INSTRUCTORS MANUAL FOR

Lean Production for Competitive Advantage: A Comprehensive Guide to Lean Methodologies and Management Practices

by

John Nicholas

CRC Press
Taylor & Francis Group

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TABLE OF CONTENTS

Preface
Suggestions for Using Book
Course Emphasis
Case Studies and Videos

Classroom Simulations
Cellular Manufacturing
Pull Production

End-of-Chapter Questions and Problems:
Level of Difficulty and Suggestions

Chapter 1. Race without a Finish Line
Answers to Questions

Chapter 2. Fundamentals of Continuous Improvement
Answers to Questions
Solutions to Problems

Chapter 3. Value Added and Waste Elimination
Answers to Questions
Solutions to Problems

Chapter 4. Customer Focused Quality
Answers to Questions

Chapter 5. Small Lot Production
Answers to Questions
Solutions to Problems

Chapter 6. Setup-Time Reduction
Answers to Questions
Solutions to Problems

Chapter 7. Maintaining and Improving Equipment
Answers to Questions
Solutions to Problems

Chapter 8. Pull Production Systems
Answers to Questions
Solutions to Problems

Chapter 9. Focused Factories and Group Technology
Answers to Questions
Solutions to Problems

Chapter 10. Workcells and Cellular Manufacturing
Answers to Questions
Solutions to Problems

Chapter 11. Standard Operations
Answers to Questions
Solutions to Problems

Chapter 12. Quality at the Source and Mistake-Proofing
Answers to Questions
Solutions to Problems

Chapter 13. Uniform Flow and Mixed-Model Scheduling
Answers to Questions
Solutions to Problems

Chapter 14. Synchronizing and Balancing the Process
Answers to Questions
Solutions to Problems

Chapter 15. Planning and Control in Pull Production
Answers to Questions
Solutions to Problems

Chapter 16 Lean Production in the Supply Chain
Answers to Questions
Solutions to Problems

PREFACE

This instructor's manual is intended to accompany Lean Production for Competitive Advantage: A Comprehensive Guide to Lean Methodologies and Management Practices. The first sections contain suggestions for using the book, information about outside material for teaching from it, two suggested classroom simulations for demonstrating principles of cellular manufacturing and pull production, respectively, and comments about the end-of chapter questions and problems. The remainder of the manual gives answers and solutions to the end-of-chapter questions and problems.

Several people assisted in the preparation of this, manual. Sosamma Mammen and Boris Pjanic helped prepare answers to questions and solutions to problems for many of the chapters, Justine Woen checked solutions and answers, Birgit Dahlberg helped with proof reading, and Elaine Strnad assisted with typing. I am grateful to all of them. I reviewed and edited everything and prepared the final copy, so I accept responsibility for mistakes and inaccuracies.

John Nicholas

SUGGESTIONS FOR USING BOOK

The author has used **Lean Production for Competitive Advantage: A Comprehensive Guide to Lean Methodologies and Management Practices** as the text for a one-term course in production management for MBA students majoring in operations.

The text is intended for a “second-level” course and assumes that students have completed an introductory course in operations management. The usual audience will be students majoring in operations management, industrial engineering, or manufacturing engineering, although I have had students with background in practically everything—nursing, marketing, advertising, bilogy, computer science, etc.

Course Emphasis

The breadth and depth of topics covered in the book is extensive, and ordinarily it will be not possible to treat all topics equally in a single course. I require students in my course to read all chapters, though my lectures and homework emphasize the following:

Chapter	Greater emphasis	Lessor emphasis
1	X	
Part I		
2	X	
3	X	
4		X
Part II		
5	X	
6	X	
7	X	
8	X	
9	X	
10	X	
11	X	
12	X	
Part III		
13		X
14		X
15		X
16	X	

Part I of the book covers introductory material for continuous improvement, value-added emphasis, and quality management. This is foundation material for the rest of the book.

Chapter 4 gives an overview of quality management concepts, including SPC. In the interest of saving time, portions of this chapter can be skimmed.

Part II covers lean-production concepts at a level beyond that offered in introductory courses. For a course emphasizing JIT and lean production, it provides the core material.

Part III covers lean production systems. Like Part II, these chapters provide core material for a course in lean production , although unless time permits portions of these chapters can de selectively skimmed or skipped at the instructor's discretion. The exception is Chapter 16; this addresses supplier partnerships, a core element in lean production and a topic that should not be skimmed or skipped.

Case Studies and Videos

In addition to assigning questions and problems from the text, I also show video in class and assign case studies for homework and class discussion. Three excellent resources for course material are the Harvard Case Study series, the Association for Manufacturing Excellence (AME) video series, and the Society for Manufacturing Engineers (SME) video series

Following are materials I have used in class and (in parentheses) the corresponding topics and chapters from the book. Some of this material might seem dated, but the concepts are timeless and, unfortunately, I have not found anything better in recent years. If you have been using newer and perhaps better course materials, please tell me about them and I will share them. Here's the material I have been using:

AME video: "On the Road to Manufacturing Excellence" (Introduction to lean and concepts such as benchmarking, concurrent engineering, DFMA, supplier partnerships, and employee involvement – Chapters 1- 4, 12, and 16).

Harvard Case Study 9-686-045, <u>EG & G Sealol (A)</u>, 1987 (Focused factories and workcells – Chapters 9 and 10).

Harvard Case Study 9-684-026, <u>Consolidated Transformer Company (A)</u>, 1983. (SPC, quality policy, and problems of implementing SPC – Chapter 4).

AME Video: "We're Getting Closer." (Employee, customer, and supplier involvement – Chapter 2, 3, and 16)

SME Video: Value Stream Mapping (Chapter 2)

Johnson Controls, Inc. /Pikeville Tennessee case, and Harley Davidson Motor Company case (concepts and tools of lean production – Chapter 3 and Part II.). These two cases are in <u>Managing Productivity and Change</u> by Robert Bell and John Burnham (Cincinnati, OH: South-Western Publishing). This book has many short (but good) case studies and case stories about lean production, however it is currently out-of-print. The authors are at Tennessee Technological University.

As mentioned, another good resource for videotapes is the Society for Manufacturing Engineers (SME). For almost every chapter in this book, there is an SME video on an identical or related topic. For example, SME video topics include DFM, simultaneous (concurrent) engineering, pokayoke, activity-based costing, setup reduction, small-lot production for JIT, managing teams, agile production, TPM, manufacturing workcells, layout for JIT, customer-focused quality, and implementing lean and TQM. For information about SME videos, write to: **Society for Manufacturing Engineers**, One SME drive, P.O. Box 930, Dearborn, MI, 48121-0930.

CLASSROOM SIMULATIONS

Cellular Manufacturing Simulation

This simulation demonstrates how cycle time is computed under different circumstances: 1) one operator in an assembly cell, 2) one operator in an assembly cell who must wait on an automatic machine, 3) two operators, each in a subcell; and 4) two operators, each in a subcell and where one must wait on an automatic machine.

Materials Required

- Child's building materials such as Legos, K'nex, etc. This simulation explained below uses Legos.
- 18 plastic or Styrofoam drinking cups
- Cards to mark the location of the "in" box, the "out" box, two holding areas, and six workstations and number of pieces to be added to the product at each station.
- Two time-keeping devices (watch, clock, cell phone, etc.) that show seconds.

Six or Seven Students Participate in the Simulation

- Two students will be cell operators and assemble the product
- One or two students will serve as suppliers to tear down products and fill parts cups (explained below)
- One student will double as both the customer and material handler, taking finished products from the "out" box, delivering them to the supplier, and returning to the cell with full cups of parts.
- One student will be the "timer." This student must have watch or other time-keeping device showing seconds.
- One student will pretend to be an automatic machine (this student also must have a time-keeping device showing seconds).

The cell is arranged into a U-shape with six workstations and an "in" box at one end and an "out" box at the other. Located at each workstation are two cups, each with the exact number and kind of parts to be added to the product at the station. Also at each station is a "model" to remind the student where the parts should be added to the product and what the product will look like upon completing tasks at the station. Figure 1 shows the arrangement of stations. In the simulation the workstations can be located on two tables, with the operators walking in between.

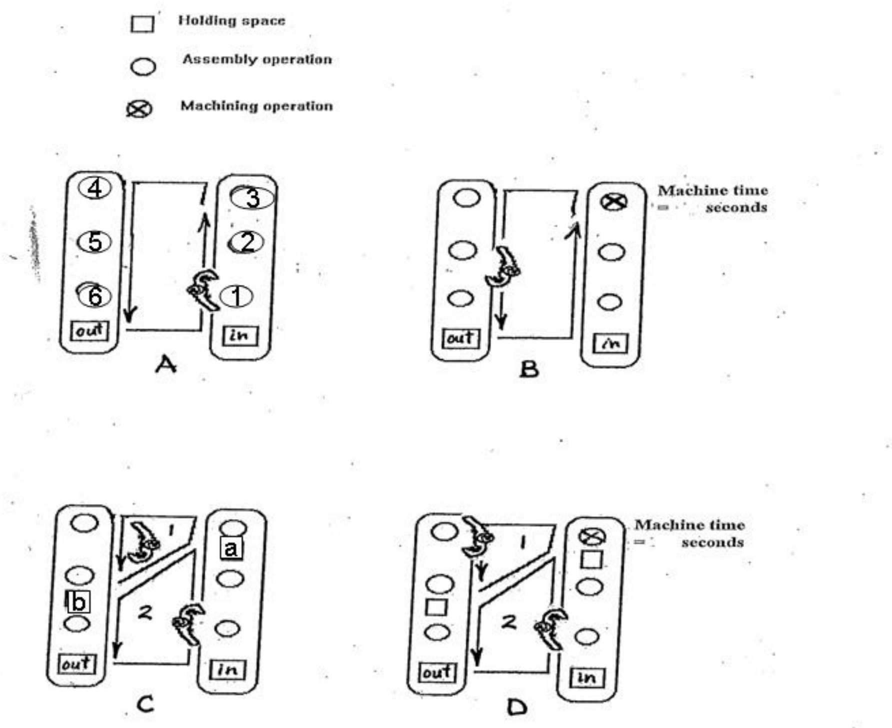


Figure 1

Figures 2 and 3 show photos of the parts to be added and the product's appearance after adding parts at the stations. (This is only a suggestion.) Note, Figures 2 and 3 include holding areas, which are not needed for Simulation A and B.

Located nearby the cell (not shown in Figures 1-3) should be one or two students who serve as the parts suppliers. Products that are taken from the out box are handed to them; the students tear the products down into pieces, and put the pieces into the parts cups. This process of tearing products is necessary to "recycle" parts and ensure enough parts for all the simulations.

At the supplier location are six empty cups and six cups containing the appropriate numbers and kinds of parts. The latter cups *are not to be used*; they are to serve as guides, showing the exact number and kinds of parts that should go into the other six cups that will be delivered to the cell. Full cups delivered to the cell are replaced with empty cups coming from the cell. The "material handler" who doubles as the "customer" takes completed products from the out box, gives them to the suppliers, and returns to the cell with full parts cups. Throughout each simulation the role of the handler is to take products from the out box and to replenish parts to the in box and the cell's six workstations.

Figure 2

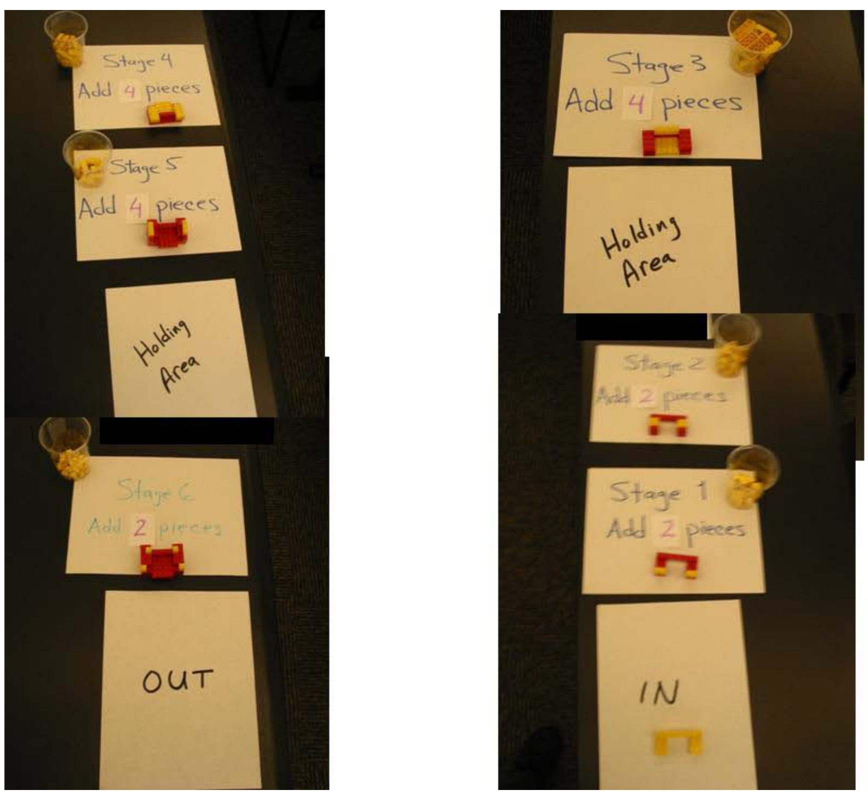


Figure 3

Workcell Simulation A. Computing Cycle Time with One Worker

One student serves as the cell operator and walks around the cell and builds the product. The student takes a product from the in box, adds pieces at each of the six stations, and puts the completed product in the out box. He then goes to the in box, takes another product and repeats the cycle. As described above, another student (the customer/ material handler) takes the completed product from the out box, gives it to the supplier, and delivers full cups of parts from the supplier to the appropriate stations in the cell.

Another student, the "timer," sits near the out box and keeps track of time. The timer determines the time when the simulation should begin, says "go," then notes the time whenever the operator puts a completed product in the outbox. The simulation should run long enough for the operator to complete at least four finished products. The cycle time of the cell is the time between when finished products are put in the out box. Ignore the time for the first product and compute the average of the time for the remaining products.

Following is recommendation for the number of parts to be added at each station:

Station 1	2 parts
Station 2	2 parts
Station 3	4 parts
Station 4	4 parts
Station 5	4 parts
Station 6	2 parts

Workcell Simulation B. Computing Cycle Time with One Worker and an Automatic Machine

This simulation is identical to the first but shows what happens when an automatic machine is inserted in the process, and when the cycle time of the machine exceeds the operator's total walk time and task time. A student pretending to be the machine sits at station 3. The operator does everything he did in the first simulation, except upon completing the assembly task at station 3 he hands the product to the "machine," then takes the product the machine previously held and continues with the assembly tasks at the other stations. (Note, in the first go-round, the machine will not be holding a product for the operator to take; *for this one instance*, the operator should make two products, one to take to the next station, the other to give to the machine.)

Upon being handed the product, the "machine" is "turned on." The student playing the machine notes the time on his watch. Assume the machine must run for 90 seconds. This means the machine will not "give up" the product it is holding until 90 seconds have elapsed. (The time does not have to be 90 seconds; it must, however, be somewhat *longer* than the cycle time computed in the first simulation, above. The purpose of Simulation B is to show that if the machine cycle time is long enough, it, not the operator cycle time from Simulation A, determines the cell cycle time.). The next time the operator arrives at the machine, the operator will have to wait until the machine is finished before he can take the product from the machine, give the machine another product, and move on the next station.

As before, the timer keeps track of each time a completed product is put in the out box. As before, the customer/handler takes products from the out box, gives them to the supplier, and returns with parts for the cell's in box and six assembly stations. Again, the simulation should run long enough for the operator to complete at least four finished products. The cycle time of the cell is the time between when finished products are put in the out box. Ignore the time for the first product and compute the average of the time for the remaining products.

Workcell Simulation C. Computing Cycle Time with Two Subcells

The six workstations are divided between two subcells with two holding areas between them as shown in Figure 1c and 1d, and Figures 2 and 3. Two students serve as operators, one for each subcell. Shown in Figure 1c and 1d, operator 2 picks up a product at the in box, adds parts at stations 1 and 2, then puts the product into holding area a. He then goes to holding area b, takes the product from there, adds parts at station 6, puts the finished product in the out box, and goes to the inbox and repeats. When operator 1 arrives at holding area a, he takes a product from there, adds pieces at stations 3-5, then puts the product in holding area b. If ever an operator arrives at a holding area that is empty, he must wait until the other operator deposits a product there.

The students acting as timer, customer/material handler, and supplier perform as before. Again, the simulation should run long enough for the operator to complete at least four finished products. The cycle time of the cell is the time between when finished products are put in the out box. Ignore the time for the first product and compute the average time for the remaining products.

Note: the assembly tasks in the workcells should be "rigged" so that operator 1 will take much longer than operator 2. In the recommendation above, operator 2 adds a total of 6 parts to the products, operator 1 adds a total of 12. As a result, every time operator 2 arrives at holding area he will have to wait for operator 1. Thus, the times when a finished product are put in the out box and, hence, the cell cycle time are determined by operator 1.

Workcell Simulation D. Computing Cycle Time with Subcells and an Automatic Machine

In this simulation everything is the same as in Simulation C except that located at station 3 is an automatic machine, which performs the same way as in simulation B. Thus, a student pretending to be the machine should sit at that station and, as in Simulation B, every time the operator hands him a product, must hold it for 90 seconds before giving it up the next time the operator comes around. Since the machine time takes longer than the cycle time as computed in simulation C the cycle time of the cell will be determined by the machine, which takes longer than the task and walk time of either operator 1 or 2.

Discussion

All the simulations should be followed with discussions about the results, lessons learned, and how the workstations, tasks, or number of workers might be altered or reconfigured to modify the cycle time.

Pull Production Simulation

This simulation demonstrates the pull production process and the ability of the process to respond to demand depending on buffer size and process cycle time.

Materials Required

- Child's building materials such as Legos, K'nex, etc. This simulation explained below uses K'nex.
- 20 plastic or Styrofoam drinking cups
- Timing device (clock, watch, etc)

Six or Seven Students Participate in the Simulation

- Four students will be line operators and assemble the product
- One or two students will serve as suppliers to tear down products and fill parts cups (explained below)
- One student will double as the customer and material handler, taking finished products from the "out" box, delivering them to the supplier, and returning to the cell with full cups of parts.
- One student to serve as timer in Pull Simulation C.

The process consists of four stages (workstations) arranged in a line. In between each pair of workstations and at the end of the line is a buffer. Located at each workstation are two cups, each with the exact number and kind of parts to be added to the product at that station. Also at the station is a "model" to remind the student where the parts should be added to the product and what the product will look like upon completing tasks at the station. Figure 4 shows the arrangement of stations and locations of WIP and finished goods (FG) buffers. Figures 5 and 6 show the actual K'nex pieces and WIP items ("To Customer" is the finished goods buffer).

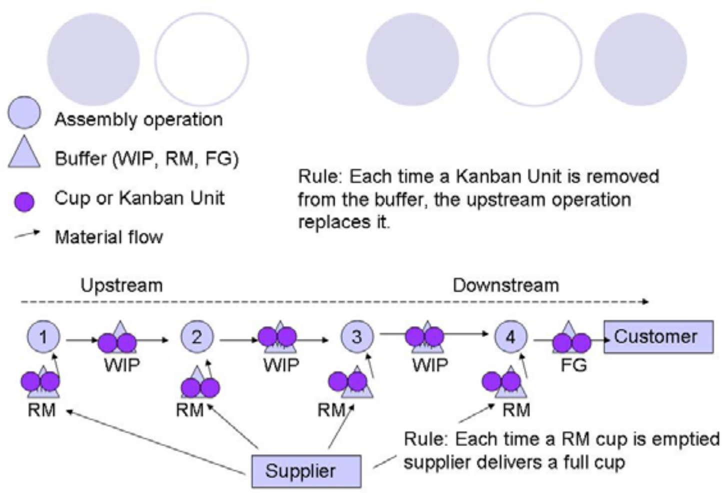


Figure 4

Figure 5.

Figure 6

Located near the line are one or two students who serve as the parts supplier. As in the workcell simulations, products taken from the FG (finished goods or To Customer) buffer are handed to these students, who tear them down into pieces and put the pieces into the parts cups. The process of tearing products is necessary to “recycle” parts and ensure enough parts for all the simulations.

At the supplier location are four empty cups and four cups containing the appropriate numbers and kinds of parts. The latter cups *are not to be used*; they are to serve as guides, showing the exact number and kinds of parts that should go into the six cups that will be delivered to the cell. A “material handler” who doubles as the “customer” takes completed products from the FG buffer, gives them to the supplier, and returns to the line with full parts cups. Throughout each simulation the role of the handler is to replenish parts in the parts cups at the line’s four workstations.

In the suggested simulation, the *buffer size* is two; thus, in between each pair of workstations are two units of WIP (partially completed products), at the FG buffer are two fully-completed products, and at every workstation are two cups of parts. Whenever the buffer anywhere drops to one unit or one cup, that signals the need to replenish the buffer or cup. This is represented in Figure 7.

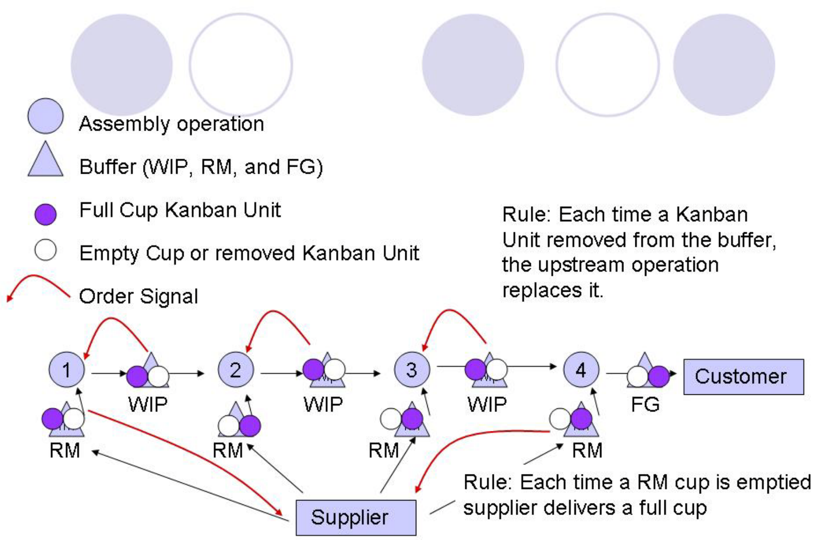


Figure 7.

Pull Simulation A: Demonstrating the Pull Production Process

The simulation begins by the customer/material handler taking one of the finished products from the FG buffer. The FG buffer then has only one unit, which signals workstation 4 to replenish it. The operator at workstation 4 takes one unit from the WIP buffer to his right (assume operators are facing *toward* the suppliers in Figure 7) and parts from one of the part cups to replenish the FG buffer. Since the WIP buffer then has only one unit, that signals workstation 3 to replenish it. The operator at workstation 3 takes one unit from the buffer to his right and parts from one of the part cups to replenish the buffer to his left. The process is the same for workstations 2 and 1. Every workstation replenishes the missing unit from the WIP buffer.

Whenever the number of full parts cups (RM buffer) drops to one, that signals the material handler to replenish it with a full cup from the supplier. (As described, the students who serve as the suppliers are filling cups with parts from torn down products delivered by the material handler.)

Pull Simulation B: Demonstrating Limitations of Pull Production Imposed by Buffer Size

The purpose of this simulation is to show that demand in the pull production process must be somewhat uniform, and that the ability of the system to respond to small demand variations is limited by the buffer size.

This simulation begins by the material handler taking *two* of the finished products from the FG buffer. Since the FG buffer is then zero, that signals workstation 4 to replenish *two* units. The operator at workstation 4 takes two unit from the WIP buffer to his right (again, assume operators are facing *toward* the suppliers in Figure 5) and parts from both parts cups to replenish the FG buffer. The WIP buffer on the right then has zero units, which signals workstation 3 to replenish it. The operator at workstation 3 takes two unit from the buffer to his right and parts from both parts cups to replenish the buffer to his left. The process is the same for workstations 2 and 1. Every workstation replenishes the two missing units from the buffer.

Meantime, the material handler is busy replenishing two parts cups at every workstation and the suppliers are busy filling the cups.

Because the entire system has two units of buffer, it is able in short time to respond to the increased demand of two units.

For another simulation, suppose demand increases to *three* units. As the simulation demonstrates, the whole system then gets bogged down. Only two units are available at FG, which means the customer has to wait for the third. As soon as the additional unit arrives at FG, it is immediately taken by the customer. Since the FG buffer is now down to zero again, that signals workstation 4 to replenish it with two more units. The same thing occurs upstream at all the workstations and at the suppliers. The entire process takes awhile to get caught up.

Pull Simulation C: Pull Production and Cycle Time

For this simulation select a student to time the process. The student must have a watch or other time-keeping device showing seconds. Before starting the simulation, measure the length of time it takes for each operator to perform the assembly tasks. Suppose the time of the *slowest* operator is 30 seconds. This says that the cycle time of the process is 30 seconds/unit and that the average demand rate for the process should not exceed two units per minutes (30 seconds per unit).

The simulation starts when the timer says “go.” At this time the customer/ material handler withdraws a product from the FG buffer. About 28 seconds later the timer tells the material handler to withdraw another unit from the FG buffer. About 35 seconds later the timer tell the customer to withdrawn another unit. The same happens after another 29, 34, 32, 29, etc. seconds. The simulation should show that long as the withdrawal interval, the takt time (30 sec/unit), for the average demand does not exceed the cycle time of the process, the process can easily meet demand.

The simulation is now repeated, beginning when the timer says “go.” But this time the timer instructs the material handler to withdraw a unit from FG buffer after 20, 22, 24, 19, etc. seconds to illustrate what happens when the takt time is *less than* the cycle time. As the simulation will show, the process falls behind and is never able to catch up with demand.

Pull Simulation D: Pull Production with Process Steps Located Far Apart

As another variation, workstation 1 through 4 can be located in various positions throughout the room. The purpose of this simulation is to show that the pull production process also works when stations of the process are not located near each other. Note, however, that if the stations are located far enough away, then the buffer sizes between station and at stations might have to be increased and/or the cycle time of the process must be decrease, depending on the demand rate..

Discussion

All the simulations should be followed with discussions about the results, lessons learned, and how the process tasks, buffers, etc., might be modified to accommodate changes in takt time.

End-of-Chapter Questions and Problems: Level of Difficulty

Most end-of-chapter questions and problems can be easily answered by reading the chapter and working through the example problems. Some of the questions and problems, however, are more challenging and require conceptualization, literature research, personal experience, or consideration of specific applications not discussed in the book. These questions and problems are denoted in the answers below with an asterisk (*).

Instructors should consider using some of these more-difficult questions and problems as part of the lecture material. The answers provided will allow the instructor to discuss problems, concepts, issues, and applications that go beyond the book.

Some of these more-difficult questions and problems can be used to illustrate and expand upon topics covered in the book, and some can be used to suggest topics and analysis methods not covered in the book.

Chapter 1
Race without a Finish Line

Answers to Questions

1. Competitive advantage is achieved through lower production *cost*, higher *quality*, faster *delivery*, and increased production *agility*. Lower production cost results in lower prices or higher profit margins, or both. Higher quality means consistently being able to meet or exceed customer requirements. Faster delivery means products are delivered within promised due dates and in less time than competitor's products. Agility means the ability to rapidly adjust production capabilities to meet shifting market demand and changing consumer preferences.

2. *Delivery time* is the time required to deliver a product or service to a customer; it is the time to fill a customer order. *Time to market* is the time required to develop a product from concept and to launch it into the marketplace for the first time.

3. *Lean Production* relies on continuous efforts at elimination of waste as the principle means to continuously improve the cost, quality, lead time, and agility of processes.

4. The *production pipeline* represents the flow of materials through a company from start to finish. The goal of lean production is to maximize quality and minimize the cost and throughput flow time of materials in the pipeline.

5. Lean organizations focus on eliminating waste, continuously improving products and processes, and fulfilling and exceeding customer requirements. In lean organizations improvement is a never-ending process that involves every employee in suggestions and implementing improvements. Lean production uses inventory reduction as a method for identifying sources of waste, costs, and inefficiency.

6. *Craft production* relies on high-level manual skills, workmanship, experience, and hand tools to produce products one by one. Craft of production was dominant in the 19th century and earlier.

7. In *mass production*, interchangeable parts are assembled by workers located at various stations along a moving assembly line. Each worker performs only one or a few tasks, and the work rate is paced by the speed of the line. Everything necessary to support the effort of the line workers (machine maintenance and setup, quality control, material replenishment, etc.) is handled by specialists.

8. Henry Ford narrowed and specialized the tasks of each worker as a way to increase efficiency. Initially, workers assembled an entire car at one location; then workers were given more specialized tasks, and each worker walked from car to car, performing only a few tasks on each. Ford then switched to a moving assembly line to eliminate time wasted by workers

walking and slower workers holding up faster workers. The combination of the moving line, specialized workers, and interchangeable parts later became known as Ford's *mass production system*.

9. Eiji Toyoda considered the Ford production system unworkable in Japan. The Japanese market was tiny and demanded a wide range of cars. Therefore, Toyoda wanted to make a variety of cars in one plant, whereas in US plants only one type of car could be produced. Also, Toyoda did not have the capital to spend on high-speed, specialized equipment as was common in US plants. He also realized that he could not treat workers the way they were treated in the US because company unions were very strong in Japan. Also, traditionally, Japanese workers had higher-level skills and were given greater responsibility for decision-making than their US counterparts. Because of these constraints, Toyoda and Taiichi Ohno had to develop a system that could produce a greater variety of products and make better use of equipment and shop-floor labor skills, and do it in a much less wasteful manner than the Ford system.

10. The principles of the Toyota Production System include reduced setup times, small lot production, employee involvement and empowerment, quality at the source, equipment maintenance, pull production, and supplier involvement. The system reduces or eliminates many of the wastes of mass production.

11. While the US concentrated on hiring professionals with skills in business systems, systems analysis, and finance (but no knowledge about production and markets), and the best US scientific brainpower went into aerospace, nuclear energy, defense, etc., Japan focused on hiring people with manufacturing engineering, product and process improvement experience, and focused on improvements in such "mundane" industries as steel and automobiles. US companies neglected shop floor work, paid little attention to the needs of manufacturing people, and hired financial managers as presidents and CEOs. Meanwhile in Japan, manufacturing was gaining higher prestige than in the US, and the presidents and boards of directors of manufacturing companies were populated with people knowledgeable about production. Slowly, Japanese producers began taking away market share from US manufacturers.

12. The emphasis in craft production is on skilled craftsmanship. Production and quality go hand in hand: the person producing the product is also responsible for judging and insuring its quality.

13. The concept of interchangeability of parts is based on making parts in large quantities such that any one part would satisfy the design tolerance and could be fit into an assembled product. All parts had to conform to a single standard, even parts produced by different manufacturers. The concept of the interchangeable part helped lead the transformation from hand labor to a division of labor and mechanization.

14. Overseas corporations, starting principally with the Japanese, had better quality and paid more attention to customer requirements. In manufacturing, they paid more attention to process

engineering and to higher reliability and durability of manufactured products.

15. Some of the barriers to improving competition are culture-based. Japan has a strong group-oriented society, whereas Western society is more individualistic and pluralistic. Relations between labor and management in the US have not traditionally been very cordial; managers and staff have been considered the *thinkers*, while shop floor workers the *doers*. Lean production requires shifting a greater share of the responsibility for decision-making to shop-floor workers; this not something everyone (managers, professional staff, or the workers themselves) are willing to accept.

16. *Employee involvement* implies the involvement of all employees in matters important to their jobs and to the well being of the company. *Employee empowerment* is empowering employees to make decisions to improve aspects of their jobs, processes, and the company. Empowerment is often considered radical because, historically, it has never been part of US corporate thinking to allow employees to participate with management in making decisions.

Chapter 2
Fundamentals of Continuous Improvement

Answers to Questions

1. *Change* is essential for business organizations because survival depends on how well an organization can adapt to the changing demands and requirements imposed by customers and competitors. Organizations must continuously improve their products and services to meet or exceed customer expectations, and improve their processes to meet or exceed the cost, quality, and delivery speed of competitors.

2. *Incremental improvement* is represented by an S-shaped curve, while innovation improvement is represented by the jump from one S-curve to another, higher-level curve. Incremental improvement is based on the concept of kaizen**,** that is, of small incremental improvement steps. In contrast, *innovation improvement* happens when one technology is replaced by a different technology that is not subject to the same physical, technological, or organizational constraints as the original technology. The new technology represents a quantum leap beyond the old technology.

3. The concept of the *S-curve* represents continuous improvement through small, incremental steps. When a process or technology is new, incremental improvement is at first slow and much effort is required to make small gains. As more knowledge about the technology is gained, less effort is required to achieve big improvements. Over the long term the accumulated series of gains may result in significant improvement. Eventually, however, as the technology or process approaches its technological or physical limits, further improvement becomes difficult and costly.

*4. An example mentioned in the chapter kaizen leading to competitive advantage is LCD technology at RCA and Sharp. RCA developed the technology, but did not bother to refine it. After RCA sold its LCD patents, Sharp initially devoted $200 million to development LCD technology for application in hand-held calculators. It then invested another $1 billion to refine the technology. Today this technology is everywhere, in watches, industrial gauges, clocks, portable TVS, computers and automobile dashboards.

Similarly, process technologies have been improved through kaizen at all major automobile manufacturers. Toyota improved and is still improving its production system in such a manner that today its cost and time to produce cars are the lowest in the industry. Toyota made the first significant improvements to shop-floor systems, and other auto makers were forced to play catch up.

Other examples of kaizen to improve or upgrade existing systems include:

- Replacing hand soldering of circuit board with wave soldering (soldering using a wave of molten solder).
- Replacing rotary telephones with push button telephones.

- Replacing manual film advance, focusing, and aperture setting in hand-held cameras with automatic advance, focusing, and exposure.
- Replacing manual transmissions in automobiles with automatic transmissions (most motor-assisted features in cars are kaizen improvements of earlier manual features—window and door lock mechanisms, seat and rear-view mirror adjustments, etc.).
- Improving automobile engines so they require a tune-up only once every 100,000 miles (instead of every 12,000 miles).
- Improving PC microprocessors so they are ever smaller and faster.
- Replacing metal components in products with plastic components that do not rust or dent (while this application represents incremental improvement, often the process of creating and incorporating these components into existing systems requires genuine innovation improvement).

*5. One example of innovation improvement in product technology mentioned in the chapter is development of jet engine technology, which subsequently became the dominant propulsion technology in military and commercial aircraft—largely replacing propeller technology.

Other examples of new technology that eclipsed old technology are:
- The backward-first Flopsbury flop replaced the sidelong technique of high jumping.
- Steam technology replaced wind technology in transoceanic shipping.
- The iron horse replaced the stage coach as the primary mode of intercontinental transportation.
- The telegraph replaced the Pony Express.
- Laser-jet technology replaced dot matrix technology in computer printers.
- Steel superstructure construction replaced traditional load-bearing walls in construction of high-rise buildings.
- Magnetic cards replaced traditional keys for door locks in hotel rooms.
- Digital camera replaced film cameras.
- Word processors replaced typewriters.
- Stealth technology replaced electronic jamming of radar (in one sense, stealth is an incremental improvement in aircraft and ship design, yet in another sense, it is a true innovation because it largely renders conventional radar technology useless).
- Tapes replaced records.
- CDs replaced tapes.
- MP3s replaced CDs.
- Disposable diapers replaced cloth diapers.
- Electronic systems that replaced mechanical systems (examples: cash registers and control systems)
- Electronic photocopying replaced carbon paper and the ditto machines.
- Nautilus equipment replaced free weights and pulleys.

6. The theory behind frontline worker participation in continuous improvement is that workers are sometimes in the best position to notice places needing improvement and to originate

improvement ideas. They are also often able to implement improvements more quickly and efficiently than if specialists were involved. For ideas that are more technologically complex and costly to implement, workers are encouraged to prepare proposals and seek assistance from specialists. Often, however, workers implement improvements themselves without assistance or approval from managers.

7. The PDCA cycle is a structured way to apply the process of perceiving and thinking about problems and solution. It is characterized by four steps, which, in terms of continuous improvement, should be thought of as steps in a continuous cycle that has no start or finish. The four steps are the **plan step**, the **do step**, the **check step**, and the **act step**.

- The *plan* step includes the four substeps of collecting data, defining the problem, stating the goal, and solving the problem.
- The *do* step is the implementation of the plan.
- The *check* step involves collection and analysis of data about the effects of the implemented plan.
- The *act* step represents follow-up actions based upon results from the check step.

8. Toyota employees are conditioned to ask why five times whenever confronted with a problem. This procedure assures that the root causes of a problem are identified and corrected, not merely the symptoms or superficial causes.

9. Value analysis and value engineering are techniques for assessing the value content of the elements of a product or a process. Value is based on the perception of the customer; it is the worth of something and how much customers are willing to pay for it. *Value analysis* refers to analysis of existing processes and it is a tool of continuous improvement. *Value engineering* refers to the first-time design and engineering of a product or process.

10. *Reengineering* refers to the rethinking and redesigning of business processes in order to achieve improvements in cost, quality, service and speed. Reengineering is best represented as innovation improvements, or the leap from one S-curve to another. It is a planned change to achieve innovation improvement and is the counterpart to kaizen.

11. A kaizen event focuses on a particular process, its problems and wastes. The event is conducted by a team facilitated by an expert (person experienced in lean production and team facilitation), led by the process owner (supervisor or manager who oversees the process), and include people who work in and are knowledgeable about the process. In addition to attacking problems and wastes in the process, a purpose of the event is to demonstrate and teach lean principles and methods. The event begins with a kick-off meeting, starting with a presentation about the focus and scope of the project, and a review of lean concepts and analysis methodology. The kaizen team sets measurable targets and decides on the data it needs to analyze the process. After a tour of the physical facility of the process, the team discusses its findings and creates a map out the process. Over the next few days, the team collects more data and meets several

more meetings, during which it create a more authentic, detailed map of the process. It identified areas of waste on the map, developed improvement plans, and set about immediately to begin implementing the changes.

12. The seven problem solving tools include the check sheet, histogram, Pareto analysis, scatter diagram, process flowchart, cause-and-effect analysis and the run diagram.

- The *check sheet* is a special sheet created for recording data from observations.
- The *histogram* is a graphical method for showing the frequency distribution (number of occurrences) of a variable.
- *Pareto analysis* is a tool for separating the vital few problems from the trivial many problems.
- A *scatter diagram* is a tool for revealing the potential relationship between two variables.
- A *process flowchart* shows the relevant steps in a procedure or process, and the role they play in the process.
- *Cause-and-effect analysis* is a method for listing possible causes (sources) of a given effect (problem).
- A *run diagram* is a continuous plot of results versus time for the purpose of revealing abnormalities or patterns.

13. Value stream mapping (VSM) is a flowcharting methodology that uses standard icons and diagramming principles to visually display the steps in the process and the material and information flowing through it, start to finish. The methodology focuses on the value stream, which is the sequence of all activities, both value-added and nonvalue-added, in the creation of a particular product or service. VSM starts with data collection and creating a map for the current process. That map, the current state map, is used to stimulate conjecture about opportunities for improvement and how the process *ought* to look, and to create an ideal or future state map.

14. After a problem solver has prepared a plan, he seeks consensus from everyone involved with or affected by the plan to help ensure that not only have the necessary perspectives been considered, but that the plan can be readily implemented. For example, senior-level managers pass a plan or goal to the managers below them, who translate it into a plan at their level, which they toss back to the managers above them and ask “is this what you intended?” Then senior managers modify their goal or plan to accommodate the subordinates’ plans. The process goes back and forth until both sides reach consensus. Next, the middle managers toss their plans to lower level managers, and the process repeats.
Nemawashi refers to the process of circulating a plan or proposal among affected parties to gain consensus or approval. The proposal is passed back and forth among parties and modified to incorporate their suggestions and opinions. The final formal approval is then merely a formality because consensus will have been achieved and approval tacitly conveyed.

15. A3 is the designation for a standard 11” x 17” sheet of paper commonly used in Japan. The format for every A3 is somewhat standardized, with topics listed in logical order. The

typical A3 report includes data charts, value stream maps, and fishbone and Pareto diagrams, and so on.

A3 reports can be used in a variety of ways, the three most common being for problem-solving, presenting a proposal, and describing the status of a plan, problem, or issue. Each of these kinds of reports corresponds to different steps of the PDCA cycle:

- A problem-solving A3 is written after the Plan, Do, and Check steps are completed (although it must be *started* much earlier).
- A proposal A3 is written during the Plan step but before starting the Do step.
- A status A3 is written during and after completing the Check and Act steps.

Solutions to Problems

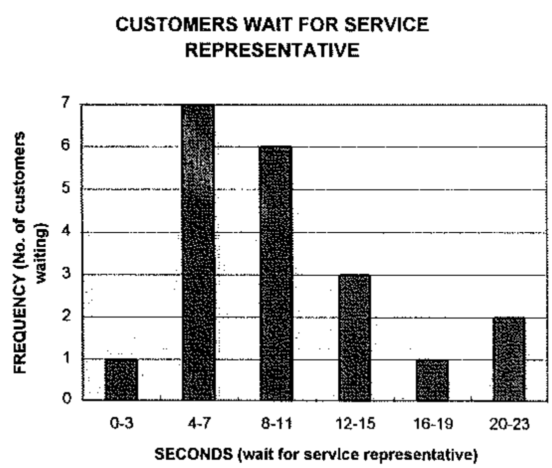
*1. The answer to this problem is somewhat open-ended. The purpose of the problem is to stimulate discussion.

One obvious question the listing of the costs raises, is, why are the overhead and administrative costs so high? To achieve big savings, a good place to begin is with the sources of the biggest costs. In the past, sources of costs associated with high overhead were ignored in cost reduction efforts, though now more companies are starting to seriously look at them. In fact, the thrust of many process reengineering programs is to improve the effectiveness and reduce costs of activities commonly labeled as overhead. Since material is the other major cost factor listed, cost reduction efforts should focus there too.

Although productivity efforts commonly focus on the shop floor and on direct labor, in the case shown even substantial cost savings in labor and processes might have relatively small effect on overall costs.

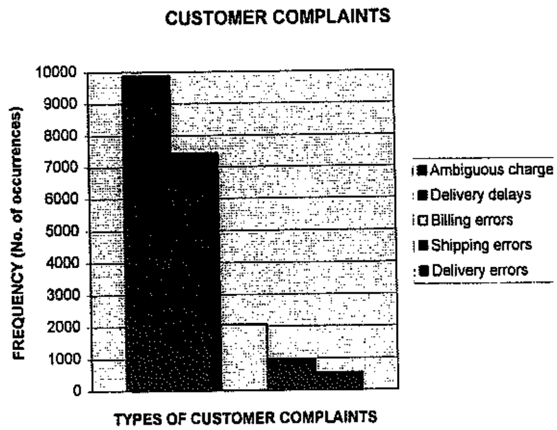
2. The histogram indicates that most customers wait 4-7 seconds.

Interval	Frequency
0-3	1
4-7	7
8-11	6
12-15	3
16-19	1
20-23	2



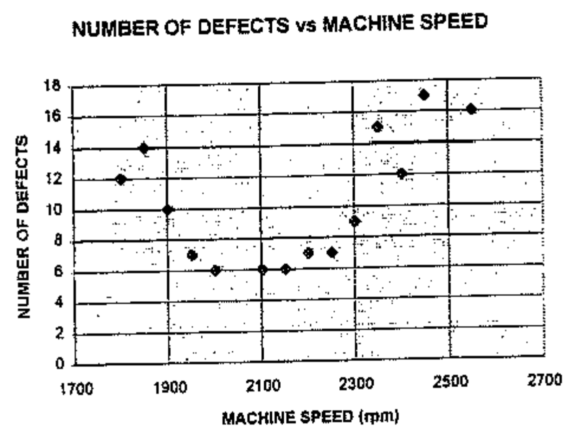
3. The histogram indicates that most complaints are for ambiguous charges. To reduce complaints this area should be addressed first.

Type of Defect	Frequency	% of Defects
Ambiguous charges	9880	47%
Delivery delays	7430	36%
Billing errors	2070	10%
Shipping errors	966	5%
Delivery errors	540	3%
	20886	100%



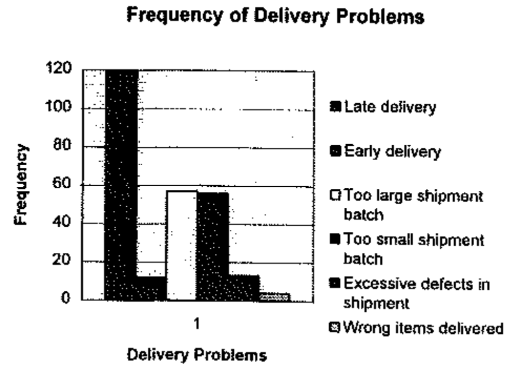
4. The pattern indicates that the number of defects decreases with increasing machine speed until approximately 2200 rpm, after which it increases. Further investigation is necessary to determine if machine speed is the cause of this defect pattern.

Machine Speed (rpm)	No. of defects
1800	12
1850	14
1900	10
1950	7
2000	6
2100	6
2150	6
2200	7
2250	7
2300	9
2350	15
2400	12
2450	17
2550	16



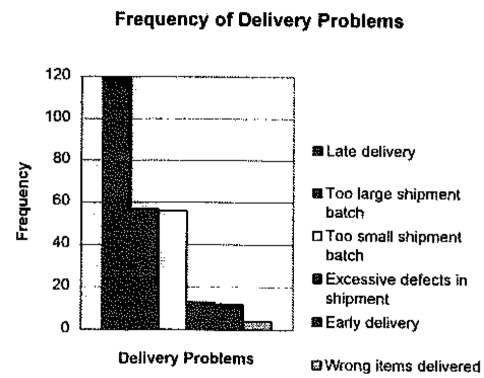
5.a.

Delivery Problem	Frequency
Late delivery	120
Early delivery	12
Too large shipment batch	57
Too small shipment batch	56
Excessive defects in shipment	13
Wrong items delivered	4



b.

Delivery Problem	Frequency
Late delivery	120
Too large shipment batch	57
Too small shipment batch	56
Excessive defects in shipment	13
Early delivery	12
Wrong items delivered	4

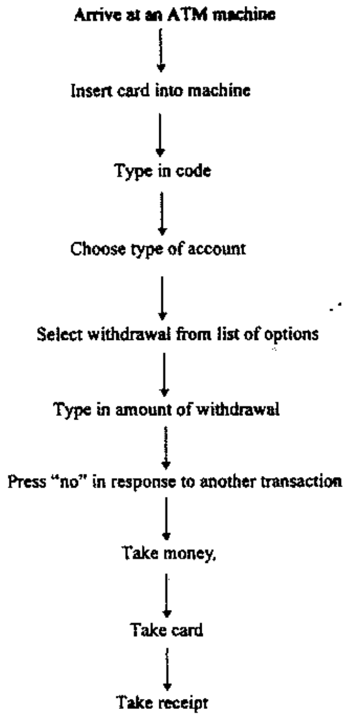


c. The sum of the delivery problems, 262, is greater than the number of deliveries, 204, because some deliveries have more than one problem. The tally sheet should be modified to permit tallying of multiple, simultaneous problems on a single delivery (e.g., too-large shipment batch *and* excessive defects in the delivery).

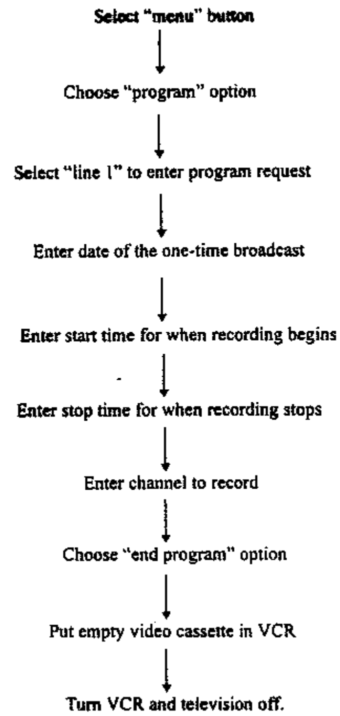
d. To find solutions to the delivery problems, begin by looking closely at the delivery process, which includes the processes of preparing shipping bills, scheduling the deliveries, and all material handling prior to delivery. A process flow diagram would be constructed and analyzed to suggest places in the process where problems originate, and data would be collected at these places using tally sheets. Cause-and-effect diagrams would also be used to identify other possible causes of problems, and the places in the process where data should be gathered. Data would then be analyzed using Pareto analysis, scatter diagrams, and so on.

*6.

a. Withdrawing money from an ATM machine.



b. Programming a VCR to record a one-time broadcast.



c. Depends on your level of experience in downhill skiing.

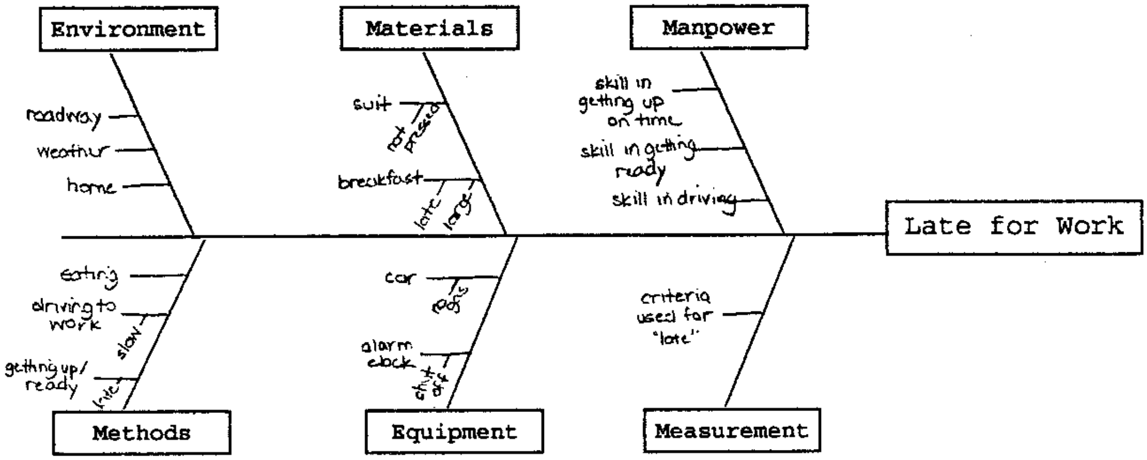
d. Depends on your experience and imagination.

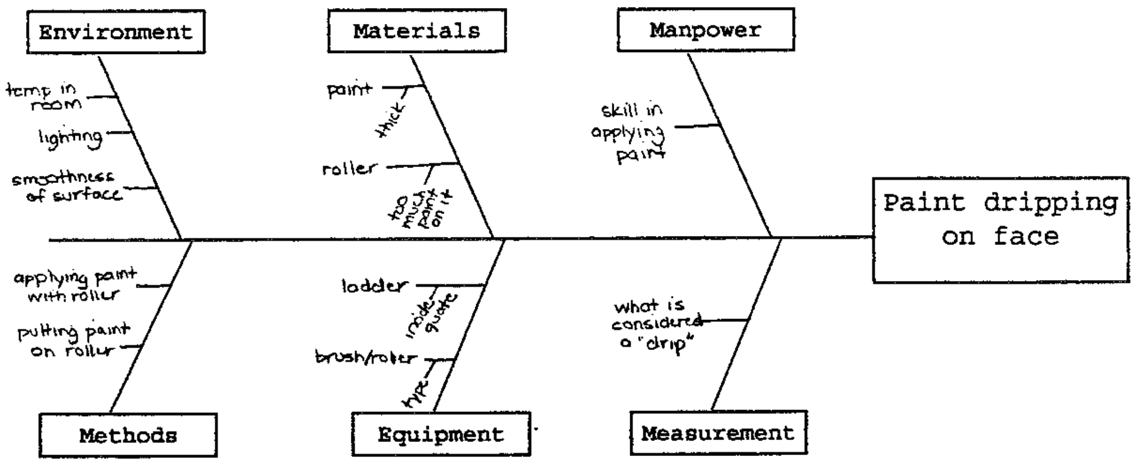
*7. Try to eliminate the steps that do not add value to the process. For example, for (a) and (b):

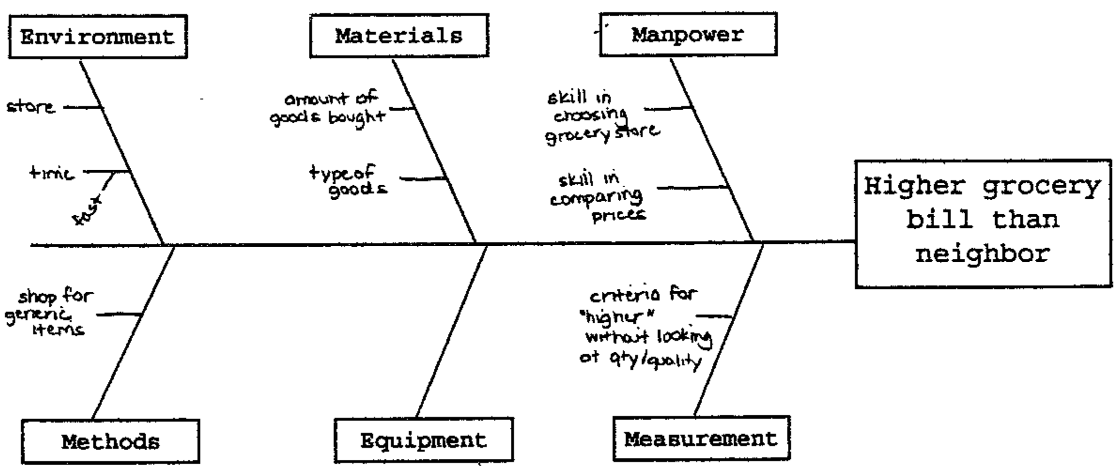
a. Select fewer buttons on the ATM. However, since all the buttons currently used are necessary, this would not result in improvement. Technology improvements might eventually lead to direct access to cash at home and eliminate the need to travel to an ATM machine. (For example, a dollar amount could be encoded on a credit card by a device attached to a home computer. This, of course, replaces one process with another that is possibly no less complicated, but it does eliminate the need to go the cash station.)

b. The user should be able to go directly to the "program" option (and eliminate the select "menu" button step). The user should also be able to directly enter the date of the program (and eliminate the select "line 1" to enter the program request). The steps for entering the date, start time, stop time and channel for a program could be eliminated by the simply entering the code specified for each program in the TV listings. These codes are unique for each program.

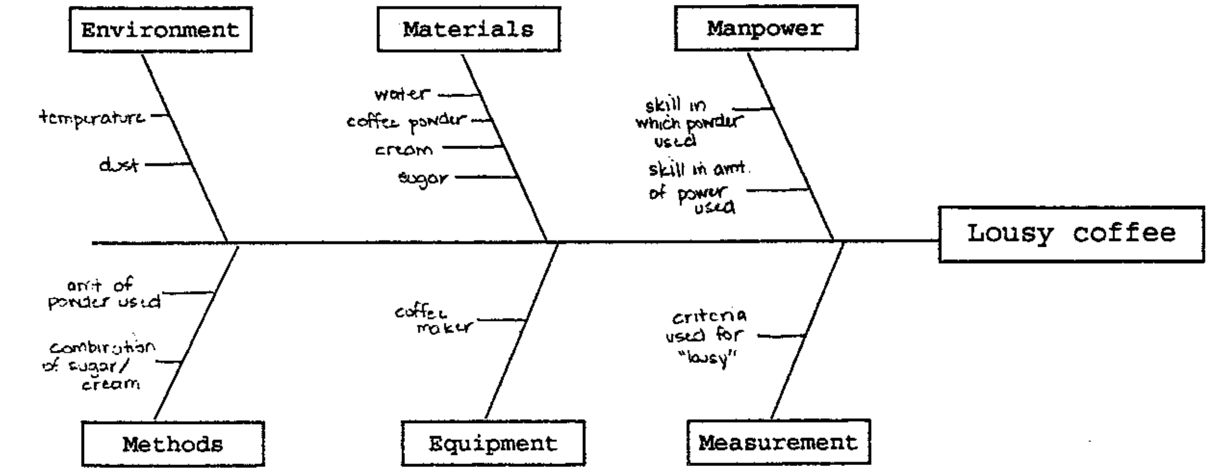
*8.a.

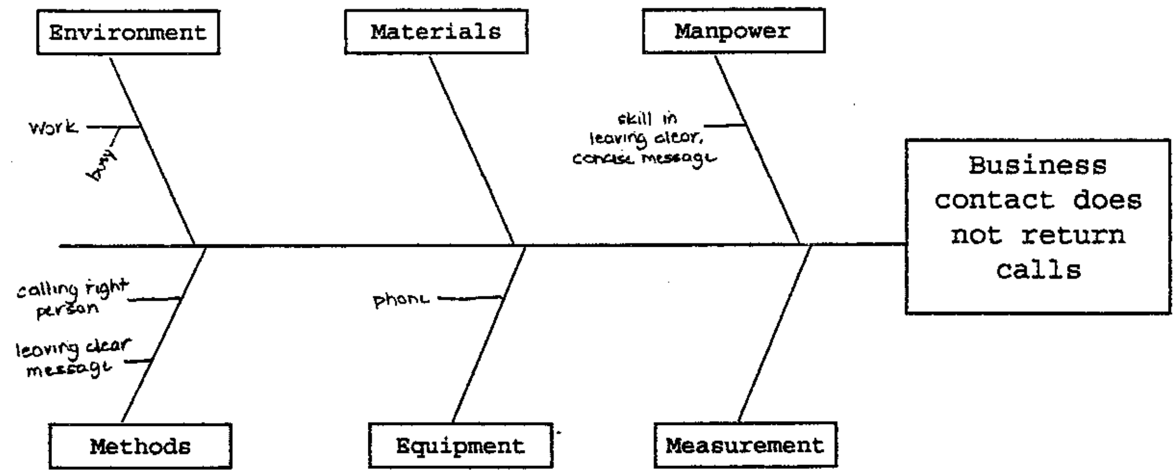

Environment
Materials
Manpower
roadway
weather
home
suit
not pressed
breakfast
late
large
skill in getting up on time
skill in getting ready
skill in driving
Late for Work
eating
driving to work
slow
getting up/ ready
late
car
alarm clock
criteria used for "late"
Methods
Equipment
Measurement

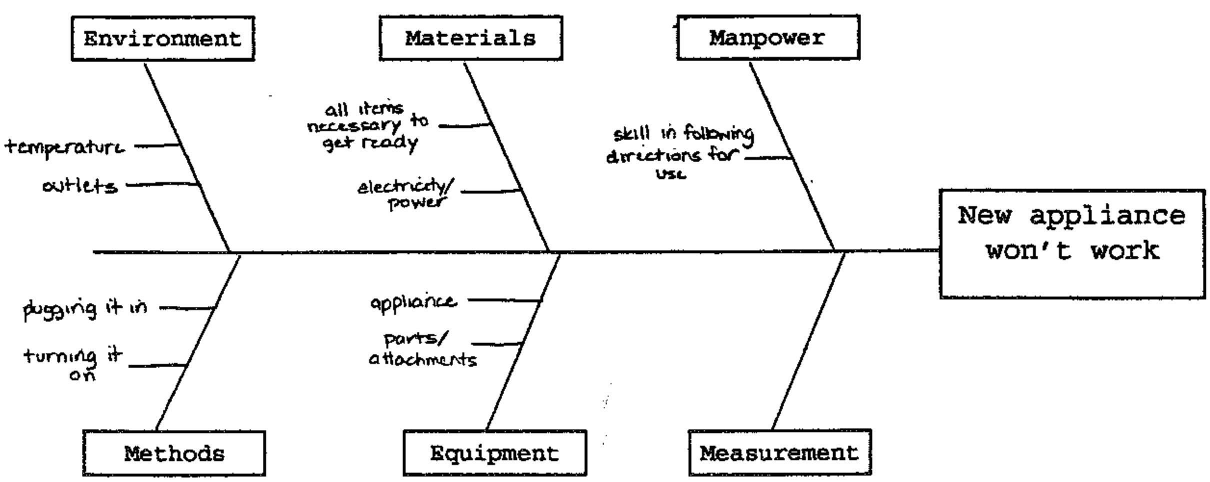

Environment
Materials
Manpower
temp in room
lighting
smoothness of surface
paint
thick
roller
too much paint on it
skill in applying paint
Paint dripping on face
applying paint with roller
putting paint on roller
ladder
inside quote
brush/roller
type
what is considered a "drip"
Methods
Equipment
Measurement


Environment
Materials
Manpower
store
time
fast
amount of goods bought
type of goods
skill in choosing grocery store
skill in comparing prices
Higher grocery bill than neighbor
shop for generic items
criteria for "higher" without looking at qty/quality
Methods
Equipment
Measurement

*8.a. (continued)







b. Various answers. Some examples follow.

Late for work: Check to see if you are getting up on time (do you hit snooze or shut off the alarm clock to sleep longer).

Paint dripping on face: Check to see if you have too much paint initially on the roller, which causes you to put too much on the ceiling.

Higher grocery bill than neighbor: Check to see the quantity of items bought and from where they were bought.

Lousy coffee: Try another brand and see what happens.

Business contact not returning calls: Check to see if she has gotten your messages (make inquiries on fax or e-mail).

New appliance won't work: Check to see if it is plugged in, is turned on, and you have followed all the directions.

*9. Various answers.

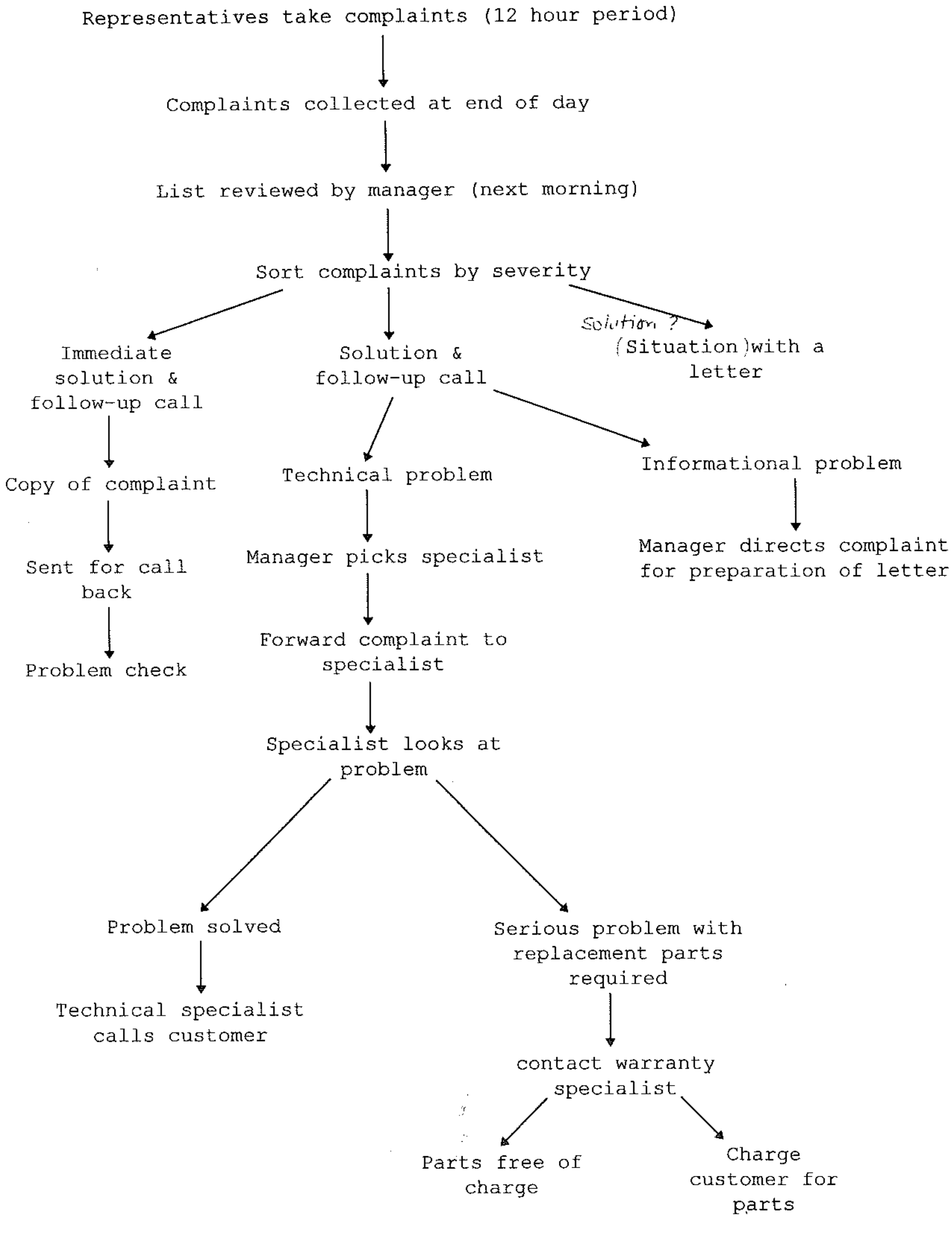
*10.a. This process is complex (and ambiguous) enough to cause different interpretations. The assignment will lead students to develop different-looking flow charts. It raises the important point of being very precise when defining a process for purposes of analysis and improvement. On the next page is one possible flow chart.

b. Every step of the process should be reviewed for improvement opportunities. Improvement can occur by redesigning each step, a sequence of steps, or even the entire process reengineering). Following are some possible ways to improve steps and portions of the process:

To improve the quality of service, the representatives who take calls can be trained to sort the complaints by severity. A computer system could be installed to help specialists decide if the technical problem is in their area of expertise. A specialist could determine from the computer system if a warranty covers the parts and charges. For informational problems, the call should be sorted and directed to the right person according to pre-specified procedure (the manager should not have to decide where every call should be directed).

The status of any problem requiring immediate attention should be updated by the specialist assigned to the problem.

Process flow chart.



11. Zemco's president might conclude that the plastic is at the end of the incremental improvement curve because, in spite of R&D efforts, no advances are happening in the plastic's

technology or profit advantage. He might decide that there are few new things to be learned about or exploited from the plastic, and to aim Zemco's R&D away from the plastic and toward looking for something new.

*12. It is important to determine the nature of the productivity efforts instituted at Division A before sending people there from Division B. The CEO of Cylo needs to examine the personnel, products and processes. It might be that equipment at Division A is older than at Division B, or that Division A is strapped with older (and possibly outdated) processes and procedures.

Perhaps, however, the differences between Division A and Division B stem from each being at a different point on the S-curve, especially with respect to the improvement thresholds for each. Division A has been operating for ten years, and possibly over that time its products and processes have been improved to the level where further improvements are very costly. Division B is younger and so are its products and processes, so possibly there is greater opportunity for improvement. Thus, perhaps, the best action for the CEO to take is the opposite of what he is considering. If Division A’s products and processes have reached the improvement threshold, then transferring designers and engineers from Division B to Division A would be wasted effort and only serve to dilute Division B's improvement, whereas transferring them from Division A to Division B would enhance Division B's improvement -- and possibly have no effect on the performance of Division A.