Simulation of Information System In a Lean Factory

Nicholas Loyd
Alabama Technology Network
University of Alabama in Huntsville
Huntsville, AL 35899
loydn@email.uah.edu

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ABSTRACT

The Manufacturing Extension Partnership (MEP) is a nationwide network of over seventy not-for-profit centers. The MEP is linked with the Department of Commerce's National Institute of Standards and Technology (NIST) and has the sole purpose of providing small and medium-size manufacturers with the assistance they need to be competitive and successful. The Alabama Technology Network (ATN) joined the MEP in 1996 and began operation through a partnership among the University of Alabama System, Auburn University, and select two-year colleges. The ATN has 10 centers statewide that are focused on providing technical and business solutions to Alabama companies in order to lead them to high performance. The University of Alabama in Huntsville (UAH) is the Region 1 center of the ATN and concentrates a large portion of its efforts in the field of Lean Enterprise Development.

Lean Manufacturing is a systematic approach to identifying and eliminating waste through continuous process improvement by flowing the product at the pull of the customer. This paper discusses recent improvements made to a hands-on simulation of a fictional factory (BUZZ Electronics) used as a training tool to demonstrate the benefits of lean manufacturing tools. The improvements include the development of computer software used to simulate an Electronic Data Interchange (EDI) system in the factory simulation's final round. The simulated EDI, which uses four portable laptop computers and utilizes a wireless network, is useful in showing the benefits of paperless information systems, which simplify shop scheduling, and sequenced supplier deliveries.

INTRODUCTION: CONCEPTS OF LEAN

Global competition continues to force companies to discover ways to reduce delivery time, improve quality, and simultaneously lower cost. To achieve this "faster, better, cheaper" mentality, many companies within the MEP target client base request assistance and guidance in lean manufacturing and lean enterprise. To address this request, a very popular lean electronics assembly training simulation that was initially developed by Toyota Georgetown was adopted by NIST. The simulation focuses on the "Buzz Electronics" assembly plant, with training participants being employees of Buzz (NIST, 1998).

The electronics assembly training simulation is designed to highlight the key objective in lean manufacturing, which is to compress time by eliminating waste and thus continually improving the process. In the training simulation, participants are exposed to lecture material covering the essential elements of lean: work place organization (5s), value stream mapping, quick changeover, batch reduction, visual factory, batch reduction, standardized work, quality at the source, teams, point-of-use-storage, pull/kanban systems, cellular design/one-piece-flow, and Takt time. The lecture contents are based soundly on the documented principles governing the Toyota Production System (Ohno, 1988; Shingo, 1989; Imai, 1986). At strategic breaking points in the class, the participants are asked to take what they have learned in the lecture and implement them on the assembly line at Buzz. The participants use 10-15 minutes to make quick changes to the line via a kaizen blitz. Kaizen is a Japanese term for continuous improvement. A total of three kaizen blitzes are performed throughout the duration of the training simulation.

In the spirit of continuous improvement, the electronics assembly training simulation itself has received a few custom modifications over the past few years. This paper will discuss the following modifications: 1) introduction of sequenced just-in-time supplier delivery in the simulations final round, 2) the use of the internet to enhance customer-company-supplier communication, and 3) the ability for remote access to the simulation via internet.

THE ORIGINAL TRAINING SIMULATION

The Buzz Electronics assembly simulation is a hands-on lean manufacturing training simulation of a factory that manufactures "security systems". The finished product materializes from assembling simple electronics components such as resistors, diodes, LEDs, and conductive springs onto a circuit board. The factory offers two similar, but different, models—a "Blue Avenger" for residential use and a "Red Devil" for commercial use. The eight-hour training simulation consists of four rounds, or shifts, lasting twenty minutes each. The following elements of a manufacturing enterprise are included in the simulation:

- Sales department that receives customer orders, notifies the shipping department of pending orders, and orders raw material from supplier
- Off-site supplier that fills orders for circuit boards and delivers them to the manufacturing line
- Manufacturing line that assembles two different models of product
- Shipping department that fills orders and ships finished units to customers

In round 1, participants are thrown into employee roles in Buzz without any lecture on lean concepts. The plant is set up in a functional layout (Figure 1) and operates in a traditional batch manufacturing system. Production control schedules the shop based on a forecast. The workers are told to make as much finished product as possible.

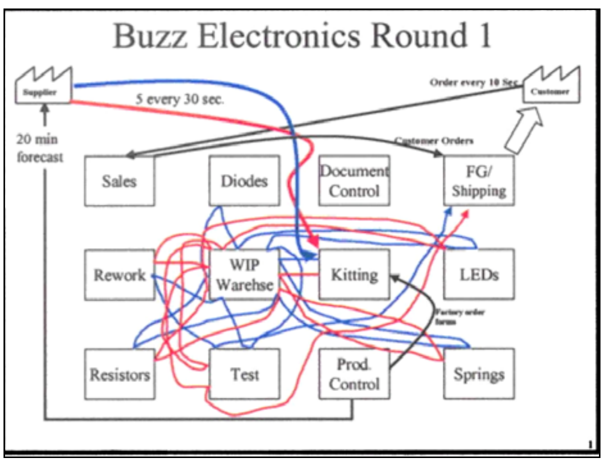


Figure 1. Functional Layout in Round 1

Round 1 of the training simulation typically results in little or no shipments, lots of in-process inventory, poor quality, chaos, discouraged workers, and red numbers on the company's financial statement. Figure 2 shows round 1 of Buzz Electronics from the perspective of a value stream map. Value stream mapping is a lean enterprise tool used to map material and information flow within an organization in order to more easily identify blockages in those flow in order to eliminate wastes (Rother and Shook, 1999). The current state value stream map reveals that the manufacturing lead time for a finished product is 23.75 minutes while the actual time spent adding value to the product is just 195 seconds (3.25 minutes). This suggests that there are several areas of opportunity to eliminate wastes (non-value added steps) in the process.

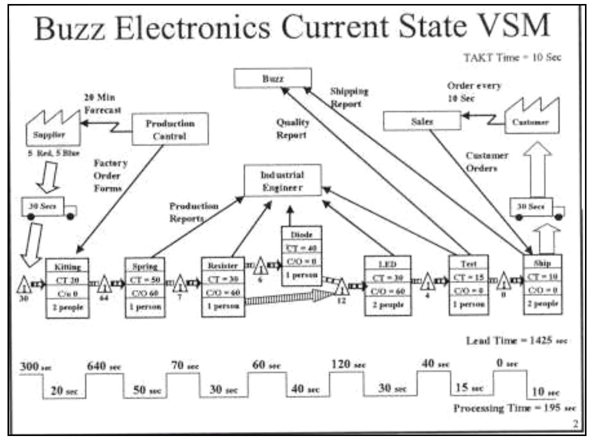


Figure 2. Current State Value Stream Map

After learning lean principles and tools via the training lecture, participants begin eliminating or reducing wastes in the process and make changes to the line. The group sees gradual positive changes in revenue, on-time deliveries, quality, and work environment throughout the succeeding rounds. Typical changes made are improved layout, raw materials stored at point-of-use, changeover elimination, 5s, and more visual work instructions. Along the way, a customer demand of 120 units per shift is introduced as design criteria for the group.

The introduction of a customer demand allows participants to design a cellular layout in the final round based on takt time. Takt time is defined as "work time available/customer demand" per period of time. For Buzz Electronics, each shift is twenty minutes long with a demand for 120 units each shift. Thus, the takt time at Buzz = 1200 seconds/120 units = 10 seconds per unit. In order to meet this rate of demand, each individual operational cycle time must be less than or equal to ten seconds. In the training simulation, participants are required to perform time studies on each operation. Figure 3 shows typical observed cycle times:

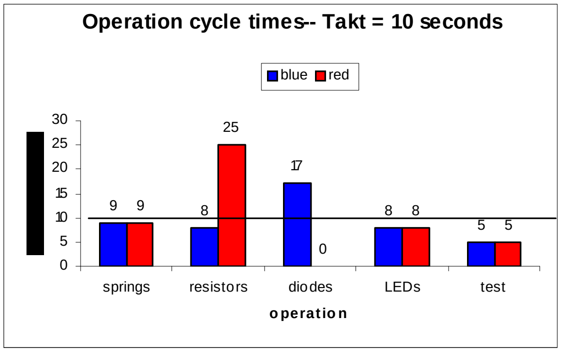


Figure 3. Cycle Times at Each Operation

As can be seen, not all cycle times at the stations are less than takt time. This forces participants to work on balancing the work using lean principles like process standardization, workstation layout, eliminating wasteful motions, and redistributing workloads. Ideally, the work is balanced to takt time and allocated evenly to six stations with one operator at each station. In the training simulation's original design, the final round (round 4) operates on a pull/kanban system. The line is designed with a red kanban and a blue kanban between each station. For example, if a sales order for a Blue Avenger is given to the shipping department, they "pull" a blue finished product out of the blue kanban. The empty space created by removing the blue product triggers the preceding operation (in this case the testing station) to go the station immediately upstream from them and "pull" a blue product, test it, and replenish the empty space. If both the red and blue kanban areas are full between stations, no work is done because there is no demand for it. Figure 4 shows the final round of the original training simulation from a value stream point of view.

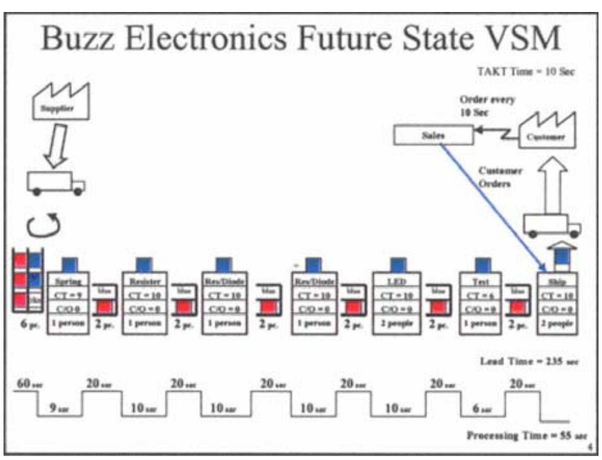


Figure 4. Value Stream Map of Original Round 4

The value stream map for the original round 4 shows many of the vast improvements typically made during the training simulation. A comparison to the value stream map for round 1 highlights: 1) a much more simplified information flow with scheduling now done off customer orders, 2) a drastic reduction in in-process inventory due to the cell design and implementation of the kanban system, which results in, 3) reduction in process time from 195 seconds in round 1 to 55 seconds, and a reduction in manufacturing lead time from 1425 seconds in the first round to 235 seconds (3 minutes, 55 seconds). Other improvements are typically seen in the areas of on-time deliveries, quality, and net income. Figure 5 shows a table comparing typical results from the 4 rounds of the original training simulation.

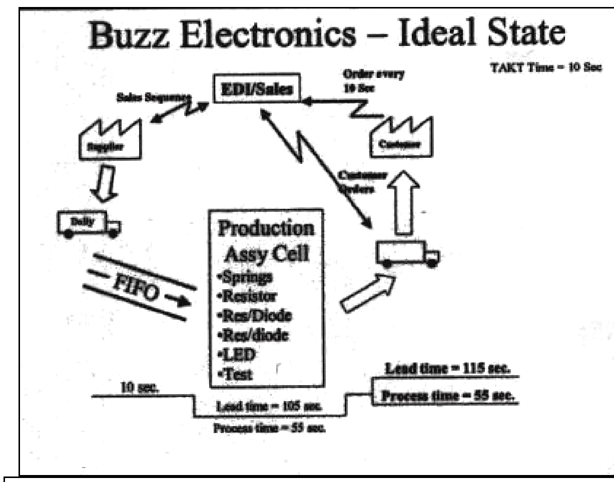
	Round			
	1	2	3	4
Lead time	20+ min	12 min	5 min	3 min
On-time deliv.	0%	6%	67%	85%
WIP	150	98	20	15
# shipped	6	36	65	96
Quality	25%	80%	90%	95%
Net Income	($1,155.00)	($225.00)	$895.00	$1,285.00

Figure 5. Comparison of Results

SEQUENCED DELIVERY MODIFICATION

As can be seen in Figure 5, drastic improvements can be obtained by implementing lean principles. Companies that have implemented lean often see results comparable to those in the simulation: as inventories drop, lead time does the same. This results in more on-time deliveries and throughput. Also, as inventories are reduced, quality problems are found faster and addressed resulting in better quality data. All of this results in profitability. But notice that even in round 4 with all the changes, the customer demand of 120 units per shift is rarely met. Although a company may reduce cost and become more profitable, if they are not meeting customer demand that could all change.

In an effort to enhance the training simulation to achieve desired results, a modification was made to the supplier relations. The typical improvements to Buzz were accelerated so that participants reach the state of the original simulation's last round by round 3. Sequenced just-in-time (SJIT) supplier delivery, a practice that is becoming popular in the automotive industry, was added in the fourth round to further reduce inventory and improve scheduling accuracy relative to customer demand. In SJIT, the sales department at Buzz communicates with both the shipping department and the off-site supplier. While the shipping department still receives the customer order form as authorization to ship product, the off-site supplier also receives information regarding the sales sequence. In the training simulation, this is achieved simply by having the sales representative verbally inform the supplier of the sales sequence, i.e. “order 1 is blue, order 2 is red, etc.”. The supplier in turn delivers the raw material circuit boards right to the first operation in that exact sequence. Product is processed first-in-first-out as delivered by the supplier, ensuring that the product coming off the end of the line is the exact product needed at shipping to fill the next order. With the product sequence now being scheduled at the beginning of the line, the kanban now must only have a place for the next product in sequence where as in the original round 4 one red and one blue kanban were required. The SJIT concept allows for inventory and lead time to be reduced even more. Figure 6 shows the value stream map for Buzz operating with sequenced supplier deliveries and also a comparison to the original round 4 of the training simulation.



	Original Rd 4	Rd 4 w/ SJIT
Lead time	3 min	1.5 – 2 min
On-time del. %	85%	100%
WIP	15	10
# Shipped	96	120
Quality	95%	98%
Net Income	$1,285.00	$1,950.00

Figure 6. Sequenced Supplier Value Stream Map and Comparison to Original Round 4

As evident in Figure 6, the integration of the supplier helped to further reduce lead time and the vast majority of training groups meet the customer demand of 120 units and typically ship all of them on-time. As a result, quality also increases and the company becomes even more profitable. Note on the “Ideal State” value stream map (Jones and Womack, 2002) that the process time did not change from the value stream map of the original round 4 (it remained at 55 seconds.) However, waste was eliminated from the system by the reduced inventory in the kanban, which allowed the lead time to drop to less than 2 minutes.

USE OF INTERNET IN THE SIMULATION

Even further improvements have been made to the original electronics training simulation with the development of a simulated EDI system. The EDI system for the Buzz Electronics was created using software developed specifically for the training simulation that utilizes four laptop computers and an Internet server. As outlined in Figure 6, the SJIT concept requires communication between the sales department, shipping department, and the off-site supplier. Laptops linked by a wireless network are placed at each of these three locations (Figure 7 shows the setup).

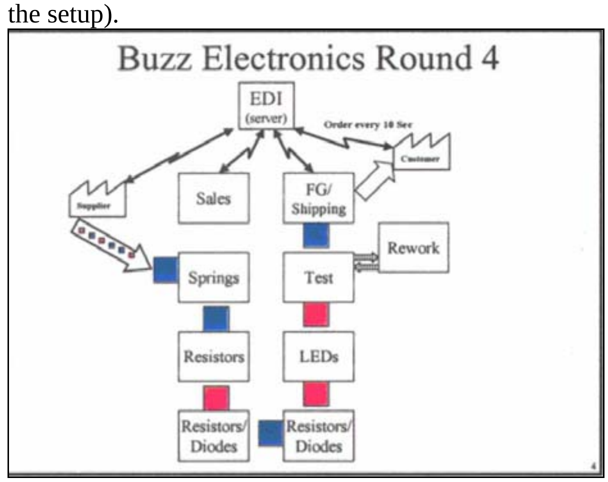


Figure 7. Electronic Communications at Buzz

The software is designed so that the laptop logged on as the sales department will generate a customer order every ten seconds (consistent with all rounds of the training simulation). When the customer order is generated, the sales representative presses ENTER to process the order (see Figure 8). Once ENTER is pressed, the order will appear on the on the off-site supplier laptop and the shipping department laptop. The display for the supplier contains the order number, required board type (red or blue), quantity, time the board was ordered, and time the board is required (see Figure 9). The supplier fills the order by delivering the required board to the manufacturing line, then presses ENTER to indicate the board was delivered. The display on the computer at the shipping department gives the status of all pending orders (see Figure 10). Once the unit has been manufactured and arrives at shipping, the shipping attendant highlights the appropriate order on the screen and presses ENTER to indicate the product has been shipped to the customer.

The time the shipping attendant presses ENTER is recorded as the shipped time and the pending order then disappears from the screen.

	SEND BOARD ORDER TO: Huntsville Board Company, Inc. 3232 Memorial Parkway Huntsville, AL 35801	00:50
1.	Order #: **17**	
2.	Serial #: **20005**	
3.	Model: **Blue Avenger**	
4.	Quantity: **1**	
5.	Time Ordered: **00:50**	
6.	Time Promised: **04:50**	

Figure 8. Sales Department Screen

	SHIP BOARD ORDER TO: Buzz Electronics, Inc. 123 West Main Huntsville, AL 35807	00:58
1.	Order #: **17**	
2.	Serial #: **20005**	
3.	Model: **Blue Avenger**	
4.	Quantity: **1**	
5.	Time Board Ordered: **00:50**	
6.	Time Board Required: **04:50**	
7.	Time Board Shipped: **00:58**	

Figure 9. Off-site Supplier Screen

PENDING SHIPMENTS 04:45

Order	SN	Model	Qty	Ordered	Required	Shipped
5	20000	Blue	1	00:50	04:50	04:45
6	20001	Red	1	01:00	06:00	
7	20002	Red	1	01:10	06:10	

Figure 10. Shipping Department Screen

The fourth laptop is the master computer. Whenever ENTER is pressed on the other computers, the master computer is updated and generates a variety of reports that are accessible during the simulation. The training participant playing the Production Supervisor role typically monitors progress on the production scoreboard displayed on the master computer (see Figure 11). The production scoreboard gives a visual report updated every 2 minutes showing whether the assembly cell is ahead, on target, or behind schedule. The master display has a green signal if the line is ahead or on-time, a yellow signal if it is 1 or 2 units behind, and a red signal if it is 3 or more units behind. The production supervisor manages the cell accordingly.

PRODUCTION SCOREBOARD (period = 2 min) 08:00

Period	Sched.	Actual	Cum -/+	On-time	Signal
1	12	10	-2	8	Yellow
2	12	13	-1	11	Yellow
3	12	14	0	12	Green
4	12	9	-3	9	Red

Figure 11. Production Scoreboard

It is also possible for individuals who are not participating in the training simulation on-site to access the server (master computer) via the Internet. This allows remote observers to obtain a feel for the training by accessing the displays such as the off-site board supplier, sales department, shipping department, and the production scoreboard (UAH, 2001).

CONCLUSIONS

In summary, the following conclusions can be made about the original electronics assembly training simulation and the recent modifications made to it:

- Training simulations are an effective tool for implementing lean. They provide hands-on demonstrations that force the participants to work as a team and focus on quickly solving problems and making process improvements.

- "Lean 101" electronics assembly training simulation as an excellent approach to grasping the basics of lean and attacking underlying cultural issues involved in a typical lean transformation. Participants see not only the value in reducing changeover time, reducing inventory, and teamwork but also how management's role changes with lean to create a new shop culture.

- The addition of the sequenced supplier delivery (SJIT) concept to the electronics training simulations demonstrates the importance of integrating outside suppliers into a lean transformation.

- The use of the Internet to develop a simulated EDI system adds a new dimension of reality to the simulation and shows the effects of elimination paperwork from a system.

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BIOGRAPHY

Nicholas Loyd is on the staff of the Alabama Technology Network at the University of Alabama in Huntsville and has trained hundreds of manufacturers from several states in Lean Manufacturing. He has a BS in Industrial and Systems Engineering and is a NIST certified Lean Manufacturing trainer. He has been active in providing lean manufacturing assistance to companies in the automotive, aerospace, electronics, plastics, meat-cutting, mining and other industries in the areas of: cellular manufacturing design, value stream mapping, TAKT time/work balancing, work standardization, kaizen facilitation, and changeover reduction. He is a member of the Institute of Industrial Engineers and the Society of Manufacturing Engineers.