	(Mtr.)	212.00	101.76	80.56	67.84
5	Weight per metre	(Tonnes)	0.07	0.18	0.24	0.29
6	Length of each CTL Plate	(Mtr.)	10	8	8	8
7	Avg. number of plates per packet	(Nos.)	7	7	9	8
8	Cutting Speed (As per Observation)	(Mtr./ Minute)	30	30	30	30
9	Total Nos. of CTL Plate made	(Nos.)	21	12	10	8
10	Avg. Length of Initial plate cut due to uneven shape	(Mtr.)	0.5	0.5	0.5	0.5
11	Length of Scrap Plate generated	(Mtr.)	1.50	5.76	0.06	3.34
12	Avg. number of Packet formation after complete coil processing	(Nos.)	3	2	2	1

Table 1: Coil parameters

Sl	Description	Product-1	Product-2	Product-3	Product-4
1	Coil Identification & Taking out the required coil from the lot & Placing on Turn Table / Telescopic Conveyor	5.1	5.1	5.1	5.1
2	Time to Feed Coil from Stand to Uncoiler	2.4	2.4	2.4	2.4
3	Total Cycle Time for Cutting 1-Coil (Mannual ID Writing)	40.9	38.4	33.7	30.3
4	Total Time for Shifting all CTL Plates of 1-Coil from Stacker to Chain Conveyors	5.8	4.7	3.5	3.5
5	Total Time for Shifting all CTL Plates of 1-Coil from Conveyors to Strapping	7.7	5.8	3.8	3.8
6	Total Strapping Time of all Packets from 1-Coil	30.3	22.8	15.2	15.2
7	Total Time for Shifting all packets of 1-coil from Stacker to end of Conveyors	4.7	3.5	2.3	2.3
8	Total Time for Stenciling, Cold Punch, Colour Coding & Sticker pasting on Top Plate of a packet made from 1-coil	28.0	21.0	14.0	14.0
9	Total Movement time of all packet of 1-coil from Conveyor to Transfer Trolley by EOT Crane	26.0	19.5	13.0	13.0
10	Total Movement time of Transfer Trolley from Loading Point to unloading point	3.0	3.0	3.0	3.0
11	Total Movement time of all packet of 1-coil from Transfer Trolley to Stacking	28.0	21.0	14.0	14.0
	Average Monthly Production capacity for different Product Mix	13,203	16,893	20,302	23,749
	(Considering Plant availabilty 20 Hr /Day)	**18537**			

Table 2: Averege monthly production capacity before implementing changes

Sl	Description	Product-1	Product-2	Product-3	Product-4
1	Coil Identification & Taking out the required coil from the lot & Placing on Turn Table / Telescopic Conveyor	5.1	5.1	5.1	5.1
2	Time to Feed Coil from Stand to Uncoiler	2.4	2.4	2.4	2.4
3	Total Cycle Time for Cutting 1-Coil (Auto ID Writing)	23.0	21.1	19.1	18.2
4	Total Time for Shifting all CTL Plates of 1-Coil from Stacker to Chain Conveyors	5.8	4.7	3.5	3.5
5	Total Time for Shifting all CTL Plates of 1-Coil from Conveyors to Strapping Point	7.7	5.8	3.8	3.8
6	Total Strapping Time of all Packets from 1-Coil	30.3	22.8	15.2	15.2
7	Total Time for Shifting all packets of 1-coil from Stacker to end of Conveyors	4.7	3.5	2.3	2.3
8	Total Time for Stenciling, Cold Punch, Colour Coding & Sticker pasting on Top Plate of a packet made from 1-coil	28.0	21.0	14.0	14.0
9	Total Movement time of all packet of 1-coil from Conveyor to Transfer Trolley by EOT Crane	26.0	19.5	13.0	13.0
10	Total Movement time of Transfer Trolley from Loading Point to unloading point	3.0	3.0	3.0	3.0
11	Total Movement time of all packet of 1-coil from Transfer Trolley to Stacking Point by EOT Crane	28.0	21.0	14.0	14.0
	Average Monthly Production capacity for different Product Mix	17,802	28,484	35,812	39,560
	(Considering Plant availabilty 20 Hr /Day)	**30414**			

Table 3: Average production capacity after implementing Phase 1 & Phase 2

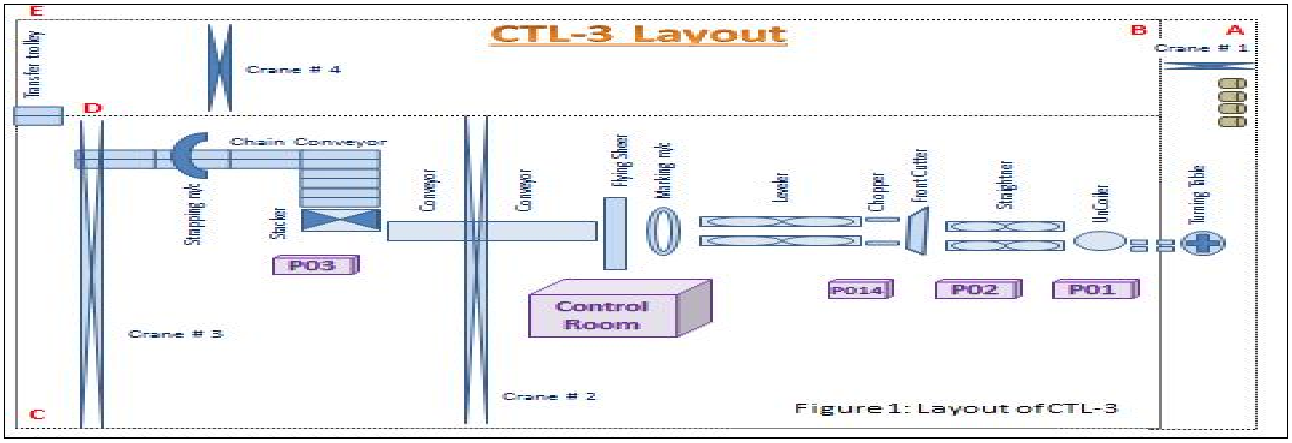

Figure 1: Layout of CTL unit- 3

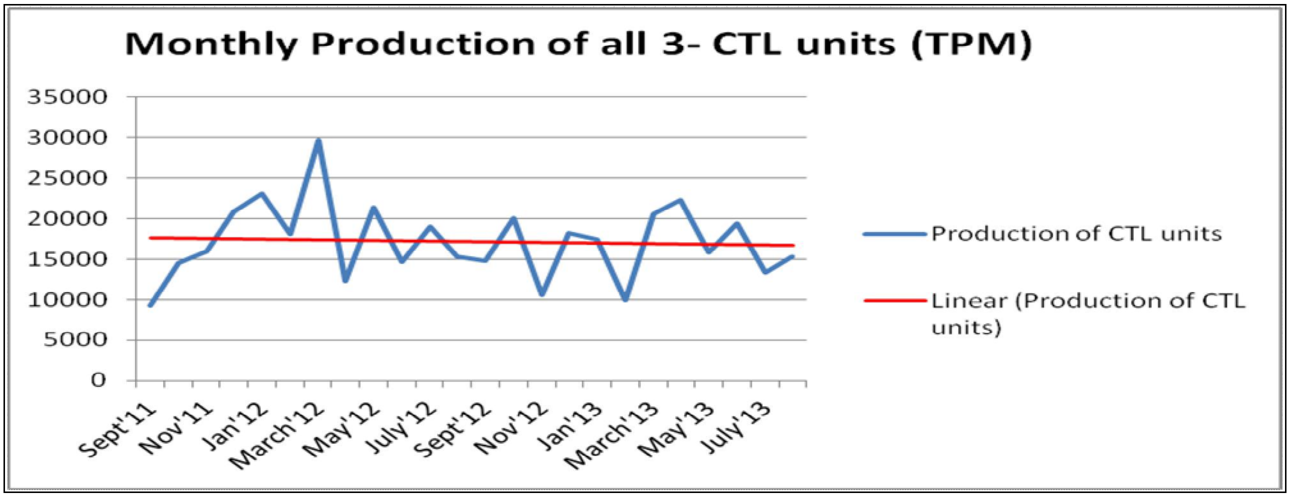

Figure 2: Production trend of CTL (all 3 units)

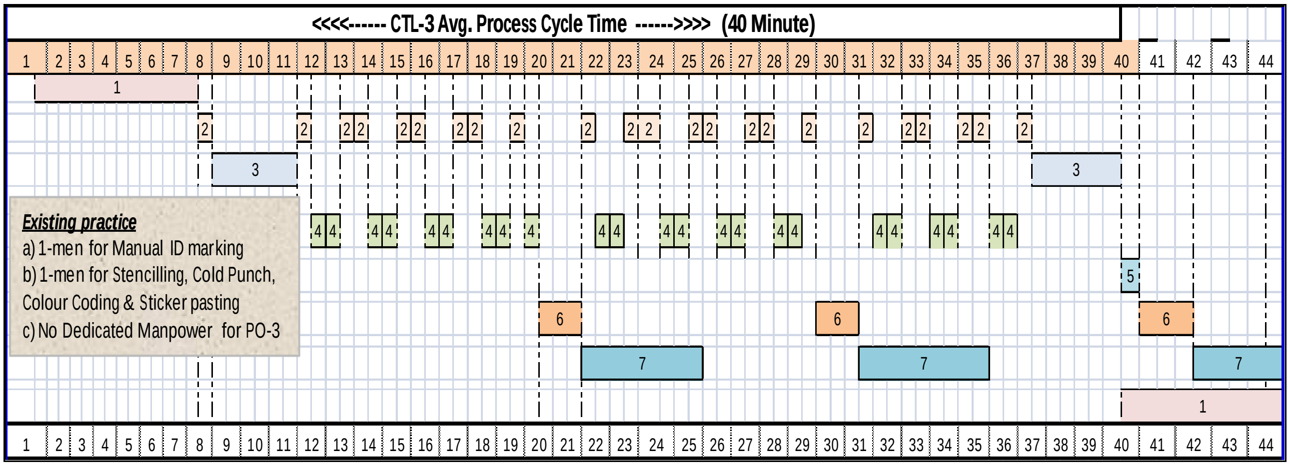

Figure 3: Gantt chart for total cycle time.

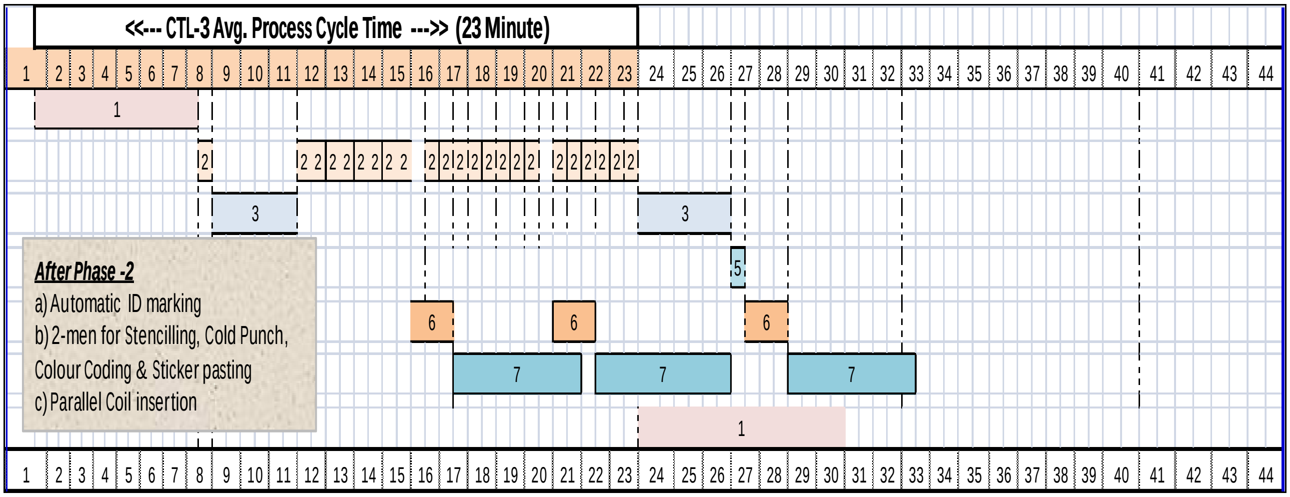

Figure 4: Gantt chart for Cycle time after implementing phase 1 & phase 2

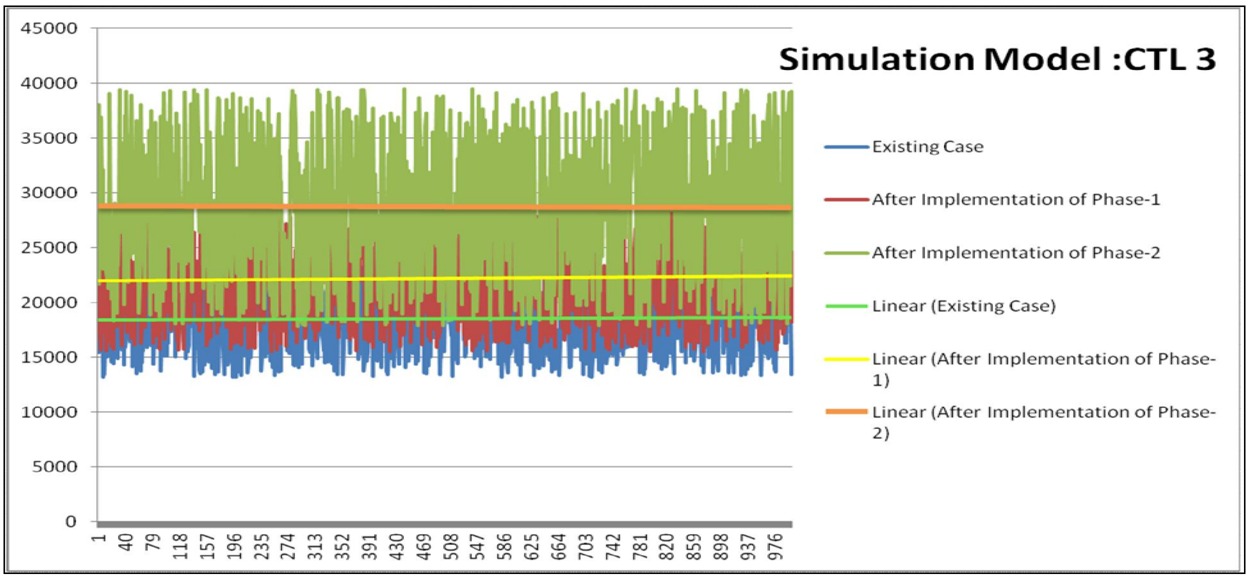

Figure 5: Simulated production for Each Phase

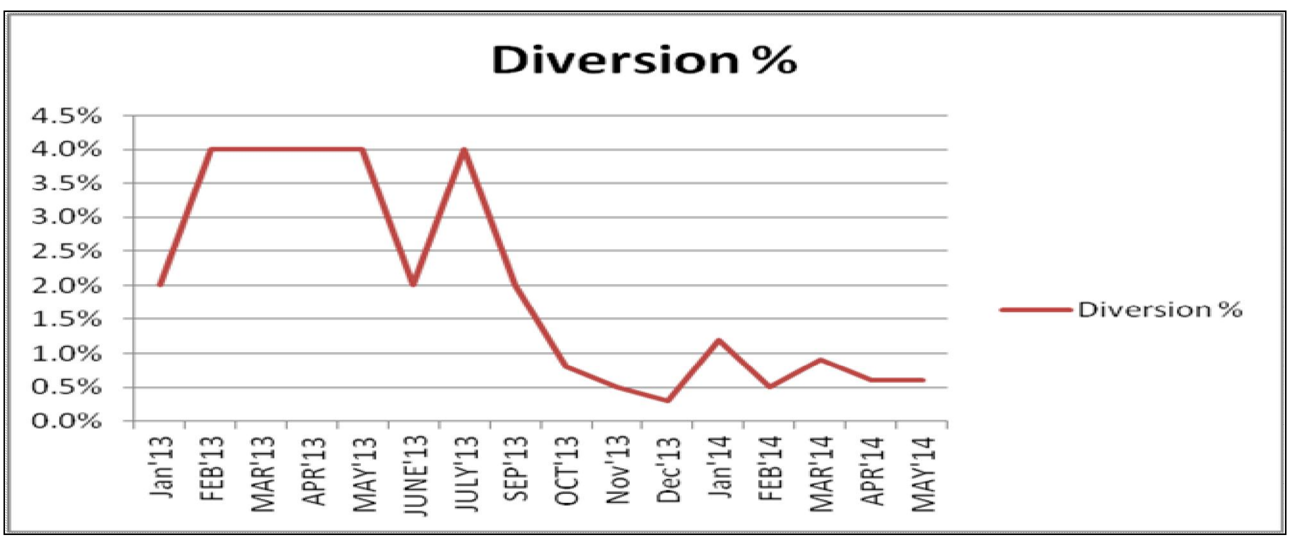

Figure 6: Reduction in Diversion

7. References

1. Barnes, R.M., 1980. Motion and Time Study Design and Measurement of Work, John Wiley & Sons, New York.
2. Kanawaty George, 1992. Introduction to work study, International Labour Organization Publication, Geneva.
3. Sharma, H.D., 1988. Textbook of Work Study, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi