Simulation Tools and Training Programs in Lean Manufacturing – Current Status

Final Report

Submitted to NSRP-ASE Program

Deliverable for Phase-0
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By

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On behalf of the
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Table of Contents

1. Executive Summary

This report presents the current state of Lean training programs and their use in shipbuilding/repair industry. This information has been presented in a spreadsheet (Appendix-d) for three types of organizations, shipyards, consulting firms and educational institutions. The report also looks at simulation tools currently used, and presents a case for the need of new simulation tools for Lean enterprise implementation. Five areas specifically related to shipbuilding and repair industry are identified based upon the feedback from Lean training coordinators and managers from shipyards.

The response rate for the first survey was 56%. Results indicate that majority of organizations use Lean training programs developed by NIST. These training programs cover a variety of Lean principles like 5S, setup reduction, value stream mapping and are usually one day long. A few of these training programs include simulation activities.

In addition to the above programs developed by NIST, several universities have developed their own Lean training programs. These range in length from one day to five days. They cover a wide variety of topics including management techniques, six sigma and supply chain management. A few universities offer certificate programs in Lean manufacturing ranging in length from 5 to 10 days.

Consulting firms use a variety of training programs including variations of those developed by NIST and some programs that were developed in-house. In addition to in-class training, some consulting firms offer in-plant Lean implementation along with training. Most of the in-class training programs are one day long. Those involving in-plant implementation can range in length from 2 to 25 days.

Our survey has identified a total of 17 simulation activities currently used in various Lean training programs. Among these the simulation activities developed by NIST (Buzz Electronics, 5S & Set-up Reduction) are most commonly used. The matrix in Appendix-e shows the use of these tools by various organizations and the Lean principles they illustrate. A majority of these simulation activities simulate production operations within an organization as indicated in Figure-1.

None of these simulation activities are designed to address issues related to Lean enterprise implementation like ship design, ship repair, contracting and acquisition, scheduling and enterprise resource planning. The lean enterprise value simulation and Beer game developed at MIT are the only activities that even try to tackle the issue of supply chain integration. In addition, all the simulation activities available are designed for the high-volume and low-variety manufacturing environment. Results of the survey establish the need for simulation activities to complement the effort of shipyards in becoming Lean enterprises. The topics identified for simulation development cover wider issues and will provide realistic training tools. Figure-2 shows the issues covered by the proposed simulation activities. The proposed tools will also complement the Extended Lean Enterprise project funded by NSRP this year.

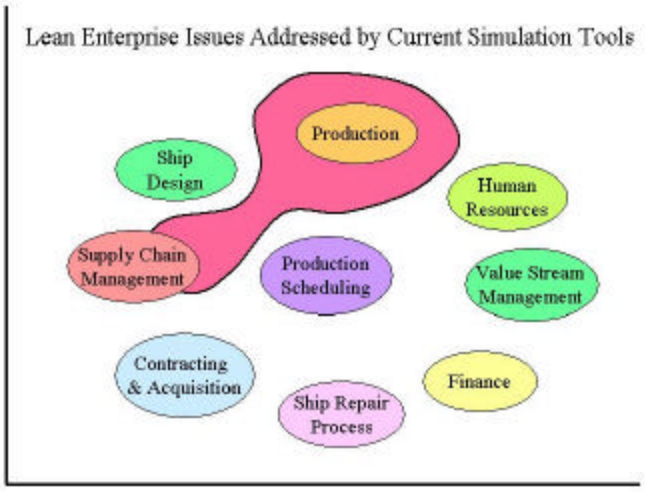


Figure 1. Areas Addressed by Current Simulation Tools

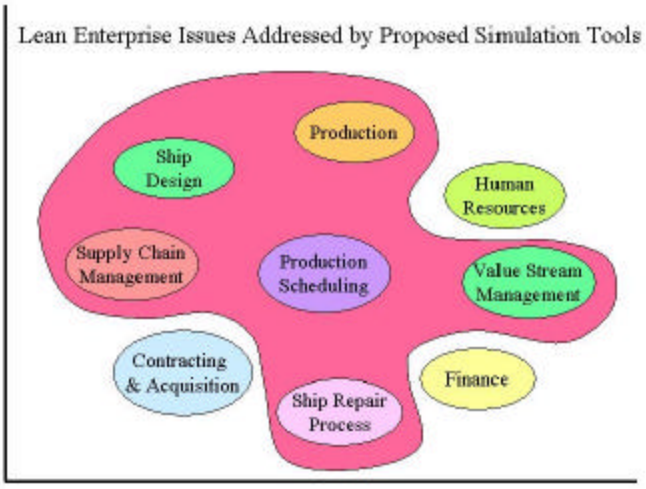


Figure 2. Areas Addressed by Proposed Simulation Tools

2. Introduction

LEAN is a philosophy adopted by manufacturers all around the world to reduce waste and improve productivity. It focuses on changing the work culture within an organization and across the supply chain. Lean philosophy's impressive performance in reducing costs of production is at the heart of the growing challenges faced by the US shipbuilding and repair industry. Today, transforming into a Lean enterprise is the ultimate goal of many shipyards.

Simulation is an effective teaching tool that makes complex concepts easy to grasp. This is mainly due to the active participation of the people involved in a workplace environment that simulates variability. According to the Encyclopedia of Educational Technology, "Simulation-based learning involves the placement of a student into a realistic scenario or situation. The student is then responsible for any changes that occur as a result of their decisions."

Though simulations are effective, the simulation models which are used currently, lack some key elements such as,

- Emphasis is laid on manufacturing operations only. Supply chain and business operations are often ignored, both of which are critical factors in the success of an enterprise. A failure or delay in either of these areas can cause reduced productivity and increased waste.

- Lack of real shipyard applications. The results of the survey indicate that most of the existing simulation tools include applications from electronics and manufacturing industries. The proposed simulation activities will be based on applications pertinent to the shipbuilding industry.

- Limited design and scope of simulation exercises. Most simulations are based on large volume discrete event manufacturing where products are manufactured as they move through the system. They do not apply to the low volume /high variety manufacturing environments found in a shipyard, where the products remain stationary and parts and services are delivered to the site. Low volume /high variety will be addressed in the proposed simulation activities.

The simulation activities developed under this project will utilize Lean tools to teach and demonstrate the effectiveness of Lean principles along a Value Stream. Simulation activities will incorporate the animation feature of discrete event simulation software like Pro-Model, to demonstrate the effectiveness of lean principles. The simulation activities will address supply chain, business operations, real shipyard applications, stationary manufacturing and low volume /high variety.

This report first examines the existing Lean simulations found in the industry and their applications. It includes the results of extensive survey of shipyards and identification of five critical areas that require simulation development. After an extensive survey of the shipyards, educational institutions and consulting firms, five critical areas are selected and presented.

3. Background Information

Old Dominion University and Northrop Grumman Newport News jointly submitted a proposal under the NSRP-ASE program in May 2003 to develop second-generation simulation tools to complement existing lean training programs used by the shipbuilding and repair industry. As a condition of full award for this project proposed under NSRP Research Announcement 3, the Executive Control Board (ECB) directed the project team to perform a Phase 0 within 60 days to "conduct a survey of existing Lean shipbuilding/ship repair training programs and simulation tools to determine the extent to which they overlap or complement those in this project. The survey shall include, but is not necessarily limited to: investigation of lean training and simulations developed and/or conducted under the ongoing NSRP Lean Enterprise Model project; investigation of lean training and/or simulations developed under the ONR project involving Northrop Grumman Ship Systems; and consultation with members of the NSRP Lean Implementers Group. The Executive Control Board of the NSRP will review the Phase 0

results and their approval will be required prior to commencement of Phase 1, which will include the remainder of the proposed work."

This report is the deliverable for Phase-0 as directed above by ECB.

4. Goal of the Study

Based upon the recommendations of ECB, the project has four primary goals as described below:

- Survey of the existing Lean Training Programs.
- Study of existing Lean Simulation Tools used in Lean Training Programs
- Identification of needs in shipbuilding and repair industry.
- Identification of five areas in which simulation tools and associated training programs will be developed during subsequent phases.

After the analysis of the existing lean training programs and simulation tools which are used in various shipbuilding/ship repair companies, consulting agencies, and universities, it was found that simulation models that are used in today's Lean training programs do not address the issues related to a Lean Enterprise. Most of these exercises focus on manufacturing operations only and ignore the Supply chain and business operations. This project focuses on incorporating these important elements into training programs. The second area of concern with existing training programs is lack of real shipyard application in simulation models currently avialiable. The third area of concern deals with Design and scope of simulation exercises. Shipbuilding and repair industry represents a low volume/high variety-manufacturing environment; these two characteristics require that simulation exercises that we propose to develop represent the flow of the entity and the variety of components moving through the system. By identifying the needs of shipbuilding/repair industry, we will identify five areas, which are critical for the development of simulation exercises and associated training programs.

5. Survey Methodology

Figure-3 represents the methodology of the survey. Initially an Internet search of various Lean training program used in the industry (ship building/ship repair), consulting agencies and universities was conducted. A survey form (Form-I, Appendix-a) was prepared to collect data regarding the Lean training programs and was e-mailed to the identified organizations. Follow-up phone calls to the survey recipients were made and their responses were compiled in a spreadsheet (Appendix-d). A second survey form (Form-II, Appendix-b) was prepared to collect detailed information about types of simulation tools available and their usage. Results of this survey are compiled in the form of a table in Appendix-e. A third survey form (Form-III, Appendix-c) was prepared to identify five critical areas in shipbuilding industry for the development of simulation tools. This form was sent to Lean training coordinators and managers in shipbuilding and ship repair industries with eleven possible areas. Based upon the responses received, top five areas were selected for the development of simulation activities and associated

training programs. Figure-3 below illustrates the sequence of activities within survey methodology.

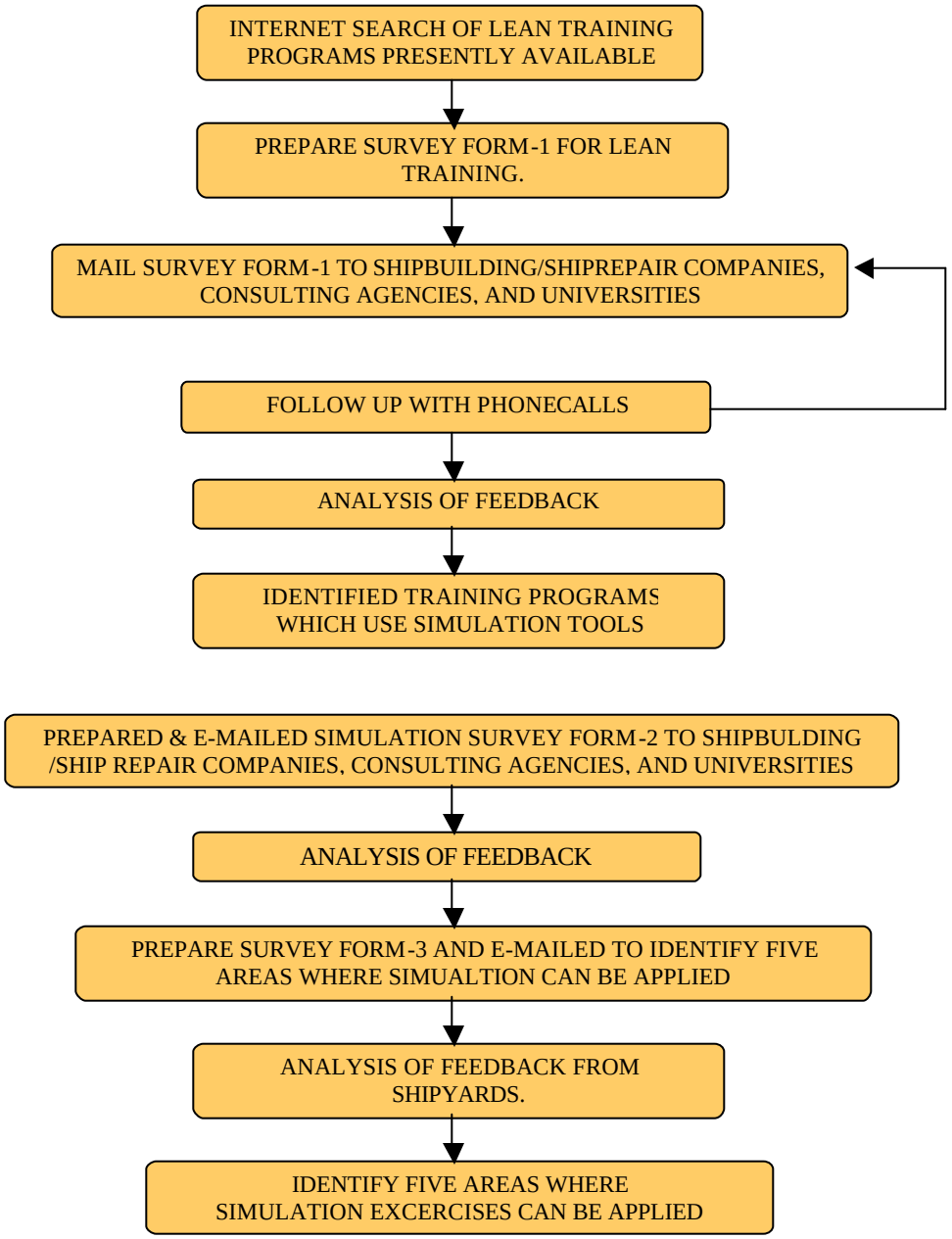


Figure 3. Survey Methodology Process Flow

6. Organizations Surveyed

Forty-eight consulting firms were contacted and asked to complete survey forms giving details about their Lean training programs and simulations. Twenty-five have responded to date. Those to be contacted were identified in a number of ways. A list of Lean consultants was provided by the Lean Training Administer at Northrop Grumman Shipyard and others were identified through a search on the internet and through market research and referrals to learn about training companies and providers of Lean training that were thought to offer simulations. Surveys were emailed if contact information was available and inquiries were sent to request contact information if none was provided. Follow up calls were made to gather necessary information about Lean simulation tools that currently exist and to learn of other known lean providers. Twelve members of the Lean Implementers Group representing U.S. shipyards were also contacted because they use or have created Lean training of some type. Follow up calls were made to ensure that the information was sent to the appropriate contact and to request that it be completed and submitted. Six have responded by submitting completed survey forms.

Out of the 22 Educational Institutions surveyed 17 are part of the Lean Aerospace Initiative (LAI) Educational Network Program, the remaining 5 namely Northwest Arkansas Community College (NWACC), Red River College, North Carolina State University (NCSU), Pueblo Community College and Auburn University were found through internet search for Lean Training Programs offered by Educational Institutions. Survey forms were sent to these 22 Educational Institutions, asking them for details regarding courses taught in Lean Manufacturing, Simulation activities used for training/courses, need for any specific simulation tools for training that they think is need of the hour. Till date 10 Educational Institutions have responded.

7. Lean Training Programs Currently Available

a. Lean Training Programs Currently Available to Industry

Research revealed that some Lean training programs conducted by consultants consist mainly of traditional classroom lecture to teach Lean concepts which are applied to case studies or to actual shop or office floor process improvement efforts. They often offer on-site "hands on" training to teach participants how to apply Lean techniques for achieving quick changeovers, eliminating wastes, 5S, cell manufacturing, and improving flow and visual controls to their own processes. There are also numerous courses available on CD's for workforce training. Videos, books, and manuals can be purchased and are often used to teach Lean concepts. Some consultants use computer applications to teach and support process improvement efforts. The consultants who incorporate live simulation exercises into their training programs use them to demonstrate pull versus push systems, cellular manufacturing, value stream mapping, set-up reduction, 5S and continuous improvement.

For the purpose of this study, the term "simulation" will refer to live simulation activities in which students participate in role plays in environments that simulate actual manufacturing processes. The term will not be used to refer to computer-based simulations, which involve engineers writing equations, and using computers to numerically solve those equations, unless the term "computer simulation" is used.

In the shipbuilding industry, most Naval Shipyards use the same training materials including the 5-week Lean Sigma College and Lean Workshops. Other shipbuilders use Buzz Electronics, a lego exercise, or a paper airplane game.

b. Lean Training Programs Currently Offered by Educational Institutions

There are many training programs/courses currently available through Educational Institutions in Lean Manufacturing, many of which are provided in collaboration with MEP.

Around 22 Educational Institutions were surveyed and it was found that almost 65% of them give training in Lean 101/Lean Manufacturing Overview. This program helps one learn how lean improves quality, reduces cycle time, improves delivery performance and reduces WIP.

47% of the Educational Institutions provide training in Value Stream Mapping, in which flow of product is mapped and work process streamlined, from the results, which helps in cutting lead-time and operating cost. 53% of the Educational Institutions have training programs/courses in 5S wherein participants are taught how implementing 5S helps in improving workplace organization and standardization. 35% of the universities also provide training in Setup Reduction, which is based on the principle of Single Minute Exchange of Dies (SMED) to dramatically reduce or eliminate changeover time. 24% of the universities provide training programs/course in TPM, Pull/ Kanban and Kaizen. There are few universities, which also provide training in supplier chain management and integration and mistake proofing.

8. Simulation Tools Currently Used

Survey results indicate that for the consultants who have responded, over half of them use a factory simulation using a type of plastic cube (legos or something similar), to represent assembling a product on a factory floor and moving it from one station to the next. Four companies developed simulations that simulate manufacturing processes using larger equipment. One involves processing golf balls, one boxes, one a metal stamping machine, and one a printing press. Some consultants use a variation of the Beer Game developed at MIT, and some use TimeWise 101 and 102 in their training.

In the shipbuilding industry, results show that Lean training simulations consist of variations of MEP exercises, Six Sigma programs, NIST-MEP 5 S training, the clock exercise developed by TimeWise, or Buzz Electronics with a circuit board. With the exception of the paper airplane game the simulations were not developed in-house.

Most of the consultants contacted that offer training and live simulation tools have developed them for mass production and build-to-stock or build-to-order in manufacturing environments rather than for situations with low volume, high mix in an engineer-to-order environment like shipbuilding and repair. Three consultants, who have extensive training experience in shipbuilding and aerospace industries, acknowledged that they have unsuccessfully looked for years for applicable simulations, and that they do not currently exist to replicate the unique set of challenges that shipbuilders face. One explained that he tried to create a simulation of a small factory

with a large mix of products and random orders, but that it became too complicated and was abandoned. Some consultants use a variation of one of the factory simulations currently on the market to teach basic Lean techniques, but none are specifically designed to be used in the shipbuilding industry.

Most of the Educational Institutions surveyed are part of the Lean Aerospace Initiative (LAI) Educational Network program. Survey forms were sent to more than 20 Educational Institutions, asking them for details regarding courses taught in Lean Manufacturing, Simulation activities used for training/courses and need for any specific simulation tools for training. Emails were sent in the third week of September. The initial emails were followed by follow-up phone calls. To date 10 Educational Institutions have responded.

Most of the universities contacted use training and simulation tools developed by NIST-MEP, which simulates high volume/ low variety manufacturing environment. Very few universities have developed their own simulation tools but they too simulate high volume/ low variety manufacturing environment. Few of the contacted universities do not use any simulations for training while few universities use discrete event computer simulations.

One university acknowledged that they require simulation tools that uses software for training value stream mapping while another university needs simulation tools that can be used for training lean concepts such as one piece flow, cellular layout, supply chain and lean enterprise.

9. Description of Simulation Tools

TimeWise Simulation:

The TimeWise Simulation game is designed by MEP-MSI (Manufacturing Extension Partnership, Management Services, Inc.) a private, nonprofit management consulting organization for small and medium sized enterprises. In the TimeWise simulation, participants work as a group to run TimeWise, which assembles two products – a blue clock and a black clock.

In this simulation supplier supplies the raw material to warehouse. From warehouse (kitting area) material handlers supply the material to various workstations. There are five workstations as Face assembly, back assembly, clock assembly, hand assembly, clock assembly, and inspection and rework. Flow of material and is shown in figure-4. In addition to those who are directly involved in assembling clocks, TimeWise employs a number of support personnel – in positions ranging from the supervisor to warehouse clerks.

There are three sessions of simulation in first round of TimeWIse; later rounds will explore the impact of redesigns on the company and process. Each session of simulation is followed by a discussion. For each session of play, participants will assume a different responsibility within the company. By playing different roles, participants will be able to observe the process from different perspectives and obtain new insight as to how the process might be improved.

MEPMSI offers following Lean Training Programs using Time clock simulation ,
Time Wise™ -- Lean 101 Principles of Lean Manufacturing
Time Wise™ -- Lean 101 Executive Overview
Time Wise™ -- Principles of Lean Manufacturing for Job Shops
Time Wise™ -- Lean Fundamentals for Shipyards.
Time Wise™ -- Principles of Lean Manufacturing for Front Office Applications

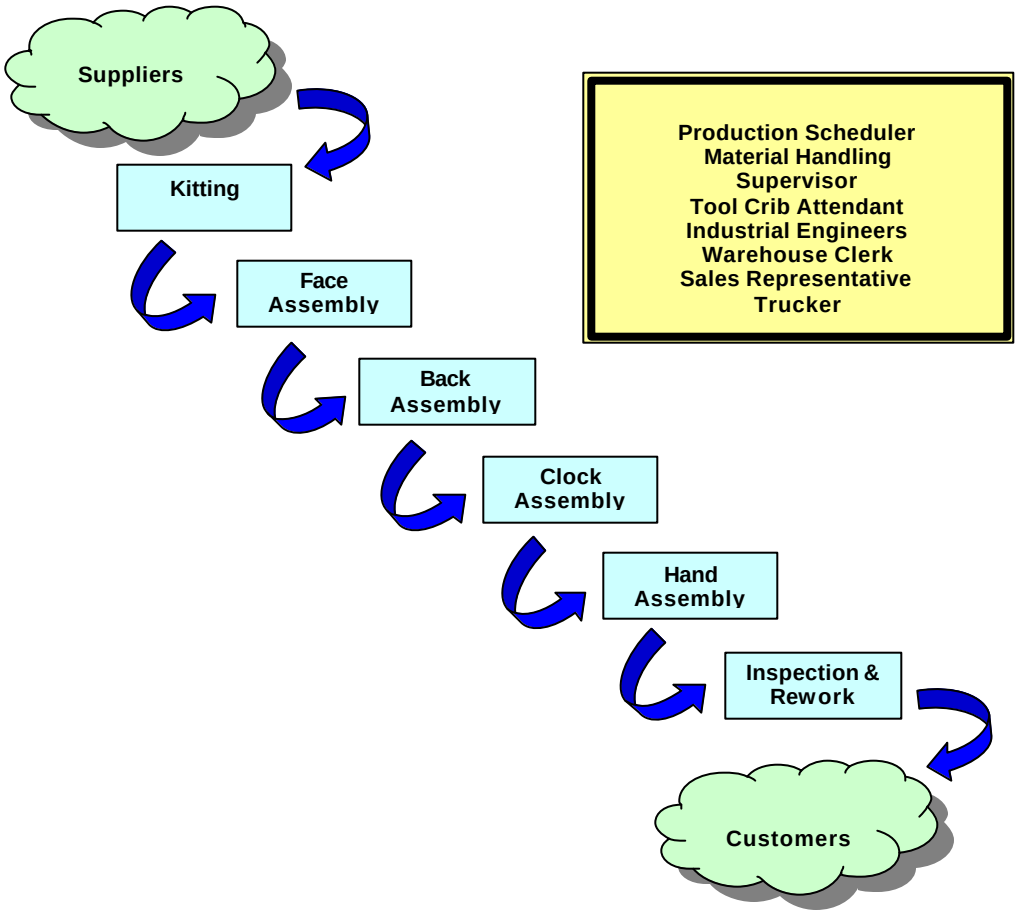


Figure 4. Flowchart for TimeWise Simulation

Pipe Factory Simulation:

University of Dayton has developed this simulation exercise for Kaizen training. In this simulation exercise participants work in teams to learn kaizen concepts.
During the first half of the training program participants take part in five simulation exercises and in the second half they learn the mechanics of simulations from the first half.

In this simulation four pipe sub assemblies (A,B,C,D) are assembled together. In all there are six workstations: one each for four sub assemblies, one for final assembly & one for inspection & repair. The First simulation is a traditional factory simulation. During Simulation 1, participants will perform subassembly operations in the "isolated islands" of traditional manufacturing environment and observe all its inherent wastes. The second simulation simulates push production. The third simulation is again a

simulation of push production but in this simulation time observations and kaizen forms are included. The fourth simulation simulates one-piece flow. The fifth simulation is optional one and it is further refinement of one-piece flow. In simulations 2,3,4,5 lean tools are applied progressively to eliminate the waste.

A performance matrix is used for work-in-progress inventory (WIP), number of parts rejected, production output, cycle time, number of operators required, floor space, and parts travel distance. Teams also apply a financial model to calculate profit and loss for each simulation.

Lean Sim Machine:

The Donnelly Corporation developed this simulation. The Lean Sim Machine is a hands-on simulation that is used to introduce core principles related to lean manufacturing and continuous improvement. The Lean Sim Machine simulates the dynamics of a factory that produces automotive components. Production processes simulated include injection molding, heat-treating, painting, assembling, conveying, and customer order fulfillment. The product variations requested from customers require die-changes.

In the Lean Sim Machine simulation, participants become employees of a company "Traditional Manufacturing Company" for the duration of the simulation. The company makes "metal linkages" for the automotive industry. The metal linkage consists of five components – 2 bolts, 2 nuts, and one flat bar. Three types of linkages - silver, black and gold are produced by the company. Figure-5 shows all three machines used in the simulation. The set up includes:
Manufacturing plant:
Nut manufacturing (simulates injection molding)
Paint Curing (includes conveyor belt)
Bolt hardening (simulates heat treatment)
Final assembly (simulates piecework assembly)
Distribution Center:
Warehouse inventory and finished goods ships products to customers.

There are 5 operators and one material handler. Remaining participants are observers. Duration of each simulation activity is five minutes. The first round is a traditional manufacturing simulation. Different lean concepts are applied in the following rounds.

The performance metrics used are quality issues, WIP inventory, and effectiveness of labor and space utilization. The equipments used for simulation are:
3 Finely-crafted oak machines that simulate typical manufacturing processes:
• a paint line (includes paint racks, paint booth, conveyor system and ramps)
• an injection molding machine (complete with 3 dies to simulate die changes)
• a heat-treating machine
• pallets, finished good racks, nuts,
bolts, linkages
• heavy-duty locking storage box

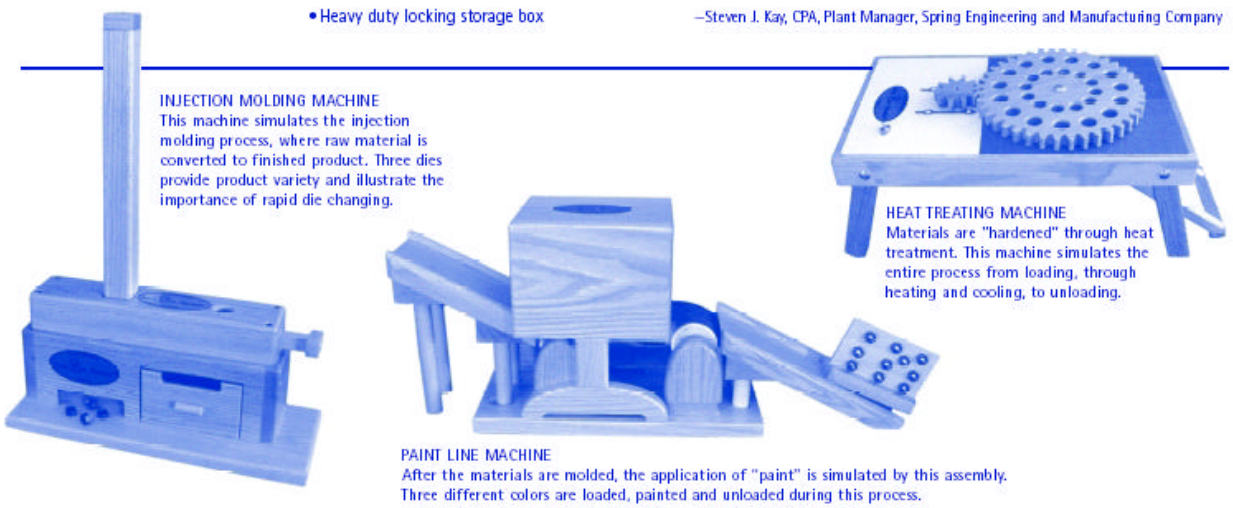


Figure 5. Models Used in Lean Sim Machine Simulation

Lean Enterprise Value Simulation Game (Aircraft Simulation):

Lean Aerospace Initiative has developed this simulation exercise. This is a simulation of a complex aerospace enterprise. Tables of 4-6 people represent major silos as manufacturing, supplier network, and product development. Each person has his own facility (manufacturing plant or individual 1st or 2nd tier supplier or product development function.) The simulation uses Legos to build aircraft. The manufacturing table is shown in figure-6.

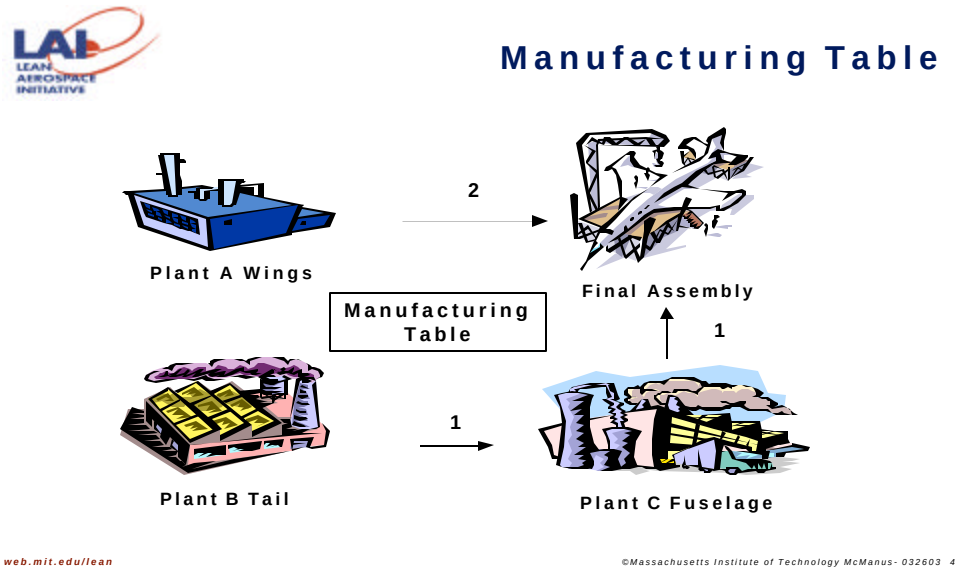


Figure 6. Manufacturing Tables in Aircraft Simulation

First work processes at the manufacturing table will receive all necessary parts/assemblies from attached facilities or suppliers and complete assembly. The second process is to rework the assembly to meet specifications.

Beer Game Simulation:

The Beer game simulation was developed at MIT in the 1960's to clarify the advantages of taking an integrated approach to managing the supply chain (i.e. to demonstrate the value of sharing information across the various supply chain components). The Beer game simulates the supply chain that exists between a beer manufacturer, distributor, wholesaler, and retailer.

The participants are assigned to a table. Everyone seated at each individual table will be considered a team and will compete against other table teams. The game can accommodate up to 9 players per table. The four channel partners that comprise the supply chain are:

Retailer
Wholesaler
Distributor
Factory

Figure-7 shows Beer game board. A participant's primary goal is to fill customer's orders in full while keeping his inventory cost to a minimum and avoiding stock-outs. During the game participants inventory levels are tracked. There are penalties for carrying too much inventory and penalties for stock-outs in the form of "cost-of-lost-sales."

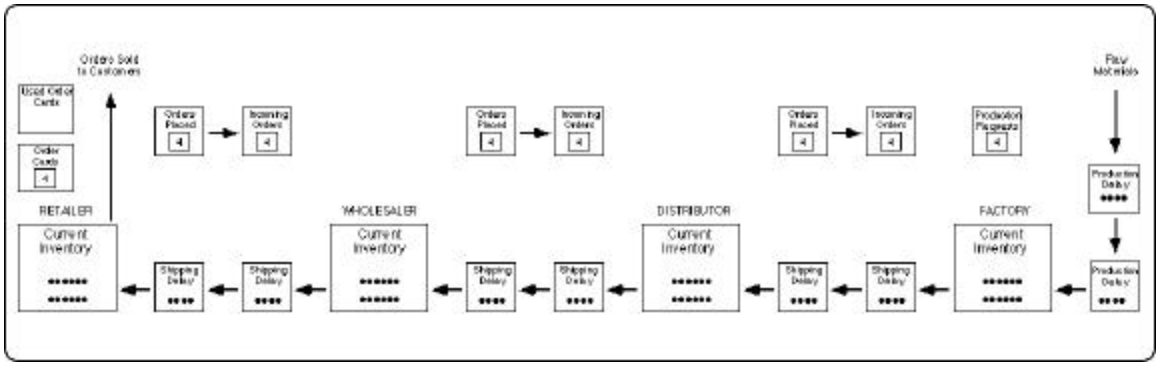


Figure 7. Beer Game board, showing initial conditions.

The Web Based Beer Game Simulation:

This simulation is based on the manual beer game simulation described above. In this exercise, the participants will be faced with the following scenario: Consider a simplified beer supply chain, consisting of a single retailer, a single wholesaler which supplies the retailer, a single distributor which supplies the wholesaler, and a single factory with unlimited raw materials which makes (brews) the beer and supplies the distributor. Each component in the supply chain has unlimited storage capacity, and there is a fixed supply lead time and order delay time between each component. Each week,

each component in the supply chain tries to meet the demand of the downstream component.

Any orders, which cannot be met, are recorded as backorders, and are met as soon as possible. No orders will be ignored, and all orders must eventually be met. At each period, each component in the supply chain is charged a $1.00 shortage cost per backordered item. Also, at each period, each location is charged $.50 inventory holding cost per inventory item that it owns. Each component owns the inventory at that facility. In addition, the wholesaler owns inventory in transit to the retailer; the distributor owns inventory in transit to the wholesaler; the factory owns both items being manufactured and items in transit to the distributor.

Each supply chain member orders some amount from its upstream supplier. It takes one week for this order to arrive at the supplier. Once the order arrives, the supplier attempts to fill it with available inventory, and there is an additional two week transportation delay before the material being shipped by the supplier arrives at the customer who placed the order.

The goal of the retailer, wholesaler, distributor, and factory, is to minimize total cost, either individually, or for the system.

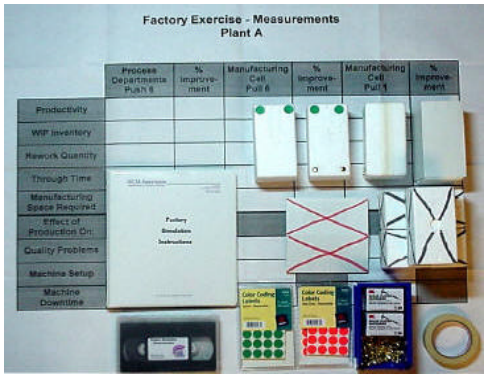
In this simulation, participants take the role of a manager of one of the components of the beer supply chain, either the retailer, the supplier, the distributor, or the factory. This will be called the interactive role. The computer and other players take the remaining roles.

Box Game Simulation:

This simulation exercise is developed by WCM Associates. The Factory Simulation (box game) is used to show the benefits of one-piece flow pull manufacturing and manufacturing cells versus push/batch manufacturing.

The game compares batch or push manufacturing techniques (traditional manufacturing) to one-piece pull manufacturing using Manufacturing Cells. It shows how quality and productivity improve while reducing WIP inventory, rework, and product through time and floor space required. It also illustrates how setup reduction and total productive maintenance are a prerequisite to pull manufacturing.

The game requires a 20’x20’ factory with four folding tables and requires 7 people to run the factory. The factory assembles a product (6"x3"x3" Styrofoam box). Three different ways to run the factory are compared (Push 6, Pull 6, and Pull 1). The game takes about 1.5 hours to complete. Figure-8 shows set up of Box Game Simulation Exercise.



Kit Typical Setup (Not yet spread out)

Figure 8. Typical Setup of Box Simulation Game

Dice Game (Parade Game) Simulation:

This simulation exercise is used to demonstrate the practical implications of some Lean Production Concepts such as the impact of uncertainty on productivity and project duration, push and pull approaches to production or the impact of multitasking. This simulation is inspired by Goldratt's "boy-scout hike".

The sequence of activities for this simulation is shown in Figure-7. The simulation exercise comprises four to six activities that are in sequence with finish to start restrictions. The activities have all the same production rate, with an associated degree of uncertainty. The uncertainty in the production rates is represented by the roll of a die that has only two values on its faces, representing the variability in the production rate. To play the game, the participants in the simulation are organized in teams of a size equal to the number of activities. Each team is assigned a different production variability (type of dice) trying to have at least one team for each type of variability.

The game consists of carrying out a project that comprises 100 production units; coins, beans, or other objects that represent the units. Each member of a team represents one activity and he/she will be responsible for "managing" the productivity of that activity. At the beginning of the game the 100 units will be stored next to member of the team representing the first activity in the sequence, as shown in Figure 9. The first member of the team will roll the die and will pass the number of units obtained from the experiment to the storage next to the following activity in the sequence. The following member of the team will roll the die and will pass on to the next activity the minimum between the number of units indicated by the die and the units available in storage from

the previous activity. The same procedure is applied in each step for the subsequent activities, and the members of the team repeat it in turns until all the units are passed through the final activity. This indicates the completion of the project.

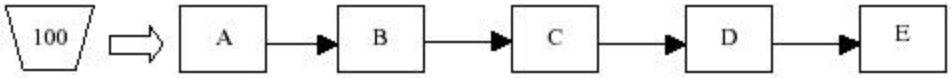


Figure 9. Dice Game Simulation

During the game each member of the team will keep a record of the productivity obtained in each step by drawing the progress for the assigned activity in a "Line of Balance" type of graph. The final drawings show the complete record of the project and allow comparison of different characteristics of the project such as productivity rates, completion dates, interference between activities, etc. for the different variabilities. The game is played with an initial time buffer (X1) of one unit among subsequent activities, this initial buffer size is kept constant over the game. In general, the game demonstrates how variability affects the production rates and can slow down the general productivity of the project, a point can be made that in many cases it could be better to focus on reduction of uncertainty rather than on increasing production rates.

Lean Product Development Simulation:

This simulation is designed by University of Tennessee for use in training on product development. It is used to cover a variety of topics all related to lean product development

K'nmex construction kits, widely available at toy stores are used. The simulation provides roles for the Customer (specific to each product); four team Members (team leader, two design engineers, and cost manager) and a possible Observer.

For round one, the customer/facilitator is set up at some central location, equally accessible to all teams. In round one, teams hole up and do not bother to talk to the customer. But, in round one the temptation to "push" information to teams is avoided. – The participants are typically divided into competing teams of 4. The teams stay together through all the rounds of competition. Usually two or three simulations are spread across anywhere from 8-24 hours of training depending on the extent of the content to be delivered in conjunction with the simulation. Round one has them approach the problem without any training. Even though simpler product are used for this round, the results are still typically disastrous: incomplete designs, tremendous efforts devoted to features that the customer does not value, frustrated teams, etc. Rounds two and three show steady progress on a variety of fronts depending on what sort of emphasis has been given to the training.

There are three dimensions along which success can be measured: cost of the product as designed, price the customer is willing to pay for perceived quality, and speed to market.

The various products that are manufactured during this simulation are shown in figure-10.

Product		RFPs*	Level of Difficulty
3DCE Drone		RFP	Moderate
Benchmark Biplane		RFP	Difficult
CessnAir Plane		RFP	Difficult
Clockspeed Stunt Jet		RFP	Moderate
Demand Dragster		RFP	Difficult
Heijunka Hang Glider		RFP	Simple
Mixed Model Moon Rover		RFP	Difficult
Six Sigma Super Box Derby Car		RFP	Moderate
Takt Time Trike		RFP	Moderate
Whirlean Copter		RFP	Difficult
World Class Windsurf Board		RFP	Simple

Figure 10. Various Products Manufactured in Lean Product Development Simulation

Cellular Manufacturing Simulation Using Aircraft:

Visionary Products Inc. has developed this simulation exercise to present advanced manufacturing concepts. In four phases this simulation exercise demonstrates and compares traditional layout, cellular layout, one-piece flow with a pull system, flexible work force (load leveling).

This simulation exercise is ideal for groups of 6-8 participants who operate four workstations along the assembly line in mythical aircraft plant. For simplicity actual construction materials and components are represented by plastic interlocking blocks. Supplier problems, deadlines, labor skills, quality control and other real life situations are incorporated into each simulation phase. Each simulation lasts 6 to 8 minutes. Figure-11 shows final product.

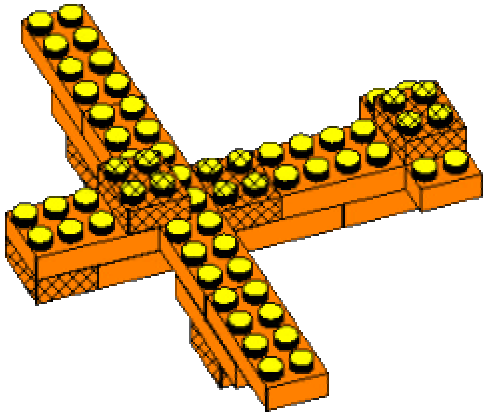


Figure 11. Final Product in Aircraft Simulation

The Widget Factory Simulation:

Lockwood Greene has developed this simulation exercise to provide training in various lean manufacturing concepts such as Visioneering, Lean and Agile Manufacturing Simulation, Integrated Forecasted production, Operations, and Warehouse, Factory Flow & Supply Chain Logistics.

The Lean and Agile Manufacturing Model produce Widgets. There are two varieties of Widgets, the Standard Model and the Deluxe Model. The Widgets are assembled from nine parts. Each of the parts is illustrated in the figure-12, which identifies all parts used to produce both models. Six of the parts are common to both models and three additional parts are required to produce the deluxe model. Eight of the parts are manufactured in the factory and one part is a purchased component that is supplied by an outside supplier. The model has six manufacturing departments and six support functions organized as follows:

Manufacturing Departments	Support Departments
1. Drilling Dept.	Warehousing
2. Sawing Dept.	Material Handling
3. Press Dept.	WIP Storage Area
4. Paint Dept.	Production Control

5. Sub Assembly	Accounting
6. Final Assembly	Quality Assurance

In addition, the model includes external representatives for suppliers, customers and transportation.

The key performance metrics used are:

- Manufacturing Cycle Time (by product)
- Manufacturing Cycle Time (by order)
- Total Elapsed Manufacturing Time
- Average Manufacturing Cycle Time Per Model
- Total Raw Material Inventory
- Total Work In Process Inventory
- Total Scrap and Rework
- Paperwork Count
- Work Team Count

Participants take part in three simulation exercises. First simulation simulates traditional manufacturing environment. Second simulation simulates Pull manufacturing, while third simulation simulates Cellular Manufacturing. 15 - 25 participants can participate in each simulation exercise.

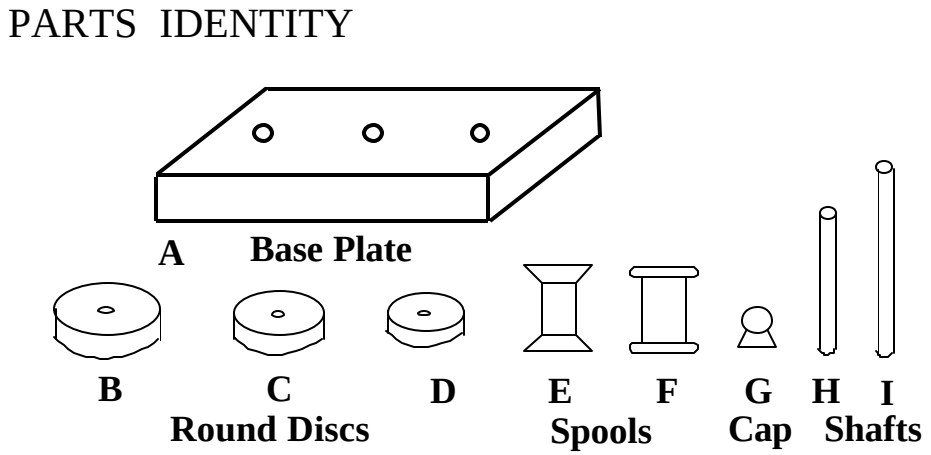


Figure 12. Parts used in Widget Factory Simulation.

The Lego Factory :

Variations of the Lego factory are used by both shipyards and consultants. This simulation has been on the market for some time, and it is used to compare the traditional push/batch manufacturing with one-piece flow pull and cellular manufacturing.

One consultant describes it this way: Legos are joined to form widgets that are shipped to the customer. Four stations are set up with five workers at each. Two represent push manufacturing in batches. The third station represents one-piece flow pull manufacturing. The forth station is Inspections and Receiving. Production stops after 10 minutes three times to calculate and record the number of widgets shipped, time of first shipment, WIP, and defects. Before the second and third phases begin, improvements

may be made to improve production. One of the push stations may be converted to cellular manufacturing to compare results.

A shipbuilder describes the variation this way: Assembly stations and warehouse locations are established and manned, along with the position of foreman, inspector and material handler(s). Instructions are provided on the way the product is to be assembled. The simulation is run in three phases. After each phase, metrics are collected on inventory (WIP), cycle time, pieces completed, rework, layout area, total cost, and customer satisfaction. The team is allowed two improvements between each round (phase) of the simulation.

A Lean provider who provides training for both a university and for private companies noted that materials other than Legos may be used to more closely resemble the customer's product. One trainer reported that his Lego simulation required purchasing a complete Lego model kit for each participant in the simulation.

The Ball Bearing Factory:

The Ball Bearing Factory was developed by Gary Randall to be used in Quality classes. In this live simulation, golf balls and four different processing stations are set up to simulate a factory in which ball bearings are manufactured. A maximum of 20 participants process and move the balls through the factory and give suggestions about improving the flow and eliminating waste. Periodically, production is stopped so the participants can make changes to reduce cycle time and defects and to improve communication, teamwork, and customer satisfaction.

Performance metrics used include cycle time, number of defects, and orders filled.

Circuit Board Simulation:

This simulation exercise is developed by NIST-MEP to train the participants in principles of lean manufacturing. 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.

First simulation round simulates traditional manufacturing environment. During next three simulation rounds participants apply various lean concepts such as POUS, quality at source, plant layout, reduced batch size, standardized work, pull/kanban etc.

The performance metrics used are cycle time, WIP inventory, distance traveled, profits, on time delivery, quality etc.

5S Simulation:

This simulation exercise is developed by NIST-MEP to train the participants in 5S systems. Participants take part in six rounds of simulation exercise. The simulation simulates the factory that manufactures two types of products. 15-20 participants can

participate in each simulation. Various workstations are: three assembly areas, inspection and rework area, shipping area, tool area, etc.

First simulation round simulates current state of the factory (traditional manufacturing environment). Second round simulates workplace scanning while sort, set in order; shine and standardization are applied in next four rounds.

The performance metrics used are quality, cycle time, on time delivery, number of products delivered etc.

Setup Reduction Simulation:

This simulation exercise simulates four-step changeover improvement process. This simulation exercise is developed by NIST-MEP. In this simulation exercise participants learn the principles of setup reduction and single minute exchange of die (SMED). This simulation exercise simulates Acme Sheet Metal Company. During this simulation exercise participants work either as changeover worker or as observers.

The first simulation round simulates traditional changeover while second simulation round simulates SMED, 5S principles.

The performance metrics used are reduced changeover time, quality etc.

The Paper Airplane Game:

The Paper Airplane simulation and a video of the simulation were developed within Northrop Grumman. The simulation can be run in class, or the video can be shown if there is not enough time for a full simulation. Lean concepts taught include one-piece flow, and batch reduction. There are 3 phases and 3 workstations in this simulation. Metric used track cycle time, inventory, and output.

10. Identification of Needs in Shipbuilding & Repair Industry

The simulation needs of the shipbuilding/ repair industry were assessed through survey form-III (Appendix-c) and phone conversations with training managers and instructors. The matrix in Appendix-f summarizes the results from the survey form – III. This survey provided eleven possible topics for simulation activities and asked lean training coordinators to identify five areas that they think are critical for the development of simulation tools. The number of responses is plotted as bar charts in the diagram below in the decreasing order of sequence as a function of topic of simulation. The top five topics are selected for the development of simulation tools.

In addition, phone conversations provided further insight into the needs. The need was identified for a simulation tool that represents a repair environment vs. an assembly line manufacturing environment. It has also been stated that there is a need to improve information flow within large organizations such as shipbuilders, improve supplier communication and connections, and organized scheduling within and between shops. Requests were also made for simulations that are relevant to process industries and for a good ship repair simulation.

Some Lean trainers stated that they have been looking for a simulation that is appropriate for shipbuilders, but that in 5 or more years they have not been able to locate any other than the ones available from the MEP's.

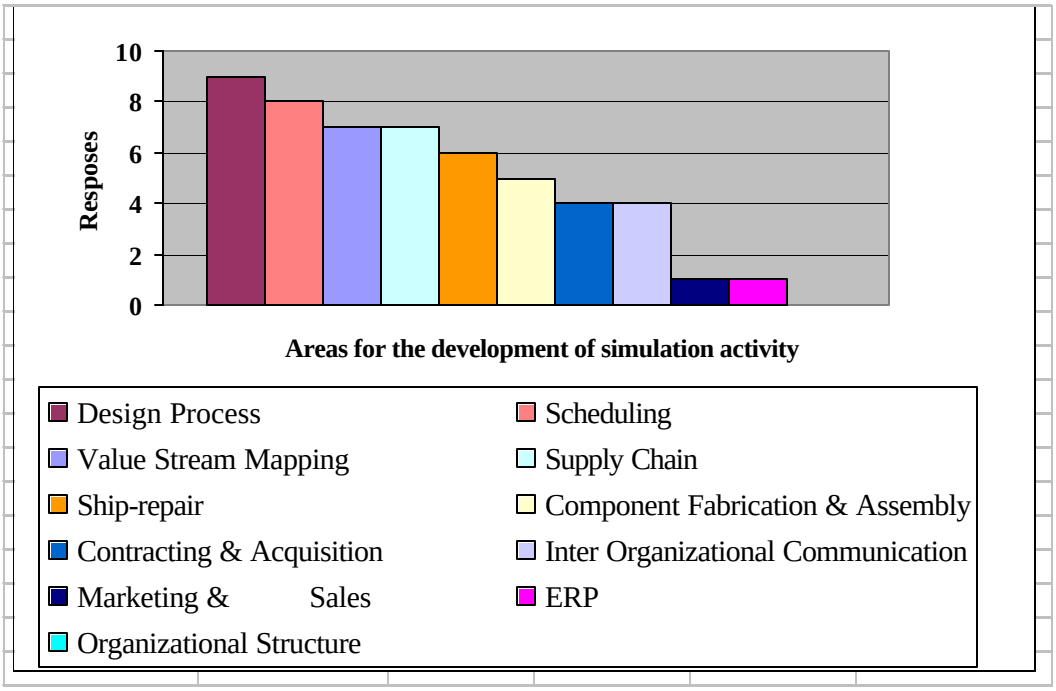


Figure 13. Bar Chart Identifying Top Five Topics

11. Proposed Areas for Simulation Activities

Based upon the results of survey –III, five areas have been identified for the development of simulation activities and associated training programs. They are listed below:

1. Ship Design Process
2. Scheduling
3. Value Stream Mapping (Using software simulation)
4. Supply Chain Integration
5. Ship-repair process

Ship design process activity will compare traditional sequential design process to concurrent design process using teams and demonstrate the effect of using this approach in a Lean enterprise.

Scheduling activity will simulate the scheduling conflicts arising due to multiple trades working in the confined areas of ship, work sequence and storage issues. Scheduling processes that take into account the entire value stream, enhance productivity by creating smooth flow of materials, workers and processes.

Value Stream mapping activity will take the participants through VSM exercise for a variety of organization and simulate the value stream flow in real time using a

discrete event manufacturing software like Pro-Model. This exercise will incorporate the benefits of both hands-on-simulation and computer based simulation.

Supply chain integration activity will demonstrate the benefit of supply chain integration and its impact on key performance metrics for a Lean enterprise. Participants will produce ship engines and its components from raw material to final product and study the effect of reliance on sole source, breakdown in communication and plant shutdown.

Ship repair process activity will utilize the Lean Enterprise Implementation Model for ship repair developed by the NSRP funded project and compare the productivity of such an enterprise with traditional ship repair organization. The activity will take participants through the model developed at Puget Sound Naval Shipyard and look at the impact on productivity through different phases.

12. Summary

Extensive survey conducted during this project has identified seventeen simulation activities currently used by shipbuilders, educational institutions and consulting firms. None of these simulation activities are designed to address issues related to Lean enterprise implementation like ship design process, value stream mapping, ship repair process, scheduling and enterprise resource planning.

In the shipbuilding industry, results show that Lean training simulations consist of variations of MEP exercises, Six Sigma programs, NIST-MEP 5 S training, the clock exercise developed by TimeWise, or Buzz Electronics with a circuit board.

Most of the consultants which offer training with simulation activities have developed them for mass production and build-to-stock or build-to-order in manufacturing environments rather than for situations with low volume, high mix in an engineer-to-order environment like shipbuilding and repair. Three consultants, who have extensive training experience in shipbuilding and aerospace industries, acknowledged that they have unsuccessfully looked for years for applicable simulations. They agree that existing simulation tools do not replicate the unique set of challenges shipbuilders face. One explained that he tried to create a simulation of a small factory with a large mix of products and random orders, but that it became too complicated and was abandoned.

Lean enterprise value simulation and Beer game developed at MIT are the only activities that even try to tackle the issue of supply chain integration. In addition, all the simulation activities available are designed for the high-volume and low-variety manufacturing environment. Results of the survey establish the need for simulation activities to complement the effort of shipyards in becoming Lean enterprises. The proposed tools will also complement the Extended Lean Enterprise project funded by NSRP this year.

13. References

Government Agencies:

- MEP-NIST <http:// ***www.mep.nist.gov***>
- NSRP **http://www.nsrp.org/**

Consulting Firms:

- Association For Manufacturing excellence – **http://www.ame.org**
- APICS Bearing point, Inc.
- Alabama Technology Network - **www.atnlean.com**
  http://birmingham.atn.org
- Business Basics, LLC-htttp://www.basiclean.com
- Bullis Lean Management- **http://www.bullisleanmanufacturing.com/**
- Buker, Inc.- **http://www.buker.com**
- Change Management Association – **http://www.comcast.net**
- Change Partners, LLC - http://www.shangepartners.com
- Camp, Inc – **http://www.camp.org**
- EWI- **http://www.ewi.org/**
- Factory Logic – **http://www.factorylogic.com**
- Global Quality Learning Center – **http://www.glearning.com**
- HPK Group, LLC – **http://www.kpkgroupllc.com**
- JCIT – **http://www.jcit.com**
- JDI associates – **http://www.jdiassociates.com**
- Kaizen Institute of America – **http://www.kaizen.com**
- Lean Learning Center- **http://www.leanlearningcenter.com**
- Lean Advisors Inc.- **http://www.leanadvisors.com**
- Lean Learning Center- **http://www.leanlearningcenter.com**
- Lean enterprise Institute- http:// **www.lean.org**
- Lean enterprise training – **http://www.leanenterprise.bigstep.com**
- Lean Plus – http://www.leanplus.com
- Manufacturing Engineering Inc – **http://www.mfgeng.com**
- Michigan Manufacturing Technology Center- **http://www.iti.org/**
- Minnesota Technology Inc.- http://**www.minnesotatechnology.org**
- Optiprise- **http://www.optiprise.com**
- Production Modeling Corporation- http:// **www.pmcorp.cpm**
- Productivity Inc. – http:// **www.productivityinc.com**
- Qi2- **http://www.qualityi2.com**
- Rockford Consulting Group – **http://rockfordconsulting.com**
- RSS solutions – http:// **www.rsssolutions.com**
- Strategos, Inc. – **http://www.strategosinc.com**
- TBM consulting Group – **http://wwwtbmcg.com**
- Techsolve- **http://www.techsolve.org**
- V2R consulting groups- http:// **www.vision2reality.com**
- VQI, Inc.- **http://www.vqi.org**
- WCM associates- http:// **www.wcmfg.com**

Educational Institutions:

- Georgia Tech Economic Development Institute: **http://www.edi.gatech.edu/**
- Michigan Engineering center - **http://www.umich.edu**
- Red River college- http://**www.rrc.mb.ca**
- Northwest Arkansas community college- **http://www.nwacc.edu**
- Iowa State University- **http://www.iastate.edu**
- Penn State University- **http://www.psu.edu**
- University of Dayton- **http://www.udayton.edu**
- Purdue University- **http://www.purdue.edu**
- University of Maryland- **http://www.isr.umd.edu**
- Massachusetts Institute of Technology- **http://www.mit.edu**
- University of Tennessee- **http://www.utk.edu**
- University of Texas Arlington- **http://www.uta.edu**
- University of Wisconsin- **http://www.uwexeced.com**
- Virginia Tech University- **http://www.vt.edu**
- Washington University – **http://www.wustl.edu**
- Wichita State University- **http://www.wichita.edu**
- University of Iowa – **http://www.uiowa.edu**
- North Carolina State University – **http://www.ncsu.edu**
- University of Massachusetts (Amherst) – **http://www.umass.edu**
- Texas Manufacturing Assistance Center – **http://www.tmac.org**

Navy Yards:

- Norfolk Naval Shipyard – **http://www.navy.mil**
- Pearl Harbor Naval – **http://www.phnsy.navy.mil**
- Portsmouth Naval – **http://www.ports.navy.mil**

Other Shipyards:

- Atlantic Marine – **http://www.atalnticmarine.com**
- Bath Iron Works – **http://www.biw.com**
- Bender Shipbuilding & Repair – **http://www.bendership.com**
- Electric Boat – **http://www.gdeb.com**
- Jeff boat LLC – **http://www.acdl.net**
- NGSS – **http://www.ngc.com**
- Puget Sound Naval Shipyard -***http://www.psns.navy.mil***

Appendix - a

SURVEY FORM - I

A Joint Project by Old Dominion University and Northrop Grumman Newport News

NSRP-ASE PROJECT

LEAN TRAINING & SIMULATION

- **Name of the Company:**

- **Type of Organization**
  Please mark the appropriate box

  ☐ **Shipbuilding** ☐ **Consulting** ☐ **Educational Institution**

  ☐ **Ship Repair** ☐ **Government Agency** ☐ **Others**

- **Lean Training Programs Offered:**

TOPICS	DURATION (1/2 Day, 1 Day, 2 Days, 3 Days….)	SIMULATION ACTIVITY YES/NO	NUMBER OF PEOPLE TRAINED TO DATE	No. OF YEARS TRAINING OFFERED

- **Brief Description of the program:** P*lease attach a brochure*

- **<u>Requirements for Certification:</u>** *Identify number of courses and sequence*

  - **<u>Developed in-house?</u>**

    - ✓ **Yes** **No**

  If No, Please provide us the following information about the source:

  Name: _____ **Phone:** _____

  Address: _____ **Email:** _____

  _____

- **<u>Description of Simulation Activity</u>:** *Please identify simulation tools and goals*

- **<u>Please Describe if you have identified any simulation tools that your organization needs, but you do not have?</u>**

- **<u>Does your Institution offer a dedicated course in Lean Manufacturing, Please describe?</u>**

- **Contact Information:**

Name: _____ **Phone:** _____

Title: _____ **Fax:**

Address: _____ **Email:**

_____ **Web Address:**

Please complete the form and mail it to the following address with additional information (flyers) for the training program.

Prof. Alok K. Verma
Associate Professor
Engineering Technology Department
Old Dominion University
Norfolk, Virginia 23529-0244
Phone (office): 757-683-3766
Fax: 757-683-5655
E-mail: averma@odu.edu

Appendix - b

SURVEY FORM - II

A Joint Project by Old Dominion University and Northrop Grumman Newport News

NSRP-ASE PROJECT

SIMULATION TOOLS FOR LEAN TRAINING

- **Name of the Company:**

- **Type of Organization**

Please mark the appropriate box

☐ **Shipbuilding** ☐ **Consulting** ☐ **Educational Institution**

☐ **Ship Repair** ☐ **Government Agency** ☐ **Others**

- **Lean Training Programs Offered:**

Name of the Simulation Activity	Lean Concepts Taught	Duration Of Each Simulation Activity	No. of Phases	Number of Workstations	Maximum No. of People That can participate in Simulation	Products Made	Performance Metrics Used

- **Description of Simulation Activity:** P*lease attach a brochure*

- **Developed in-house?**

Yes **No**

If No, Please provide us the following information about the source:

Name: **Phone:**
Address: **Email:**

- **Please Describe if you have identified any simulation tools that your organization needs but you do not have?**

- **Description of Simulation Activity:**

- **Contact Information:**

Name: **Phone:**

Title: **Fax:**

Address **Email**:

Web Address:

Please complete the form and mail it to the following address with additional information (flyers) for the training program.

Prof. Alok K. Verma
Associate Professor
Engineering Technology Department
Old Dominion University
Norfolk, Virginia 23529-0244
Phone (office): 757-683-3766
Fax: 757-683-5655
E-mail: averma@odu.edu

Appendix - c

SURVEY FORM - III

A Joint Project by Old Dominion University and Northrop Grumman Newport News

NSRP-ASE PROJECT

LEAN TRAINING & SIMULATION

Please identify five areas that you feel are most Important for the development of simulation activities for LEAN training within your organization:

- **Type of Organization**
  Please mark the appropriate box

☐ **Shipbuilding** ☐ **Ship Repair**

☐ **Others** _____

1. **Supply Chain** ☐
2. **Design Process** ☐
3. **Value Stream Mapping (Using Software Simulation)** ☐
4. **Contracting and Acquisition** ☐
5. **Component Fabrication and Assembly** ☐
6. **Ship-Repair Process** ☐
7. **Simulation of Vertical Vs. Horizontal Organizational Structure** ☐
8. **Scheduling** ☐
9. **ERP- Enterprise Resource Planning** ☐
10. **Marketing & Sales** ☐
11. **Inter Organizational Communication** ☐

- **Contact Information:**

Name: _____ **Phone:** _____

Title: _____ **Fax:** _____

Address: _____ **Email**: _____

Web Address: _____

Please complete the form and send it electronically to the following e-mail address:

Prof. Alok K. Verma
Associate Professor Phone (office): 757-683-3766
Engineering Technology Department Fax: 757-683-5655
Old Dominion University **E-mail: averma@odu.edu**

Appendix - d

SURVEY 10/16/2003

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
GOVERNMENT AGENCY	1. NIST	i) Lean Enterprise	1 Day	YES	dierdre.mcmahon@nist.gov	301.975.8328
		ii) Value Stream Mapping	1 Day	NO		
		iii) Flow Manufacturing	1 Day	YES		
		iv) The 5S System	1 Day	YES		
		v) Pull System / Kanban	1 Day	YES		
		vi) Kaizen Blitz		NO		
NAVY YARDS	1. Norfolk Naval Shipyard	i) Lean Sigma College	5 wks	YES	TidwellTD@nnsy.navy.mil	757.396.9018
		ii)Lean Training	2 Day	YES		
		iii)Lean Basics	1.5 hrs	NO	IsaksonPJ@nnsy.navy.mil	757.396.9826
		iv) BB Certification Exam Preparation	6 mo	NO	Paul Isakson	
	2. Pearl Harbor Naval	i) Lean Sigma College	5 wks	YES	RadvanskyCS@phnsy.navy.mil	808.473.8000
		ii)Lean Training	2 Day	YES		
		iii)Lean Basics	1.5 hrs	NO		
		iv) BB Certification Exam Preparation	6 mon	NO	Chuck Radvansky	ext. 2659
	3. Portsmouth Naval	uses TimeWise for Ships requested brochure from MEP		YES	Jeremy Baird Bairdjs@mail.ports.navy.mil kucnerrj@mail.ports.navy.mil Bob Kucner	207.438.2042
OTHER SHIPYARDS	1. Puget Sound Naval Shipyard, Code 980.1	Introduction to Lean	1/2 Day	YES	clarkg@psns.navy.mil	360.476.1088
		Senior Management Training	1 Day	YES	Doug Smith	
		Dot Game	1/4 Day	YES	SmithDD@nnsy.navy.mil	
		Value Identification	1/4 Day	YES		
		M&M Exercise	1/4 Day	YES		
		Lean Improvement Workshop	1/4 Day	NO	tibkem@psns.navy.mil	360.476.9407
		Value Stream Map Exercise	1/2 Day	YES	Michelle Tibke	
		Beer Production Distribution Game	1/2 Day	YES		

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	2. Atlantic Marine				lsovilla@atlanticmarine.com Lisa Sovilla	904.251.1632
	3. Bath Iron Works				eric.suehrstedt@biw.com Eric Suehrstedt	
	4. Bender Shipbuilding & Repair	i)Principles of Lean & 5S's ii)In-House Training - Prin. of Lean and 5 S's iii)Value Stream Mapping	1 DAY 1/2 day 2 DAYS	YES YES NO	jerm@bendership.com Dale Jermyn Salsobrooks@mmep.datastar.net Scott Alsobrooks	251.431.8049 228.214.3505
	5. Electric Boat	i) Lean Six Sigma ii) Lean Awareness	23 days 1 Day	YES YES	dpalmier@ebmail.gdeb.com Mattv@BMGi.com Matt Vargas at BMGi	860.433.3336 800.46.sigma
	6. Jeffboat LLC	i) Greenbelt Training Lean / Six Sigma	26 Hrs.	NO	joseph.browning@acbl.net	812.288.1935
		ii) Lean / Six Sigma for Managers	20 Hrs.	TBD		
	7. NGNN	i) Lean 101 Prin of Lean ii) Lean 202 VSMapping iii) Lean 203 5S iv) Lean 204 Set Up Red v) Lean 205 Cellular Flow vi) Lean 206 Pull Systems vii) Lean 207 TPM viii) Lean 302 Ent. VSM ix) in-house training	1 DAY 1 DAY 1 DAY 1 DAY 1 DAY 1 DAY 1 DAY 1 DAY 2 to 4 hr	YES NO YES NO NO NO NO NO YES	Tim.Sweitzer@ngc.com Bill McHenry william.mchenry@ngc.com	757.380.4190 757.688.1756
	8. NGSS - Avondale	uses Optiprise exercise with lego simulation for push-pull, one-piece flow and kanbans		YES	shawn.wilkerson@ngc.com	504.436.5709 cell phone: 504.616.5533

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	9. NGSS - Ingalls				danny.bruhl@ngc.com	228.935.3154
	10. Todd Pacific Shipyards				john.nelson@toddpacific.com	206.623.4635
CONSULTING updated 10-10-03	**1. AME**				jrweitz@ame.org cc: gmack@scinternet.com	847.520.3282
	2. APICS Bearing Point, Inc.				edtraining@apicshq.org	
	3. ATN	i)Lean mfg. Certificate Prog.	5 Days	YES	contact@atn.org	800.637.4634
	4. Brian Maskell Assoc. (BMA)					609.239.1080
	5. Buker, Inc.	i)Lean Manufacturing	2 Days	YES	info@buker.com	847.395.3050
	6. Bullis Lean Manufacturing	i) Lean Mfg. Simulation/ Overview & Value Stream Mapping	2 Days	YES	belean@earthlink.net Ben Bullis	810.385.4881
		ii) Lean Paper Simulation		YES		
		iii) Lean Mfg. Overview & Simulation	1 Day	YES		
		iv) Kanban / Pull System	1 Day	YES		
		v) Value Stream Mapping	1 Day	YES		
		vi) Lean Simulation Kit		YES		
	7. Camp, Inc.				bill.barnes@camp.org	216.432.4346

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	8, Change Mgmt. Assoc.	i) Lean Overview ii) Pull Systems iii)Quick Changeover iv) Cellular Flow Manuf. v) TPM vi) Lean Admin. vii) 5S viii) Value Stream Mapping iX) Kaizen Facilitation	1 1 1 1 1 1 1 1 1	YES NO YES YES NO NO YES NO NO	drewlocher@comcast.net	856.235.8051
	9. EWI	i) Understanding Lean Techniques through Hands-on-Simulation	1 Day	YES	john_metscher@ewi.org Rich Green rich_green@ewi.org	614.688.5176 614.688.5126
	10. Factory Logic	streamline software				
	11. Global Quality Learning Ctr	Lean6 tools and team trng		YES	sixsigma@qlearning.com Mark Delahunty	908.672.1493
	12. HPK Group, LLC				rapidresults@kpkgroupllc.com	
	13. JCIT				dmarshall@jcit.com David Marshall	800.457.4548
	14. JDI Associates **15. Kaizen Inst. Of America**				 usa@kaizen.com Charlie Colosky	

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	16. Lean Advisors, Inc.	i) Introduction to Lean	1 Day	YES	lcote@leanadvisors.com Larry Cote	613.821.4545
		ii) Value Stream Mapping	2 to 3	YES		
		iii) 5S	2 to 4	YES		
		iv) Quick Change Over	2 to 4	YES		
		v) Quality Tools	2 to 4	YES		
		vi) Cells - Flow	3 to 4	YES		
		vii) Pull - kanban	3 to 4	YES		
		viii) Visual Controls	3 to 4	YES		
		ix) Office Value Strm Map	3 to 4	YES		
	17. Lean Enterprise Institute	Value Stream Mapping Creating Continuous Flow Mixed Model Value Stream Making Materials Flow Administrative Value Stream Mapping Train the Trainer in Value Stream Mapping Pull/ Kanban Systems		NO	info@lean.org breisman@lean.org	617.713.2900 John Shook
	18. Lean Enterprise Center	i) Prin. Of Lean Mfg.	1	YES	Scott Alsobrooks David.alsobrooks@usm.edu	601.329.1730
		ii) Set up Reduction	1	YES		
		iii) Cellular Mfg.	1	NO		
		iv) TPM	1	NO		
		v) Value Stream Mapping	1	NO		
		vi) 5S System	1	NO		
		vii) Activity Based Costing	1	NO		
	19. Lean Enterprise Training				Gary conner lean1mfg@aol.com	541.574.0398
	20. Leanhelp.com	i) Lean Sim Machine™	1 Day	YES	office@scanlonleader.org sent to Paul Davis	517.332.8927

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	21. Lean Learning Center	i) Lean Experience	5 Days	YES (2)	jamie@leanlearningcenter.com	248.478.1480
		ii) Lean Leadership	2 Days	NO		
		iii) Lean Kaizen	5 Days	NO		
		iv) Lean Value Stream	2 Days	NO		
		v) Custom Training	1-25 Days	YES (3)		
	22. Manufacturing Engineering Inc.				Jerryhoskins@mfgeng.com Jerry Hoskins	614.487.7900
	23. MMTC	i) Champion Training	9 Days	YES	inquiry@mmtc.org	888.414.6682
		ii) Kaizen Events	5 Days	YES		
		iii) Pull System implementation	12 Days	YES	bsmith@mmtc.org Bob Smith	
		iv) Training and implementation	18 Days	YES		
	24. Minnesota Technology, Inc	i) Path to Lean Manufacturing	8 Days	YES	leantraining@mntech.org dahlquist@mntech.org	218.741.4241
		ii) NIST MEP Lean 101				
		iii) Timewise 101 & 102 MEP MSI				
		iv) NIST-MEP 5S		YES		
	25. Optiprise, Inc	Lean Manufacturing 101			kknoth@optiprise.com Kurt Knoth	616.846.3493
		Visual Controls				
		Business Process Kaizen				
	26. Production Modeling Corporation (PMC)	i) Lean Simulation Workshop	4 Hours	YES	sales@pmccorp.com	313.441.4460
		ii) 5S Visual Workplace Workshop	1 Day	YES		
		iii) Productivity Workshop	1 Day	YES		
		iv) Pull System Workshop	1 Day	YES		

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	27.Productivity Inc.	i) Value Stream Mgmt ii) 5S iii) Sigma Tools iv) QCO v) Mistake Proofing vi) Cell, one-piece flow vii) Kanban- pull sys viii) 3 P ix) Leading World class teams	2 days 3 days 3 days 2 days 2 days 5 days 4 days 1 day 2 days	YES YES YES YES YES YES YES YES YES	lprovenzano@productivityinc.com Lisa Provenzano	800.394.6868 ext. 132
	28. Qi2	Lean Mfg	3.5 days	YES	qi2@qualityi2.com Mike White	714.871.7308
	29. Rockford Consulting Group				Richard G. Ligus, Pres	
	30. RSS Solutions					
	31. Strategos, Inc.	Lean Manuf. Game and seminar	1 DAY	YES	Q@strategosinc.com Quarterman Lee	913.901.9586
	32. TBM Consulting Group	i)Quest for the Perfect Engine (QPE) ii) Lean Mgmt Accounting iii) LeanSigma Fundamentals iv) The Perfect Service Engine		YES YES YES YES	jbarbato@tbmcg.com Janet Barbato	919.471.5535

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	33. Techsolve	Lean- Pathways	2-5 Days	YES	moehring@techsolve.org Susan Moehring	513.948.2000 800.345.4482
		Lean Manufacturing simulation		YES		
		Lean Office Simulation				
		Team Training				
		Manufacturing Leadership Series				
		Setup Reduction,		YES		
		Decision Tools for Lean Machining Environment	3 Days	YES		
		Cellular Manufacturing				
		Value Stream Mapping				
		TPM				
		5S				
	34. TPM Unlimited LLC				tpmunlimited@cs.com	
	35. V2R Consulting Group , LLC	Lean Shipbuilding New Construction Basic Education Module			mboyer@v2rcg.com Michael Boyer	425.313.0409
		Lean Shipbuilding Repair Basic Education Module				
		Lean Shipbuilding Product and Process Mapping Basic Education Module				
	36. VQI, inc.	Process Improvement I Process Improvement II	1 DAY 1 DAY	YES YES	gary.randall@vqi.org	757.865-3137
	37. WCM Associates	i) Factory Simulation	1/2 Day	YES	Larry Rubrich	260.637.8064 260.413.5219
		ii) Value Stream Mapping		YES		

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
EDUCATIONAL INSTITUTIONS	**1. Georgia Tech- Economic Development Institute**	i) Lean Manufacturing: An Overview and Live Simulation	1 Day	YES	lean@edi.gatech.edu	404.894.6100
		ii) Lean USA Program	5 Days	YES		
		iii) Value Stream Mapping	1 Day	NO		
		iv) Principles of 5S	1 Day	YES		
		v) Pull Systems		NO		
		vi) Building a Lean Enterprise	2 Days	YES		
	2. Michigan Engineering-Center for Professional Development	i) Lean Manufacturing Certificate Program	10 Days	YES	cpd-info@umich.edu Jim Warren Manager- Prog dev. + Mktg.	734.647.7176
		ii) Lean Pharma	3 Days	YES		
		iii) Lean Six Sigma Certificate Program	9 Grad Credits	NO		
		iv) Lean product-process Development	5 Days	YES		
	3. Red RiverCollege	i) Workshop on Lean Thinking and Value Stream Mapping	1 Day	NO	jroehle@rrc.mb.ca Cindy Sam Lacoste 204-632-3078	204.694.1789
	4. Northwest Arkansas Community College	i) Lean Manufacturing Certification Program	5 Days	YES	jcorbin@nwacc.edu	479.936.5177
	5. Iowa State University	i)Lean Enterprise and Lean Manufacturing		YES	jblack@ciras.iastate.edu	515.294.1507
	6. Penn State University	i)Lean Manufacturing Series		YES	jlm40@psu.edu	

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	7. University of Dayton	I)Foundations of Lean	2	YES	UDCCC@udayton.edu	937.229.4632
		ii)The Journey to Perfect Quality through Poka-Yoke and ZQC	2			
		iii)Kaizen: Maximizing Production Flow	5	YES		
		iv) Pipe Factory Simulation	1	YES		
	8. Purdue University					
	9. University of Maryland					
	10. MIT	Enterprise value stream mapping and Analysis		YES		
		Supplier management assessment tool		YES		
		Operational flight program install time line		YES		
		Alpha contracting		YES		
		Product development value Stream analysis and mapping manual		YES		
		Government lean enterprise Self assessment tool		YES		
		Integrated development of Product tools		YES		

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	11. University of Tennessee	i)LEAN 301 Lean Manufacturing / Lean Office NEW CLASS!		YES	tmep@utk.edu	888.763.7439
		ii)LEAN 101 Lean Manufacturing / Introduction to Lean Manufacturing Principles	1 Day	YES		
		iii)LEAN 208 Lean Manufacturing / Mistake Proofing Your Manufacturing Process	1 Day	YES		
		iv)LEAN 204 Lean Mnfg. / Quick changeover /Setup Reduction	1 Day	YES		
		LEAN 207 Lean Manufacturing / Total Productive Maintenance	1 Day	YES		
		v)LEAN 202 Lean Mnfg. / Value Stream Mapping	1 Day	YES		
		vi)LEAN 203 Lean Mnfg. / Workplace Org. & Visual Controls (5-S Systems)	1 Day	YES		
	12. University of Texas Arlington TMAC	Lean Enterprise			info@tmacgc.com	713.743.0632
		Principles of Lean Office & Admin	1 Day			
		Principles of Lean Prod.	1 Day			
		Value Stream Mapping	1 Day			
		Problem Solving / Quality Tools	1 Day			
		5-S Workplace Org.	1 Day			
		Set Up Reduction	1 Day			
		TPM	1 Day			
		Cellular Flow	1 Day			
		Pull / Kanban				

Type of Organization	Name	Topics	Duration	Simulation	Contact Email	Phone
	13. University of Wisconsin	Lean Enterprise	2 Days		info@uwexeced.com	800.292.8964
	14. Virginia Tech	Lean Manufacturing	2 Days	NO	kline@vt.edu	540.231.5876
	15. Washington University	Master of Engineering Management			pdp@seas.wustl.edu	314.935.5484
	16. Wichita State University	IE 780S Lean Mnfg.			larry.whitman@wichita.edu	316.978.5907
	17. University of Iowa	Kanban based pull production	1/2 Day	YES	ew-kusiak@uiowa.edu	319-335 5934
		Kaizen or continuous Improvement				
		Elimination of waste	2 Day	YES		
		Emphasis on human Resources				
		Importance of Quality	2 Day	NO		
		Reduction in set up time	1/2 Day	NO		
		Integration of suppliers	1/2 Day	NO		
		Efficient cellular layouts with balanced material flow	2 Day	YES		
	18. NCSU	Lean Manufacturing overview	1 Day	YES	deborah_porto@ncsu.edu	828.452.3794
		LEAN 100: Manufacturing Principles with Factory Simulation	1 Day	YES		
		5S/Visual 203	1 Day	YES		
		Value Stream Mapping 202	1 Day	YES		
	19. University of Massachusets - Amherst	Shop floor kaizen		YES	suglia@ecs.umass.edu	413.545.5676
		Toyota Production System		YES		

Type of Organization	Name	Topics	Duration	Simulatio	Contact Email	Phone
	20. Texas A&M University	Enterprise value stream mapping and Analysis		YES	q-forworth@tamu.edu	979.845.1812
		Supplier management assessment tool		YES		
		Operational flight program install time line		YES		
		Product development value Stream analysis andl mapping manual				
		Govt. lean enterprise Self assessment tool				
	21. Auburn University	i) Lean Overview	1 Day	YES	fostemc@auburn.edu	334.844.3881
	22. Pueblo Community College	i)Principles of Lean Manufacturing with Live Simulation	1 Day	YES	technology@pueblo.edu	866-478-3256
		ii)Basics of Lean	1/2 Day	YES		
		Manufacturing (MINI LEAN)				
		iii)How to Organize a Visual	1 Day	YES		
		Workplace with the "5S"				
		System				

Appendix - e

COMPANIES USING VARIOUS SIMULATIONS

PRINCIPLES USED

COMPANIES	Pull System	Batch Reduction	Plant Layout	Cellular Mfg.	Value Stream Mapping	Setup Reduction	Standardized Work	TPM	POUS	5S	Continuous Improvement	Organizational Structure	Cultural Change	Quality	Leadership
ATN	NIST-MEP			NIST-MEP	NIST-MEP	NIST-MEP		NIST-MEP		NIST-MEP					
BULLIS LEAN MANAGENENT	Lean Paper Sim.				Lean Paper Sim.						Lean Paper Sim.				
EWI	NIST-MEP			NIST-MEP	NIST-MEP	NIST-MEP		NIST-MEP		NIST-MEP					
LEAN ADVISORS Inc.															
LEAN LEARNING CENTER					Beer Game						Beer Game				Beer Game
LEAN ENTERPRISE INSTITUTE															
MINNESOTA TECHNOLOGY	TIME WISE			TIME WISE		TIME WISE									
NMTC															
OPTIPRISE (LEGOS)	NIST-MEP	NIST-MEP													
PMC															
TECHSOLVE															
WCM ASSOCIATES	Factory Sim	Factory Sim													
VQI	Lego	Lego	Ball Bearing Factory(bbf)	Lego	BBF						BBF				
Change Management Associates	Lego NIST-MEP Factory Simulation			Lego NIST-MEP Factory Simulation	NIST-MEP Factory Simulation	Stamping equipment NIST-MEP Factory Simulation		NIST-MEP Factory Simulation		NIST-MEP Factory Simulation					

(Shaded) Simulation tools not Known

COMPANIES USING VARIOUS SIMULATIONS

PRINCIPLES USED

	Pull System	Batch Reduction	Plant Layout	Cellular Mfg.	Value Stream Mapping	Setup Reduction	Standardized Work	TPM	POUS	5S	Continuous Improvement	Organizational Structure	Cultural Change	Quality	Leadership
Change Management Associates	Lego NIST-MEP Factory Simulation			Lego NIST-MEP Factory Simulation	NIST-MEP Factory Simulation	Stamping equipment NIST-MEP Factory Simulation		NIST-MEP Factory Simulation		NIST-MEP Factory Simulation					
Baker Inc.	Birdhouse Video														
Lean Enterprise Center	NIST-MEP			NIST-MEP	NIST-MEP	NIST-MEP		NIST-MEP		NIST-MEP					
Lockwood Greene	Widget Factory Simulation			Widget Factory Simulation											
Productivity Inc.						Printing Press Simulation									

Simulation tools not Known

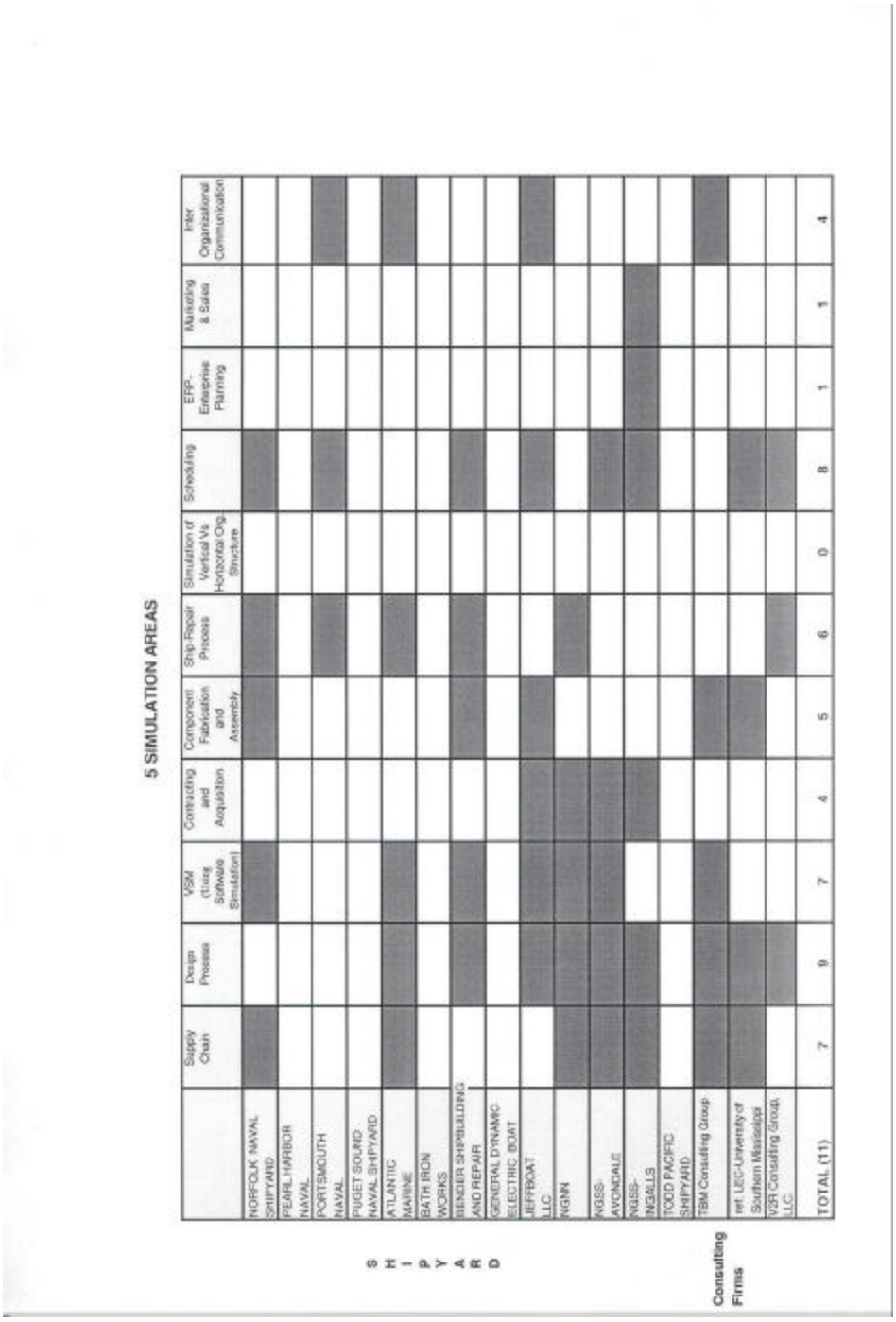
COMPANIES USING VARIOUS SIMULATIONS

PRINCIPLES USED

UNIVERSITIES

	Pull System	Batch Reduction	Plant Layout	Cellular Mfg.	Value Stream Mapping	Setup Reduction	Standardized Work	TPM	POUS	5S	Continuous Improvement	Organizational Structure	Cultural Change	Quality	Leadership	1-Piece Flow	Supply Chain
MIT																	Beer Game Legos
Pennsylvania State University	NIST MEP			NIST MEP	NIST MEP	NIST MEP		NIST MEP		NIST MEP							
University of Michigan	Lean SIM Machine Lego Paper House Factory	Lego		Lego	Paper House Factory						Paper House Factory						
University of Texas-Arlington	NIST MEP			NIST MEP	NIST MEP	NIST MEP		NIST MEP		NIST MEP							
Northwest Arkansas Community College																	
Auburn University- ATN	NIST MEP			NIST MEP	NIST MEP	NIST MEP		NIST MEP		NIST MEP							
University of Dayton	Tube Factory			Tube Factory							Tube Factory					Tube Factory	

Appendix - f



		5 SIMULATION AREAS												
		Supply Chain	Design Process	VSM (Using Software Simulation)	Contracting and Acquisition	Component Fabrication and Assembly	Ship Repair Process	Simulation of Vertical Vs Horizontal Org. Structure	Scheduling	ERP- Enterprise Planning	Marketing & Sales	Inter Organizational Communication
SHIPYARD	NORFOLK NAVAL SHIPYARD	■							■			
	PEARL HARBOR NAVAL											
	PORTSMOUTH NAVAL						■		■			■
	PUGET SOUND NAVAL SHIPYARD											
	ATLANTIC MARINE	■		■			■					■
	BATH IRON WORKS											
	BLENDER SHIPBUILDING AND REPAIR		■	■		■	■		■			
	GENERAL DYNAMIC ELECTRIC BOAT											
	JEFFBOAT LLC		■	■	■	■			■			■
	NGNN	■	■	■	■		■					
	NGSS-AVONDALE	■	■	■	■				■			
	NGSS-INGALLS	■	■		■				■	■	■	
	TODD PACIFIC SHIPYARD											
Consulting Firms	TBM Consulting Group	■	■	■		■						■
	ret. UEC-University of Southern Mississippi	■	■			■			■			
	V3R Consulting Group, LLC		■				■		■			
	TOTAL (11)	7	9	7	4	5	6	0	8	1	1	4