



OPTIMIZATION OF WHEEL AXLE PLANT MANUFACTURING ENVIRONMENT BY SIMULATION

R. Pugazhenth¹, R Saravanan², M. Chandrasekaran¹, R Franklin Issac³ and P. Vivek¹

¹Department of Mechanical Engineering, VELS University, Chennai, Tamil Nadu, India

²Department of Mechanical Engineering, Ellenki College of Engineering and Technology, Hyderabad, Telangana, India

³Department of Mechanical Engineering, Anna University, Chennai, Tamil Nadu, India

E-Mail: pugal4@gmail.com

ABSTRACT

The current world economic crisis every industry needs to improve the productivity with the minimum and available recourses. This article presents an optimization of simulation methodology for the production environment to improve the productivity by reducing the process cycle time. Simulation models were allowing the users to easily understand the system performance and assist in behaviour prediction, to support system diagnostics and design. The manufacturing environment was modelled in Arena simulation software and the same can be simulated, the optimum sequence was obtained by iterative optimization methods. The productivity of the manufacturing environment is obtained by using the best operational sequence.

Keywords: optimization, arena, simulation, cycle time reduction, plant optimization.

1. INTRODUCTION

Nowadays the manufacturing and service industries strive to realize the worth of six sigma and design for six sigma with a wider acceptance, growth and investment for the same. (Ricardo Banuelas and Jiju Antony, 2004). The Byrne *et al.*, (2007) reported that lean Six Sigma initiatives led to product innovations, redesigned processes, and streamlined supplier chain and increase revenue growth by 80%. Trevor Cadden and Stephen John Downes (2013) suggested a business model which makes every effort to create a more holistic view of supplier integration; extending the scope beyond the individual firm centric factors. Jiju Antony (2008) conducted an opinion survey and concluded that Six Sigma is uniformly applicable for large, medium and small companies. In fact, the responses are results are more rapidly and much more visible in smaller companies than in larger corporations.

Hence Six Sigma not a global to the organization, it is specific too. Because the literature evident that six sigma approach can be used for improving quality in injection molding process (Vikas Dwivedi *et al.* 2014, Vikas Tayal and Jitendra Kumar, 2012, Rishi Pareek and Jaiprakash Bhamniya, 2013 and Bharati *et al.* 2011 in small scale jobbing industries (Darshak and Desai, 2006 and 2008), in metal casting foundry industries (Vijayaram *et al.* (2006), Darshak A and Desai (2012a and 2012b) and Gijo *et al.* 2014), in semiconductor foundry (Chao-Ton Su and Cha-Jen Chou, 2008), in rolling mill by Kunal Ganguly, 2012. In a manufacturing industry (Mehdiuz Zalan *et al.* 2013). In specific cases of solution for engine-overheating problem by using six sigma approach (Antony *et al.* 2005). Apart from manufacturing industries, Shanmugaraja *et al.* 2011 and 2012 used to improve quality and productivity using six sigma in project industries and furnished Literature snapshot on Six Sigma project selection for future research. As lean

Six Sigma is a powerful business improvement methodology for improving the efficiency and effectiveness, Antony *et al.*, (2012) made attempts to implement it in higher education institutions. Antony *et al.* (2007) discussed the feasibility of six sigma implications for service industries, Rupa Mahanti, Jiju Antony, (2009) for software industries, Jiju Antony *et al.*, (2009) provided assessing the status of Six Sigma implementation in the Indian industry.

Darshak *et al.*, (2009) furnished the impact of Six Sigma in a developing economy analysis on benefits drawn by Indian industries. Jagdeep Singh and Harwinder Singh (2012) discussed important concepts, surveys and case studies in continuous improvement methodology and highlighted future implications. The authors noticed that the literature on this classification is limited. Jiju Antony, (2008) highlighted the role and responsibilities of academic institutions in developing six sigma by research. Jiju Antony, (2004) highlighted the pros and cons of six sigma with academic perspective. Neha Gupta, 2013 presented an overview on six sigma quality improvement program. Jiju Antony, (2011) distinguished that even though Six Sigma and lean methodologies are focused on process and quality improvement, Lean has special features of formalization and codification of experience and judgement where as in Six Sigma has not.

2. PROBLEM DEFINITION

a) Business case (Financial impact)

The company has planned to produce 2021 SWL (Small Wheel Loader), 777 Dumper, 773 Dumper & 1035 Water Splitter to meet the customer demands. At present the axle sub-assemblies and main assemblies are spread in the 5th and 6th bays. So the material handling is improper. Transportation time for sub-assemblies and main assemblies are very large. So they have planned to rearrange the sequence of operation.

**b) Specification of new axle assembly sequence**

- Length of the axle plant = 65m
- Breath of the axle plant = 8.3 m
- Provided with 12 pneumatic hoses
- The rail track constructed for making the movement of materials easy.
- Availability of cranes up to 5 tons 5 No's.

Value added time in order to decrease the Non Value Added Time by the proper handling of the materials in the new plant; this will increase the turnover up to 20,000 USD.

STEP 1: Determine the current standard

The tools and tasks involved in this step are: Safety Learning / ergonomics Assessment Process, Value Stream Map the area, Work Measurement, Calculate the Takt Time. The stop watch time study type work measurement technique was used for determining the current standard. The time studies for four models were conducted and area wise details were tabulated in Table-1(a) to Table-1 (e). The personal allowance was 5% for males and 7% of female worker of the total working time. The fatigue allowance was 1% of the total time. Contingency Allowances was considered less than 3% of the total time and special allowance 1% of the total time is considered as a special allowance. The task wise allowances were established with the help of company experts and same was used to measure the current time consumption.

c) Problem statement

The Company has 10 bays in it. The 7th bay is the production area for the Sub assembly & Main Assembly. As per the marketing department data in next 12 months the production volume of the factory is going to increase. In that transmission area plays a major role, so they have planned to increase the production of the axles. This area so called axle assembly plant. The major problem over here is the improper Handling of materials. A large amount of floor space area is wasted for the storage,

d) Goal statement

The main objective is to find the necessary

Table-1(a). Work measurement details at 777 front axle area.

S. No	Work Stations	Time Taken	Performance Rating	Normal Time	Allowances	Standard Time
1	FRONT AXLE LH	115	0.9	104	12	116
2	FRONT AXLE RH	115	0.9	104	12	116

Table-1(b). Work Measurement details at 777 rear axle area.

S.No	Work Stations	Time Taken	Performance Rating	Normal Time	Allowances	Standard Time
1	Brake group S/A LH.	344	0.9	310	35	345
2	Differential & pipe	346	0.9	312	35	347
3	Banjo S/A	353	0.9	318	35	353
4	Planetary & Front axle	216	0.9	195	22	217

Table-1(c). Work measurement details at 2021 loader (front & rear).

S. No	Work Stations	Time Taken	Performance Rating	Normal Time	Allowances	Standard Time
1	Brake group S/A 1 LH	142	0.9	128	14	142
2	Brake group S/A 2 LH	130	0.9	117	13	130
3	Brake group S/A 1 RH	142	0.9	128	14	142
4	Brake group S/A 2 RH	130	0.9	117	13	130
5	Differential S/A	147	0.9	133	14	147
6	Line assembly	130	0.9	117	13	130
7	Brake wheel Mounting	128	0.9	116	13	129
8	Planetary & Diff	128	0.9	116	13	129
9	Pipe & A Frame S/A	145	0.9	131	15	146

**Table-1(d).** Work measurement details at 773 front & rear axle.

S. No	Work Stations	Time Taken	Performance Rating	Normal Time	Allowances	Standard Time
1	Planetary S/A (Front & Rear)	95	0.9	86	10	96
2	Brake, Wheel S/A (Front & Rear)	125	0.9	113	13	126
3	Front differential S/A	124	0.9	112	13	125
4	Rear differential S/A	124	0.9	112	13	125
5	Main Assembly (Front & Rear)	118	0.9	106	12	118

Table-1(e). Work measurement details at 1035 front & rear.

S. No	Work Stations	Time Taken	Performance Rating	Normal Time	Allowances	Standard Time
1	Brake group S/A	292	0.9	263	30	293
2	Differential & pipe connection	277	0.9	250	28	278
3	Banjo S/A	282	0.9	254	28	282
4	Planetary & Front axle	272	0.9	245	28	273

e) Takt time

One of the most important numbers, driving all decisions around work load balance, scheduling and capital expenditure is Takt time. It is the time required between completion of successive units of end product and it keeps the beat for customer demand. The takt time can be found by the formula (1)

$$\text{Takt time} = \text{Net available time} / \text{Customer demand} \quad (1)$$

Where Net Available Time is the available time per period of time (for example, per shift) excluding breaks and scheduled down time and the

Customer Demand is Customer demand per period of time (for example, per shift). In the case study organization, averagely 21 working days per month, there are two shifts per day with each have 9.5 hours. There is break and scheduled down time of half an hour per shift, hence the actual available the hours per annum will be 4536 working hours (272160 minutes). The model wise customer demand and takt Time is furnished in Table-2 for the demand in the year of 2016 which estimated based on the rate of consumption of previous years up to December 31st, 2015.

Table-2. Model wise customer demand in 2016 and Takt time.

Model	Quantity	Product variety	Customer Demand	Takt Time in Min.
777 Dumper	600	3	1800	151.2
2021 Loader	1080	2	2160	126.0
773 Dumper	300	3	900	302.4
1035 Dumper	252	3	756	360.0

f) Optimizing number of work stations

Number of workstations can be reduced by introducing the track and by the new fixture in the axle assembly plant. TAKT TIME / CYCLE TIME (TTCT) BAR CHART was used to visually display how long an operation takes relative to the Takt Time, to visually show the workload balance between operations, to serve as an analysis tool and identify improvement opportunities and to document improvements made during the RIW. The vertical bar representing the Cycle Time of one (for each) operation for one operator, the horizontal line representing the Takt Time. For balance the work load one must calculate the number of operators required Add the Cycle Times for all operations them divide it by the Takt Time. Usually calculating the number of operators is used ONLY to determine if and where the employer can redeploy resources. If not, it is used as a tool to determine how to eliminate people.

The details of workload status in each work stations were identified in terms of standard time and categorized as Standard Time Before Improvement (STBI). The operational requirement can be obtained using the relationship (2)

$$\text{Number of operators} = \frac{\text{Standard time of all the operations}}{\text{Takt Time}} \quad (2)$$

3. SIMULATION

Simulation is the best choice to analyze and evaluate complex system and simulation is often preferred as a performance evaluation tool (Saravanan and Raju, 2010). Simulation is a flexible tool for modelling complex system. Simulation helps in gradient computation to identify the solution or choice easily. Simulation is also used for comparing configurations; validate models, various policies and many other



qualitative features for obtaining solution to many what if ?questions. The basic models of improved assembly lines such as 773 Front Axle, 773 Rear Axle, 2021 Front & Rear Axle, 777 Front Axle, 777 Rear Axle and 1035 Rear Axle were created by using Arena, then refined by adding real world information such as process times, resource requirements, staff levels etc., The created models were simulated, verified with real time output and validated well. The simulated the proposed assembly line models and generated the outputs (refer Table for standard Time before Improvement and STAI is a short form of Standard time after Improvement. The Details of STBI, TKAT and STAI are graphically depicted workstation wise in Figure-1 to Figure-5. The table also reveal that:

4. RESULT AND DISCUSSION

The improvements were measured by time study. The standard time is a measure of performance. The performances were compared with Takt time. The Before and after implementation of Integrated approach were tabulated from Table-2(a) to Table-2(e). Where STBI stands for standard Time before Improvement and STAI is a short form of Standard time after Improvement. The Details of STBI, TKAT and STAI are graphically depicted workstation wise in Figure-1 to Figure-5. the table also reveals that

Table-2(a). Load balancing at 777 front axle.

S. No	Work Stations	STBI	STAI
1	Frontaxle LH	195	116
2	Frontaxle RH	195	116

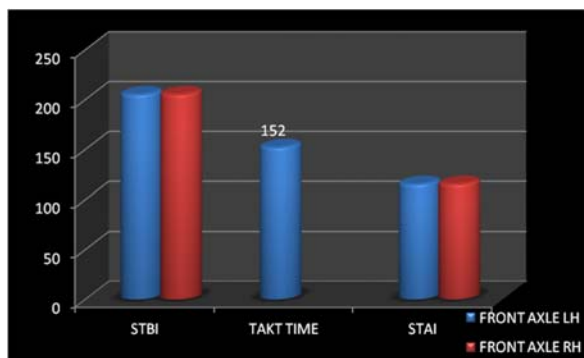


Figure-1. Load balancing at 777 front axle.

Table-2(b). Load balancing for 777 rear axle.

S. No	Work Stations	STBI	STAI
1	Brake group S/A LH	377	143
2	Brake group S/A RH	377	130
3	Differential sub assy	284	143
4	Wheel Pre loading	235	130
5	Line Assy	275	148
6	Brake, Wheel Mounting	181	130
7	Planetary & Differential Mounting	177	129
8	Hydraulic pipes & Transmission Mounting	227	129

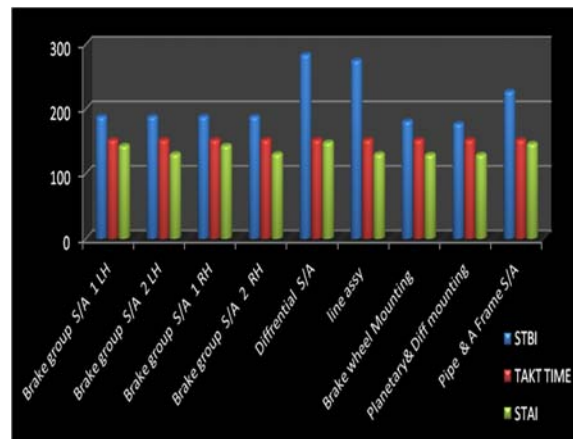


Figure-2. Load balancing for 777 rear axle.

Table-2(c). Load balancing for 2021 front & rear axle.

S. No	Work Stations	STBI	STAI
1	Planetary S/A (FRONT & REAR)	115	96
2	Brake, Wheel S/A (FRONT & REAR)	220	126
3	Front Differential S/A	161	125
4	Rear Differential S/A	161	125
5	Main Assy (FRONT & REAR)	213	118

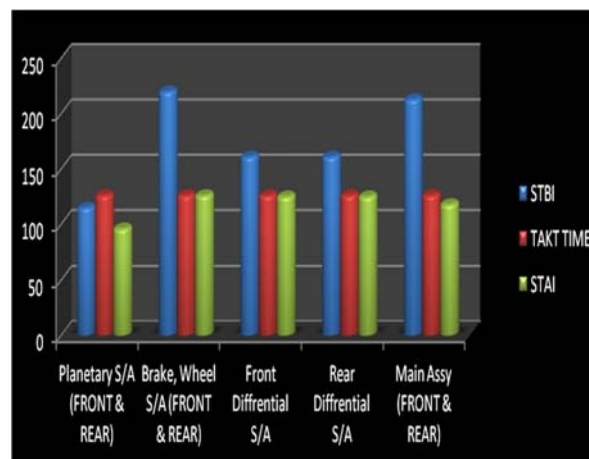
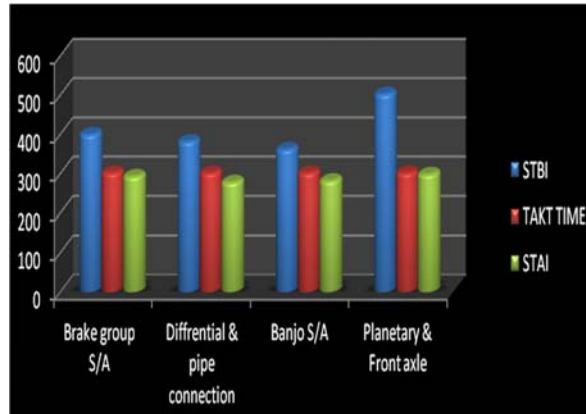


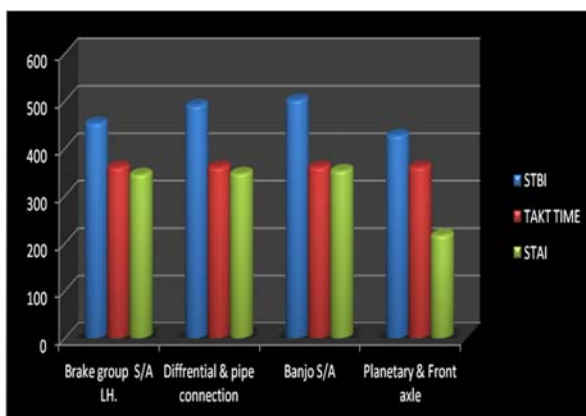
Figure-3. Load balancing for 2021 front & rear axle.

**Table-2(d).** Load balancing for 773 front & rear axle.

S. No	Work Stations	STBI	STAI
1	Brake group S/A	400	293
2	Differential & pipe connection	382	278
3	Banjo S/A	362	282
4	Planetary & Front axle	450	298

**Figure-4.** Load balancing for 773 front & rear axle.**Table-2(e).** Load balancing for 1035 front& rear axle.

S. No	Work Stations	STBI	STAI
1	Brake group S/A LH.	453	345
2	Differential & pipe connection	490	347
3	Banjo S/A	502	353
4	Planetary & Front axle	427	217

**Figure-5.** Load balancing for 1035 front & rear axle.**Table-3.** Simulated results of improved performance.

S.No.	Assembly Line	No of Axles produced (Output)
1	773 Front Axle	619
2	773 Rear Axle	320
3	2021 Front & Rear Axle	2176
4	777 Front Axle	1237
5	777 Rear Axle	627
6	1035 Rear Axle	375

5. CONCLUSIONS

This work is focused to optimize the manufacturing environment by simulation method. The manufacturing plant designed and simulated with the help of Arena simulation environment. The flow sequence was modified with the help of simulation model which is going to increase the turnover by 20,000 USD in 2016, with the utilization of available resources.

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