USING SIMULATION TO TEACH BUSINESS PROCESSES DESIGN AND IMPROVEMENT

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ABSTRACT

A course titled, "Process Design and Improvement – Computer Based Tools" was developed and offered by the authors in Fall 2000 and 2001 for part-time graduate students in Manufacturing Systems Engineering and Technology Management programs at the University of St. Thomas, Minnesota, <www.stthomas.edu/technology/2001Fall/MMSE 850-13-F01.htm>. The objective of the course is to introduce students to the current software and methods used to organize data and model manufacturing and industrial systems through virtual representation of business operations choosing problems from their workplaces. The course was created to make the complex processes and tools of computer modeling more accessible to non-specialists for a better understanding of how their operations work. It is not unusual that people only know a small part of their overall system. This gives them a way to see the big picture. A case study illustrates the application of these tools.

1 INTRODUCTION

Competing effectively is as important today as it was before the personal computer, but the tools available have created an environment that requires more speed, collaboration, targeted data analysis, and reliability than ever before. The paper will showcase the use of popular and easy to use software tools, which can be used in demonstrating how learning in current Internet era requires a regimen of pedagogy complemented by practice. Pedagogy and practice must be integrated by designing a decision-making framework. This paper specifically illustrates the use of software tools such as, Microsoft Excel, Visio, and VBA, and also Rockwell Software Arena to successfully and conveniently design either a new business process or analyze and improve an existing business process and also to show how an effective decision making framework in a business organization can be established.

We start with identifying opportunities to improve a business process, which we cover in the next section.

1.1 Process Design and Improvement Opportunities

In the wake of increasing global competition, the manufacturing environment has to continuously change in order for businesses to remain productive and efficient. A growing number of businesses are going multinational to strategically position themselves in global markets with worldwide manufacturing operations. Changing business conditions have prompted manufacturers to design equipments to accommodate new products without expensive retooling. This has enabled manufacturers to move into new markets and leave them just as quickly. These new markets impose demands for products to match specific consumer needs requiring customization of products or even altering an entire product line. Facilities are now being utilized whereby for new products, manufacturers could create prototypes in remarkably short durations. "Flexible manufacturing systems" techniques are being utilized which are enabling companies to offer lower costs, faster turnaround time and quality that meet or exceed customer expectations. Quality of products is more uniform and predictable with low wastage on scrap and rework and manufacturers are reaping benefits of greater flexibility and optimum utilization of production facilities and equipment. Consequently, we need to identify improvement opportunities in: Product quality, Material handling, Product design time, Manufacturing setups, and Factory and office overhead.

We propose Integration and Standardization to facilitate these improvements.

1.1.1 Integration

Most of the manufacturing and service systems are currently being run on an informal basis. In an informal system, a feeling prevails that information could not be used properly in planning and decision making functions. A formal system, however, is run on numbers and these numbers are common, coming from the same database. These numbers differ in the level of their details.

Integration within a company is achievable through a common policy, a common action plan and most importantly, through shared information used in various decisions, based on common knowledge bases.

1.1.2 Standardization

Decision-making in a typical company is hierarchically distributed. Detailed decisions are taken at lower levels within the framework of macro decisions made at higher levels. For the operational level, the goal is to achieve more standardization and automation of operations, whereas for the strategic level, it is to outline policies for smooth functioning of operational activities.

We achieve standardization in a manufacturing or service environment by identifying commonalities within, a) Operations, b) Processes, and c) Services.

Standardizing operations result in common manufacturing strategies and techniques for similar operations, for instance, sheet metal fabrication operation performed at different locations may be based on a common methodology, of course allowing flexibility to recognize unique needs of different markets.

Similarly, process standardization should be carried out on a corporate basis allowing flexibility to recognize differences in markets. In the sheet metal fabrication example, the process of shearing would require cuts made with the same geometry, stress and tolerances.

We provide a preview of computer-based tools and a case study to demonstrate their application for process mapping and business system analysis and design.

1.2 Computer Based Tools

The computer software required to successfully and conveniently analyze a business process, design a new business process, and improve an existing business process include the popular software: Microsoft's Excel, Visio, and Rockwell Software's Arena. Figure 1 illustrates a potential flow of data between computer tools. Each of these tools supports Visual Basic for Applications (VBA) that can be used to move data between applications.
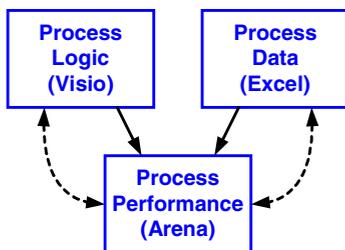

Figure 1: Computer Based Tools

1.3 Analysis and Design Case Study

The focus of this example is to design a fast food drive-through operation for maximum capacity to meet the expected noon-hour rush. The Drive & Eat operator would like to minimize the labor input and just meet the expected demand. Specifically the operator would like to determine, if a staff of two could handle the expected volume of 60 customers between 11:30 AM and 12:30 PM. We will use the computer tools to analyze the Drive & Eat design problem.

1.3.1 Visio Process Map

We start the analysis of the Drive & Eat operation, by developing a Visio process map for the operation shown in Figure 2. Arriving customer vehicles join a queue or waiting line in front of Order Speaker station used to place orders by talking with a member of Crew Type 1. After placing the food order, the customer drives forward to the Pay Window and the food order is dispatched to the kitchen for preparation. At the Pay Window a member of Crew Type 1 collects the customer's payment. The customer then drives forward to food Pickup Window. When a member of Crew Type 2 has prepared the food order, it is delivered to the customer at the Pickup Window. Being a drive through operation, the customer leaves the system after receiving the food order.
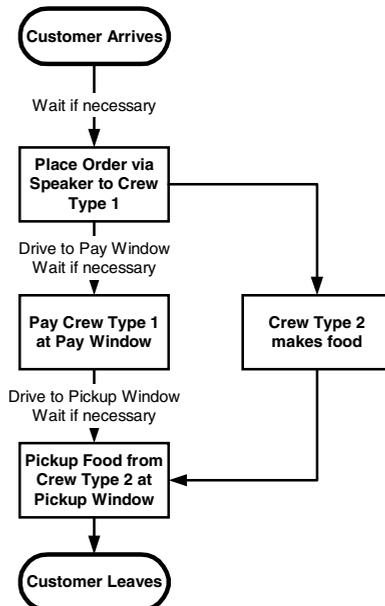

Figure 2: Visio Process Map

Although not directly apparent from the process map, we assume in this analysis that the Drive & Eat facility has a single line of traffic flow, one order speaker, one pay window, and one pickup window. The kitchen has adequate space for more than one crewmember to be simulta-

neously making food. From a practical standpoint the kitchen at some point is likely to become too crowded for efficient operation, but it is beyond the scope of our current investigation.

For our initial investigation we placed no limit on the number of customers who can wait at any of the service points: order speaker, pay window, and pickup window.

1.3.2 Excel Data Analysis

Some rough time process estimates were available from a similar fast food operation. We organized the available data into the spreadsheet illustrated in Figure 3.

Expected Customers per Hour						60
Customer	**Process Times in Seconds**				**Crew**	**Expected Minutes /**
		Most				
Process Steps	**Minimum**	**Likely**	**Maximum**	**Mean**	**Type**	**Hour**
Enter Order Station		10		10.0		
Place Order Station	30	45	70	48.3	1	48.3
Enter Pay Window		10		10.0		
Pay for Food	15	20	30	21.7	1	21.7
Enter Pickup Window		10		10.0		
Pick up Food	15	20	22	19.0	2	19.0
Make Food Time	**Process Times in Seconds**				**Crew**	**Expected Minutes /**
		Most				
Items Ordered	**Minimum**	**Likely**	**Maximum**	**Mean**	**Type**	**Hour**
1	15	25	35	25.0	2	25.0
2	20	35	50	35.0	2	35.0
3	25	45	65	45.0	2	45.0
4	30	55	80	55.0	2	55.0
5	35	65	95	65.0	2	65.0
6	40	75	110	75.0	2	75.0

Figure 3: Excel Input Data Analysis

The time required for the customer to drive from one station or window to the next was estimated to be a constant 10 seconds plus any delays created while waiting for other customers to move forward. The minimum, most likely, and maximum processing times were available for the three customer processing steps: Place Order Station, Pay for Food, and Pick up Food. For example the time to place an order ranged from 30 to 70 seconds with a most likely value of 45 seconds. We automated the calculation for the mean of these three values, 48.3 seconds, using the Excel formula:

=SUM(B6:D6)/COUNT(B6:D6)

The time to make the food for a particular order was found to depend on the order size, which ranged from 1 to 6 items.

Based on the data illustrated in Figures 2 and 3 the owner of the proposed Drive & Eat became concerned that two crewmembers might not be adequate to handle the 60 customers expected to arrive during the noon-hour rush. Two columns were included in Figure 3 to indicate which Crew Type is assigned to each processing step on the Expected Time in minutes was calculated using the Excel formula:

=E6*G$2/60

or 48.3 minutes for Crew Type 1 to take order from 60 customers. In total Crew Type 1 has been assigned 48.3 + 21.7 = 70.0 minutes of work for this one-hour period. Clearly, unless Crew Type 2 can help out, we have a problem with the original assumption of two crewmembers. The total workload for Crew Type 2 is more difficult to calculate because of the variable order size. If most of the orders were for three or less items a single Crew Type 2 may be able to help.

1.3.3 Arena Simulation Analysis

We developed an Arena simulation model for the proposed Drive & Eat operation to help determine just how large a crew is needed to meet the noon rush hour. Figure 4 illustrates the basic structure of that model. The model tracks the flow of customer through the Drive & Eat operation. After the order has been placed, the food order is sent to the kitchen while the customer drives forward to pay window and then to pickup window. Because of the wide range in the time required to "Make Food" it is possible when two Type 2 crewmembers are working, that the order for a single item might be ready before a larger order placed by the prior customer. To assure that each customer receives the food they ordered, we included in the Arena model a customer sequence number.

The Arena simulation model includes a clock to show the current simulation run and a plot to show the Work In Process (WIP) for the number of customers and food orders in the Drive & Eat system.

We initially tested the Arena simulation using the sought for solution, namely sixty customers per hour being handled by one crewmember of each type. Not surprisingly, based on the preliminary analysis we conducted using Excel, this combination is quite unsatisfactory. Based on a five-day simulation, we found that only 47 of the desired 60 customers were served during the one-hour period. Further we found that as many as 29 customers were waiting to place orders. It is unlikely that so many customers would desire the food at Drive & Eat that they would wait so long just to order. We found that the average customer spent 8.8 minutes at Drive & Eat. Further this solution, with an average of 9.3 customers in the system, would not fit the physical layout of the Drive & Eat building site.

Certainly some additional staffing would be required to meet the noon rush hour. Should the additional staff member be of type 1 or 2 or are two or more additional staff members required? In addition, the owner of the proposed Drive & Eat wanted to know at what customer volume level would the two staff crew be adequate.

We conducted a series of simulation experiments with varying crew sizes and customer arrival rates. First, the customer arrival rate was reduced from 60 to 50 to 40 and finally to 30 per hour with the original crew configuration. Next, the 60 per hour customer arrival rate were tested with various increases in the crew size. Results are reported in Figure 5.
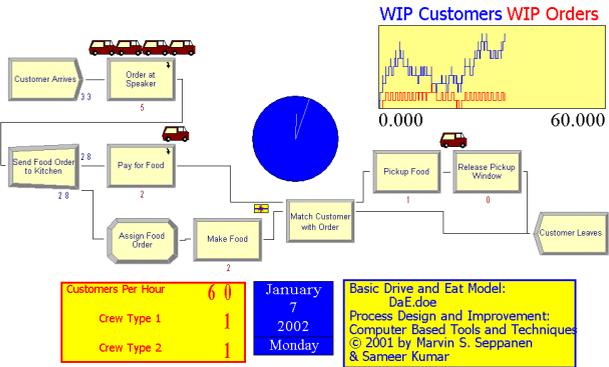
Figure 4: Arena Drive & Eat Simulation Display

Number of Crew Members		Customer Arrivals	Simulation Results 20-Day Averages					
Type 1	Type 2	Number Per Hour	Customers Served	Customer Minutes	Customers in System	Customers Waiting to Order	Profit	Items Delivered
1	1	30	28.8	3.69	1.83	0.29	($3.24)	102
1	1	40	38.8	5.11	3.56	1.23	$1.27	138
1	1	50	44.3	6.56	5.45	2.49	$3.52	155
1	1	60	47.7	8.76	8.61	5.26	$4.76	165
1	2	60	47.5	8.27	8.71	6.19	($3.61)	166
2	1	60	48.5	9.48	9.52	3.67	($1.80)	173
2	2	60	55.8	5.14	5.46	3.38	($7.22)	198
2	3	60	55.8	5.10	5.42	3.34	($15.89)	196

Figure 5: Arena Simulation Results

While the analysis presented in Figure 5 does not evaluate the cost/benefit of each simulated configuration, we can draw several conclusions based on statistics provided. The originally proposed two-person crew should be able to handle a customer arrival rate of up to 40 per hour with a minimum of customer delay. Adding only one crewmember of either type has a limited benefit, adding one of each type seems to be the best solution. Adding more than two crewmembers was of limit value in terms of customer service.

Based on the analysis just presented, it seems that the owner of Drive & Eat has two options: either staff the rush hour period with four crew members, or attempt to reduce the estimated processing times. One option for reducing processing time might be a credit card swiping unit at the Order Station to eliminate the need for all charge customers from stopping at the Pay Window. Other measures might also be incorporated to reduce the Make Food time.

The next section briefly describes the framework of the graduate course titled, "Process Design and Improvement – Computer Based Tools'.

2 COURSE STRUCTURE

This section outlines the course objective, learning outcomes, methodology used, topics covered and brief description of student projects completed:

2.1 Course Objective

The intent is to introduce students to the current software and methodologies used to organize data and model manufacturing and service systems. The course was created to make the complex processes and tools of computer modeling more accessible to non-specialists for a better understanding of how their operations work. Students then apply computer tools, Visio for process mapping, Excel for data organization and Arena for process simulation, to problems from their workplaces.

2.2 Learning Outcome

Successful completion of the course implies achieving the following outcomes by the students:

1. Learn the potential roles of data analysis, process mapping and simulation.
2. Learn process modeling for system improvement.
3. Develop an advanced level of Excel proficiency.
4. Develop a medium level of Visio proficiency.
5. Develop a beginning level of Arena proficiency.
6. Learn a disciplined approach to business system modeling and simulation.
7. Learn introductory level of VBA for transferring data between computerized tools – Excel, Visio, and Arena.
8. Present project results to class orally and in writing.

2.3 Course Methodology

Each class session includes a traditional lecture/discussion period to review problems and to introduce new concepts. At the close of each session, time is allowed for hands-on computer applications and help with assignments. Students may wish to use their own personal computer for this work.

Widely used computerized business tools; Visio, Excel, and Arena, are covered in detail throughout the course. Students gain hands-on experience in developing graphical and simulation models using personal computers. The statistical data analysis and animation aspects of simulation are also covered.

The primary thrust of the course is the Term Project that has been designed to closely follow the process used in industry to conduct computer assisted analysis studies. All class sessions in the second half of the course include some Term Project related activities. These activities include discussions of general problems in the class sessions and

individual student presentations. Both instructors are available via the Internet to assist students with problem solving. The last two class sessions involve reporting of the Term Project results by each student. Major Assignment in this course is the Student Term Project.

Topics covered in each weekly session are listed in Table 1.

Table 1: Course Topics by Week

Week	Topics Covered
1	1. **Introduction to Process Design and Improvement**
	a. Introduction to Computer Based Tools: Excel, Visio, & Arena
	b. Drive & Eat Case Study
2	1. **Application of Computer Based Tools and Techniques**
	a. Customer Service Center Case Study
	b. Arena Contact Center Edition
	2. **Course Project Requirements & Software Problems**
3	1. **Process Improvement Using Visio**
	a. Seven Process Improvement Tasks
	b. Process Mapping Symbols and Visio Stencils, Templates, & Shape Sheets
4	1. **Applications Using Visio**
	a. Cause and Effect Diagram
	b. Process Improvement Using Value Analysis
	c. Building an Organization Chart
	b. Creating an Office Layout
5	1. **Data Management and Analysis Using Excel**
	a. Basic Excel Concepts
	b. Advanced Excel Techniques: Data Filters, Pivot Tables, Optimization
6	1. **Applications using Excel**
	a. Quality Function Deployment, QFD
	b. Technology Function Deployment, TFD
	c. Six-Sigma
	b. Operating/Repair Cycle
7	1. **Mid Term Exam**
	2. **Queuing System Analysis and Process Simulation Using Arena**
8	1. **Applications Using Arena**
	a. Manufacturing Simulation Models
	b. Arena Academic Edition Limits
9	1. **Applications Using Arena Continued**
	a. Inspection – Rejection – Rework
	b. Material Handling Equipment
	c. Multiple Product Flows
10	1. **Computer Based Tools Integration using VBA**
11	1. **Application of Computer Based Tools and Techniques: Business Case Studies**
12	1. **Application of Computer Based Tools and Techniques: Supply Chain Management**
13	1. **Future Computer Based Tools for Process Design and Improvement**
	2. **Course Evaluation**
14	1. **Final Project Presentations**

3 STUDENT PROJECTS

The following are cross section of student projects, which utilized the software tools described earlier in the paper:

One student project related to map and model a typical semiconductor wafer fabrication operation. Process simulation in the semiconductor industry is vital when one examines the significant capital resources that are used in a typical state-of-the-art wafer fabrication facility. Most new facilities that are built from the ground up cost in excess of $1.5 billion. Individual machines that line the facilities walls and aisles typically cost from $500,000 to $2 million per unit. Therefore, capitalization decisions are key to the success or failure of the business.

The objective of this project was to determine if, using parameters for fabrication - typical processing times, machine downtimes, and process yield information - it would enable in finding some constraints in the current fabrication facility that could be lessened or eliminated through process changes. Using the data that was accumulated in Excel from internal processes and control mechanism, no constraints in the flow of the processes involved in fabrication were found when modeled using Arena. Furthermore, the simulation calculated process costs that were reasonably accurate when compared with their actual costs. It appeared from results of simulation that the company has done a good job of optimizing their work processes and managing the capital assets that they have been employing in the manufacture of silicon integrated circuits.

Another student project related to Pulsed Laser Welds in batteries for implantable medical devices manufacturer. Most batteries manufactured by this company are prismatic, single-cell batteries. There are as many as six laser welds per cell. Many of the batteries' components are highly sensitive to thermal input. The cover to case weld generates the greatest thermal risk. The cover to case weld joint geometries vary in length, width, height and corner radius. A cover design which minimizes the cover to case gap is generally chosen for qualification. This helps provide a more uniform weld both visually and thermally. The purpose of this project was to create a system that would allow a user to select a different starting locations of a battery cover to case weld, then select different locations in the battery that are thermally sensitive and finally to simulate the weld while charting the thermal profile of the preselected locations. For this project, two of the most common battery geometries were modeled and targeted for simulation. This simulation system was intended for use during the development stages of a battery. It must simply demonstrate approximate thermal profiles in key locations internal to the battery. This tool would guide development engineers when determining material selection and internal component placement so that thermal damage from the weld zone can be avoided. Microsoft Visio VBA code was created to interface between Excel and Visio to provide the laser weld simulation. A master shape was created to imitate a single laser pulse.

The last student project described here relates to production process associated with a newly introduced consumer Treadmill product line. This company has had numerous and significant manufacturing challenges in achieving their production commitments. To meet the fulfillment of a demanding forecast, they began an aggressive ramp-up in their factory to secure enough work center capacity to produce treadmills at a rate of 100 to 125 units per day. It quickly became apparent to them that to meet the constant and rising sales demand for the new treadmill product line, that they could no longer fabricate the components for the treadmill weldments through their tradi-

tional, functional process layout. In this project, various processing options were explored by modeling alternatives using Excel, Visio and Arena software tools for improving their current process which could be implemented to dramatically increase their fabrication process throughput, reduce overall cycle time, minimize non-value-added process time, and improve process quality.

4 CONCLUSION

In summary, authors have presented their experiences in integrating computers and software tools in learning design and improvement of business processes. Until last year, there was no graduate course in University of St. Thomas's books, which provided a hands-on computer based integrative approaches to modeling and improving business processes. The proposed course was meant to fulfill the needs of senior undergraduate and beginning graduate students and practitioners in technical and managerial fields interested in analytical approaches to process modeling and improvement. The basic premise was to provide students completing this course with a high level of Excel application knowledge, moderate proficiency in Visio, and basic understanding of simulation using Arena and also expose them to learning how to interchange data between applications using Visual Basic for Applications (VBA). The ultimate objective of the course was to prepare students to more effectively solve complex business problems using popular software tools by exposing them to a number of industrial case studies. As we say, "proof is in pudding", successfully completed industry projects with measurable improvement outcomes was the ultimate test of success for the course.

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