Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 4 Issue 5, May - 2017

Using Simulation to Justify Lean Implementation in Manufacturing

A Case Study

Kambiz Farahmand
Department of Industrial Engineering
North Dakota State University
Fargo, ND
kambiz.farahmand@ndus.edu

Xiaoxia Li
Department of Industrial Engineering
North Dakota State University
Fargo, ND
xiaoxia.li@ndus.edu

***Abstract*— Discrete event simulation is used to quantify the performance improvements expected from applying Lean manufacturing principles in an aviation part repair shop. Lean recommendations, including two new shop layouts are proposed to reduce the non-value added activities prevalent in the present shop. Simulation models are developed for the existing operation as well as for both proposed Lean Systems. The developed models predict the resource requirements and performance statistics for all three systems. The unique operation of the shop and the critical nature of the product make the simulation unique and interesting. A comparison of all three systems is made to determine the effect of proposed changes on the desired performance variables. As expected, significant improvements in various important indexes are observed for the proposed Lean systems. (*Abstract*)**

Keywords*— Lean Manufacturing, Simulation of Lean Implementation, Lean Transition (key words)

I. Introduction

The facility considered is a maintenance and repair shop. Defective parts arrive from Arenanational inventory and are categorized according to the extent of the repair required by them. The parts undergo a number of repair processes before they are declared refurbished and ready for the field use. The shop consists of various workstations scattered on two floors of the building. Most of the workstations have the capacity to work on just one part at a time, also requiring only one worker to perform the operation. Following is the list of processes performed at these workstations:

- Electrical Inspection
- Pre Shop Analysis
- Non-Destructive Testing
- Red BIM Inspection (Leak Test)
- Sanding Room
- Cuff Assembly
- Bonding Room
- Paint
- Deicer
- Autoclave
- Balancing

The current layout contributes largely to the non-value added activities carried out at every operation and during transfer, handling, and storage of parts. Flow of repair parts from one floor to another is done in batches and is accomplished using an elevator. Extended delays are experienced at different workstations since the processes are not balanced in the shop. Frequent random machine breakdowns are also experienced reducing productivity of the shop. Thus vast improvements could be expected from implementing Lean principles in the current process.

II. Process Flow

The parts arrive and depart from the shop in containers or "cans". They are categorized into four repair categories and require one or several operations depending on the category they fall under.

- Category I parts need very little work, in most cases just moisture removal. So after Non Destructive Testing they are sent for moisture removal and then packaged inside a can and sent back to inventory.

- Category II parts are inspected for leaks using NDI (Non Destructive Inspection) with the use of an X-Ray device. After the Leak test, they are sent to the sanding room for removal of cuffs, inboard and outboard seals. The parts are then sent to the bonding room for installation of inboard seals. Following this they go to the cuff assembly section. Again the Leak Test is performed and if a leak is found the process is repeated. If there is no leak, skin repair and wire mesh repair is performed in the bonding room. The parts are painted and final assembly is completed. The finished parts are canned and sent to the warehouse.

- Category III parts undergo the same processes performed on the Category II parts along with two new operations, to repair and install deicer in the autoclave.

- Category IV refers to the parts that cannot be repaired or are beyond economic repair. These parts are normally sent to SAFER (Storage Analysis Failure Evaluation and Reclamation).

Fig. 1 shows the location of various workstations and the process sequence followed by Category III parts in the shop. The process flow is depicted only for Category III parts since they require repair in all areas of the shop using all available resources.

III. Simulation of Current Process

Due to run time constraints and insignificant process flow for Category I and Category IV parts, only Category II and Category III parts are considered in simulation. Output Analyzer tool is used to deduce a warm up period of 60000 minutes. The simulation is run for a month, 10000 minutes approximately, considering 8 hours per day. Ten replications are made for the model. A run time image of the entire system is shown in the Fig. 2. Statistics are collected for the following performance parameters [2]:

1) Total time spend by parts in the system (TIS)

2) Work-In-Process (WIP) for Category II and Category III parts

3) % Utilization of resources

4) Throughput

5) Waiting times for all processes

Table I shows the various times categorized as value added (VA), wait time, and Total Time in the System (TIS) for both category of parts in the current system. All values are in minutes. Average work in process for both Category II and Category III parts are shown in Table II. The average time that the entities have to wait in the queues for all the processes and the % utilization of all resources used in the current model is shown in Tables III and IV respectively.

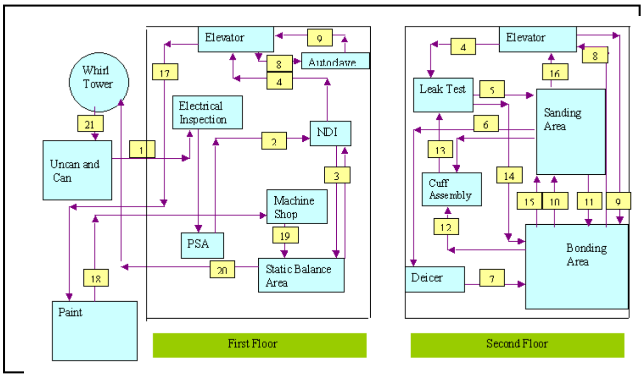


Fig. 1. *Process Flow for Category III Parts in the Current Layout caption)*

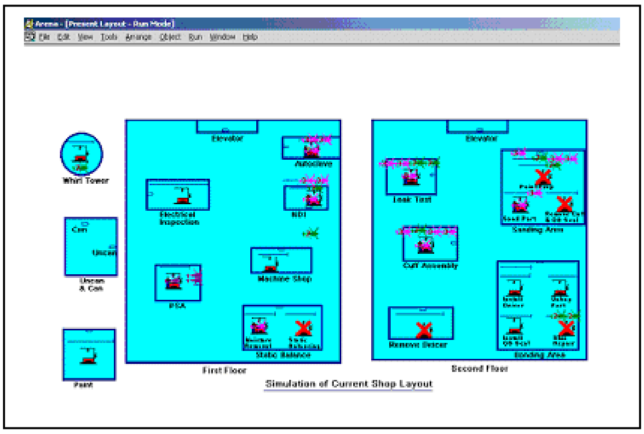


Fig. 2. *Simulation Run Time Image of Current Process*

TABLE I. Part Times in Current Process (minutes)

Part Type	VA Time	Wait Time	Total TIS
Category II	5094.05	32920.76	42188.45
Category III	6984.49	34893.69	47101.30

TABLE II. WIP values for Current Process

Type of Part	Average WIP
Category II	43.6918
Category III	33.6200

Queues	Waiting Times (minutes)
Autoclave process. Queue	758.56
Cuff Assembly Process. Queue	16736.64
Deicer Process. Queue	26.55
Dynamic Balancing Process.Queue	324.22
EI process. Queue	42.00
Install Deicer process. Queue	64.85
Install OB Seal process. Queue	54.55
Install Tip Cap process. Queue	30.44
Leak test Process.Queue	8651.63
Moisture removal Process.Queue	396.45
NDI Process.Queue	677.43
Paint process. Queue	894.32
PSA Process.Queue	91.55
Remove Cuff and OB Seal process. Queue	229.33
Sand Part process. Queue	3173.00
Skin Repair Process.Queue	86.57
Static Balancing. Queue	32.86
Unbag Part process. Queue	28.04

TABLE III. Average Queue Waiting Times

Sensitivity analysis on the present model is performed by varying the independent variables of the model and examining their effect on performance parameters and overall behavior of the model. Three cases are considered and reaction of the model to all cases is as expected. The model is also sensitive to extreme values of variables considered.

IV. Proposed Lean Changes for Current Process

The results of the simulation of the shop is similar to performing an as-is assessment which would show large time values for TIS, WIP, and queue times, indicating a large number of non–value added activities performed at all levels. Certain Lean Manufacturing tenets [3] need to be implemented in the present process to eliminate the prevalent non-value added activities and to improve efficiency of the system. These tenets are:

TABLE IV. % UTILIZATION OF RESOURCES FOR CURRENT PROCESS

Resources	% Utilization
Autoclave	.2990
Cuff Assembly	.8367
Deicer Removal	.1407
Dynamic Balancing	.3875
Electrical Inspection	.043
Install Deicer	.1952
Install OB Seal	.4044
Install Tip Cap	.063
Leak Test	.821
Moisture Removal	.6030
NDI	.7343
Paint	.3939
PSA	.148
Remove Cuff and OB Seal	.5223
Sand Part	.805
Skin Repair	.1656
Static Balancing	.1758
Unbag Part	.0684
Worker	.4045

A. Continuous Flow: The present layout of the plant promotes irregular flow of the parts as clearly evident in Fig. 1. The parts have to constantly move from one floor to the other and are also moved forward and backward in the shop when traveling from one workstation to another. This inefficient workplace layout adds significantly to the transportation or the conveyance waste. There is also excessive material handling of the parts. In general, there are more defects, breakdowns, and unnecessary storages associated with the current layout.

To implement Lean and to promote more continuous flow and less cross-tracking, two different layouts are proposed.

1) Proposed layout with Current State Configuration

The first proposed layout considers the same space availability as that of the present layout. The proposed layout includes dividing the bonding room and the sanding room into smaller workstations, with a separate cell for operations that are just required for Category III parts. There is an addition of a Leak Test workstation in the first floor. Also the workstations in the first floor are rearranged to promote more continuous flow. The proposed layout with process flow for Category III parts is shown in the Fig. 3. In this layout both Category II and Category III primarily follow the same sequence, except for the extra deicer and the autoclave work being done on the Category III parts.

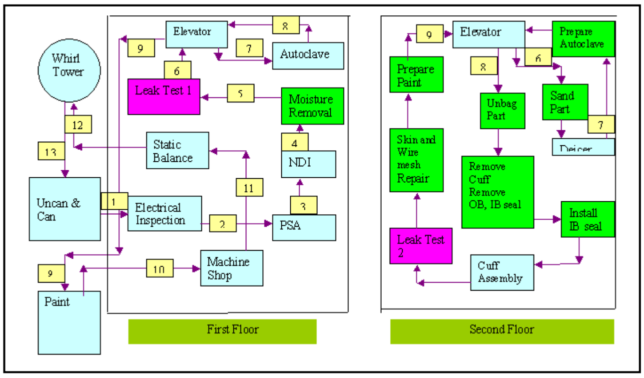


Fig. 3. *Process Flow for Category III parts in Proposed System with Current State*

2) Proposed layout with Ideal State Configuration

The second layout considers expansion and increase in space available. Here all the operations are accommodated at one level. Bonding and sanding areas are still divided into smaller workstations to promote continuous flow of the parts. Some related operations such as paint preparation and paint, preparing autoclave, and autoclave are performed at the same workstation rather than at different workstations. Fig. 4 shows the process flow for Category III parts in the proposed layout with ideal state configuration.

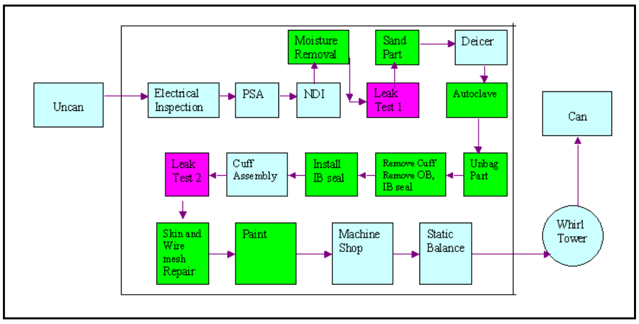


Fig. 4. *Process Flow for Category III Parts in Proposed Layout with Ideal State Configuration*

B. One Piece Flow: Even though the parts are always processed one at a time, they are moved in batches of 2-3 whenever they are transferred from the first floor to the second floor or from the second floor to the first floor. The parts have to wait for the formation of batches and this adds to the total time the parts spend in the system. Also the parts have to wait for the processing after reaching the destination workstation. In order to reduce wait times and the WIP, it is recommended that the parts are not moved in batches but transferred only one at a time.

C. Immediate Transfer: After parts have been processed at a workstation they encounter a delay before getting transferred to the next required workstation. This delay is totally unnecessary and should be removed. Thus parts transfer should be immediate, i.e. as soon as they are processed at a workstation and are ready to be moved to the next process, they should be transferred. Considering that the processes are not balanced, delays are now allowed at the beginning of the process.

D. Implementing Total Productive Maintenance: There are a lot of breakdowns experienced in the present layout. All the resources are associated with some kind of failures and have downtime of 6-8 hrs. Thus there is an urgent need of implementing another key lean tool, TPM to improve machine stability and effectiveness.

E. Reducing Corrections: Another important lean policy is to reduce the corrections i.e. having to fix defective products. In the present process, moisture is detected in the parts at NDI (Non Destructive Inspection). After moisture detection, the moisture is removed and inspection is again performed at NDI to verify if any moisture is left. This unnecessary step should be eliminated and after moisture removal, the parts should be moved to the leak test 1. For this purpose, another moisture removal resource is being added to the system. Additional leak test station is also added to improve utilization and minimize delays.

F. Adding capacity to busy resources: It is observed from the simulation results, that % utilization for some resources is very high in the present process. For some of these resources, such as sand part and cuff assembly, capacity is increased in the proposed processes when allowed (not requiring additional processes) in the ideal state configuration. Capacity increases are only considered in the Ideal State configuration.

V. PRESENT AND PROPOSED SYSTEMS

Simulation models for both the proposed systems (including the Lean recommendations) are developed. Warm up periods for both models are determined and then the models are run for one month, 10000 minutes. The same performance parameters are considered while collecting the statistics. A simulation run time image of the proposed system with current state configuration is shown in the Fig. 5. Furthermore, Fig. 6 shows the run time image for ideal state simulation model.

A comparison of all three systems is made to determine the effect of the proposed systems on the selected performance variables. Table V displays the average total times spend by both Category parts in all the three systems. Time spent in the system is significantly reduced for proposed system with current state configuration, 59% and 52% respectively, for category II and category III parts. Additional improvement of 65% is made from proposed system

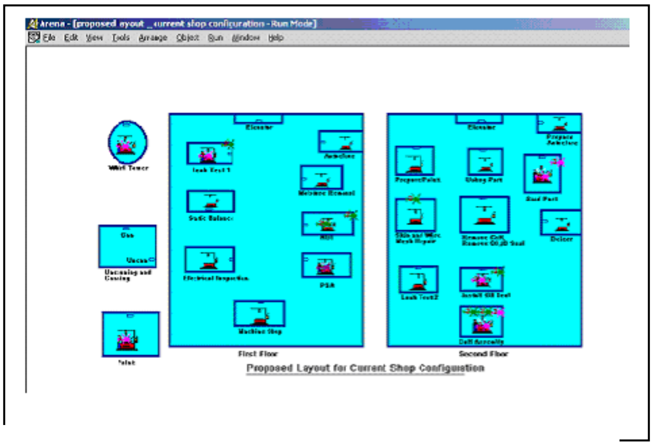


Fig. 5. *Simulation Run Time Image of Proposed Layout with Current Configuration*

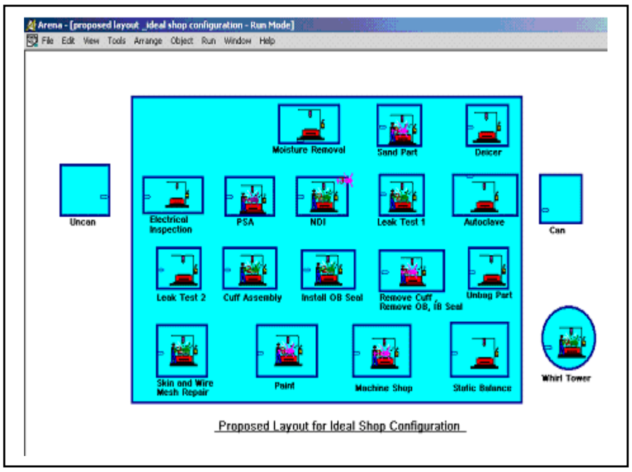


Fig. 6. *Simulation Run Time Image of Proposed Layout with Ideal Configuration*

with current state configuration to proposed system with ideal state for category II parts and 59% for category III parts.

TABLE V. TOTAL TIS COMPARISON

Part Type	Present System (Minutes)	Proposed System with Current State (Minutes)	Proposed System with Ideal State (Minutes)
Cat. II	42188.43	17148.17	5930.06
Cat. III	47101.30	22686.37	9333.94

Fig. VII show the comparison of total time spend by Category II parts in all the three systems. It is evident from the plot that Category II parts spend maximum time in the present layout and least in the proposed layout with ideal state configuration. Fig. 8 shows similar kind of results for Category III parts in all the three layouts. For clarity purposes, only one replication is shown in the Figures.

Table VI presents the comparison of average in – process inventory for both Category II and Category III parts. WIP is reduced over 50% by implementing Lean

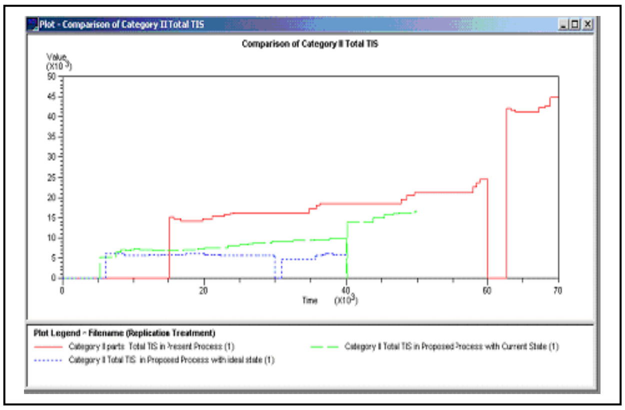


Fig. 7. *Comparison of Category II Total TIS*

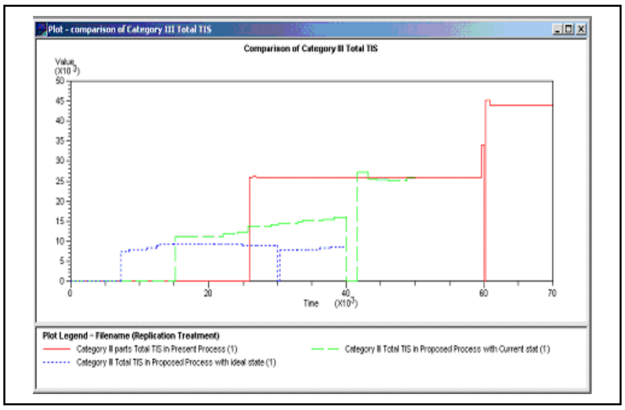


Fig. 8. *Comparison of Category III Total TIS*

in the current process and reduced 5 to 8 fold for the

Part Type	Present System	Proposed System with Current State	Proposed System with Ideal State
Category II	43.69	17.8714	5.5317
Category III	33.62	15.6197	6.0339

ideal state for Category III and Category II respectively.

TABLE VI. WIP COMPARISON

Fig. 9 is the plot of WIP for Category II parts for all the three systems. The x- axis is for simulation run time whereas the y-axis is for WIP values. Fig. 10 is the similar plot for Category III parts. It can be seen from the plots that WIP for present system is much larger than both the proposed systems at all times.

Table VII shows the throughput or the number of fully repaired parts for all three systems. An average of 50% increase in throughput for the proposed system with current state configuration and 100% increase when using the ideal state is experienced.

The time that the parts wait in queues, for getting processed is shown in Table VIII. All values are in minutes. Waiting time for the major processes is reduced significantly. The waiting time for other processes is almost eliminated. Fig. 11 is the plot of queue waiting time of cuff assembly process against the simulation run time for all the three systems. Fig. 12 is the similar plot for leak test process.

TABLE VII. THROUGHPUT COMPARISON

Part Type	Present System	Proposed System - Current State Configuration	Proposed System – Ideal State Configuration
Cat. II	5	7	9
Cat. III	3	5	7

TABLE VIII. WAITING TIMES COMPARISON

Fig. 10. *Comparison of Category III WIP*

Type of Process	Present System	Proposed System - Current State Configuration	Proposed System – Ideal State Configuration
NDI	**677.43**	**177.58**	**142.24**
Cuff Assembly	**16736.4**	**11420.36**	**51.06**
Leak test	**8651.63**	**Leak Test 1 – 302.21 Leak Test 2- 46.85**	**Leak Test 1 – 315.58 Leak Test 2- 278.68**
Sand Blade	**3173.00**	**2713.85**	**47.4**

It is also observed that % utilization of all resources is reduced significantly in the proposed Lean systems.

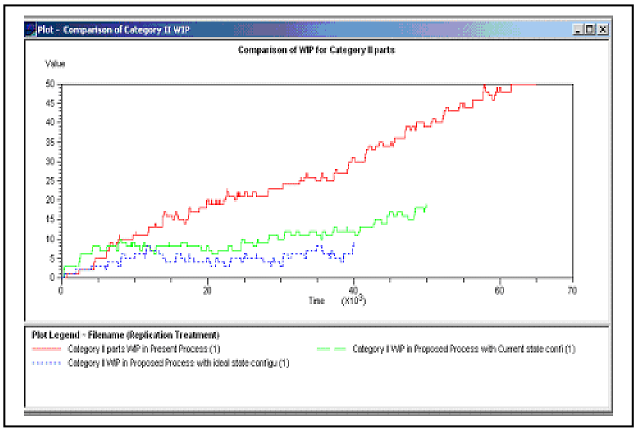


Fig. 11. *Comparison of Cuff Assembly Process Queue Waiting Time for all systems*

Thus for all the desired performance parameters,

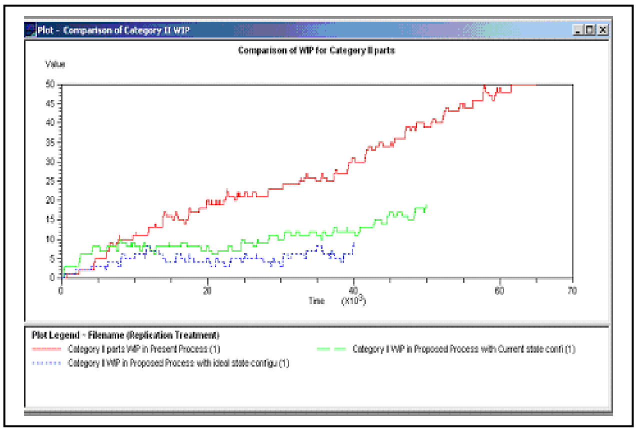
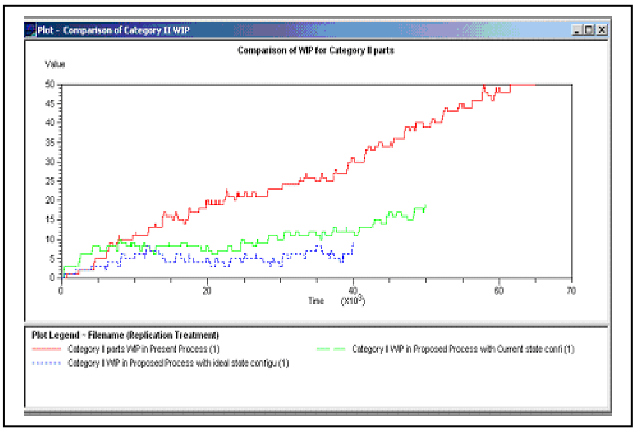


Fig. 12. *Comparison of Leak Test Process Queue Waiting Time for all systems*

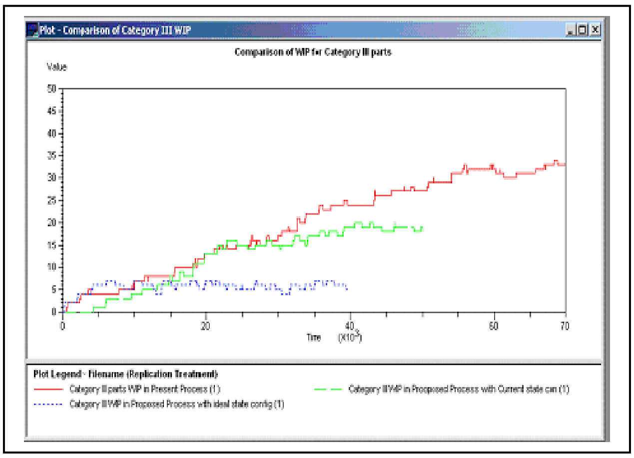
proposed systems prove to be better than the present system.

VI. Conclusion

The results show that both proposed Lean systems have lower time in system, lower work in process inventory, lower queue waiting times, and more throughput than the present layout. The reduction in times could be attributed to the combination of lean implementation and layout redesign for the proposed systems. The decision to implement Lean manufacturing principles in not an easy one for the organization and a tool is required that could depict, both at planning and evaluation stages, the



advantages of transition to lean. The project aims at



projecting simulation as that tool. It successfully demonstrates that simulation can provide creditable estimates of improvements in performance statistics that accrue on implementing Lean principles. It also makes the case for a more aggressive approach such as complete tear down and rebuilding the current shop.

REFERENCES

[1] W.D. Kelton, R.P. Sadowski, and D.T. Sturrock, Simulation with Arena, 3rd Edition, McGraw Hill.

[2] K. Farahmand, An Integrated Technique for Minimizing WIP and Maximizing Throughput, International Conference in Industrial Engineering productivity 97, Matamoros, Mexico, November 10 – 14, 1997.

[3] R. Detty and J. Yingling, Quantifying benefits of conversion to lean manufacturing with discrete event simulation: a case study, International Journal of Production research.