Lean Strategy Implementation in Metal Job Shop Manufacturing Firm: A Simulation Modelling Approach

Ma. Teodora E. Gutierrez[1,2], Arriane A. Palisoc[1,2]

Abstract

In this paper, a Lean Strategy for a job shop manufacturing company has been modelled for implementation. This strategy started in the known car manufacturing company named Toyota Automobile Company. The philosophy behind the strategy is that there will be a value created from the waste materials. Using a software, the Lean Strategy was developed for the job shop manufacturing. The study designed two approaches in lean, which are the Just in Time approach and Kanban approach. The performance measures investigated in the study are Average Time in System, Production Throughput, Work in Process and bottlenecks. The model developed provided understanding on the managerial practices; technology used and decision process in implementing lean enterprise. Based on the results of the simulation model, Just in Time approach is best for companies with few processes while Kanban approach is best for companies with several to many processes.

Keywords: **Lean Strategy, Simulation Modeling, Just in Time approach, Kanban Approach**

I. Introduction

The traditional definition of Lean Strategy is zero inventory. As of today, the Lean Strategy evolved from elimination of waste to value creation. Lean Philosophy, which was originally implemented in the production settings, can now be implemented in the whole organization or enterprise. Lean Philosophy is a continuous process of striving for perfection and it leads an organization to a world-class operational effectiveness [12].

Taiichi Ohno, founder of Toyota Automobile Company in Japan, developed Lean Philosophy. Toyota was able to beat Ford Company in 1990s. In that case, most of the companies around the world were interested to find out the strategy of Toyota Company. Taiichi Ohno shared their strategy to all who came into their factory. That was the start of the term "lean". Lean Philosophy is a continuous process of striving for perfection and it leads an organization to a world-class operational excellence[1],[2]. Managing lean means "doing more with less" [3] which focuses on waste identification and organizing operations around value stream [4]. Many studies and journals indicated the effectiveness of lean strategy; however, it is widely implemented in large and medium enterprises. Application of Lean Strategy in small enterprises have been ignored for a long time and special investigation about this topic are rare [5],[6]. It is for this reason that the study conducted a simulation modeling for a small enterprise business using pull system as tools in implementing lean enterprise. The pull system in lean enterprise has two approaches. The Just in Time approach which means zero inventory and Kanban approach with minimum optimal inventory.

The philosophy encapsulating the Just-in-Time (JIT) inventory strategy is 'inventory is a waste'. JT is also known as Toyota Production system wherein the main goal is to improve the business return of investment by cutting in-process inventory and associated carrying cost. On the other hand, Kanban refers to a visual cards which plays an important role in the implementation of JIT. It serves as trigger actions and visual aids. But the two are not the interchangeable [11][15].

[1]Polytechnic University of the Philippines
[2]Technological Institute of Technology
dhorieg@gmail.com
arriane.palisoc@tip.edu.ph

The study aims to model Lean Strategy implementation in a typical metal job shop manufacturing process using simulation software. The lean strategy implementation will make the organization's business process more efficient with better management of customer demand and increase productivity with less wastes.

II. Historical Contexts and Fundamental Principles of Lean Strategy

Toyota Motor Corporation initiated the lean strategy which makes the manufacturing process efficient called Toyota Production System (TPS). TPS is a management philosophy grounded on Just-in-Time system. The management practice is to organize production and logistics for the automobile industries. The organization covers the suppliers and the interaction with customers. Between the years 1948 to 1975, the Japanese Industrial Engineers Taiichi Ohno and Eiji Toyoda developed the system [13]. The lean system was taken from previous Japanese Manufacturing Techniques [7], [8], [9] and Zero Inventory [10].

III. Simulation Model for Lean Strategy

A. Design Consideration

The factors to be considered in the implementation of both the JIT and Kanban for manufacturing firms are the location, entities, arrivals and performance measures such as production throughput (total exits), bottle-neck operation, work in process, average time in the manufacturing system.

B. Simulation of Job Order Manufacturing Process

In a typical job shop, where it manufactures metal parts, 2 jobs are being processed in a cellular production layout. The typical job shop consists of multi-functional machines. One machine is for forming the metal and the other automatic machine is for cutting the metal. Job 1 processed first the metal in the forming machine. After that, job 2 processed the metal in the cutting machine. All jobs are being processed on a first in first out basis.

Supplier x is the vendor for the case study company and produces all their raw materials for them. Forging are produced every day in 5 batches. The study designs a lean enterprise for the job shop company.

C. Overview of Simulation Model

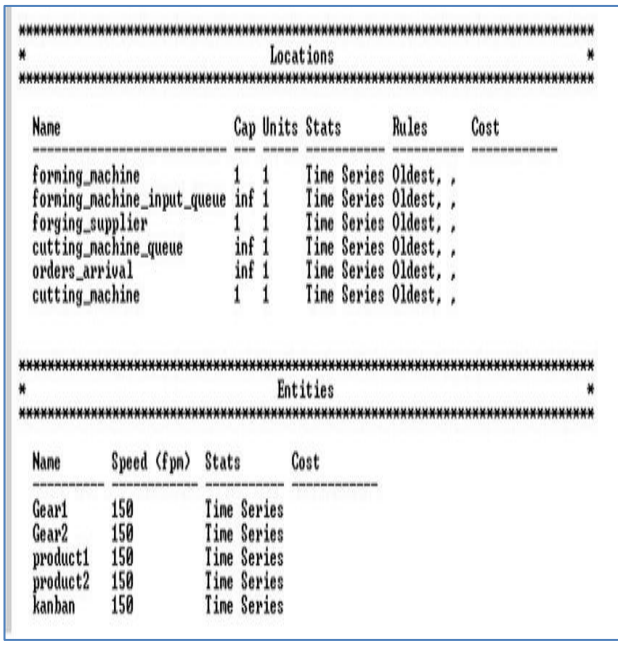
In order to simulate the production process of the case study company, six (6) locations were identified. These are Forming machine, Cutting Machine, Forging, Order Q, Forming Machine Q, and Cutting Machine Q. Four entities; Product 1, Product 2, Orders 1 and Orders. Performances of the proposed lean enterprise were measured in terms of its production throughput, bottleneck operations, and work in process and average time in system [14].

The simulation is for 240 hours, which are the company's total available hours per month with one replication.

Table I.
Simulation Model Function

Entities	Gear 1 , Gear 2 , Product 1 , Product 2 , Kanban
Arrivals	Gear 1 , Gear 2 , Product 1 , Product 2 , Kanban
Locations	Forming machine, Cutting Machine, Forging supplier, Order Q, Forming Machine Q, Cutting Machine Q.
Performance measures	Production throughput (Total Exits), Bottle-neck operation, Work In Process, Average Time in System

Figure 1 is the details of the location syntax and entities syntax entered in the promodel software. The study designs a lean production enterprise for a typical job shop. It uses two types of lean approach, Just in Time (JIT) approach and Kanban Approach.



Locations

Name	Cap	Units	Stats	Rules	Cost
forming_machine	1	1	Time Series	Oldest, ,	
forming_machine_input_queue	inf	1	Time Series	Oldest, ,	
forging_supplier	1	1	Time Series	Oldest, ,	
cutting_machine_queue	inf	1	Time Series	Oldest, ,	
orders_arrival	inf	1	Time Series	Oldest, ,	
cutting_machine	1	1	Time Series	Oldest, ,	

Entities

Name	Speed (fpm)	Stats	Cost
Gear1	150	Time Series	
Gear2	150	Time Series	
product1	150	Time Series	
product2	150	Time Series	
kanban	150	Time Series	

Fig.1. Locations and Entities

D. Simulation Layout for JIT Approach

Figure 2 shows the graphic layout for JIT. The actual customers demand triggers the production of the products with no inventories to be carried out in the production. The Just in Time approach is a pull system where there is no inventory in the finished products [16]. While, the Kanban approach is a pull system where there is a minimum units of inventories in the finished products produced. In this study, a comparison of Just in Time approach and Kanban approach in implementing the pull system were done.

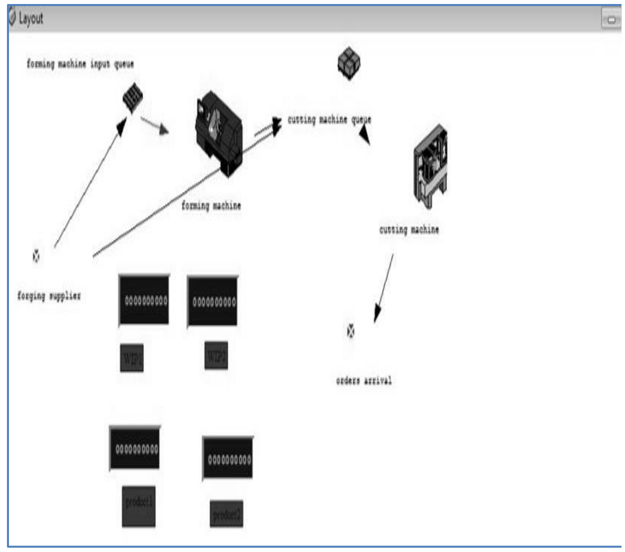


Fig. 2. Simulation Layout of Just in Time Approach

```
********************************************************************************
*                                  Processing                                  *
********************************************************************************

                                          Process                                         Routing

Entity   Location                     Operation           Blk  Output   Destination                  Rule     Move Logic
-------- ---------------------------- ------------------- ---- -------- ---------------------------- -------- ------------
Gear1    forging_supplier                                 1    Gear1    forming_machine_input_queue  SEND 1   WIP1 = WIP1 +
Gear1    forming_machine_input_queue                      1    Gear1    forming_machine              FIRST 1
Gear1    forming_machine              WAIT E(1.5)
                                                          1    Gear1    cutting_machine_queue        FIRST 1
Gear1    cutting_machine_queue                            1    Gear1    cutting_machine              FIRST 1
Gear1    cutting_machine              WAIT U(2,.3 )
                                                          1    Gear1    orders_arrival               JOIN 1
Gear2    forging_supplier                                 1    Gear2    cutting_machine_queue        SEND 1   wip2 = wip2 +
Gear2    cutting_machine_queue                            1    Gear2    cutting_machine              FIRST 1
Gear2    cutting_machine              WAIT U(3, .5)
                                                          1    Gear2    orders_arrival               JOIN 1
product1 orders_arrival               SEND 1 Gear1 TO forming_machine_input_queue
                                      JOIN 1 Gear1
                                      WIP1 = WIP1 - 1
                                      prod1 = prod1 + 1
                                                          1    product1 EXIT                         FIRST 1
product2 orders_arrival               SEND 1 Gear2 TO cutting_machine_queue
                                      JOIN 1 Gear2
                                      wip2 = wip2 - 1
                                      prod2 = prod2 + 1
                                                          1    product2 EXIT                         FIRST 1

********************************************************************************
*                                   Arrivals                                   *
********************************************************************************

 Entity   Location         Qty Each   First Time Occurrences Frequency  Logic
 -------- ---------------- ---------- ---------- ----------- ---------- ------------
 Gear1    forging_supplier 5                     inf         e(12)
 Gear2    forging_supplier 5                     inf         e(12)
 product1 orders_arrival   1                     inf         e(6)
 product2 orders_arrival   1                     inf         e(8)
```

Fig. 3. Processing and Arrivals of Just in Time Approach

E. Simulation Syntax for the Processing and Arrivals

Figure 3 shows the production process flow of product 1 and product 2 using Just In Time approach. Figure 4 shows the graphic layout of Kanban Approach where actual demand also triggers the production of the products but with minimum inventories on the products and parts and Figure 5 shows the production process flow of product 1 and product 2 using Kanban approach.

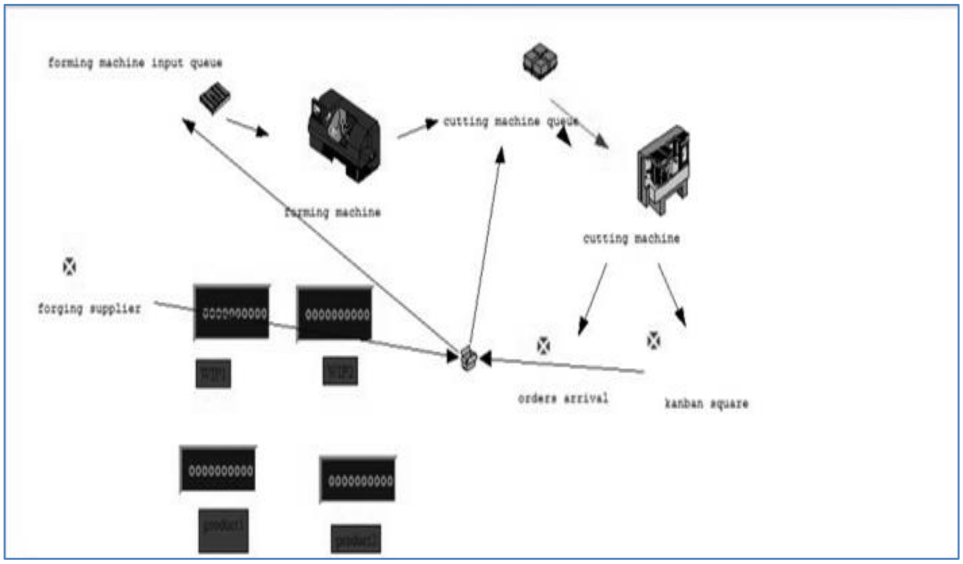


Fig. 4. Graphic Layout of Kanban Approach

```
********************************************************************************
*                                  Processing                                  *
********************************************************************************

                                                  Process                                          Routing

Entity   Location                     Operation            Blk  Output   Destination                  Rule     Move Logic
-------- ---------------------------- -------------------- ---- -------- ---------------------------- -------- ----------
kanban   kanban_square                                     1    kanban   orders_q                     LOAD 1
Gear1    forging_supplier                                  1    Gear1    orders_q                     SEND 1
Gear1    orders_q                                          1    Gear1    forming_machine_input_queue  FIRST 1
Gear1    forming_machine_input_queue  WIP1 = WIP1 + 1      1    Gear1    forming_machine              FIRST 1
Gear1    forming_machine              WAIT E(1.5)
                                                           1    Gear1    cutting_machine_queue        FIRST 1
Gear1    cutting_machine_queue                             1    Gear1    cutting_machine              FIRST 1
Gear1    cutting_machine              UNLOAD 1
                                      WAIT U(2, .3)
                                      WIP1 = WIP1 - 1
                                                           1    Gear1    orders_arrival               JOIN 1
kanban   cutting_machine                                   1    kanban   kanban_square                FIRST 1
Gear2    forging_supplier                                  1    Gear2    orders_q                     SEND 1
Gear2    orders_q                     LOAD 1
                                                           1    Gear2    cutting_machine_queue        FIRST 1
Gear2    cutting_machine_queue        wip2 = wip2 + 1      1    Gear2    cutting_machine              FIRST 1
Gear2    cutting_machine              WAIT U(3, .5)
                                      UNLOAD 1
                                      wip2 = wip2 - 1      1    Gear2    orders_arrival               JOIN 1
product1 orders_arrival               SEND 1 Gear1 TO orders_q
                                      JOIN 1 Gear1
                                      prod1 = prod1 + 1

                                                           1    product1 EXIT                         FIRST 1
product2 orders_arrival               SEND 1 Gear2 TO orders_q
                                      JOIN 1 Gear2
                                      prod2 = prod2 + 1

                                                           1    product2 EXIT                         FIRST 1

********************************************************************************
*                                  Arrivals                                    *
********************************************************************************

 Entity   Location         Qty Each   First Time Occurrences Frequency  Logic
 -------- ---------------- ---------- ---------- ----------- ---------- ------------
 Gear1    forging_supplier 5                     inf         e(12)
 Gear2    forging_supplier 5                     inf         e(12)
 product1 orders_arrival   1                     inf         e(6)
 product2 orders_arrival   1                     inf         e(8)
 kanban   kanban_square    5                     1           0
```

Fig. 5. Processing and Arrivals of Kanban Approach

IV. Results and Discussion

Figure 6 shows that the average time in system for product 1 is 0.85 hours and product 2 is 0.46 hours using Just in Time implementation. Figure 7 shows that the average time in system for product 1 is 0.88 hours and product 2 is 0.47 hours with Kanban implementation. The throughput as measured by the average time in system is from the time the orders arrived in the job shop company up to the delivery to customers. This throughput includes the following activities: order arrival to the job shop company, job shop company order raw materials to suppliers, supplier's arrival of materials, and production process and order delivery to customers.

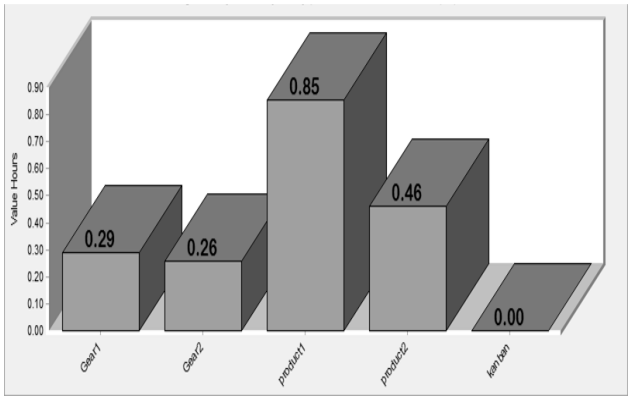


Fig. 6. Throughput (Average Time in System): Just In Time Approach

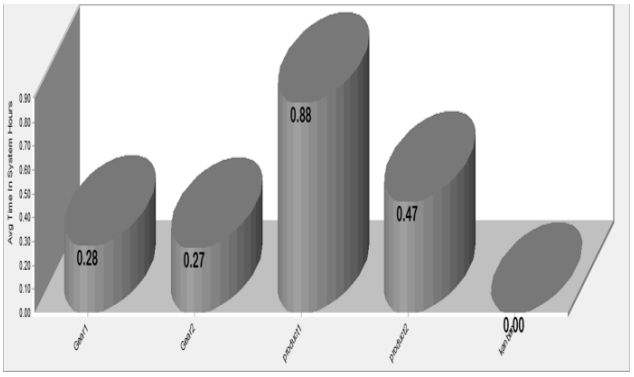


Fig. 7. Throughput (Average Time in System): Kanban Approach

The monthly production units as measured by the total exits or total production units for product 2,404 units and for product 2 is 1,775 units with Just In Time implementation as seen in Figure 8.

On the other hand, with Kanban implementation production units measured on the total exits or total production units for product 1 is 2,390 units and for product 2 is 1,772 units as seen Figure 9.

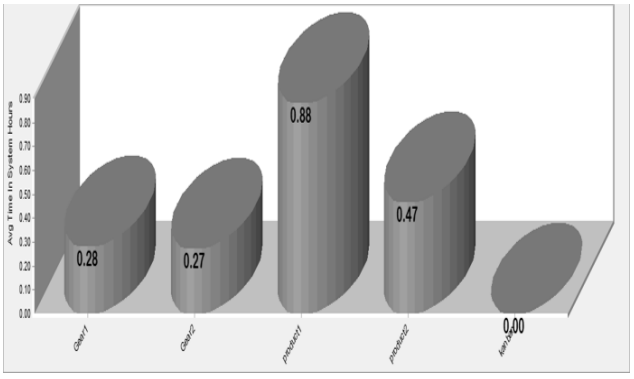


Fig. 8. Monthly Yield - Production Units (Total Exits): Just In Time Approach

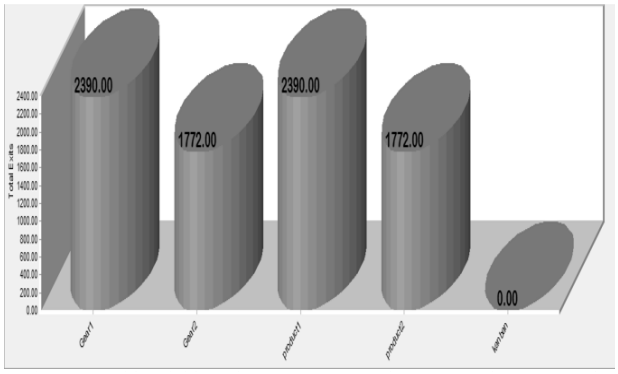


Fig. 9. Monthly Yield Production Units (Total Exits): Kanban Approach

In a month the average work in process in JIT approach for product 1 is 2.77 units and for product 2 is 1.59 units seen Figure 10 while in Kanban approach, product 1 has 2.67 units and for product 2 has 1.41 units as seen in Figure 11.

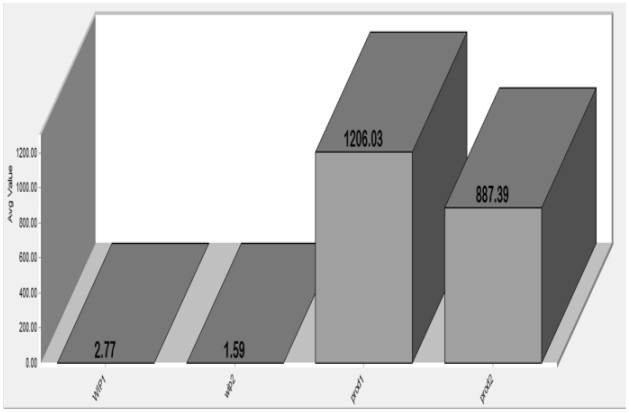


Fig. 10. Performance Measure (Work in process): Just In Time Approach

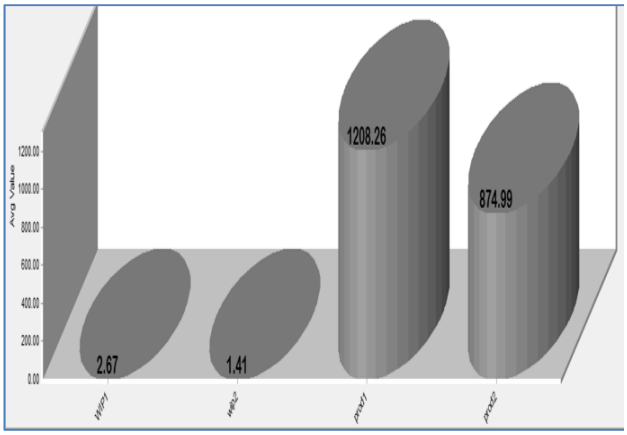


Fig. 11. Performance Measure (Work in process): Kanban Approach

The bottleneck in the system with JIT implementation is the orders arrival with 11.99 orders waiting to be processed as seen in Figure 12 while with Kanban implementation the bottleneck is also in orders arrival with 12.31 orders waiting to be processed.

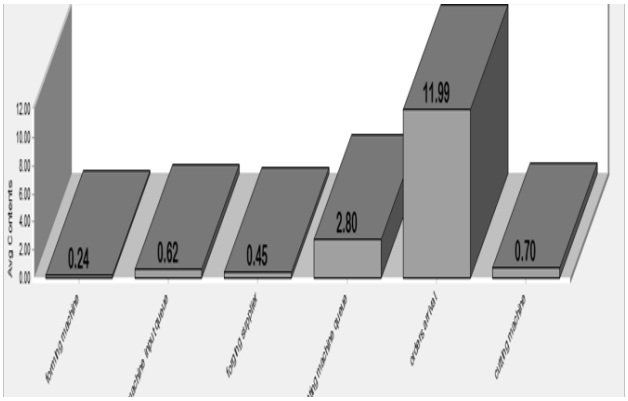


Fig. 12. Performance Measure (Bottleneck): Just In Time Approach

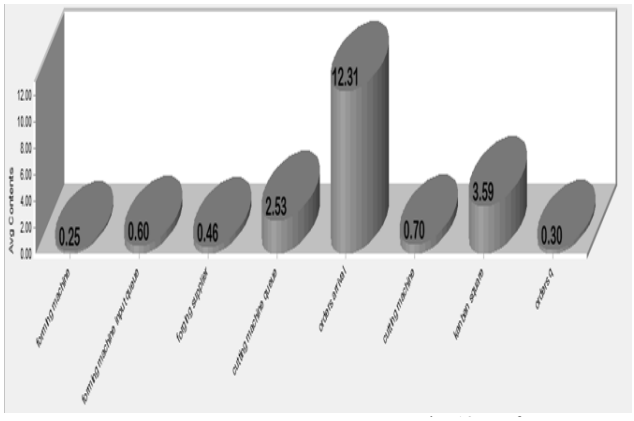


Fig. 13. Performance Measure (Bottleneck) : Kanban Approach

There is no significant differences on the performance measures of Just in Time approach and Kanban approach. The Kanban approach with the set of 5 units' inventory for product 1 and product 2 is the optimum inventory level since it does not have significant difference on the performance of Just in Time Approach (i.e. zero inventory). Thus, it is recommended to the case study company to apply Just in Time approach and Kanban Approach with maximum of 5 units' inventory for finished products 1 and products 2 in order to have efficiency in the production.

V. CONCLUSION

The study models a job shop company into becoming lean enterprise where pull system approach is used. Lean enterprise is considered as an advance strategy to improve the efficiency of the company. The scope of the model is from the supplier's production up to the customer's (client) job shop production; hence, lean enterprise was used as a term in the study because it includes the supplier's production activities. The simulation model provides information on how pull system works in production. Pull system is one of the several tools to implement lean enterprise and the study designs two approaches in lean, which are the Just in Time approach and Kanban approach. The performance measures investigated in the study are supply chain throughput, average monthly yield (production units), work in process and bottlenecks.

The overall findings of the study based on the simulation results is Just in Time approach is best for companies with few processes. While Kanban approach is best for companies with several to many processes. Future work to look at is to include the logistics and distributions of the finished product into the transformation of the company to a lean enterprise.

VI. ACKNOWLEDGMENT

This study was supported by Polytechnic University of the Philippines – Open University System. The authors would like to thank Dr. Ira Valenzuela for the guidance in constructing this paper.

REFERENCES

[1] Papadopoulou, T.C., & Ozbayrak, M. (2005). "Leanness: experiences from the journey to date". Management Volume 16, pp. 784 -807. 2005.

[2] Ejsmont, K., Gladysz, B., Corti, D., Castano, F. (2020) . "Towards Lean Industry 4.0". – Current Trends and Future Perspectives. Congent Business Management Volume 7 .Issue 1. 2020

[3] Rymaszewska, A.D. (2014). "The challenges of lean manufacturing implementation in SMEs Benchmarking". An International Journal, Volume 7. pp.987- 1002.2014

[4] Liker, J. (2004). "The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer" New York: McGraw Hill .2004

[5] Alkhoraif, A., Rashid, H, McLaughlin, P (2019). "Lean Implementation in Small and Medium Enterprises: A Literature Review". Operations Research Perspectives Volume 6, 2019.

[6] D.T. Matt*, E. Rauch (2013) . "Implementation of Lean Production in small sized Enterprises". CIRP Conference on Intelligent Computation in Manufacturing Engineering. Procedia CIRP 12 pp. 420 – 425. 2013

[7] R. Schonberger, "Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity," Operations Management Review, Vol. 1, 1983.

[8] R. W. Hall, Zero inventories, Homewood, Ill. : Dow Jones-Irwin, 1983.

[9] M. Emiliani, "Origins of lean management in America: Role of Connecticut businesss," Journal of Management History, vol. 12, 2006.

[10] Shmula (2017). TPS – The History of the Toyota Production System. https://www.shmula.com/tps-the-history-of-the-toyota-production-system/23618/.

[11] Difference between. [Online]. http://www.driveyoursuccess.com/2010/03/simplifying-minmax-jit-inventory-do-you-know-what-your-company-should-run.html

[12] K. Bazan-Rios, C. Chavez-Canales, E. Ramos-Palomino, J. Eyzaguirre-Munarriz and R. Mesia, "An Integrated System: Lean, Six Sigma and Theory of Constraints, a Study Applied in Wooden Furniture Industry in Lima, Peru," 2019 7th International Engineering, Sciences and Technology Conference (IESTEC), 2019, pp. 347-352, doi: 10.1109/IESTEC46403.2019.00070.

[13] J. Alejandrino et al., "Audit Pattern Optimization in Service Industry using Six Sigma Methodology," 2020 IEEE REGION 10 CONFERENCE (TENCON), 2020, pp. 1340-1345, doi: 10.1109/TENCON50793.2020.9293829.

[14] T. M. Shahada and I. Alsyouf, "Design and implementation of a Lean Six Sigma framework for process improvement: A case study," 2012 IEEE International Conference on Industrial Engineering and Engineering Management, 2012, pp. 80-84, doi: 10.1109/IEEM.2012.6837706.

[15] C. Mego-Aranguri, M. Roque-Soriano, E. Carvallo-Munar, R. Salas-Castro and L. Cardenas-Rengifo, "Combined Model of Lean Six Sigma and Work Method for a Peruvian Ammunition Manufacturing," 2020 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), 2020, pp. 1-4, doi: 10.1109/CONIITI51147.2020.9240372.

[16] M. K. Adeyeri and M. G. Kanakana, "Analysis of packaging and delivery operation in a cucumber packaging factory using Lean Six Sigma," 2015 Portland International Conference on Management of Engineering and Technology (PICMET), 2015, pp. 1407-1414, doi: 10.1109/PICMET.2015.7273079.