Developing the Computer Simulation Model

of Buzz Electronics Simulation

by

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A Research Paper
Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
in

Technology Management

Approved: 3 Semester Credits

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August, 2009

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Title: ***Developing the Computer Simulation Model of Buzz Electronics Simulation***

Graduate Degree/ Major: MS Technology Management

Research Adviser: **Thomas Lacksonen, Ph.D.**

Month/Year: **August, 2008**

Number of Pages: **46**

Style Manual Used: **American Psychological Association, 5th edition**

ABSTRACT

Lean Manufacturing is the manufacturing process to reduce waste. Companies are interested in this process because it is helpful to reduce costs. Northwest Wisconsin manufacturing outreach center (NWMOC) conducts Lean Manufacturing training for companies in Wisconsin. NWMOC conducts Lean Manufacturing training using the Buzz Electronics simulation. This training is helpful for workers to learn why lean is necessary for their company.

The purpose of the study is to develop a simulation model for Lean Manufacturing training, using Arena simulation software for NWMOC. The goals are to increase the participants understanding and to improve impacts on business by adding animated visual representation of the Buzz Electronics simulation.

The researcher participated in Lean Manufacturing training and captured the Buzz Electronics simulation rounds in video. The video films were reviewed and tracked the process time of batches or parts to determine the process time distributions. Also, the parts shipped and orders completed were recorded from the video film. The Arena simulation software was used to create the computer simulation models using process time distributions as input. The model was validated comparing the actual and simulated orders completed and parts shipped. The result of this project makes the Lean Manufacturing training more effective by providing the visual information of Buzz Electronics simulation, showing the manufacturing process and collecting the additional data for further discussion about the production.

Acknowledgments

I respectfully acknowledge and am grateful to Dr. Thomas Lacksonen for his willingness to act as my advisor on this project and paper, and his assistance in the successful completion of it.

I am very grateful to Dr. Renee Surdick and Mr. Kelly Sullivan for their genuine friendliness, and accommodating cooperation with this project.

Also, I would like to thank Northwest Wisconsin Manufacturing Outreach center for providing me the opportunity to work on this project.

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Chapter I: Introduction

The Stout Technology Transfer Institute (STTI) is a non-profit unit of the University of Wisconsin-Stout and was established with the mission to promote technology transfer between Stout and business and industry (University of Wisconsin-Stout, 2009). The institute, a division within Stout's College of Management, draws on the University's extensive technical resources, including the expertise of faculty, staff, and students, well-equipped and diversified laboratories, and a substantial network of private sector and public partners.

The Stout Technology Transfer Institute's Northwest Wisconsin Manufacturing Outreach Center (NWMOC) provides on-site principle of Lean Manufacturing training seminars to manufacturers in Wisconsin. These training seminars support small and medium sized manufacturer's efforts in successfully transforming their business, incorporating Lean Manufacturing principles and practices.

The concept of Lean Manufacturing is often described as a systematic approach to identifying the non-value added activities and eliminating them through continuous improvement, resulting quality product for customers (NIST-MEP, n.d). The goal of Lean Manufacturing is to eliminate waste in overproduction, motion, inventory, waiting, transportation, defects, underutilized people, and extra processing in effort to maximize their competitive efforts in our global environment.

Generally, participants in principles of Lean Manufacturing training seminars, represent a wide range of positions within the manufacturing plant from front line production workers, quality control, to the plant manager. This leaves the program managers, who facilitate the training seminars, with several challenges that relate to learning the subject matter of Lean Manufacturing. The objective of lean manufacturing training is to give in-depth knowledge of lean concepts and principles. In each training program, the variation of skill level requires the infusion of multiple teaching methods to both, promote active learning and be responsive to various learning styles. The instructional strategies, learning methods and context currently utilized to convey lean subject matter include facilitating group discussions, short focused lectures, and use of physical simulations.

Typically, within principles of Lean Manufacturing training, NWMOC trainers utilize Buzz Electronics simulation, which is a simulation process that provides hands - on activity utilizing the concepts and practices of Lean Manufacturing principles. Buzz Electronics enterprise manufactures two types of security systems, the blue avenger, basic model for everyday use and the red devil, industrial model for commercial use. The blue avenger is made with one unit each of a; kit, spring, diode, and 1K resistor and the red devil is made with one unit each of a; spring, 1K resistor, LED, 100K resistor each.

In Buzz Electronics simulation, participants take part in four rounds of simulation, 20 minutes each. In the first round of simulation participants work in traditional manufacturing layout. The blue batch of six parts passes through the spring, diode, resistor, LED, testing, and warehouse stations and the red batch of four parts passes through the spring, resistor, LED, testing, and warehouse stations in an order. In the second round of Buzz simulation the layout and the sequence change from the first round. The sequence of stations and the flow of batch in this round are spring, resistor, diode, LED, testing, and warehouse for blue batch and spring, resistor, LED, testing, and warehouse for red batch. In the third round of simulation, the batch is reduced to half of the previous size and follows the sequence of spring, resistor, diode, LED, testing, and warehouse for blue batch and spring, resistor, LED, testing, and warehouse for red batch. The stations are arranged close to each other. The fourth round pull and kanban concept is implemented. In this round, the production lines are two and each part must pass through spring, diode, 1K resistor, LED, 100K resistor and testing workstations. The kanban is full with one blue avenger and one red devil.

Statement of the Problem

The present module of Lean Manufacturing training does not have any visual information about the simulation. Also, participants of Buzz Electronics simulation cannot see other stations and they are able to collect only limited data. Because of these reasons, participants of the training do not have good understanding about the production for further discussion, which does not make the training able to produce the desired outcome set by the trainer and management of the company.

Purpose of the Study

The purpose of the study is to develop the simulation model of Lean Manufacturing training using Arena computer software, capturing the actual Buzz Electronics activities.

Goals of the Research

The goals of this research are:

1. To increase participant-learning outcomes as reported on self-evaluations
2. To improve the business impacts (increase revenue) by adding animated visual representation of the Buzz Electronics simulation

Limitations of the Study

1. The physical simulation data are based on the Lean Manufacturing training at Chippewa Valley Technical College (CVTC), the data could be different if the physical simulation runs in a different place and time
2. The Arena simulation software used for this research is a training version that allows us to use only limited number of blocks

Methodology

The methodology used for this research was video capturing all four rounds of Buzz Electronics simulation of Lean Manufacturing training with three video cameras. These video films were carefully reviewed and tracked process times in all stations for red and blue batches/parts. Also, other information like parts out, order completed and distance between the stations were tracked. The input analyzer of Arena software was used to determine the distribution of process time recorded from the video films. This process time distribution was used to create the simulation model for Lean Manufacturing training using Arena simulation software.

Chapter II: Literature Review

To prepare for the research, a literature review was conducted to cover these topics: Lean Manufacturing, Lean Manufacturing principles, Lean Manufacturing Elements, Lean Manufacturing training, Lean Manufacturing training with live simulation, computer simulation, computer-aided simulation training, and Arena simulation software.

Lean Manufacturing

Lean Manufacturing is the term first used in the book, "The machine that changed the world" by James Womack and David Jones, which describes the manufacturing philosophy pioneered by Toyota (Allen, Robinson & Stewart, 2001). Lean Manufacturing is the systematic elimination of waste (Santos, Wysk &Torres, 2006).

Lean Manufacturing is the systematic elimination of waste from all aspects of an organization's operations, where waste is viewed as any use or loss of resources that does not lead directly to creating the product or service a customer wants when they want it (Caulkin, 2002). In many industrial processes, such non-value added activity can comprise more than 90 percent of a factory's total activity.

The National Institute of Standards and Technology-Manufacturing Extension Partnership's (NIST-MEP) lean network defines "Lean Manufacturing as a systematic approach to identifying the non-value added activities and eliminating them through continuous improvement, which results the quality product for customers" (n.d).

When the lean team is established, and if the team operates effectively, the most important wastes like overproduction, inventory, transportation, defects, processes, operations and inactivities are detected and eliminated (Santos et al., 2006).

Principles of Lean Manufacturing

Lean Enterprise Institute (LEI) specifies the Principles of Lean as (2009):

1) Specify value from the standpoint of the end customer by product family.
2) Identify all the steps in the value stream for each product family, eliminating every step and every action and every practice that does not create value.
3) Make the remaining value-creating steps occur in a tight and integrated sequence so the product will flow smoothly toward the customer.
4) As flow is introduced, let customers pull value from the next upstream activity.
5) As these steps lead to greater transparency, enabling managers and teams to eliminate further waste, pursue perfection through continuous improvement.

Lean Manufacturing Elements

Several Lean Manufacturing elements are taught in Buzz Electronics simulation of Lean Manufacturing training.

Standardized work: Standardized work is a method used by the operator to organize his or her tasks in a safe and efficient manner (Allen et al., 2001). Standardized work reduces waste by identifying and eliminating unnecessary motion and effort. When standardized work process is followed, they maintain quality and prevent equipment damage.

5S system: 5S system is the key strategy for the work place organization (Allen et al., 2001). The 5S system elements are sort- nothing is extra or unnecessary, set in order- a place for everything and everything its place, shine- the environment is immaculate and self cleaning, standardized- standards are easy to see and understand, and sustain- pride is created in the work place, as well as the discipline to maintain it and to continuously improve.

Plant layout: Plant layout is change in the factory resources (Santos et al., 2006). It seeks the optimal location for optimal production flow of all production resources, as safe as possible and satisfactory for employee.

Team work: Teamwork in a lean environment espouses that each person is a member of a work team (Allen et al., 2001). The importance of teamwork should be addressed regarding problem resolution, work-group skill requirements, quality improvements, workplace organization etc.

Batch reduction: Batch size reduction is making the smaller size of batch from an existing batch size (Allen et al., 2001). Smaller batch size allows companies to produce customer requirements and ship, rather than store, product. From production of smaller batch sizes, less time is spent maintaining inventory, quality problems quickly detected, response is quicker to customer demand and material is handled more efficiently.

Push System: Push system is a process in which goods are produced and then placed in the consuming process and stored until needed (Ortiz, 2006).

Pull system: Pull system is a key tool in Lean Manufacturing that enables effective just-in-time (JIT) material management (Allen et al., 2001). The pull system makes JIT possible by transferring the responsibility of JIT from the materials management group to the production or operations group. In a pull system, the products are produced only when they are pulled by the prior process.

Kanban: The kanban system is a means to communicate materials needs between two process centers (Hernandez, 1989). Kanban means a visible record in Japanese. An effective kanban system will result material being delivered only in small quantities as it is needed (Allen et al., 2001). Kanban is a communication device telling the supplier or supplying operation when to deliver.

Line balancing: Line balance is the method in manufacturing process to assign the approximately same amount of workload to each work station (worker) in an assembly line (Santos et al., 2006). Line balancing is the technique to assign tasks to work-station so the minimum number of work stations can be achieved.

Lean Manufacturing Training

A number of lean training options are available for both industry and educational institutions (Verma 2003). For industry, the first option is that the consultants who conduct Lean Manufacturing training programs in traditional classroom lecture setting to teach Lean Manufacturing concepts, which are applied to case studies or to actual shop process improvement efforts. Sometimes, the consultants incorporate live simulation exercises into their training programs or use computer simulation to demonstrate some of the Lean Manufacturing elements and principles. The second option is to get the various workforce training course CD's that are available through different distribution channels. The third option is videos, books, and manuals which can be purchased and are often used to teach Lean Manufacturing concepts. Some consultants use computer applications to teach and support process improvement efforts.

Many educational institutions have the training programs which are closely tied to Manufacturing Extension Partnership (MEP) – almost 65% of educational institutions offer different versions of Lean Manufacturing training classes. Traditional lectures setting by the instructors preparing their own teaching materials and case studies.

Lean Manufacturing Training with Live Simulation

Simulation refers to a broad collection of methods and applications to mimic the behavior of a real system (Kelton, Sadowski & Sturrock, 2007). Simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time (Maria, 1997).

The simulation is used as a tool for teaching complex lean concepts (McManus, Rebentisch, & Stanke, 2007). The goals for using simulation in the training are:

- Increased comprehension of the curriculum,
- Better understanding of the context and holistic,
- System-spanning nature of the material,
- Learning though experience via use of the simulation as a practical field and increased student involvement and enthusiasm for the material.

There are 17 different simulation games available to help teach Lean Manufacturing (Verma, 2003). Among these the simulation activities developed by NIST, Buzz Electronics, 5S & Set-up Reduction are most commonly used.

Buzz Electronics simulation: The Buzz Electronics simulation exercise is developed by NIST-MEP to train the participants in principles of Lean Manufacturing (Verma, 2003). During this exercise, participants participate in four rounds of simulation each of twenty minutes. This simulation exercise simulates manufacturing of circuit boards. Two types of products (red devil & blue avenger) are manufactured during the simulations. 15-25 participants can take part in each simulation. Various workstations are inspection and rework, four assembly stations, finished goods warehouse, kitting area, shipping area etc.

Computer Simulation

Computer simulation refers to the method of studying a wide variety of models of real world systems by numerical evaluation using software design to imitate the system's operations or characteristics (Kelton et al., 2007). Computer simulation is the designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give us a better understanding of the behavior of that system for a given set of conditions.

The basic idea of simulation is to build an experimental device that will act like the system of interest in certain important aspects in a quick, cost effective manner (Moore & Weatherford, 2001). Simulation models are used to analyze a probabilistic system, that is, a model in which the behavior of one or more factors is not known with certainty. The factor that is not with certainty is thought of as random variable and the behavior of random variable is described by a probability distribution.

Computer simulation is a technology that can be used to model the operational behavior of a system such as manufacturing facility, production process, or service station (Egelenhoven, 2001). Computer simulation is one of the most frequently used system analysis method which offers the following benefits.

- Accounts for complex factors and relationships
- Shows performance changes over time dynamically
- Permits experiments; answers "what if" questions
- Evaluates changes without disrupting the actual system
- Stimulates ideas and promotes total system optimization
- Uses animation for "realistic" representation

- Provides cost-effective ways to develop and evaluate system designs

Simulation has many advantages but it also has some disadvantages (Banks, 1999)

- Simulation models building requires special training
- Simulation results may be difficult to interpret
- Simulation modeling and analysis can be time consuming and expensive
- Simulation may be used inappropriately
- The output is probabilistic which changes with each input

Computer-aided Simulation Training

Information technology is an instrument for training and education, with its ability to (National Science Foundation, 1998):

- Facilitate the accumulation, generation, and presentation of data
- Provide tools for analysis and modeling of more or deeper and more realistic examples in a short time
- Enable enquiry and extend the human capability to visualize, organize, and analyze data
- Provide immediate feedback to the student, either from the technology itself or the facilitator/instructor

Also, National Science Foundation characterized the effective use of IT in education applications. IT stimulates students and engages them with the material, such as role playing simulations, helps to illustrate the workings of complex systems by exploring cause-and-effect relationships, or demonstrate microscopic, molecular, or hypocritical scenarios, and foster development of critical skills, visualization, conceptualization, integration of disparate data, and resolution of patterns within data. This research is to create computer simulation models for Lean Manufacturing training.

Arena Simulation software

Arena simulation software combines the ease of use found in high-level simulators with the flexibility of simulation languages (Kelton et al., 2007). It does this by providing alternative and interchangeable templates of graphical simulation modeling and analysis modules that can combine to build a fairly wide variety of simulation models. For ease of display and organization, modules are typically grouped into panels to compose a template. The modules in Arena are composed of SIMAN components, from that it can be created own module and collect them into own templates for various classes of systems. The Arena simulation software which is used to create computer simulation model of Buzz Electronics simulation has many modules and blocks, modules and blocks used in creation of these models are as follows.

Create module: The create module is birth node for arrival of entities to the model's boundary into the model from outside (Kelton et al., 2007). The key inputs on the create block are entity type, interval time distribution between arrivals, time, unit of time, entities per arrival, maximum arrival and first creation.

ReadWrite module: The ReadWrite module reads one or more values from a source external to Arena and assigns these values to model variable (Kelton et al., 2007). The data can be read from external file or keyboard. The key inputs in this module are type of data source, Arena file name, which is used as model identifier for the file.

Delay module: The Delay module delays an entity by a specified amount of time (Kelton et al., 2007). When an entity arrives at a Delay module, the time delay expression is evaluated and the entity remains in the module for the resulting time period. The key inputs are delay time and its unit.

Separate module: The Separate module can be used to either copy an incoming entity into multiple entities or to split a previously batched entity (Kelton et al., 2007). Rules for allocating costs and times to the duplicate are specified. Rules for attribute assignment to member entities are specified as well.

Decision module: The Decision module allows for decision-making processes in the system (Kelton et al., 2007). It includes options to make decisions based on one or more conditions or based on one or more probabilities. Conditions can be based on attribute values, variable values, the entity type, or an expression.

Assign module: The Assign module is used for assigning new values to variables, entity attributes, entity types, entity pictures, or other system variables (Kelton et al., 2007). Multiple assignments can be made with a single Assign module.

Station module: The Station module defines a station (or a set of stations) corresponding to a physical or logical location where processing occurs (Kelton et al., 2007). If the Station module defines a station set, it is effectively defining multiple processing locations.

Enter module: The Enter module defines a station (or a set of stations) corresponding to a physical or logical location where processing occurs (Kelton et al., 2007). If the Enter module defines a station set, it is effectively defining multiple processing locations. An entity can move from a previous module to an Enter module in one of two ways: by transferring to the station (or a station in the station set) associated with the module or through a graphical connection.

Leave module: The Leave module is used to transfer an entity to a station or module (Kelton et al., 2007). An entity may be transferred in one of two ways: it can be transferred to a module that defines a station by referencing the station and routing, conveying, or transporting to that station or a graphical connection can be used to transfer an entity to another module.

Process module: The Process module represents the main processing method in the simulation (Kelton et al., 2007). The process time is allocated to the entity and may be considered to be value added, non-value added, transfer, wait or other. The report statistics check box allows a choice of output statistics like utilizations, queue lengths, and waiting times in queue.

Record module: The Record module is used to collect statistics in the simulation model (Kelton et al., 2007). Various types of observational statistics are available, including time between exits through the module, entity statistics, general observations, and interval statistics. Tally and Counter sets can also be specified.

Hold module: The Hold module will hold an entity in a queue to either wait for a signal, wait for a specified condition to become true or be held infinitely (Kelton et al., 2007).

Signal module: The Signal module sends a signal value to each Hold module in the model set to wait for signal and releases the maximum specified number of entities (Kelton et al., 2007).

Dispose: The dispose module represents entities leaving the model boundaries (Kelton et al., 2007). The name box allows writing descriptive name of the module. The check box option allows option for the entity statistics like average and maximum time in the system of entities that go out through this module and costing information on these entities.

Input Analyzer: Input analyzer is use to determine the probability distribution of the input data (Kelton et al., 2007). The input analyzer provides the estimates of the parameter value (based on the data supply) and ready-made that can just copy and paste in the model. When input analyzer fits a distribution to the data, it estimates the distribution's parameters and calculates a number of measures of how good the distribution fits the data. This information can be used to select the distribution that is best to the model.

Animation: Simulation animation is intended to provide dynamic graphical insight conditions (Kelton et al., 2007). A variety of plots, graphs, and counters are available to animate specific elements. The primary use of the animation is to show entities, idle and busy resources and material handler. These animations are often useful for validation and verification of the model.

Output: The Output of the Arena simulation is basically in the form of statistics like tally, time-persistent, counter and outputs (Kelton et al., 2007). The tally statistics include several process times, queue times, and the interval times collected by record modules. The time-persistent statistics include number waiting in queue, resource usage, and resource utilization. Counter statistics include accumulated time, number in, number out and total number seized. The output statistics includes statistics analysis of Arena simulation.

Arena uses a hierarchical approach to provide the user with the power of a simulation language and the flexibility of a simulator (Hammann & Markovitch, 1995).

The object-oriented approach that was central to Arena's development, coupled with the hierarchical architecture, enables the professional user to define the personality of the system for the end-user. The Arena simulation software was used to create the four rounds of simulation models.

Chapter III: Methodology

This chapter includes the process of Lean Manufacturing training using Buzz Electronics, videotaping of the four simulation rounds of Buzz Electronics, tracking the process time in each station from video films, determining the process time distribution and validation of models.

Introduction

Buzz Electronics products are used in Lean Manufacturing training. Products used in simulation training are red devil and blue avenger. Red devil products are used in home security system and blue devil products are used in commercial building security system. The components required to manufacture a red devil are one piece spring, 1K resistor, 100K resistor and LED each. Similarly, the components required to manufacture a blue avenger are one piece spring, diode, 1K resister and LED each.

Lean Manufacturing Training Procedure

North West Manufacturing Outreach Center conducts eight hour long Lean Manufacturing training program and recommends the participation of 12 to 20 trainees. The training starts with an introduction and agenda of the training. Trainees are given an orientation on the live simulation and are given employee role without a lecture on Lean Manufacturing concepts. Students are to assume different functions of employees in a mock circuit board assembly job shop – Buzz Electronics – as assembly operators, shipping clerk, scheduler, etc.

Workstations are complemented with a sales office, a scheduling office, a warehouse and a shipping area. The arrangement of the job shop work stations represents a traditional functional layout. The job shop is operated with a traditional batch manufacturing system – the production is pushed by the scheduling or forecasting. The workers are instructed to make as many finished products as possible.

This first round of hands-on simulation of twenty minutes typically yields a little or no shipment but large work-in-process (WIP), poor quality, discouraged workers, and a financial statement in the red. The operation results are then reviewed by the instructor with the trainees. Following, the instructor teaches Lean Manufacturing principles, standardized work, 5S system, visual controls and plant layout in the lecture format. Then the trainees are expected to apply what they just learned in a second round of the live simulation game. Next, even more lean concepts about teams, quick changeover, batch reduction, and quality at the source are presented before third round of live simulation, likewise lecture is presented about pull system, kanban, cellular flow and total productive maintenance before the fourth round of simulation.

Throughout the lecture and simulations, trainees are steered to identify the advantages of Lean Manufacturing as well apply newly acquired Lean Manufacturing knowledge and techniques. The trainee will participate in implementing Lean Manufacturing tools. They will also notice the positive change in the performance matrix such as work-in-process reduction, on-time delivery increase, and profit improvements.

Data collection procedure

Videotaping of the four rounds of live production was the specific work for this research. This training seminar of live production was captured by three video cameras. The production forecast and sales order data were tracked from the simulation rounds. Also, the work-in-process, rejected parts, production outputs, and distance between workstations were tracked. These films were reviewed and the process times of each batch were tracked in each station.

Data Analysis

Utilizing Input Analyzer of Arena simulation software the distribution of process time was determined. Using these process time distributions in Arena simulation software, four simulation models were created. The Arena simulation model outputs were validated by comparing blue and red, parts shipped and orders completed, with the Buzz Electronics simulation output.

Limitations

The videos were captured by placing the three cameras in different places to capture all the workstations and manufacturing processes. These three cameras were insufficient to cover all the activities of Buzz Electronics simulation. Because of this reason, it was difficult to record the exact time for some batches or parts.

Chapter IV: Results

This chapter includes a discussion on the results obtained from Arena simulation and compares them with the physical simulation data of Lean Manufacturing training. This chapter concludes with interpretation of the data.

Data Collection

Video films, captured during the physical simulation, were reviewed and process times were recorded. The process time for blue and red batch or part was recorded in each station. For example, the process times recorded in resistor station for blue batches of third round simulation were 36, 28, 32, 33, 30, 26, 31, 28, 33, 36, 29, 26, 28, 27,34, 31 and 35 seconds. The input analyzer was used to determine the distribution of process times which are shown in Table 1, Table 2, and Table 3.

Table 1

Process time distribution for blue parts of physical simulation

Station	Round 1	Round 2	Round 3
Kit	UNIF(99.5, 146)	TRIA(68.5, 88.5, 11)	0
Spring	UNIF(60.5, 70.5)	UNIF(60.5, 70.5)	UNIF(14.5, 22.5)
Diode	UNIF(145, 198)	UNIF(123, 198)	UNIF(43.5, 56.5)
Resistor	115 + 66 * BETA(0.49, 0.61)	UNIF(72.5, 103)	UNIF(23.5, 37.5)
LED	UNIF(69.5, 88.5)	UNIF(69.5, 88.5)	19.5 + 19 * BETA(1.01, 1.58)
Testing	UNIF(28.5, 52.5)	UNIF(28.5, 52.5)	TRIA(9.5,10.5, 19.5)

Table 2

Process time distribution for red parts of physical simulation

Stations	Round 1	Round 2	Round 3
Kit	UNIF(104, 127)	59.5 + 66 * BETA(1.18, 0.69)	0
Spring	UNIF(34.5, 56.5)	UNIF(34.5, 56.5)	9.5 + 6 * BETA(0.787, 0.97)
Resistor	TRIA(68.5, 77, 94.5)	TRIA(48.5, 51, 74.5)	TRIA(18.5, 21.1, 31.5)
LED	TRIA(56.5, 69, 69.5)	TRIA(56.5, 69, 69.5)	TRIA(14.5, 20, 22.5)
Testing	20.5 + GAMM(19, 0.65)	20.5 + GAMM(19, 0.65)	TRIA(7.5, 10, 12.5)

Table 3

Process time distribution for fourth round of physical simulation

Stations	Blue Part	Red Part
Spring	TRIA(8.5, 10.6, 16.5)	TRIA(8.5, 10.6, 16.5)
Diode	UNIF(4.5, 8.5)	0
1K Resistor	4.5 + 3 * BETA(1.33, 1.33)	4.5 + 3 * BETA(1.33, 1.33)
LED	4.5 + 4 * BETA(0.768, 1.28)	4.5 + 4 * BETA(0.768, 1.28)
100K Resistor	0	TRIA(4.5, 5.14, 7.5)
Test	4.5 + 4 * BETA(1.11, 1.72)	4.5 + 4 * BETA(1.11, 1.72)

Arena Simulation Model

Process time distributions were used to create four rounds of Arena simulation models. Figure 1 is the sales block, Figure 2 is the production order block, Figure 3 is the spring to test block, and Figure 4 is the warehouse block of third round of Arena simulation model. Figure 5 is the animated model of Arena simulation for the third round physical simulation of Lean Manufacturing training. The Arena model for the first, second, and third round of simulations are similar but the fourth round Arena model is different (See Appendix A).

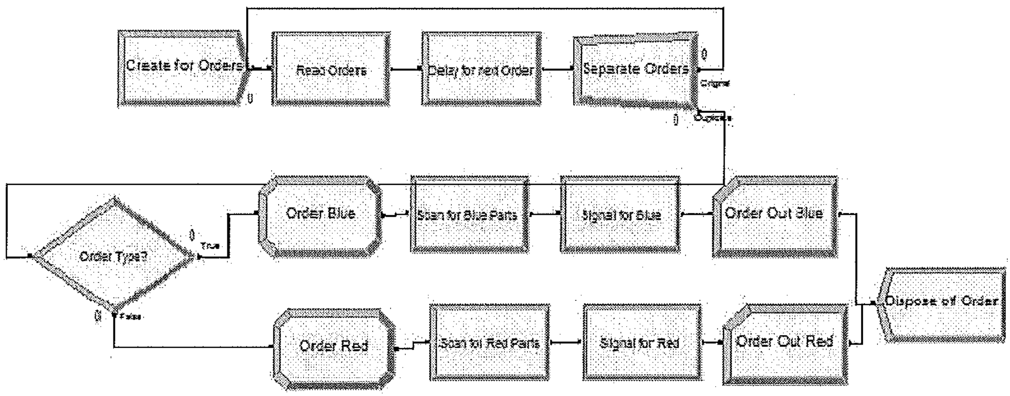

Figure 1. Sales order block

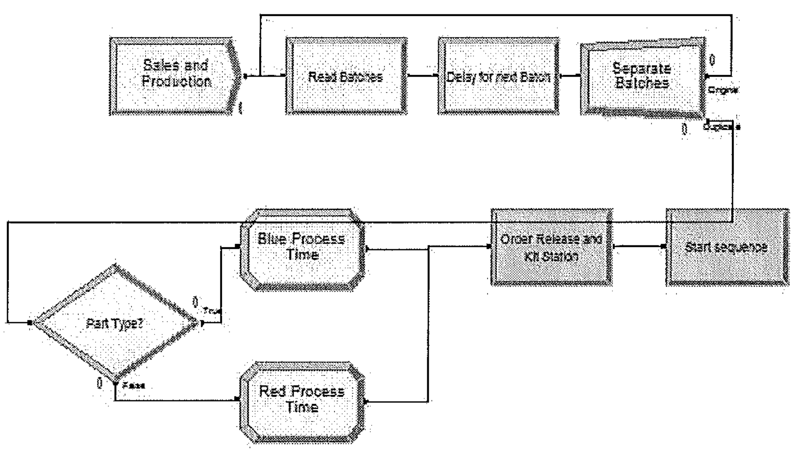

Figure 2. Production order block

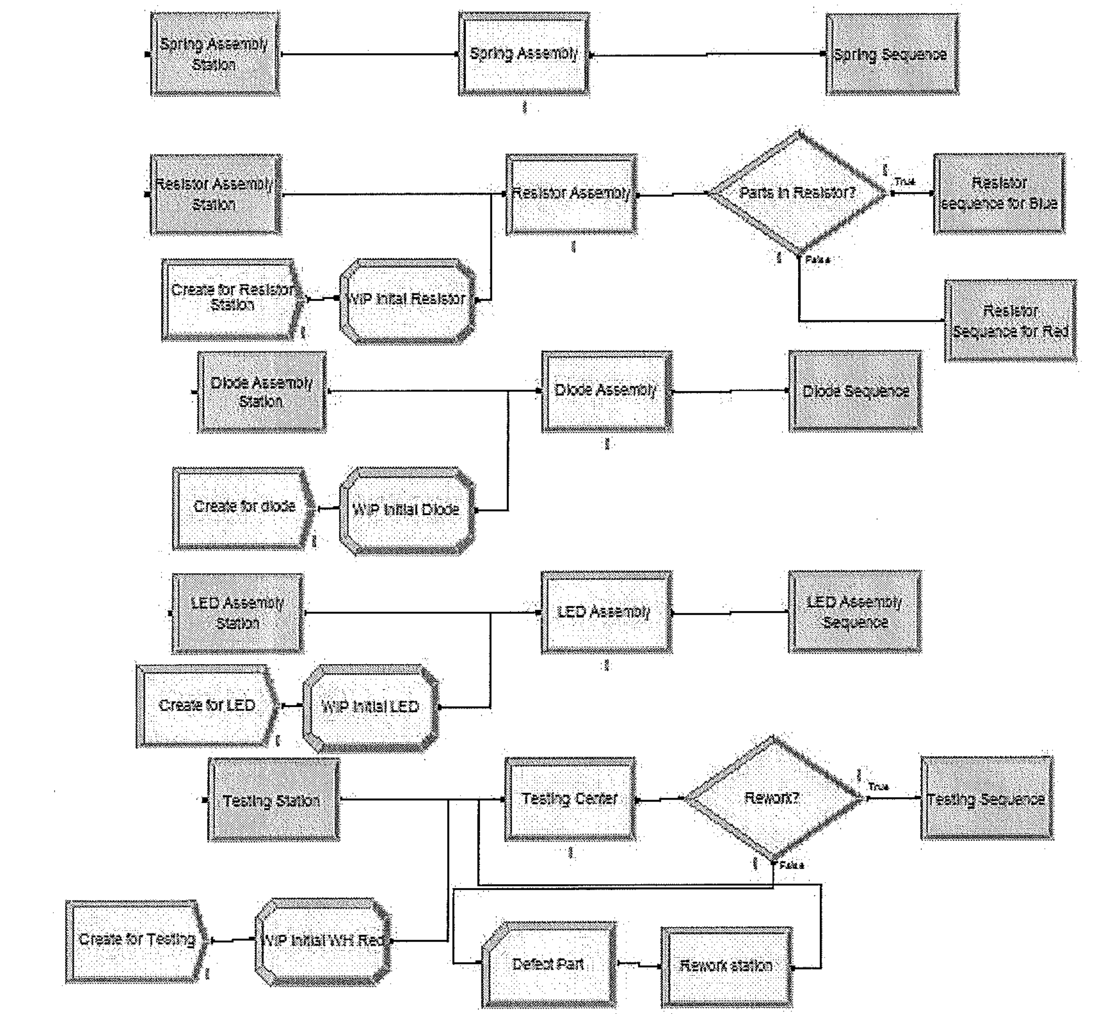

Figure 3. Spring to testing block

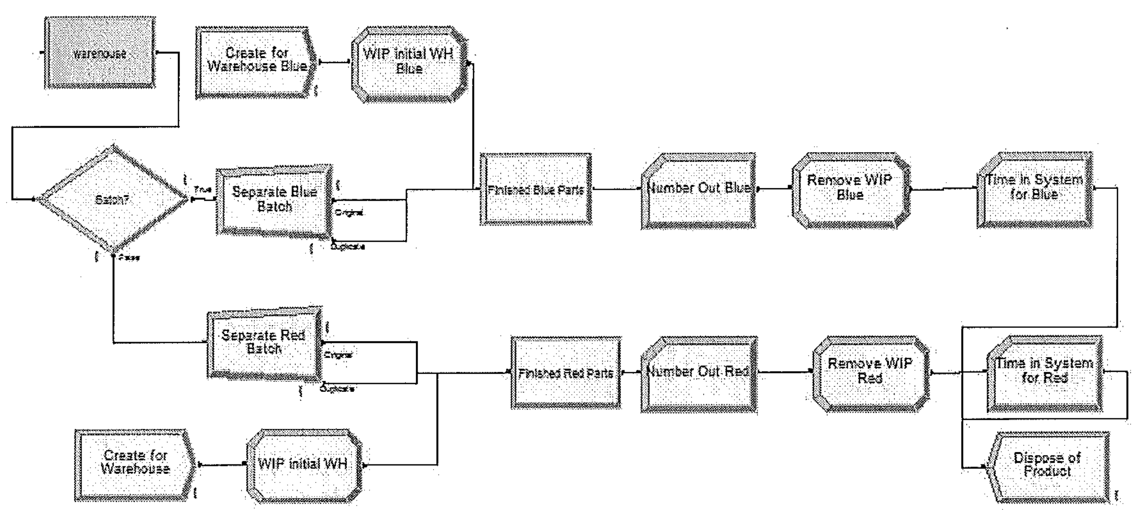

Figure 4. Warehouse block

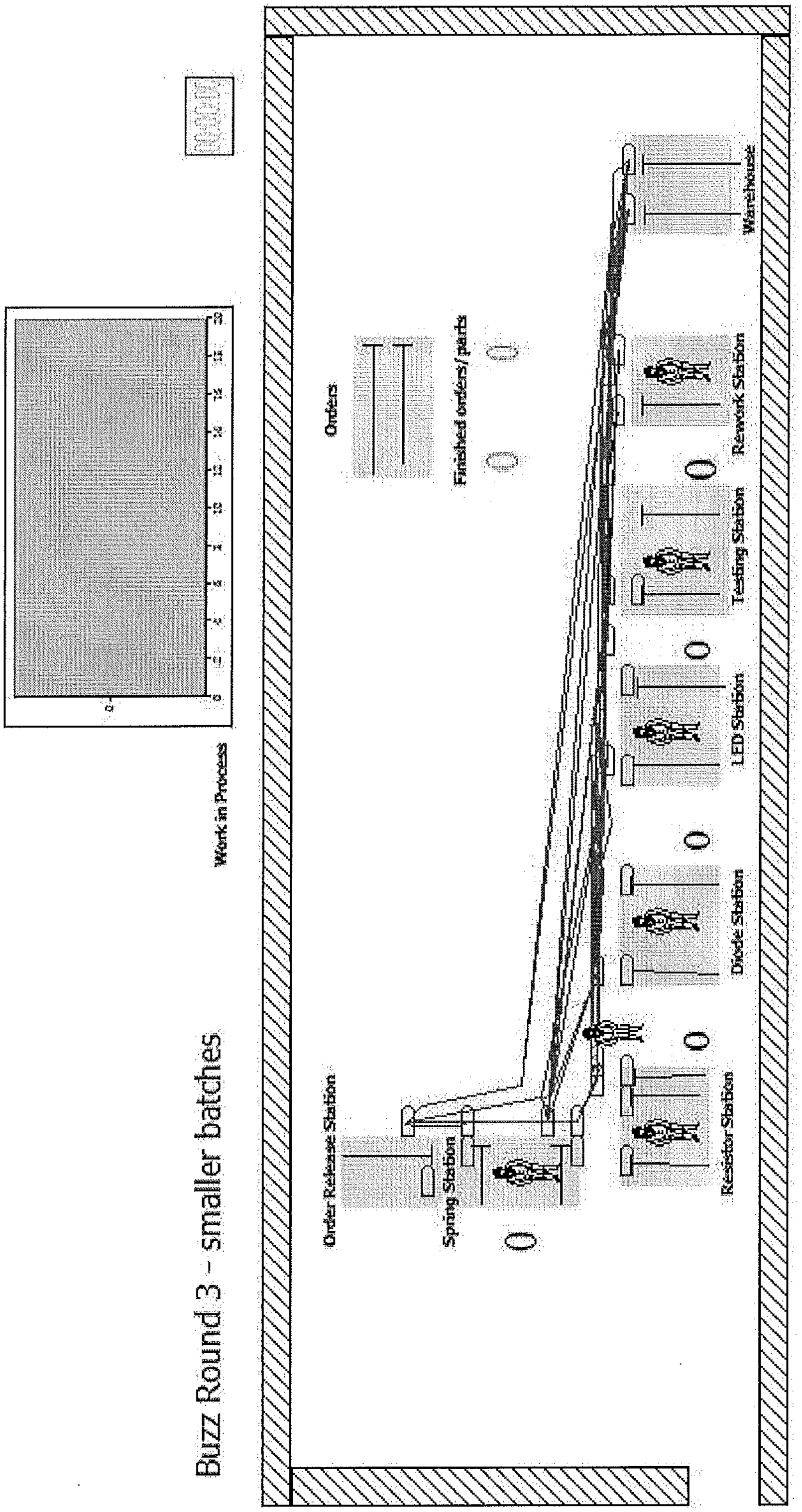

Figure 5. Animated model for third round simulation

The Arena simulation model was created using Create, Readwrite, Delay, Separate, Decision, Assign, Station, Enter, Leave, Process, Record, Signal, Hold and Dispose blocks of simulation software. The functions of these blocks in these models are described as:

Create Block: Create blocks are used to create batches, parts and sales orders.

Readwrite Block: Readwrite blocks are used to read the data for production forecast of batches and sales orders from excel files.

Delay block: Delay blocks are used to maintain production time interval and sales order time interval.

Separate block: Separate blocks are used to duplicate the original batch and order and separate the batch to parts.

Decision block: Decision blocks are used to separate red and blue parts; also it is used to separate defect and defect free parts.

Assign block: Assign blocks are used to assign process times, start time, initialize the WIP and remove WIP.

Station block: Station block is used to locate and route the part.

Enter block: Enter blocks are used to locate and route the part. Also, these are used to release the material handler.

Leave block: Leave blocks are used to pick up the parts by material handler and route the part to next station.

Process block: Process blocks are used to process the parts in respective station.

Record block: Record blocks are used to record the time in system and number of parts and orders.

Signal block: Signal blocks are used to generate the signal to release the parts from Hold block for shipment of parts and kanbans.

Hold block: Hold blocks are used to hold the parts or orders until the condition doesn't satisfy.

Dispose block: Dispose blocks are used to dispose the parts or orders when the parts are shipped and orders are completed.

Output Analysis

The red and blue, orders completed and parts shipped of Arena simulation was compared with physical simulation. Figure 6 shows the comparison of outputs from first round of simulation, Figure 7 shows the comparison of outputs from second round of simulation, Figure 8 shows the comparison of outputs from third round of simulation, and Figure 9 shows the comparison of outputs from fourth round of simulation.

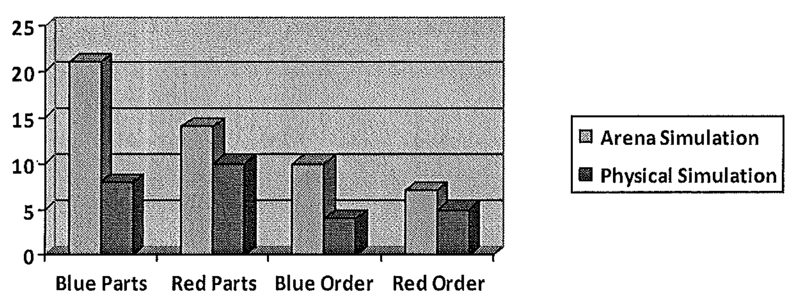

Figure 6. Output for first round of simulation

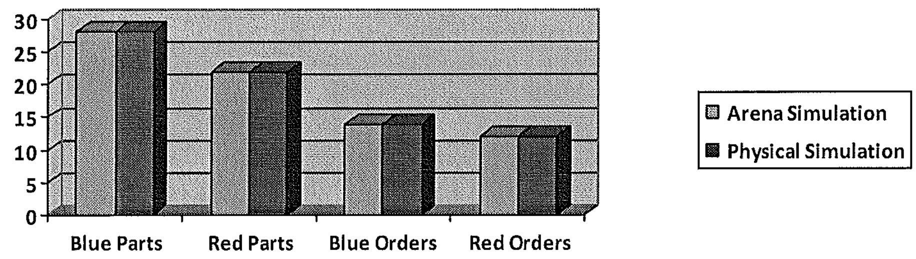

Figure 7. Output for second round of simulation

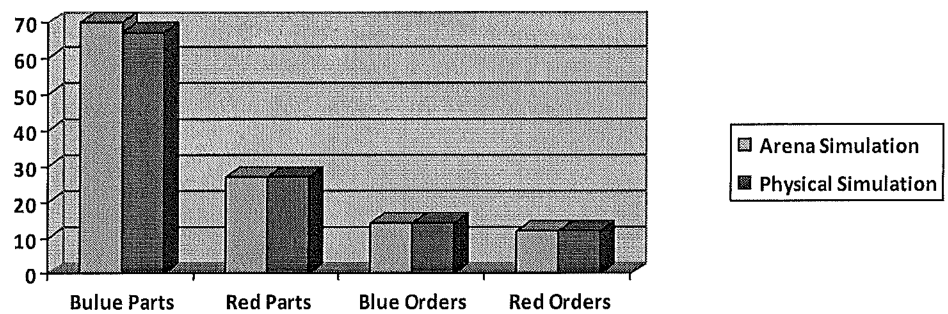

Figure 8. Output for third round of simulation

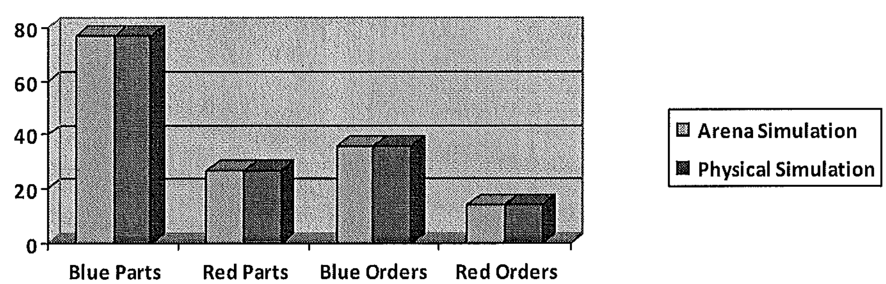

Figure 9. Output for fourth round of simulation.

The first, second and the third rounds of physical simulations were run for 20 minutes, but the fourth round of simulation was run for only 5 minutes. The outputs of the fourth round of physical simulation were based on an estimation of 20 minutes.

The Arena simulation models for the first three rounds were created exactly the same as the physical simulation, but the fourth model was not. In the fourth round of physical simulation, there were two assembly lines up to testing station and one station for rework and warehouse each. But in Arena simulation model, the single assembly line was created because the Arena software used to develop this model was a training version that limited the use of number of blocks. The outputs of this model were from single assembly line.

The parts shipped and orders completed outputs of the Arena simulation and physical simulation model, were compared to validate the models. The outputs of the second, third, and fourth rounds of simulation were similar, but the outputs of first round of simulation were slightly different.

The outputs of the first round Arena simulation model are different, because participants in this round were learning to assemble the circuit board. They spent more time in some batches and used to be idle after finishing a batch to learn more about components and process of the circuit board assembly. The outlier process time and the idle time were not considered to determine the process time distributions, which were the major input for Arena simulation models. This was the main reason for more parts output in Arena simulation model than in physical simulation. Another reason for variation in the output of the model is due to the random process distribution time. These models are good and valid because the results are close with the physical simulations.

The other outputs from the Arena simulation models are shown in Table 4. These outputs are time in system, average waiting time for parts, average and maximum work-in-process, bottlenecks of the stations, average and maximum open orders, and average and maximum lateness. It is impossible to collect this information from the physical simulations.

Table 4

Other useful output from Arena simulation models

Arena Simulation Output	Simulation Rounds			
	1	2	3	4
Time in system-blue parts (in minutes)	13.0	11.9	5.2	2.4
Time in system- red parts (in minutes)	5.8	8.2	3.4	4.9
Average waiting time-parts (in minutes)	10.4	8.3	3.0	3.0
Average work-in-process (parts)	68.5	64.3	30.9	20.3
Maximum work-in-process (parts)	114	102	46	25
Bottlenecks				
Handler	97.2%	95.6%	98.3%	-
Diode	83.2%	88.5%	96.6%	-
Spring	-	-	-	97%
Average number open orders	17.7	15.7	3.0	1
Maximum number open order	34	28	5	2
Average lateness orders(minutes)	6.3	6.4	0.8	0.0
Maximum lateness (minutes)	14.2	11.6	3.0	0.0

The utilization of the handler was 97.2%, 95.6% and 98.3% for the first, second, and the third rounds of simulation respectively. The bottle neck for the first, second, and the third rounds of simulation was diode and the utilization was 83.2%, 88.5% and 96.6% respectively. Also, bottle neck for the fourth round was spring and utilization was 97.0%.

Chapter V: Discussion

Buzz Electronics simulation is the part of Lean Manufacturing training. In this training the participants are given employee role of an employee to work in assembly stations, testing, warehouse and scheduling. There are four rounds of simulation and each runs for 20 minutes.

The Arena simulation model provides visual information about the Buzz Electronics simulation. This simulation model shows floor layouts, assembly stations, testing, warehouse, and scheduler of the simulation in visual form. This model shows each and every process of physical simulation from production forecast to shipping. Also, the flow of parts in the whole manufacturing process and work done can watch in this model. The model gives information about the time it takes to complete one batch or part, number of batches or parts completed in each station, total parts shipped and orders completed. Also, it gives the information on which stations are bottlenecks. This data is helpful for the trainee to get more knowledge about the manufacturing process and the concept of Lean Manufacturing.

During the Lean Manufacturing training, the Arena simulation model provides visual information of Buzz Electronics simulation to the trainee, from this visual information, the trainees are able to see the whole simulation process that helps them to better understand it. In Arena simulation model, trainees can see the entire manufacturing system and know how the work is done in other stations. They gain the knowledge of other stations where they did not work. Similarly, pupils can see the other various data (e.g bottleneck station, handler utilization, time in the system, number of late orders etc.)

from the Arena simulation models, which help them to analyze the process and brainstorm for the process improvement.

The objective of the training is to gain specific knowledge, skills, or attitude that result from the training activity. NWMOC conducts the 8 hour long Lean Manufacturing training. The method of training is class room lecture about Lean Manufacturing elements, Buzz Electronics simulation and simulation review session. During the review session of simulation, the trainer discusses about the data collected from a simulation round which is insufficient to achieve the training objective. To achieve the goal of the training, set by the trainer and the company, NWMOC can add the Arena simulation model in review sessions.

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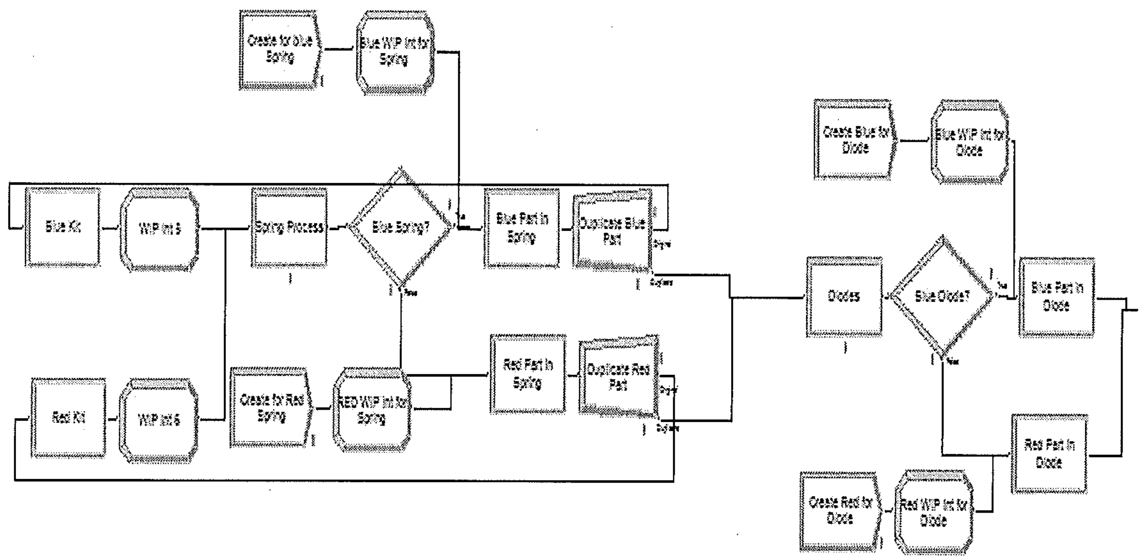
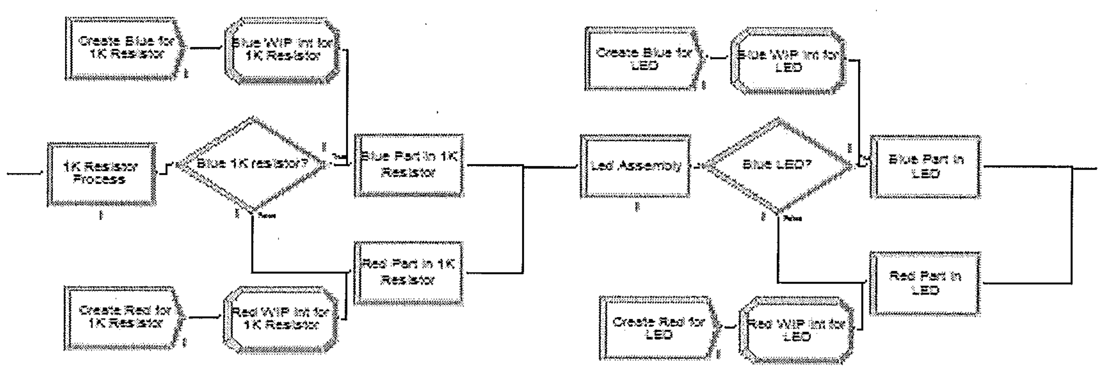
Appendix A

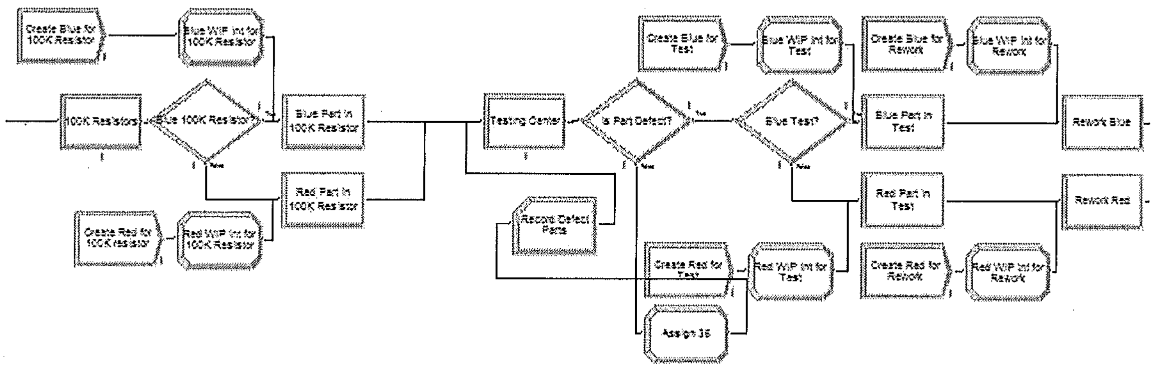
Fourth round of Arena simulation model



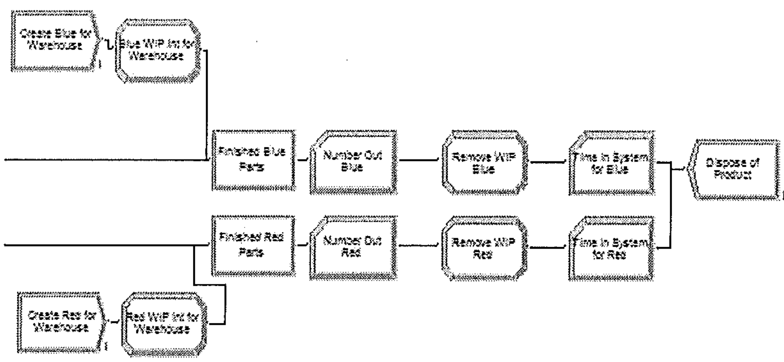
Spring and diode block



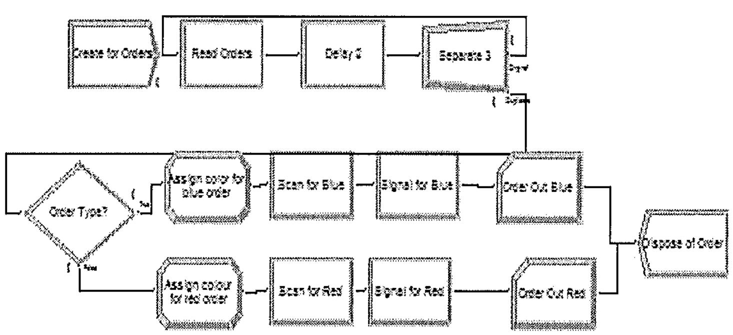
1K resistor and LED block



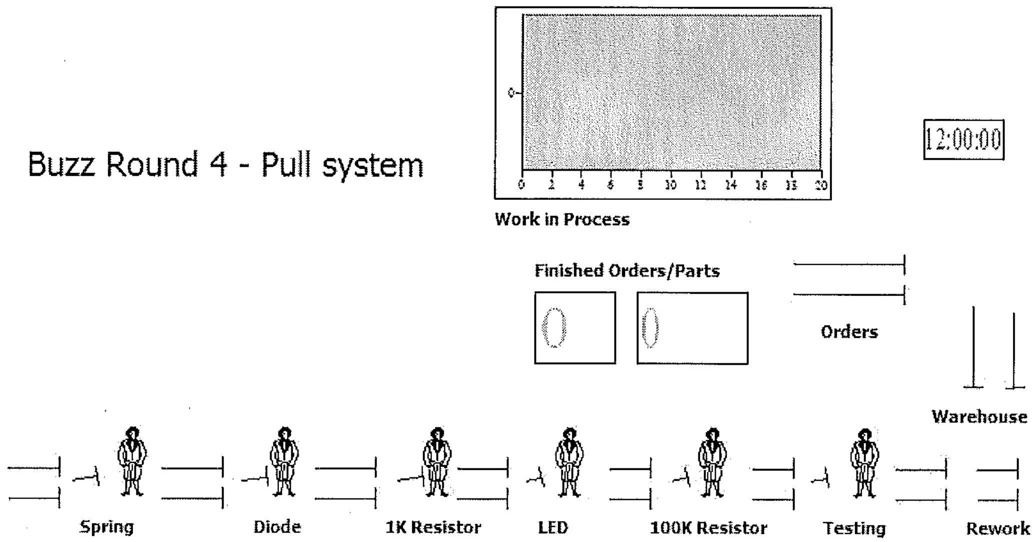
100K resistor to rework block



Warehouse block



Sales order block



Animation for fourth round simulation