IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 17, Issue 9.Ver. I (Sep. 2015), PP 106-120
www.iosrjournals.org

Study of Total Productive Maintenance and Manufacturing Performance of a Manufacturing Industry

[1]Mr. Kishor Kumar Aroor, [2]Mr. Madhukara Nayak, Prof. Er.U.Sai Krishna[3]
(Formerly Post Graduate student) (Assistant Professor)[2],
[1](Manipal Institute of Technology (A Constituent of Manipal University), Manipal, India)
[2](Mechanical Engineering, Shri Madhwa Vadiraja Institute of Technology and Management, India)
[3](Mechanical Engineering , Malla Reddy College Of Engineering & Technology (U.G.C-Autonomous),India)

Abstract : *Now a day's manufacturing systems have become continuously complex with the introduction of new technologies and are more costly to operate and maintain. The manufacturing systems are often operated at less than their full capacity, resulting in low productivity and high operating costs. In today's global economy, the survival of companies are depends on their ability to rapidly innovate and improve. As a result, an increasing search is for methods and processes that drive improvements in quality, costs and productivity. TPM is a one such standard philosophy, which emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment. This research work deals with study of TPM and Manufacturing performance of a manufacturing industry. Methodology has been framed to obtain best possible results based on target objectives. After finishing of detailed literature survey, two small scale manufacturing industries are selected for data collection and TPM analysis work. By visiting those two industries both primary and secondary data's are collected. Values of Overall Equipment Effectiveness(OEE) and Partial productivity are calculated by using standard formulae's and standard methods. By Scheduling method of data collection four TPM pillars are analyzed by framing questions. Finally all required results are obtained and analyzed properly for obtaining conclusions.*
Key Words: *OEE, Manufacturing, TPM , Quality*

I. Introduction

Total Productive maintenance (TPM) is a well-defined innovative Japanese concept for maintaining plant and equipment. It can be consider as science of machinery and plant health. Higher manufacturing performance will provide competitive advantage to the organization. TPM is a highly structured and planned production approach which adopts a series of tools and techniques to achieve higher effective plants and machinery. In a highly competitive contemporary environment, TPM has proven to be an effective maintenance improvement philosophy for preventing the failure of an organization. Manufacturing systems have become increasingly complex with the introduction of new technologies and are more costly to operate and maintain.

The manufacturing systems are often operated at less than that of full capacity, resulting in low productivity and high operating costs. The cost of operating and maintaining equipment has become a significant factor in the production of goods in an increasing competitive global environment. Now a days, consumers expect manufacturers to provide highest quality, reliable delivery and competitive pricing. This demands that the manufacturer's machines and machining processes are highly reliable. In order to maintain highly reliable machines, there is a need of smooth manufacturing process. Many organizations have been implemented Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment by setting and maintaining the optimum relationship between people and their machines. The maintenance function has gone through many changes over the past few decades. The traditional way of perception of maintenance's role is, get into action whenever a breakdown occurs. Total productive maintenance therefore shifts the paradigm of company's traditional maintenance system from being reactive to being more proactive by maintaining the equipment in optimum condition at all times. Total Productive Maintenance (TPM) provides a continuous, life cycle approach, to equipment management system that minimizes equipment failures, production defects, wastages, and accidents. It involves each and everyone in an organization, from top level management to machine operators, and production support groups to outside suppliers. The objective is to continuously improve the availability and prevent the degradation of equipment to achieve maximum effectiveness. These objectives required strong management support as well as continuous use of work teams and small group activities to achieve incremental improvements in the shop floor. In TPM Maintenance is recognized as an important and valuable resource. Maintenance group now has a role in making the business more profitable and the manufacturing system more competitive by continuously improving the capability of the equipment, as well as making the practice of efficient maintenance. To gain the full benefits of TPM, it must be applied in the proper amounts in proper way and should be integrated with the production system and other improvement initiatives.

Effectiveness and efficiency of equipment plays a major role in modern manufacturing industry to determine the performance of the organizational production function as well as the level of success achieved in the organization. The losses or gap between 100% and actual efficiency can be categorized in to 3 categories.

1. Availability losses: Which is result of Breakdowns and changeovers, where the production line is not working while it should be.
2. Performance losses: It occurs as a result of Speed losses and small stops/idling positions, which leads to reduced capacity than standard one.
3. Quality/Yield losses: It occurs as a result of losses due to defects and start-up- quality losses.

Overall Equipment Effectiveness (OEE) is the basic measure for Total Productive Maintenance. OEE highlights the actual "Hidden capacity" in an organization. It measures the both efficiency and effectiveness of the equipment. Thus OEE is a function of the three factors namely Availability, Performance rate and Quality rate.

OEE = Availability X Performance rate X Quality rate. General problem in manufacturing companies especially in middle and small scales industries, they are operating less than their capacity due to high rate of unplanned failure. Introducing TPM in a developing country, such as India, is still considered as a major challenge due to several practical problems with respect to implementation. Also resistance from employees, lack of commitment from top management is other major reasons why TPM fails in many local organizations.

II. Background Theory

2.1.Literature Survey

K.C Ng and Goh, conducted numerical investigation to study the effect of TPM in a semiconductor manufacturing company and they concluded with the evidence that supports the below statements. There is an improvement in equipment availability, equipment process performance, equipment throughput, equipment unscheduled down time and overall equipment effectiveness after the implementation of TPM in the global semiconductor manufacturing firm. Also they given the world standard values for OEE are as follows:

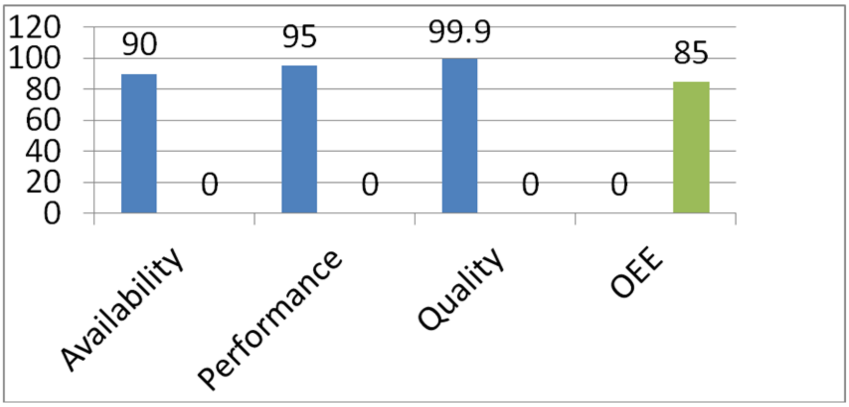


Fig. 2.1 World standard values of OEE[1]

Pradeep Kumar Shetty and Dr. Rodrigues conducted a TPM study on four diesel power generating units and by comparing OEE of those four units they highlighted the importance of speed efficiency and they concluded with “OEE is a Powerful Tool to identify previously hidden manufacturing losses and inefficiencies. Tracking OEE scores and using them to drive improvements in manufacturing processes is a vital step forward towards world-class lean manufacturing for organizations of all sizes and industries[2].Ma Lixin et al, IEEE 2011, Conducted study on application of TPM in small and Medium sized enterprises. Change of OEE values before and after implementation of TPM will be given by them and it will be given in below table[3].Further in information about TPM and its applicability has been well documented in literary sources [4-26]

Table.2.1.OEE value after implementation of TPM

Machine Number	1	2	3	4	Average
June OEE	62.7	60.5	62.1	60.8	61.5
December OEE	74.1	73.5	75.2	73.7	74.1

Table 2.2 Industries for data collection

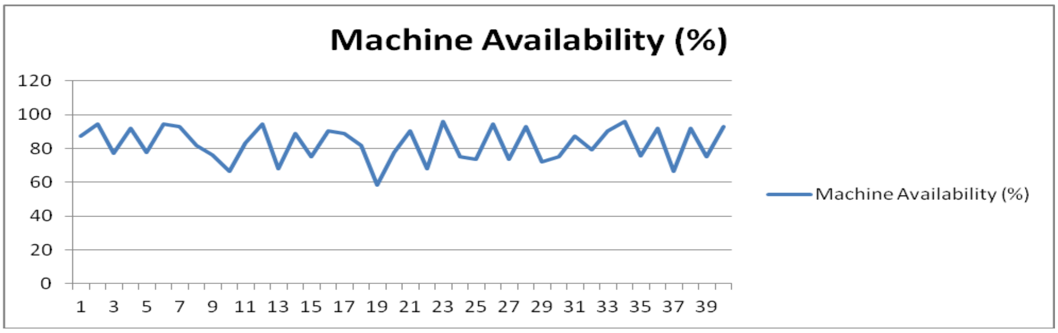
Serial Number	Full Name of Company	Capacity (Tones /month)	Type of products
01.	L.G INDUSTRIES Koteshwara. (Company A)	200	Sunrise ISI, Sunrise, Tejasvi, Orbit brand Rigid PVC pipes.
02.	SHAKTHI PLASTICS Barkur, Brahmmavar. (Company B)	30	Normal Rigid PVC pipes.

III. Result Analysis

3.1.Analysis of OEE Results

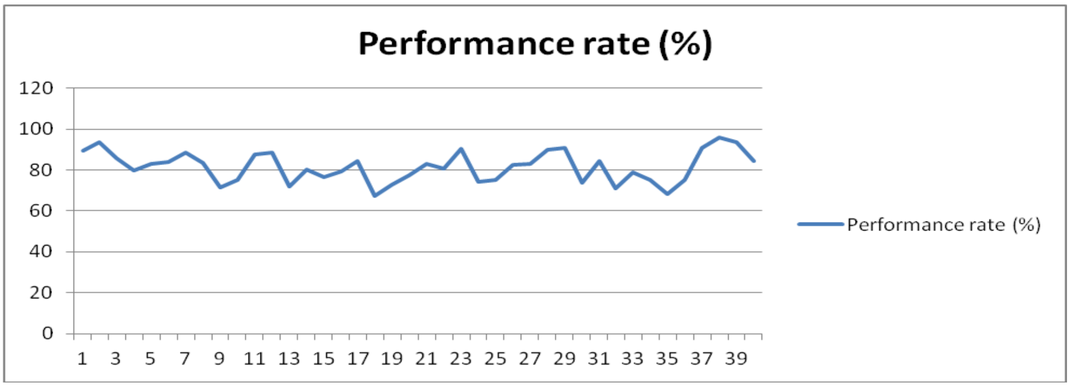
3.1.1.Result Analysis for L.G Industries:

OEE is depends on Availability, Performance and Quality rate, it's important to analyze those three parameters to identify hidden problems.



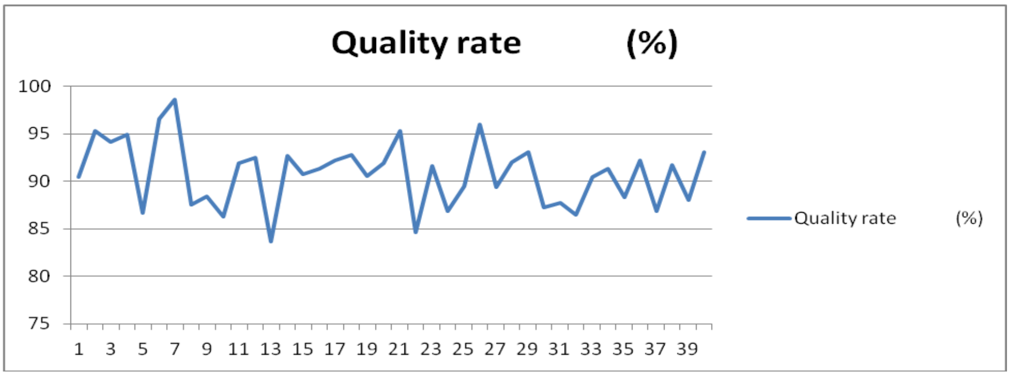
Graph3.1. Machine Availability Graph

Above graph will gives the Machine Availability rate of L.G industries for 40 shifts. Availability represents out of the total time what is the percentage of time is available for production. From this graph we can observe that values of availability will be continuously varying from its standard value of 90%. Also there is a lot fluctuations can be observed in the values.



3.2.Graph of Performance rate

Above graph 3.2 represents the 40 shifts values for Machine performance rate of L.G industry. Mainly it gives the speed losses from standard value. From graph we can observe that performance rate also continuously fluctuating from its standard value of 95%. For every 2 to 3 shifts we can observe change in direction of performance rate line.



Graph 3.3 Graph of Quality rate.

Above graph 3.3 will represents the Quality rate of L.G industry for 40 shifts. Here we can observe that similar to Availability and Performance rate, quality rate is also not showing constant values. It's fluctuating in Zigzag manner and varies continuously from standard value of 99.9%.

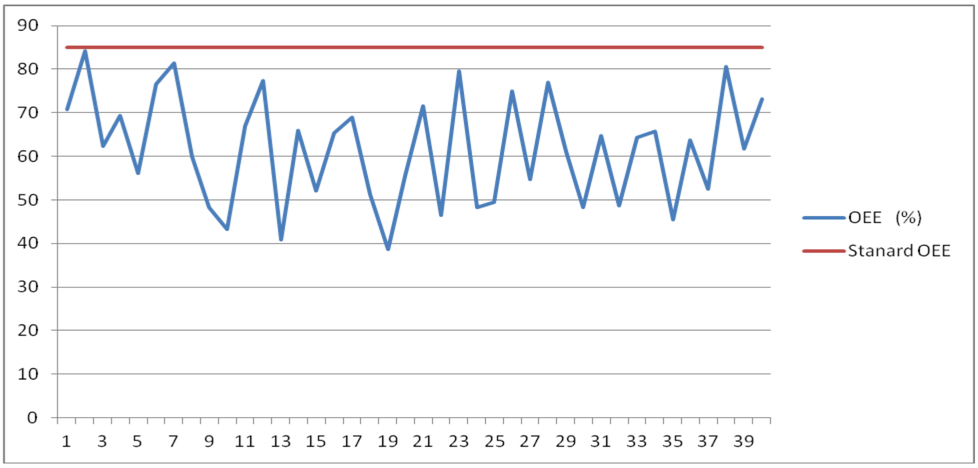


Fig. 3.4 OEE Graph.

Above graph 3.4 will helps to observe how OEE values of L.G industry is continuously varying from its standard value. World standard says that 85% will be the standard value of OEE that one should try to achieve and here we can observe that except one shift almost all shifts are lagging to achieve standard OEE. Also we can observe, OEE values are showing lot of fluctuations in continuous manner.

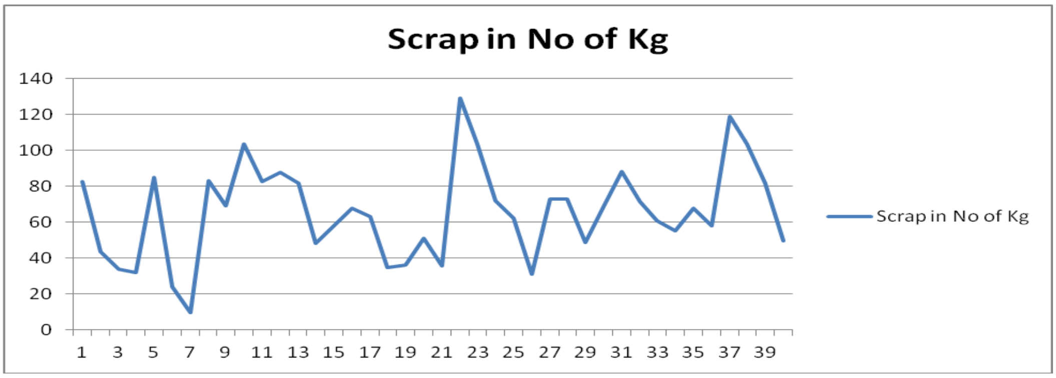


Fig. 3.5 Graph of Scrap rate.

Above graph 3.5 represents the scrap rate of L.G industry. Reason for scraps can be categorized in to two category and they are: 1. Trail run scrap and 2.Production defects. Here we can observe that whenever continuous production of same type of pipe takes place, scrap rate will be decreased and whenever changeover is there we can observe increase in scrap. Hence this variation is mainly due to trail run scrap.

3.1.2 .Result Analysis for Shakthi Plastics:

Compare to L.G industry, almost similar kind of Availability, Performance rate, Quality rate, Scrap and OEE graphs are observed for Shakthi plastics Industry, with same type of variations. Below figures 3.6, 3.7, 3.8, 3.9, 3.10 will represents those graphs for Shakthi Plasitcs.

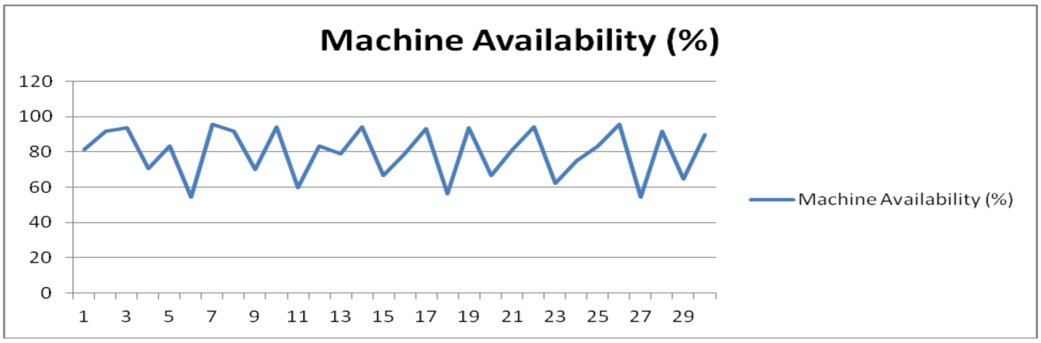


Fig. 3.6 Graph of Machine Availability

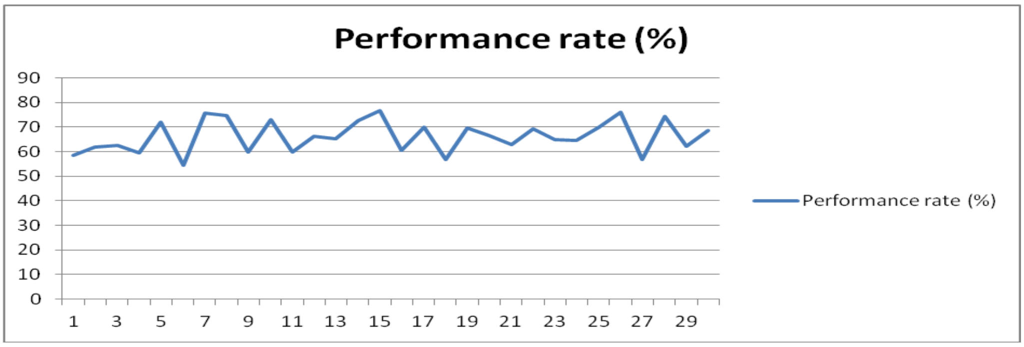


Fig. 3.7. Graph of Performance rate

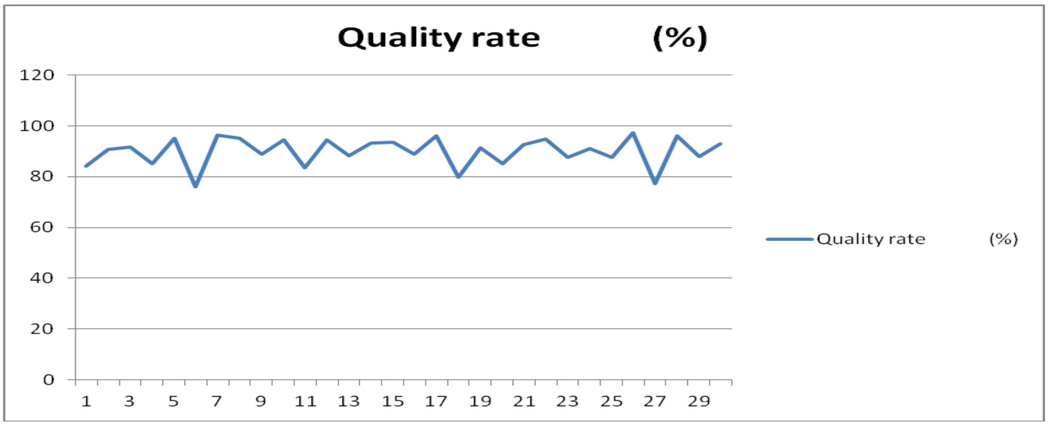


Fig. 3.8 Graph of Quality rate

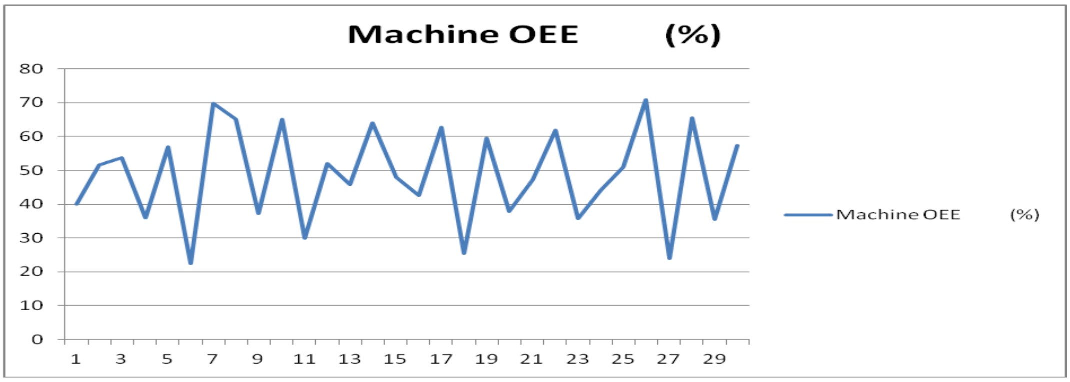


Fig. 3.9 Graph of OEE

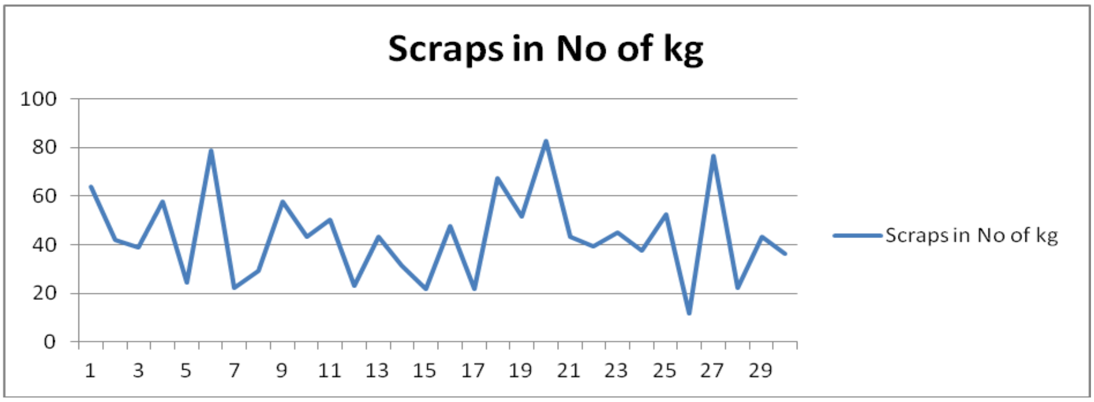


Fig. 3.10 Graph of Scrap rate.

3.2.Comparison of OEE between Company A and Company B:

Comparing the values of Availability, Performance, Quality and OEE of Company A and Company B will helps to measure the level of TPM in both the company and to measure deviation of values from world standard parameters. Both Table 3.1 and figure 3.11 below are gives the comparison of all three parameters of OEE and OEE values between two company and with world standard.

Table 3.1 Comparison of parameters between two industries A and B.

PARAMETER	World standard values (%)	COMPANY A (L.G)	COMPANY B (SHAKTHI)
Machine Availability	90	82.6	79.72
Performance Rate	95	81.56	66.23
Quality rate	99.99	91	89
OEE	**85**	**61.6**	**48.63**

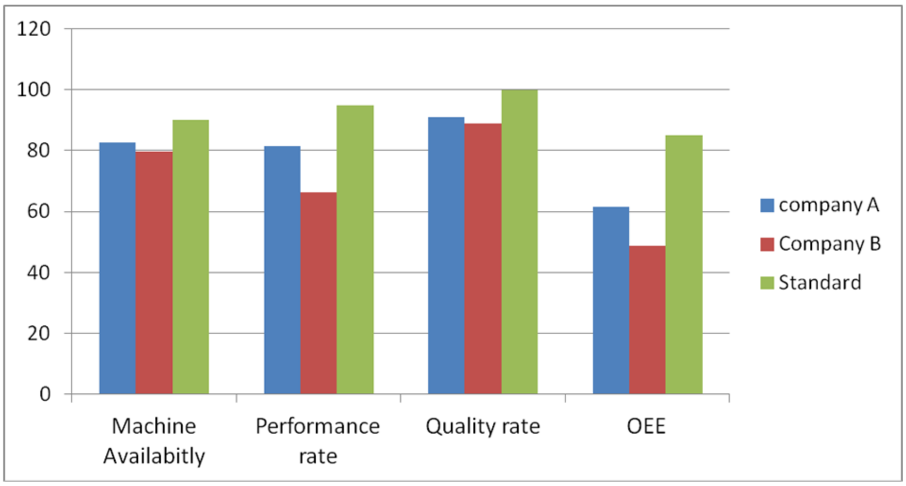


Fig. 3.11 Graphical representation of parameters of OEE and its comparison

From the above table as well as from above graphical representation it's clear that all parameter values of both Company A and Company B are lagging from world standard values. Also one can observe that Company A showing better results for all parameters compare to company B. Hence we can come to an conclusion that overall performance level or TPM level of Company A is better than Company B.

3.3.Key observation:

By analyzing all the above graphs, and standard OEE sheets (ANNEXURE A), one important key factor is observed that, whenever there is continuous production of same type of pipe for more than one or two shifts, there is a increment in values of Availability, Performance, Quality and OEE. Similarly in the shifts where changeover is there from one type of pipe to other pipe there is reduction in all parameters which leads to reduction in OEE value.

3.5 Correlation Analysis:

Karl Pearson's Coefficient of correlation equation is used for find outing the relation between the variables. I considered OEE as dependent variable and other three parameters (Availability, Performance and Quality) are considered as independent variables. For calculation of Correlation all 70 shifts values of both industries are used as a sample size. The correlation relationship and its values between, dependent and independent variables are as follows in below tables.

Table 3.2 Correlation between OEE and Availability

Parameters	OEE (%)	Availability (%)
OEE (%)	1	0.8676
Availability (%)	0.8676	1

Both OEE and Availability are positively correlated with the correlation value of 0.8676.

Table 3.3 Correlation between OEE and Performance rate

Parameters	OEE (%)	Performance (%)
OEE (%)	1	0.802
Performance (%)	0.802	1

OEE and Performance parameters are positively correlated with the value of 0.802.

Table 3.4 Correlation between OEE and Quality rate

Parameter	OEE (%)	Quality rate (%)
OEE (%)	1	0.782
Quality rate (%)	0.782	1

OEE and Quality rate are positively correlated with the correlation value of 0.782.

From above tables it's clear that the dependent variable OEE is having positive relation with all three independent variables. In that OEE is highly influenced by Availability that is around 86% and Performance rate will be the second highest factor which having influence on OEE (80%) and finally compare to both above mentioned parameters Quality rate will be having less relation and it occupy third place in relation with OEE.

3.5.Analysis of Productivity Results

Partial productivity values with respect to Men, Material, Power, Number of Kg output per day per Men, Number of Kg output per unit power consumptions, and Total productivity are founded for both the companies. Below Tables 3.5 and 3.6 are gives the productivity calculations for L.G and Shakthi industry respectively.

Table 3.5 Partial and Total Productivity of L.G industry

Category	Equations	Calculations	Partial productivity
Men Productivity	OUTPUT/ HUMAN INPUT	3354685/56000	**59.99**
Material Productivity	OUTPUT/ MATERIAL INPUT	3354685/2039119	**1.645**
Power Productivity	OUTPUT/ POWER INPUT	3354685/68224	**49.171**
Total Productivity	OUTPUT/ (HUMEN + MATERIAL + POWER INPUTS)	3354685/2163343	**1.55**
Productivity With respect to: No of Kg /day/men	(NO. OF KG OUTPUT PER DAY) / (NO. OF PERSON WORKING PER DAY)	1324.15/12	**110.34**
Productivity with respect to: No of kg output/ unit.	(NO. OF KG OUTPUT PER DAY) / (NO. OF UNITS CONSUMING PER DAY)	1324.15/386	**3.43**

Table 3.6 Partial and Total Productivity of Shakthi Industry

Category	Equations	Calculation	Partial productivity
Men Productivity	OUTPUT/ HUMAN INPUT	1247500/35000	**35.64**
Material Productivity	OUTPUT/ MATERIAL INPUT	1247500/907592	**1.3745**
Power Productivity	OUTPUT/ POWER INPUT	1247500/33000	**37.8**
Total Productivity	OUTPUT/ (HUMEN + MATERIAL + POWER INPUTS)	1247500/975592	**1.28**
Productivity With respect to: No of Kg /day/men	(NO. OF KG OUTPUT PER DAY) / (NO. OF PERSON WORKING PER DAY)	864/10	**86.4**
Productivity with respect to: No of kg output/ unit.	(NO. OF KG OUTPUT PER DAY) / (NO. OF UNITS CONSUMING PER DAY)	864/288	**3**

This will helps to analyze the Manufacturing Performance of a Company. By comparing the values of partial productivities and total productivity of both companies we can easily identify that which company having better level with respect to manufacturing performance. Below table 3.7 will gives the comparison of productivity values of Company A and Company B.

Table 3.7 Comparison of Productivity

CATEGORY	L. G INDUSTRY	SHAKTHI INDUSTRY
HUMAN PRODUCTIVITY	59.99	35.64
MATERIAL PRODUCTIVITY	1.645	1.3745
POWER PRODUCTIVITY	49.171	37.8
PRODUCTIVITY WITH RESPECT TO: NO. OF KG/ /DAY/MEN	110.34	86.4
PRODUCTIVITY WITH RESPECT TO: NO. OF KG OUTPUT/UNIT POWER	3.43	3
TOTAL PRODUCTIVITY	1.55	1.278

Below figures 3.12 and 3.13 gives the graphical representation for comparison of Productivity values of L.G and Shakthi industries.

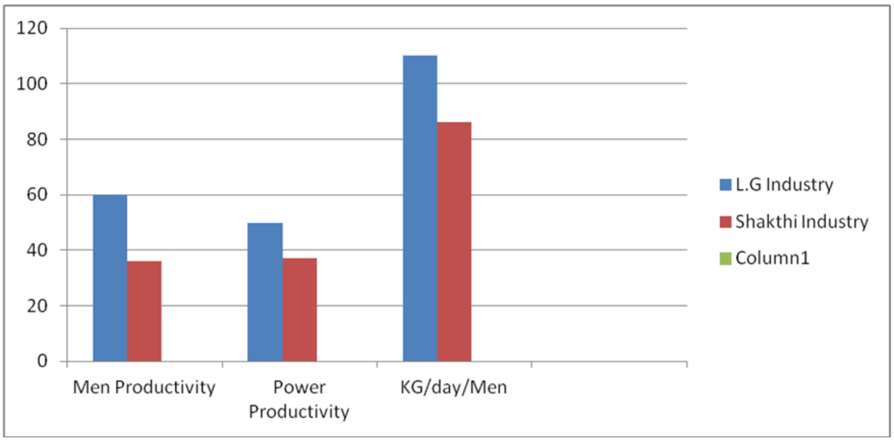


Fig. 3.12 Partial productivity graph

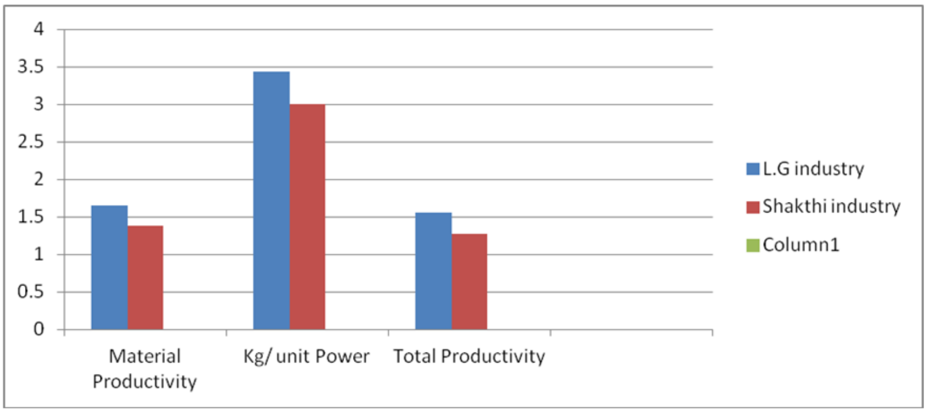


Fig. 3.13 Partial and Total productivity graph

By comparing all above mentioned partial productivity values and final Total productivity values it's clear that Productivity values of L.G industry showing better results for all productivity types with respect to values of Shakthi Industry.Hence L.G industry having better manufacturing performance compare to Shakthi industry with respect to cost.

3.6. Analysis of TPM Pillar

Table 3.8 Analysis of TPM pillars

S. No.	Factor and Questions.	L.G Industry		Shakthi Industry	
Factor: Planned Maintenance.		**% of YES**	**% of NO**	**% of YES**	**% of NO**
01	In this plant they have a separate shift or a part of shift reserved only for maintenance activities.	0	100	0	100
02	In this plant machine breakdowns and stoppages are very less.	20	80	25	75
03	In this plant need for preventive maintenance is determined for every machine.	0	100	0	75
04	In this plant maintenance department uses most of its time for improve the equipment and advanced inspection.	20	80	25	75
05	The lubrication points/surfaces are identified on the equipment and serviced as per the specified standard.	80	20	100	0
Factor: Autonomous Maintenance.					
01	In this plant the production personnel are responsible for most of the maintenance inspections on their machines.	60	40	25	75
02	What is to be done, who is responsible and when it was last time checked/ repaired is clearly communicated to all operators.	80	20	75	25
03	In our plant Production personnel are well trained for trouble shooting and maintenance job.	20	80	0	100
04	In this plant operators are held responsible for un keep of their equipment to prevent it from deteriorating.	80	20	25	75
Factor: Training.					
01	Employees at this plant trained to perform multiple tasks/jobs.	80	20	100	0
02	They have formal quality training program for employees.	0	100	0	100
03	Employees are capable of performing variety of jobs.	80	20	100	0

Table 3.9 Analysis of TQM Pillars

S. No.	Factor and Questions.	L.G Industry		Shakthi Industry	
Factor: Supplier selection.		**% of YES**	**% of NO**	**% of YES**	**% of NO**
01	In this plant quality is number one criterion for selecting suppliers.	100	0	0	100
02	While selecting suppliers this plant give importance to suppliers who have certified.	80	20	25	75
03	Always this plant management will select a supplier who gives raw material with least cost.	0	100	25	75
Factor: Customer Focus.					
01	Plant collects feedback from customer regarding quality of products.	40	60	0	100
02	This plants management frequently are in close contact with their customers and regularly survey their customer requirements.	80	20	50	50
03	This Plant is highly responsive to our customer's complaints.	80	20	25	75
Factor: Recognition and Reward.					
01	In this plant employees are get reward for quality improvement.	0	100	0	100
02	If any employee improves quality, management will reward him.	20	80	0	100
Factor: Employee Empowerment.					
01	In this plant employees have the authority to halt the production process when any problem arrives in production line.	80	20	25	75
02	Independent decision making by employees are encouraged in the company.	40	60	0	100
Factor: Process Quality Management.					
01	In this plant causes for Scarp and Reworks are identified.	0	100	0	100
02	Corrective action is taken immediately when a quality problem is identified	80	20	100	0
03	Key processes are systematically improved to achieve better product quality and performance.	40	60	25	75
Factor: Top Management Leadership.					
15	In this plant top management strongly encourage employee involvement.	40	60	75	25
16	Plant management communicates a vision focused on quality improvements.	100	0	50	50
17	All major department heads within this plant accept their responsibility for quality.	100	0	75	25

IV. Conclusions

Based on the investigation conducted on the industries and by analyzing the different results we can come to conclusion that due to the lagging in implementation of TPM both industry A and B are having less OEE than standard OEE values, which leads to many losses. There is lot of fluctuations are observed in the values of Availability, Performance rate, Quality rate as well as OEE of both industries.

- Company A has got better OEE value compare to Company B and same time Partial Productivity of Company A showing better results compare to Company B. From this we can come to conclusion that Partial Productivity or productivity values are directly proportional to OEE.
- This study supports that both industries are lagging in effective implementation of important pillars of the TPM (Planned maintenance, Autonomous maintenance, Quality maintenance and Training). Still Company A has got little bit better implementation of TPM pillars (quality, autonomous, planned maintenance) than Company B, same time OEE value of Company A is higher than Company B by 12%. By this we can come to conclusion that values of OEE is directly depends on the level of implementation TPM pillars.
- Analysis of coefficient of the Correlation gives the result that OEE has got positive correlation with Availability, Performance and Quality rate. Also by looking at the values of correlation we can come to conclusion that OEE is highly correlated with Availability then Performance rate and then Quality rate.

Hence effort should be there to minimize the losses in following order.

1. Increase Availability by reducing Downtime losses.
2. Increase Performance Rate by reducing Speed losses.
3. Increase Quality Loss by reducing startup and production rejections

- By this study it's clear that these small scale manufacturing industries are not aware of this TPM concepts, as well as they don't know the importance of finding and analysis of Overall equipment effectiveness (OEE). Also the management of the companies are does not having any key interest in implementation of TPM. Companies have got less interest about Training, Motivating and empowering employees which will effect on their production as well as productivity. So it is required to create awareness about the TPM and its benefits to them.

- TPM is proven to be a program that works. Today with competition in industry at an all time high TPM may be the only thing that stands between success and total failure for companies. Based on my study I prepared general relationship model for Pillars, OEE and Productivity as in below figure 4.

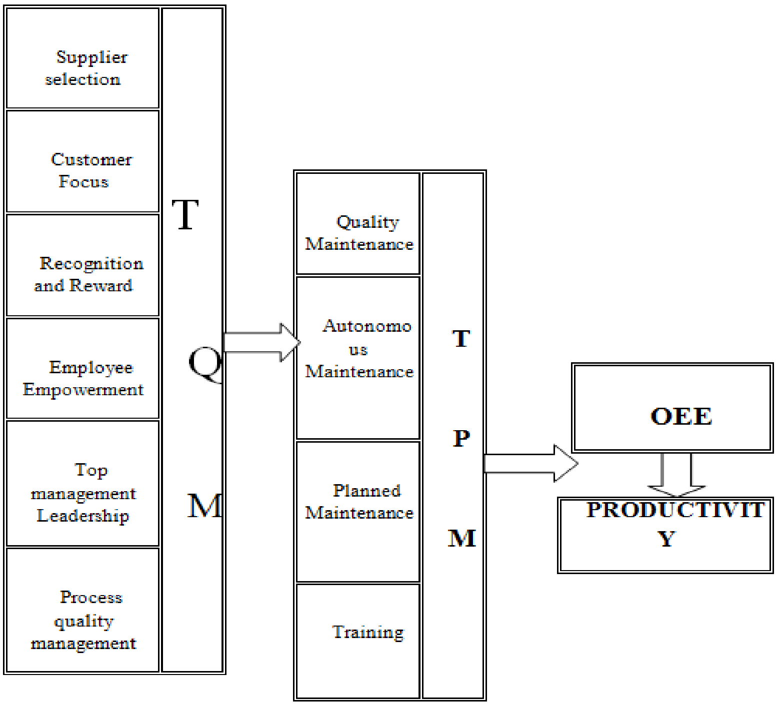


Fig. 4.1 OEE-Productivity Model.

From this model it is clear that factors like supplier selection, Customer focus, Recognition Reward, Employee Empowerment, Top management leadership and process quality management are helps to increase the level of Total Quality Management for any industry. TQM being one Pillar with other pillars like Autonomous maintenance, Planned maintenance and Training, are directly influencing TPM and those pillars helps to increase the level of TPM for any industry. TPM having direct influence on OEE and as TPM level increases OEE value will also get increase. Finally Productivity is directly depends on value of OEE and varies accordingly.

References

[1]. K.C Ng and Goh and Eze, "Critical success factors of Total Productive Maintenance Implementation: Review", IEEE, pp.269-273, 2011.
[2]. Pradeep Kumar and Dr. Rodrigues, "Total Productive Maintenance of a Diesel Power generating unit of a Institution Campus", International conference on Mechanical and Electrical Technology, IEEE, pp.68-71, 2010.
[3]. Lixin and Dong and Gong and Yu, "Study on Application of TPM in small and Medium-sized enterprises", IEEE, pp.678-681, 2011.
[4]. K.C Ng and Goh and Eze, "Total Productive Maintenance in Semiconductor manufacturing firm", IEEE, pp.829-833, 2011.
[5]. Abdul and Lim Ping, "Implementation of Total Productive Maintenance in Automotive Industry", conference on Symposium on Business, Engineering and Industrial applications, Malaysia, IEEE, pp.55-58, 2011.
[6]. J.Venkatesh. "An Introduction to TPM", April 16, 2007.
[7]. A.Wadood and Pankaj and Singh and Dr.Suhil, "TPM implementation in Indian manufacturing industry for sustained competition", 34th International conference on computers and industrial engineering, pp.602-607.
[8]. Abhishek Jain and Rajbir Bhatti, Harwinder Singh Deep, Shiv kumar Sharma, "Implementation of TPM for Enhancing OEE of Small Scale Industry", International Journal of IT, Engineering and Applied science Research, I-Xplore International Research Journal Constorium, pp.125-136, 2012
[9]. Prof.K.ShridharaBhat, "Total quality management", Himalaya Publishing house,2010.
[10]. PremVrat, "Productivity management A system approach",Narosa publishing house,1998.

[11]. John.L, “Productivity quality improvement”, McGraw- Hill book company,1988.
[12]. A.Sivakumar and K.saravanan, “A systemized operational planning, Implementation and Analysis of Robust frame work for improvement of partial and total productivity in Textile fabric industry”, European Journal of scientific research, pp.385-399,2011.
[13]. A.P. Kedar and R.R.Lakhe et al, “A comparative review of TQM, TPM and related organizational performance improvement programs”, First international conference on emerging trends in Engineering and Techonology, pp.725-730, 2008.
[14]. G.Ravishnkar, Chip Burczak, Robert De vore, “A competitive manufacturing through total productive maintenance”, Conference on International Semiconductor manufacturing science symposium, pp.85-89, 1992.
[15]. Shambh Nath Benerjee, “Quality Management”, Allen Bradley India Ltd, pp.170-177.
[16]. Pule A. Kholopane et. Al, “Some effects of human resources strategy on total productive manufacturing (TPM) improvement”, PICMET 2007 Proceedings Portland-USA, pp.2296-2304, 2007.
[17]. B.N Meggard, “Total productive maintenance, TPM that works”, IEEE, pp.13-17,1989.
[18]. Ramayah.T, Muhammad jantan and Mohd Mustapha Hassan, “Change Management and implementation of Total productive maintenance and exploratory study of Malsysian manufacturing companies”, 2002, Vol.3.
[19]. Tsuchiya.S, “Quality maintenance: Zero defects through equipment management, 1992, Oregon, productivity press.
[20]. Will mott. P “TPM: Total Productive Maintenance”, 1997, The western way, Butterworth Heinemann, Oxford.
[21]. David J.Sumanth, “Productivity Engineering and Management”, Mc Graw-Hill Book Company, 1984.
[22]. Raymond H. Mayer, “Probability and Statistics for Engineers and Scientists”, Macmillar publishing Company, pp.391-398, 1992.
[23]. S.Fore and L.Zuze, “Improvement of overall equipment.effectiveness through Total productive maintenance”, World academy of science and Engineering, pp.402-410, 2010
[24]. Suzaituladwini Hashim, Nurul Fadly Habidin, Juriah Conding, Seri Lanang Jwaya, Anis Fazdlin Mohd Zubir, “ Total Productive Maintenance and Innovation Performance in Malaysian Automotive Industry ”, International Journal of Engineering Research and Development , PP. 62-67 ,2012.
[25]. Jirarat Teeravaraprug*, Ketlada Kitiwanwong, and Nuttapon SaeTong, “Relationship model and supporting activities of JIT, TQM and TPM”, Songklanakarin J. Sci. Technol., pp.101-106, Jan. - Feb. 2011
[26]. Monica Sharma and Rambabu Kodali, “Validity and reliability of proposed framework of manufacturing excellence in the Indian industry”, Taylor and Francis group, pp. 1-21,2011.

ANNEXURE A

Sample of OEE data sheet of L.G industries (only 10 shift out 40 is displayed here).

Machine Production Parameter	Shift No.1	Shift No.2	Shift No.3	Shift No.4	Shift No.5	Shift No.6	Shift No.7	Shift No.8	Shift No.9	Shift No.10
Total time (in minutes)	720	720	720	720	720	720	720	720	720	720
Sheduled Production breaks (minutes)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total planned production time. (Minutes)	720	720	720	720	720	720	720	720	720	720
Type and Diameter of pipes. (mm) (Normal pvc)	S.B.T.P 50mm	S.B.T .P 50mm	S.B.T .P 20mm	S.B.T .P 20mm	S.B.T .P 25mm	S.B.T .P 25mm	S.B.T .P 25mm	S.B.T .P 25mm	S.B.T .P 32mm	ISI 75mm
Machine down time (production change over and other stoppages) (in minutes)	90	40	165	60	160	40	50	130	170	240
Total operating time (in minutes)	630	680	555	660	560	680	670	590	550	480
Gross Output, including rework and defects (No of units)	178	191	950	1040	398	438	446	417	267	146
Total units Rejected. (in No's)	17	9	56	53	53	15	6	52	31	20
Total Acceptable units. (in no's)	161	182	894	987	345	423	440	365	236	126
Cycle time (seconds/unit)	210	210	32	32	81	81	81	81	100	172

Machine Availability (%)	87.5	94.44444	77.08333	91.66667	77.77778	94.44444	93.05556	81.94444	76.38889	66.66667
Performance rate (%)	89.4444444	93.67647	85.90991	79.75758	83.16964	83.97794	88.65672	83.51695	71.51515	75.25
Quality rate (%)	90.4494382	95.28796	94.10526	94.90385	86.68342	96.57534	98.65471	87.52998	88.38951	86.30137
OEE (%)	70.7892478	84.30337	62.3186	69.38526	56.07334	76.59632	81.39013	59.90333	48.28686	43.29452

Sample of OEE data sheet of Shakthi industries (only 10 shift out 40 is displayed here).

Machine Production Parameter	Shift No.1	Shift No.2	Shift No.3	Shift No.4	Shift No.5	Shift No.6	Shift No.7	Shift No.8	Shift No.9	Shift No.10
Total time (in minutes)	720	720	720	720	720	720	720	720	720	720
Sheduled Production breaks (minutes)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total planned production time. (Minutes)	720	720	720	720	720	720	720	720	720	720
Type and Diameter of pipes. (mm) (Normal pvc)	25	25	25	32	32	50	50	50	75	75
Machine down time (production change over and other stoppages) (in minutes)	135	60	45	210	120	330	30	60	215	40
Total operating time (in minutes)	585	660	675	510	600	390	690	660	505	680
Gross Output, including rework and defects (No of units)	387	430	439	270	345	145	280	268	142	219
Total units Rejected. (in No's)	61	40	37	40	17	35	10	13	16	12
Total Acceptable units. (in no's)	326	390	402	230	328	110	270	255	126	207
Cycle time (seconds/unit)	63	63	63	79	79	116	116	116	144	144
Machine Availability (%)	81.25	91.66667	93.75	70.83333	83.33333	54.16667	95.83333	91.66667	70.13889	94.44444
Performance rate (%)	58.5128205	62.04545	62.53333	59.37908	71.97778	54.52991	75.65217	74.69697	59.88119	73.05882
Quality rate (%)	84.2377261	90.69767	91.57175	85.18519	95.07246	75.86207	96.42857	95.14925	88.73239	94.52055
OEE (%)	40.0480189	51.5843	53.68394	35.82905	57.02587	22.40741	69.91071	65.15081	37.26761	65.21918

Annexure B

For L. G industries:

Calculation of Partial Productivity: (20 days values are considered for calculations)

1. Output:

S.No	Diameter of pvc pipe (mm)	No. of units	Unit length price (Rupees)	Output (Rupees)
01	20	5895	141.87	836324
02	25	3992	187.67	749179
03	32	1397	273.73	382400
04	50	1443	514.13	741890
05	75	1248	516.74	644892
Total				3354685

2. Material input:

Raw material cost for unit Kg: 77 Rs.

Diameter of pipe.	No of pipe produced.	Unit weight (Kg)	Total weight (Kg)	Rate for unit Kg (Rupees)	Total cost (Rupees)
20	5895	0.6	3537	77	272349
25	3992	1.6	6387	77	491799
32	1397	2.225	3108	77	239316
50	1443	4.85	6999	77	538923
75	1248	5.17	6452	77	496804
Total			26483	77	2039191

3.Power: (20 days)

Category	No. of KW-Hr consumed.	Unit price (Rupees)	Total (Rupees)
Electric Supply from Mescom.	7734	6.5	50272

Category	No. of liters consumed	Price for unit liter.	Total
Diesel consumption	352	51	17952

Total : <u>Rs 68224/=</u>

Human Input:

No of Direct Employees Per shift	No of employees per day	Average salary	Monthly salary	For 20 days
06	12	7000	84000	56000

For Shakthi Industry:

Calculation of Partial Productivity: (15 days values are considered for calculations)

1. Output:

S.No	Diameter of normal pvc pipe (mm)	No. of units	Unit length price (Rupees)	Output (Rupees)
01	20	2725	78	212550
02	25	1743	90	156870
03	32	2221	138	306498
04	50	1366	212	289592
05	75	815	346	281990
Total				1247500

2. Material input:

Raw material cost for unit Kg: 70 Rs.

Diameter of pipe.	No of pipe produced.	Unit weight (Kg)	Total weight (Kg)	Rate for unit Kg (Rupees)	Total cost (Rupees)
20	2725	0.7	1907.5	70	133525
25	1743	1.05	1830.15	70	128110.5
32	2221	1.45	3220.45	70	225431.5
50	1366	2.25	3073.5	70	215145
75	815	3.6	2934	70	205380
Total					907592

3. Power: (15 days)

Category	No. of KW-Hr consumed.	Unit price	Total
Electric Supply from Mescom	4320	6	25920

Category	No. of liters consumed	Price for unit liter.	Total
Diesel consumption	139	51	7080

Total : <u>Rs 33000</u>

Human Input:

No of Direct Employees Per shift	No of employees per day	Average salary	Monthly salary	For 15 days
05	10	7000	70000	35000

Annexure C

Cycle time Calculation L.G industry:

Type and Diameter of Pipe	Rated output No. of Kg's per 12 hour	No of Kg/Hour.	Weight /unit length (in Kg)	**Cycle time (in seconds)**
S.B.T.P 50mm	1000	83.33	4.85	**210**
S.B.T.P 25mm	850	70.833	1.6	**81**
S.B.T.P 20mm	800	66.66	0.6	**32**
S.B.T.P 32mm	950	80	2.225	**100**
ISI 75mm	1300	108.33	5.17	**172**

Sample calculation for find outing cycle time:

<u>For S.B.T.P 50mm</u>

Unit length weight = 4.85 Kg.

Unit hour output = 83.33kg/hour

Hence,

3600 – 83.33

? -- 4.85

= <u>210 seconds.</u>

Cycle time calculation for Shakthi Industry:

Diameter of Pipe (mm)	Rated output No. of Kg's per 12 hour	No of Kg/Hour.	Weight /unit length (in Kg)	**Cycle time (in seconds)**
25	720	60	1.05	**63**
20	680	56	0.6	**48**
32	790	66	1.45	**79**
50	840	70	2.25	**116**
75	1080	90	3.6	**144**