Job Shop Lean Production Implementation Using Program Evaluation and Review Technique (Pert)

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Abstract

This paper presents an application of one of the Network Analysis tools namely the Program Evaluation and Review Technique (PERT) for the implementation of lean production in Job Shops. The Lean Production philosophy tries to identify wastes then eliminate them. Job shops only work on one customized product at a time; they are usually characterized with low production rate. From a lean perspective the most critical waste is underutilized worker time. The paper presents a practical methodology on how to redesign the production process, reducing the production time and estimating the product delivery time and Service Level using information based on PERT. The research was performed in an Elevator factory. Results show a decrease in manufacturing lead time by 35% and a reduction in the completion time variance of about 39% was achievable using the proposed approach.

Keywords
Lean Production, Job shop, Manufacturing, PERT, Service Level

1. Introduction

In the recent years great focus is given to Lean Production as a tool to achieve excellence in production by maximizing the output and minimizing resources used (Groover, 2007). Companies that effectively applied such concept were able to reduce cost, increase the production capacity, and decrease waste resulting in an increase in their competitiveness advantage (Rajenthirakumar & Shankar, 2011). Lean production can be defined as “a philosophy of manufacturing that focuses on delivering the highest quality product on time and at the lowest cost” (Jeffrey & Yen-Chun., 2000). For more information about lean production please see (Womack & Jones, 1996) and (Liker, 2003).

Lean Production has emerged as methods to eliminate the bad sides of Mass production. However, most adopted production methods in Palestine are very far from mass production since they target local markets. The Palestinian industrial sector (and to some extent in the Middle East) is mostly based on family businesses that are characterized as small and medium enterprises (Zain & Kassim, 2012). The objective of this work is to help job shop production companies adopt and benefit from Lean production ideas by proposing a practical tool that can be effectively implemented.

It should be known that the economic situation in Palestine is very difficult for industrial companies to compete at an international level. Due to the Israeli occupation of the West Bank/Gaza, consumer power is heavily fluctuating causing a very variable demand, supplies of raw material and equipment can be heavily delayed, and heavy competition from Chinese and Israeli producers. All these factors make the adoption of Lean Production philosophy essential for their survival and to achieve economic sustainability and excellence.

This work presents an actual case study on one of the local elevator producers in Palestine. Their method of production is heavily based on manual assembly with coupled with some machining operations. Products produced are fully customizable based on requests from the customer (It can be classified as engineering-to-order). The company has 8 workers with different various skills and it also has a team responsible for installation of finished elevators to their clients.

2. Literature Review

Lean Production for job shops is relatively old concept; however papers studying this topic are relatively few, see (Sandras, 1985) and (Kelleher, 1986). A case study performed by Brink and Ballard studied if lean production can be applied to Job shops showed that lean tools (like Value Stream Mapping) made great success. They also noticed that the greatest improvement was the cultural change, the company transformed into a learning organization (Brink & Ballard, 2005). Van Goubergen and Vandewalle developed a lean scheduling system for job shop environments for improving flow, although their work is related to scheduling it is strongly connected to the concept if lean production as it tried to reduce manufacturing lead time and keep the work in process under control (Van Goubergen & Vandewalle, 2011).

Papadopoulou and Mousavi used leading edge intelligent agent simulation to extend the lean principles and techniques to the scheduling of dynamic job shop with stochastic order arrivals and processing times. They were managed to study the effect of the various forms of the stochastic disruptions considered and their effect on the system performance metrics. (Papadopoulou & Mousavi, 2008). Other works that tried to apply the concepts of Lean Manufacturing in Job shops include (Papadopoulou & Mousawi, 2007), (Gupta & Rajesh, 2013) and (Lasserre, 1992).

Due to the benefits of lean production presented in the literature, this research tries to use its concepts for improving current performance at the studied job shop. Furthermore, this work tries to introduce the use of a well-established project management tool, the Program Evaluation and Review Technique (PERT), for the lean production implementation which was not previously proposed in the literature.

3. Methodology

The production of elevators is a collection of labor intensive activities that are coupled with a lot of fine details that should be performed carefully. Since each elevator is unique in its dimensions (length, width, and height), door location and type, finishing (type of metals used, mirrors …). The processing requirements can be sometimes very different, the use of techniques that can take into account stochastic behavior of operations are needed. Normally, to model a stochastic behavior intensive data collection should be performed. Since job shops usually produce small amount of products per year, it would be very hard to find processing distributions based on observation.

In project management theory, a very similar situation occurs constantly. The literature in such area proposed a well-establish method, Program Evaluation and Review Technique (PERT) that takes into account the completion time variability of activities when considering the total completion time of the project. PERT is a planning tool for application to construction and other projects, it was originated by the U.S. Navy in 1958 as a tool for scheduling the development of a complete weapons system (Cottrell, 1999). In PERT any activity has three time estimates; Optimistic time estimate (t_o), most likely time estimate (t_m) and Pessimistic time estimate (t_p). Optimistic time estimate (t_o) can be defined as the time needed to finish the operation when everything goes under control (no power cut, no missing tools, no stock outs in materials,…). Most likely time (t_m) is the time needed usually to perform the processing, while pessimistic time (t_p) is the longest time needed to perform the processing, it includes adverse conditions that will delay time needed for completion.(Hemalatha & Krishna Reddy, 2011).

In the production of elevators PERT's concept can be applied as follows; the time to produce a similar product is known, the worker can give an estimate of what the expected time could be. He also can give an optimistic time if the part is done with no problems. On the other hand, he can also give pessimistic time to finish the activity if unforeseen assembly problems occur. This happens because elevators can be fully customized, and it is probable that some parts for some given dimensions are being produced for the first time.

3.1 Data Collection

The studied company produces an elevator by performing 32 different operations *sequentially*. Due to the agreement with the company the detailed steps cannot be explained in details. However, symbolically they can be presented as shown in Table 1. The data presented in Table 1, were collected from studying and observing one of the standardized elevators created at the factory (collecting from such data t_m). Then for each process the experienced workers estimated t_o and t_p based on their experience and old cases they previously faced. The last two columns in Table 1 namely, the Expected Time (t_e) and the activity variance (v_t), were calculated by:

$$t_e = \left(\frac{t_o + 4t_m + t_p}{6} \right) \quad (1)$$

$$v_t = \left(\frac{t_p - t_o}{6} \right)^2 \quad (2)$$

Table 1 also shows the optimistic, mean, pessimistic and expected time to produce one elevator when all processes are performed sequentially (each activity needs the previous one to be performed before it is started).

3.2 Current Situation Analysis

The literature in lean production suggests that there are seven main types of wastes: Overproduction, excessive inventory, waiting, unnecessary motion, transportation, rework and over processing (Liker, 2003). Performing the processes in a sequential manner is easy, convenient and does not need in depth analysis of the interdependencies between processes. However, it will cause increased waiting times and will cause underutilization of labor. Based on the collected data, the time needed to perform the whole production of one elevator (as shown in Table 1) 96 working hours (about 14 working days) are needed. The results were presented to the production engineer and who indicated that it is in line with the company's average production capacity of 2 elevators/month. It should be noticed that from the collected data the expected variance for completing one elevator is about 8.7 ($hours^2$).

The company has 11 workers, some of them are specialized, and others are general assembly/production workers. It was very obvious during the observation period that workers who are not needed for an ongoing operation are sent to a sister company which is 300 meters away to work there. So these workers were not utilized within the factory. In other occasions, when one specialized worker is absent the whole work in the elevator in hand is stopped, and again workers are sent to the sister company. The principles of lean production indicate that waiting is a form of waste that should be eliminated.

4. Job Shop Lean Production Implementation

The proposed solution for the studied job shop is to redesign the production process. This requires transforming the sequential line processes to two or more parallel sequences of processes. Figure 1 shows a small example on how this should be done. The benefits of parallel processes is that workers waiting times would greatly decrease. Some managerial difficulties would rise due to added complexity in the new production line design. In total, it should decrease the production lead time due to the increase of the line's production rate.

Redesigning the sequence of operations needs a lot of attention and a deep understanding of the operations. It would also require input from the production engineer and experienced workers who are working on the processes on daily basis. After deep investigation of the company's current sequential production process, it was transformed into three parallel set of processes each called phases. Since a detailed explanation of the processes cannot be shown, the general form of the processes is shown in flow chart in Figure 2.

Figure 2 shows the new production sequence that is based on three parallel phases; from Table 1 shows the length of each phase which can be calculated from the summation of processing times needed to finish all the processes. Now the time needed to produce one elevator should be the time needed to complete the longest phase, given that other phases are also carried out during that time. PERT adds more information; it can also assign a variance to each phase, which is the summation of the variances of the processes in each phase (For detailed information on how to calculate PERT projects see (Cottrell, 1999) and (Hemalatha & Krishna Reddy, 2011).

6. Preliminary Results

Initial results show that the duration of each parallel phase is presented in Table 2. The Ideal duration is the time needed for the completion of each phase given that the factory has abundant number of workers. This means any delay in a process would not be due to lack of available workers. Actual duration is the time needed to complete each phase given the actual number of workers currently at the factory is 11. These values were calculated using a commercial project management software. Of course, the higher the number of workers the lower the duration needed to complete each phase. It should also be noticed that the completion time variance does not change, because the difference between the theoretical duration and the actual duration of processes does not affect the variability. So the total time needed to finish the production of one elevator in the proposed line configuration equals 63.56 hrs (9.08 days), the variability associated is 5.36 hrs^2. This corresponds to a decrease of lead time of about 35% and a reduction in the variance of about 39%.

Table 1 The activities Estimated Mean Time and Variance

Activity /Process	t_o	t_m	t_p	t_e	v_t
A	4	6	8	6.0	0.444
B	2.5	3	3	2.9	0.007
C	1	1	3	1.3	0.111
D	4	4	8	4.7	0.444
E	1.5	2	3.5	2.2	0.111
F	1.5	2	3.5	2.2	0.111
G	12	16	24	16.7	4.000
H	4	4	8	4.7	0.444
I	3.5	5	5	4.8	0.063
J	1	1	2.5	1.3	0.063
K	3.5	4	8	4.6	0.563
L	1.5	2	2	1.9	0.007
M	1	1	2	1.2	0.028
N	1	1	1.5	1.1	0.007
O	1	1	1.5	1.1	0.007
P	2	3	4	3.0	0.111
Q	0.5	1	2	1.1	0.063
R	1	2	4	2.2	0.250
S	3	3	8	3.8	0.694
T	1	3	3	2.7	0.111
U	3	3	5	3.3	0.111
V	1.5	2	2.5	2.0	0.028
W	0.5	1	2	1.1	0.063
X	0.5	1	2	1.1	0.063
Y	0.5	0.5	1	0.6	0.007
Z	0.5	0.5	1	0.6	0.007
AA	0.5	0.5	1	0.6	0.007
AB	3.5	4	6	4.3	0.174
AC	8	8	12	8.7	0.444
AD	2	2	4	2.3	0.111
AE	1	1	2	1.2	0.028
AF	1	2	3	2.0	0.111
TOTAL	**73**	**90.5**	**146**	**96.8**	**8.792**

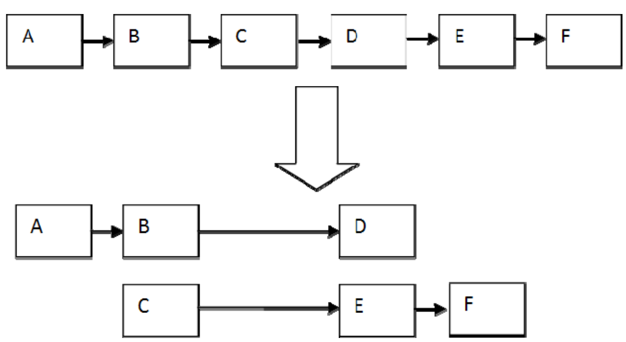

Figure 1: Redesigning a sequential production process into two parallel processes

Table 2: Ideal Duration, Actual Duration and Variance for each Production Phase

Phase	Ideal Duration (hr)	Actual Duration (hr)	Variance (hr^2)
1	14.9	32.27	1.007
2	38.2	63.56	5.361
3	43.8	62.30	2.424

One of the assumption used in PERT is that the project completion time is approximately normally distributed (Cottrell 1999). Based on this assumption, the service level for the job shop can be calculated. The Service Level (SL) can be defined in the context of job shops as the probability to deliver a finished product within a given time (t) for a certain customer (Bookbinder & Noor, 1985). For the studied job shop the service level can be calculated approximately using the normal distribution with mean = 63.56 hours and variance = 5.361 hours^2. This represents the actual duration of the longest phase. Figure 3 shows the SL for given delivery time in hours. It can be seen that the probability to finish the elevator before 54 hours is almost zero, while for example the probability to finish the elevator in 66 hours is approximately 0.70.

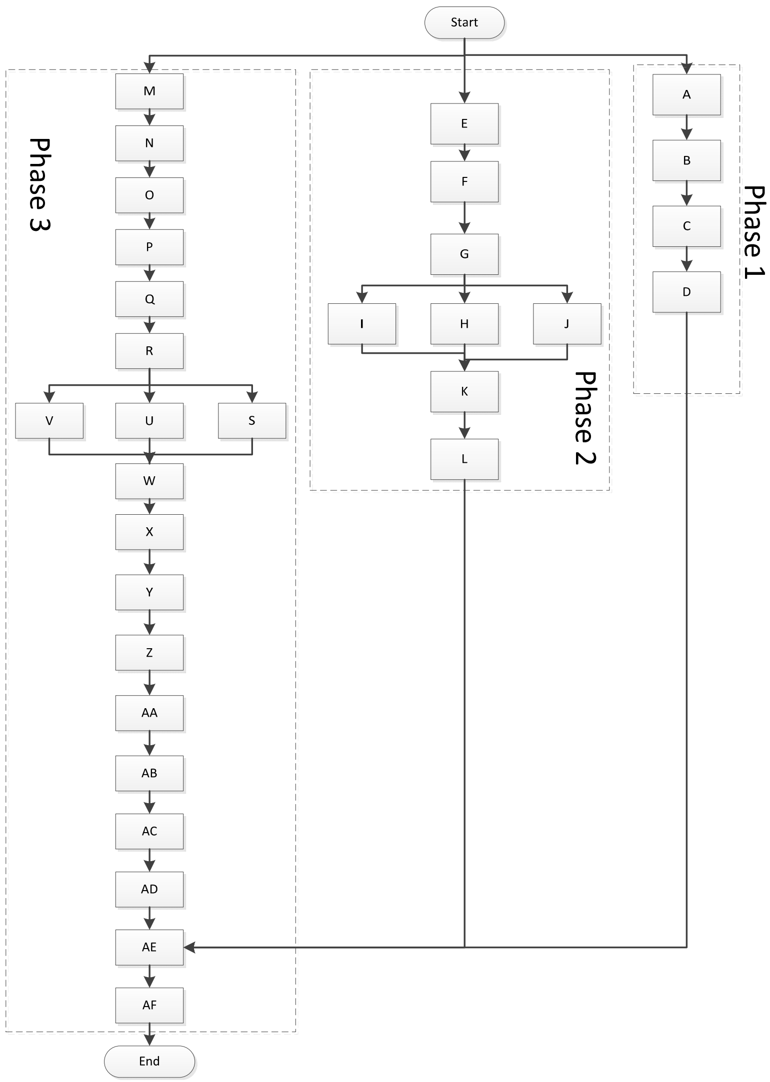

Figure 2: The New Parallel Production Sequence

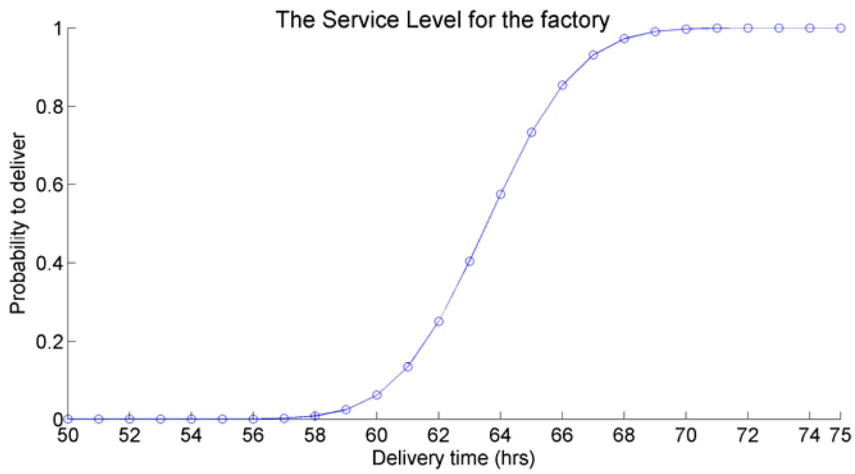

Figure 3: The Service Level for Producing One Elevator

7. Conclusions and Future Extensions

The work presented how lean production can be applied to job shop using PERT tool. The work identified major wastes in job shops and presented how they can be eliminated through parallel production processes rather than all sequencing production processes. The work presented how PERT can be used to calculate the service level of delivering a product to a customer. The presented case showed that improvement can be achieved using the proposed methodology, and particularly a reduction of about 5 working days were saved coupled with a reduced completion variance of around 39%.

This work is still work in progress, future extensions include: developing a clear methodology on how to create parallel production processes. This would benefit a lot of job shop industries on how to apply lean production concepts in their facilities. Another direction is to try identifying and investigating more in common found wastes in job shops and trying to remove them by the proposed approach. Finally, this work used the approximate normal distribution to find the Service Level; more investigation needs to be performed to find the nature and characteristics of the true distribution which in turn would give more accurate estimation of the SL.

References

Bookbinder, J. H., & Noor, A. I. (1985). Setting job-shop due-dates with service-level constraints. *Journal of the Operational Research Society*, 1017-1026.

Brink, T., & Ballard, G. (2005). A Case Study in Applying Lean to Job Shops. *Construction Research Congress* (pp. 1 -12). San Diego, California: ASCE.

Cottrell, W. D. (1999). Simplified Program and Evaluation Technique. *Journal of Construction Engineering & Management*, 16-22.

Groover, M. P. (2007). *Automation, production systems, and computer-integrated manufacturing.* Prentice Hall Press.

Gupta, A. K., & Rajesh, K. M. (2013). Lean Manufacturing Practices: Emerging Issues. *International Journal of Innovative Research and Development*, 69-78.

Hemalatha, K., & Krishna Reddy, B. (2011). Network Analysis for Optimum Scheduling of Machine Time in Granite Processing. *The IUP Journal of Operation Management*, *10* (3), 7-13.

Jeffrey, K. L., & Yen-Chun, W. U. (2000). Japanese Automakers, U.S. Suppliers and Supply-Chain Superiority. *Sloan Management Review*, *42* (1), 81-93.

Kelleher, J. P. (1986). JIT Application in the Job-shop Environment. *APICS Conference Proceedings* (pp. 348-351). APICS.

Lasserre, J. B. (1992). An Integrated Model for Job-Shop Planning and Scheduling. *Management Science*, *38* (3), 1201-1211.

Liker, J. K. (2003). *The Toyota Way.* Wisconsin: McGraw-Hill.

Papadopoulou, T. C., & Mousavi, A. (2008). Scheduling of non-repetitive lean manufacturing systems under uncertainty using intelligent agent simulation. *The 6th International Conference on Manufacturing Research (ICMR08)* (pp. 207-215). Uxbridge: Brunel University.

Papadopoulou, T. C., & Mousawi, A. (2007). Peformance Modelling of Dynamic Lean Job shops with Basestock Shop floor control using Intelligent Software Agents. *ICMR Conference Proceeding* (pp. 185-190). ICMR.

Rajenthirakumar, D., & Shankar, R. G. (2011). Analyzing the benefits of lean tools: a consumer durables manufacturing company case study. *Annals of the Faculty of Engineering Hunedoara - International Journal of Engineering. , 9* (3), 335-339.

Sandras. (1985). Job-Shop JIT. *APICS Conference Proceedings* (pp. 448-452). APICS.

Van Goubergen, D., & Vandewalle, W. (2011). Lead Time Reduction through Cyclic Scheduling in a Job Shop. *The 2011 Industrial Engineering Research Conference* (In Proceedings of Institute of Industrial Engineers (IIE).). 61st Annual IIE conference and expo (IERC 2011): Institute of Industrial Engineers (IIE).

Womack, J. P., & Jones, D. T. (1996). *Lean thinking.* New York: Simon & Schuster.

Zain, M., & Kassim, N. M. (2012). Strategies of family businesses in a newly globalized developing economy. *Journal of Family Business Management*, *2* (2), 147-165.

Biography

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