



Modeling and Analysis of Flexible Manufacturing Systems: A Simulation Study

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Abstract

Flexible Manufacturing Systems (FMS) are highly modular reconfigurable systems, consisting of a group of processing workstations (such as CNC machining centers), and interconnected by an automated material handling and storage system. The adoption of a Flexible Manufacturing System involves a substantial investment and a high degree of uncertainty for today's factories. With the aim of combining production flexibility and productivity, the design decisions of a flexible manufacturing system must be based on FMS system performance. The current literature does not, however, provide enough detail to analyze the system performance in a Flexible Manufacturing System with different layout configurations. Models based on discrete-event simulation can be utilized to design production systems such as FMSs. In this study, ProModel software is used to simulate different models and evaluate the system performance in different FMS layouts. Based on the simulation models, we investigated the effectiveness and efficiency of FMS including system performance metrics such as manufacturing lead time (MLT), resource utilization, inventory and queue levels, throughput, bottleneck analysis, and the number of workstations. These decisions of FMS design are critical and need to be investigated in the initial phase with extreme care ensuring that the designed FMS will successfully fulfill the demands of a fluctuating market. Finally, this paper presents a case problem for performance evaluation of an existing manufacturing system. The result shows that the simulation models can effectively help the users to rapidly response to a mix of part styles and changes of demand patterns.

Keywords: Flexible Manufacturing System (FMS), Performance Measurement, Simulation Modeling, Case Study, ProModel, Automated Guided Vehicle System, Layout Design

Introduction

A Flexible Manufacturing System (FMS) usually includes (1) workstations (such as CNC machine centers, industrial robots, washing, and measuring machines), fixtures, tools, and other related hardware, (2) a Material Handling System (MHS), (3) a computer system to control all the manufacturing activities, and (4) operators and/or management.¹ The reason an FMS is called flexible is that it is a manufacturing system with the ability to efficiently responds to fluctuation in both products it manufactures and the demand levels for the products being produced as well as other uncertainties such as machine downtimes, repairs, and various processing times. A number of benefits can be realized in successful FMS applications. They are: ¹

1. Reduced Manufacturing Lead Times (MLT),
2. Improved machine utilization,

3. Lower Work-In-Process (WIP) inventory requirements,
4. Greater responsive to change,
5. Reduced labor requirements,
6. Fewer machines required, and
7. Enhanced operational control

FMS planning and implementation problems can be classified as (1) design, (2) planning, (3) scheduling, and (4) control problems.¹ Although the main body of the recent research on FMS has been shifted to the operational aspects of FMS, a number of studies have been conducted on using computer simulation to address issues concerning the design and analysis of flexible manufacturing systems. Computer simulation is the imitation of a dynamic system using a computer model to analyze, evaluate and improve system performance.² In particular; simulation has played a significant role in evaluation the design and operational performance of an FMS. Several studies have shown that computer simulation is a very useful tool to model and analyze the performance of a Flexible Manufacturing System (FMS) given its flexibility.³ It has only been in the few decades that computer simulation has gained popularity as a decision-making tool in many manufacturing and service industries. For many companies computer simulation has become a standard practice when a new facility is being planned and changes to a production line or a manufacturing process are being evaluated.

As a decision-making tool, computer simulation has been utilized to plan and make improvements in different areas of flexible manufacturing systems. Typical FMS applications of simulation are:⁴

1. Evaluate the system performance of alternative designs and the effectiveness of alternative operating policies.
2. Select the type and quantity of machines, equipment, and tooling should be used in an FMS
3. Decide the production capability (throughput rate) for a given layout configuration.
4. Analyze bottleneck, number of buffers and storage required, and conveyor speed
5. Calculate number of shifts required to meet production and customer requirements
6. Optimize production sequence for producing a set of jobs
7. Minimize total processing time in an FMS system (make-span or throughput time analysis)

Simulation is now considered an indispensable tool to study system performance. This paper investigates the effects of different factors such as layout and MHS configuration (which includes numbers of MCs, buffers, and conveyor speeds), under stochastic parts inter-arrival and processing time, production cost, manufacturing lead time and throughput. A student case problem is included to show and explain how applications of computer simulation and digital manufacturing have been incorporated into our engineering technology curriculum to provide students an opportunity to gain practical experience. By providing a discussion on interesting results of several student teams, the students better understood the mechanisms that enable flexibility to reduce manufacturing lead times. This case problem has significantly benefited the students with their exposure to simulation tools, their application in this area (FMS), and application experience by using data from an actual system in the case problem.

FMS Design and Simulation

Several research studies within manufacturing systems design have been focused on finding improved layout configurations and resources to solve particular issues or extend existing modeling techniques. The optimal design of FMS is a critical issue and it is a complex problem with the selection of: (1) layout configurations from the wide variety available, (2) specific workstations, (3) a supporting materials handling and storage system, and (4) a computer control system. Several decision analysis techniques and tools have been applied to the evaluation of FMS design. As flexibility and modularity become more critical in a successful design of FMS, the important factors that must be specified in design parameters and standard resources include the following five different categories shown in the Table 1.

Table 1 – Design Parameters and Standard Resources of FMS⁵

Design Attributes	FMS components		Configuration Parameters	No. of alternatives
A	Work-in-Process (WIP) -Storage Capacity		1 No storage	4
			2 Buffer Storage	
			3 Storage Rack	
			4 Storage Rack with Aisle	
B	Layout Configuration -Transport Path		1 Linear	5
			2 Loop	
			3 Ladder	
			4 Open	
			5 U Shape	
C	Workstation Processing Time	Machining and Preparation Time	1 Machining only	4
			2 Machining + Washing Machine	
			2 Machining + Measuring Machine	
			2 Machining + Washing Machine	
	Transition Time		3 + Measuring Machine	
			1 No buffer	
		2 Common Buffer		
		3 Pallet Stand		
D	Loading/Unloading station		1 No Station	3
			2 Common Loading/Unloading station	
			3 Separate Loading/Unloading Station	
E	Tool Handling and Preparation		1 Off-line	2
			2 On-line	

In the design stage of FMS, once a prior system definition, description and sizing analysis has been made, the next step is to determine layout configuration. The principal factors of prior analysis are: part family considerations and resource (ex. AGVs, buffers) allocation, process routings or plans, production quantity, and tooling/fixturing. Proposed layout design and simulation procedure of FMS are itemized as follows: ⁵

1. Selection of layout parameters
2. Feasibility determination of layout alternatives
3. 2D graphical layout generation of feasible alternative

4. 3D layout model creation for discrete event simulation using commercial package (ex. ProModel, Arena, SIEMENS Plant Simulation)
5. Optimization analysis for system performance using Taguchi methods and simulation

Several researchers who have used computer simulation to model and analyze FMS performance have found that FMS performance is significantly affected by layout configurations, resource allocation, buffer capability, process routing flexibility, and choice of scheduling rules. The performance of an FMS is evaluated by using measures such as make-span, throughput, average machine utilization, average flow time, and average blocked time (see table 2).

Table – 2 Typical FMS Performance Measures

Performance Measures	Description	Objective
Manufacturing Lead Time (MLK)/ Make-span / Total flow time	The total time required processing a product through the FMS, including any lost time due to delays, time spent in buffers, reliability problems, and part transfer time.	$Min(MLK) = \sum MLK_j$
Throughput (Production Quantities)	Daily and weekly quantities of different parts produced by the FMS. Comparison of actual quantities against the production schedule	$Max(p_j) = \sum (P_j)$
Availability	Uptime proportion (Reliability) of the workstations.	$Max(A) = (MTBF_j - MTRR_j) / MTBF_j$
Utilization	Utilization of each workstation as well as the average utilization of the FMS specified periods (days, weeks, months)	$Max(U_j) = Q_j / PC_j$
Tooling	Information on various aspects of tool control,	

This project uses a hypothetical case problem for designing a factory that produces 5 parts. These parts run through a series of processes, including: (1) Loading/Unloading, (2) Turning, (3) Milling, (4) Drilling and (5) Cleaning, with different machining sequences⁶. A list of workstation processing time and costs for different product mixes is shown in the Table 3. This data is based on an actual system.

Table 3 – Workstation Processing Times and Costs for Different Product Groups⁷

Part mix	Attributes	Operation Sequence				Quantity
		Operation 1	Operation 2	Operation 3	Operation 4	
1	Sequence	MC 1	MC 4	MC 5	MC 3	250 pcs
	Process time and Cost	$N(10,2)$ /\$12	$N(25,3)$ /\$18	$N(25,1)$ /\$10	$N(30,1)$ /\$24	
2	Sequence	MC 2	MC 3	MC 5	MC 4	150 pcs
	Process time and Cost	$N(10,2)$ /\$17	$N(10,2)$ /\$19	$N(10,2)$ /\$18	$N(10,2)$ /\$6	
3	Sequence	MC 5	MC 4	MC 1	MC 3	150 pcs
	Process time and Cost	$N(25,1)$ /\$10	$N(25,3)$ /\$18	$N(10,2)$ /\$12	$N(30,1)$ /\$24	
4	Sequence	MC 4	MC 3	MC 2	MC 5	125 pcs
	Process time and Cost	$N(26,3)$ /\$19	$N(27,3)$ /\$22	$N(24,3)$ /\$18	$N(25,2)$ /\$12	
5	Sequence	MC 3	MC 4	MC 1		90 pcs
	Process time and Cost	$N(18,1)$ /\$20	$N(15,1)$ /\$15	$N(12,1)$ /\$14		

Note: $N(\mu, \sigma)$ is Normal distribution with the parameter μ - average processing time and σ - standard deviation.

The workstations in the FMS are connected by an automated material handling and transferring system which transfers parts, tools and fixtures among workstations. Creating the material handling system concurrently establishes the FMS layout. Some of the most commonly used layout configurations found in today's flexible manufacturing systems can be classified in four categories: (1) in-line layout, (2) loop layout, (3) ladder layout and (4) open field layout (see Figure 1)⁵. An Automated Guided Vehicle (AGV) system is a common material handling system that uses independently operated, self-propelled vehicles with the ability to transfer loads to distance locations and through complex paths. The AGV system is a very important component in today's FMS and this AGV technology is also being increasingly used in flexible manufacturing systems.

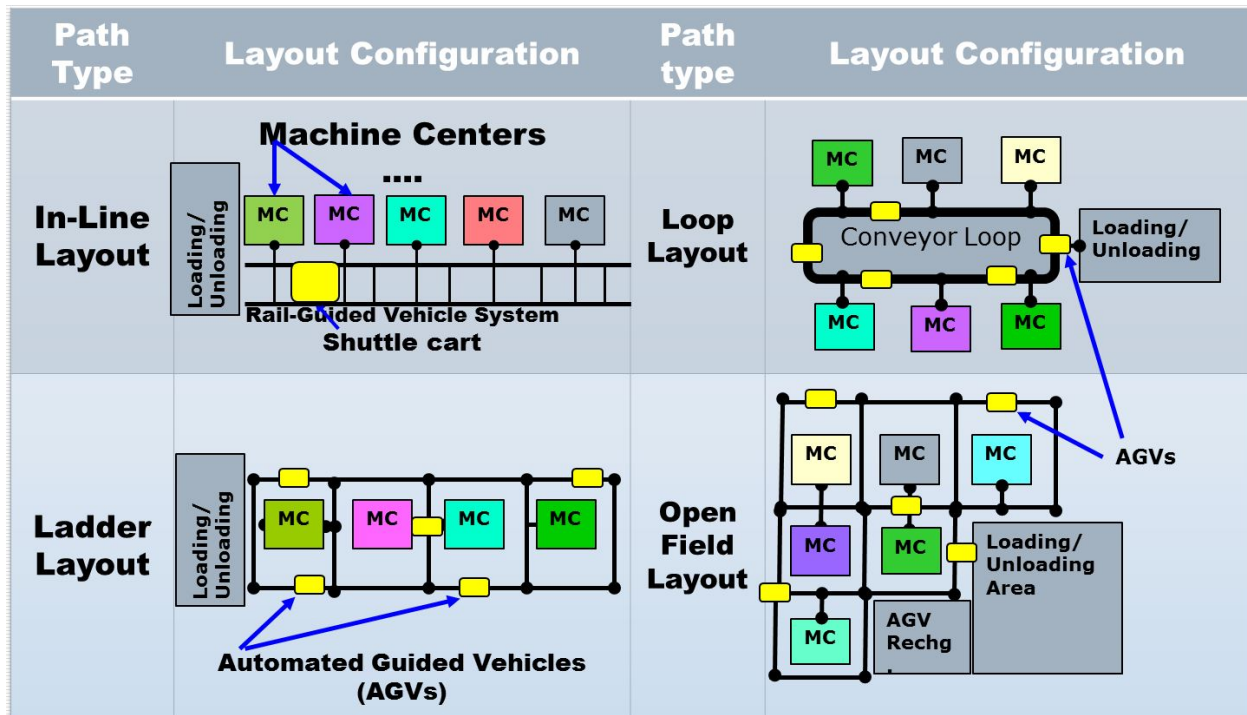


Figure 1 – 2D view of four different FMS layout configurations

Although the overall performance of the FMS is higher than traditional job shops, many implementation issues can be associated with FMS design and modelling. It is very important that the installation of the FMS system be preceded by thorough design and planning, and that its operation is controlled by good management of all related resources such as machines, tools, parts, and people⁸. Some assumptions have been considered for the implementation of the model to study the case. The FMS considered for the student case problem has the following features:⁶

1. Five workstations (e.g. Haas EC-400PP Machining Center, Ass DT-1 Drill/Tap Center)
2. An AGV material handling system (e.g. 2 AGVs/FMS or 5 AGVs/FMS)
3. 6-station pallet pool with 400 mm pallets (e.g. 1-6 buffers)
4. AGV speed – low, medium and high (e.g. 30 ft./min., 60 ft./min., or 90 ft./min.)
5. Set up times and tooling change times are independent of the job sequence and can be included in machine processing times

Layout of proposed FMS

In the in-line layout, the workstations and a rail guided vehicle (RGV) system are arranged in a straight line (see Figure 2). In the transportation station, the RGV is adopted for the default transportation resource in the in-line layout and loop path configurations. Five workstations are for processing of parts and input/output of the part temporally. Processing operations consist of standard resources for machining, washing and cleaning, inspection. The pallet pool has both an input and a separated output buffer, whereas a common buffer has temporal space for both input and output to wait for processing or transportation device (e.g. AGVs, RGVs or stacker crane).

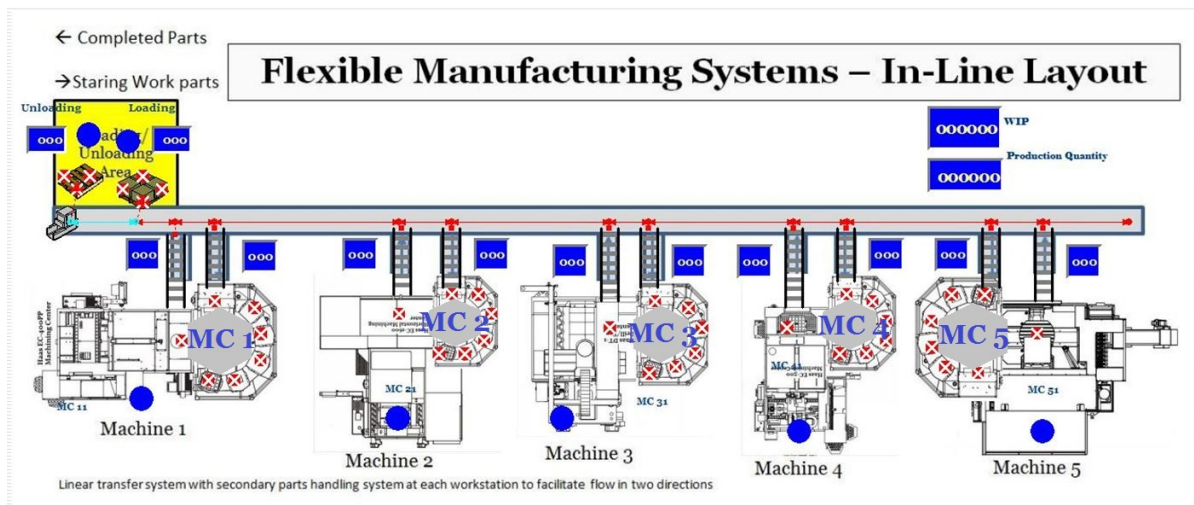


Figure 2 – FMS in-line layout with 5 CNC Machining Centers (MCs), a load/unload station, and a Rail Guided Vehicle (RGV) System

In the ladder layout, the workstations are inside of each small loop. The system consists of a big loop with rungs between the straight sections of the loop, on which workstations are located (see Figure 3). The rungs actually create the number of possible paths of moving from one workstation to the next, and eliminate the need for a secondary transportation system.

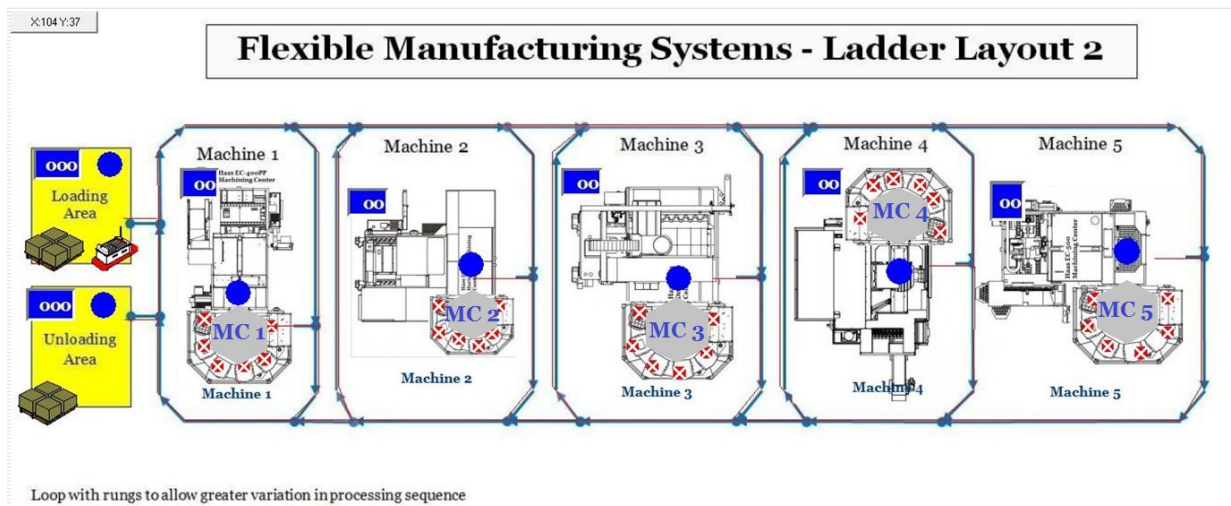


Figure 3 – FMS ladder layout with 5 CNC machining centers, a load/unload station, and an

Automated Guided Vehicle (AGV) System

Compared with the in-line layout, the ladder layout design reduces the average travel distance and minimizes congestion in the handling system.

Simulation Use in a Graduate Automation Systems Course

Computer simulation is an excellent tool for students to analyze complex systems and usually used to develop a simplified model of a complex system with the objective of providing predictions of the system's performance measures. The use of the simulation software ProModel in the Engineering and Technology program at Western Carolina University provides several opportunities for faculty and students to explore system design and performance in different areas such manufacturing, material handling and health care systems. After the first trial run of actively engaging twelve graduate students with a realistic simulation case problem, faculty determined that they must create an opportunity within the graduate curriculum to incorporate this powerful tool with different applications in the Engineering and Technology discipline.

When redesigning the ET 642 Automation Systems course to incorporate simulation modelling and analysis techniques, several case problems were introduced to the class assignments. The teaching materials that were included focus on the following topics:

1. Simulation Basics
2. Data Collection and analysis for use in simulation models
3. Model building
4. Model Verification and Validation
5. Simulation Output Analysis
6. System Optimization – Taguchi Methods and ANOVA analysis
7. Case Study Assignments – a real-world simulation experience

In order to better create the models, there are many simulation software packages available on the market. ProModel is one of popular software which allows students and practitioners after collecting the relevant data to create a 2D graphical model in 45 or 60 minutes. Figure 4 and 5 show two screen shots of information input menus.

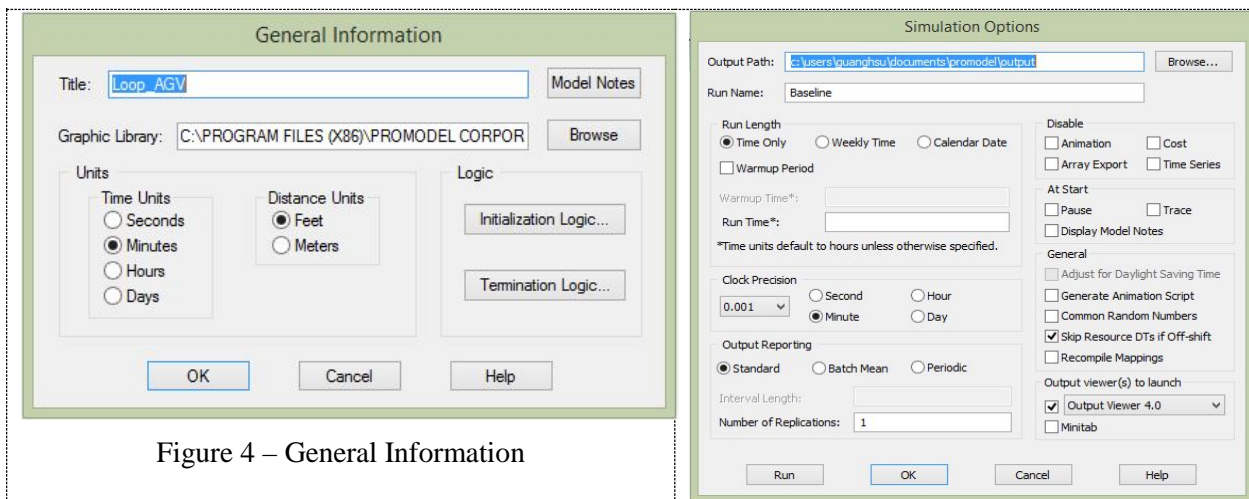


Figure 4 – General Information

Figure 5 – Simulation Options

In ProModel, routing rules are used in selecting among the next processes for routing an entity. Sometimes students prefer one particular resource to another. The selection among several resources may look like the following screen shots in Figure 6 and 7.

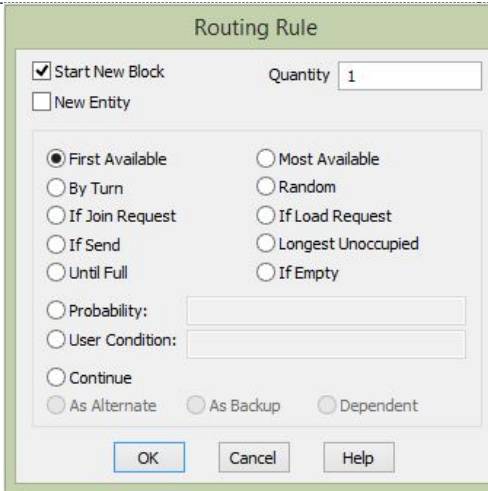


Figure 6– Routing Rule for Workstation Location 1

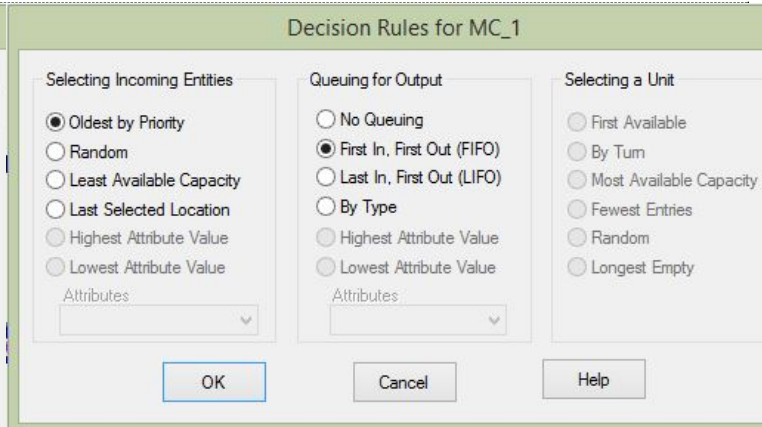


Figure 7 – Decision Rules for Workstation 1

Entity arrivals define the time, quantity, frequency and location of entities entering the system. To create arrivals, you enter various data about the arrival process. Figure 8 shows a screen shot of first time/arrival scheduling.

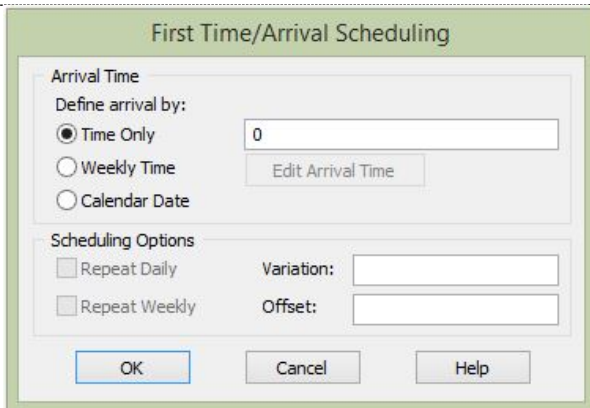


Figure 8 – First Time/Arrival Scheduling

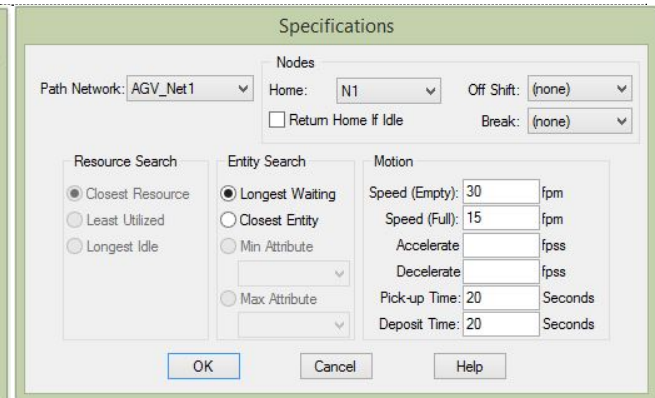


Figure 9 – AGV Specifications

Lessons Learned

In the beginning of the spring semester of 2014, many students were reluctant to use ProModel simulation software package because they felt unqualified. Certainly some reading and practice is required to use any simulation software, but the ability to use simulation to model and evaluate proposed systems and changes to these systems is a skill professionals need when dealing with a

flexible manufacturing system. Incorporating computer simulation into an Automation System course has proven to have many benefits not only for students when they are practitioners but also for faculty and local manufacturing facilities. The constraint that was faced in the spring semester 2014 was finding adequate discussion time to explore the details of each simulation scenarios in conjunction with existing FMS design concepts.

Case Problem - Loop Layout Configuration

The material handling system generally is a key factor in determining the type of layout to be used in the FMS. In the literature, number of popular layout types have been highlighted, such in-line layout, loop layout, ladder layout, open field layout etc. After a detailed study of the plant including space availability, number of operators working etc., the loop layout was considered for the implementation for the new FMS. The key rationales are given below:

1. Loop layout is suitable for mid variety and mid volume range of the case company.
2. Loop layout consists of secondary handling system which is required to provide desirable flexibility of routing.
3. It has reduced material transfer time.
4. In the case company, the manpower will be greatly reduced as workers are required only at load/unload station.
5. Traffic control is easy to implement in loop layout.

The layout configuration and flow diagram for loop layout is given in Figure10.

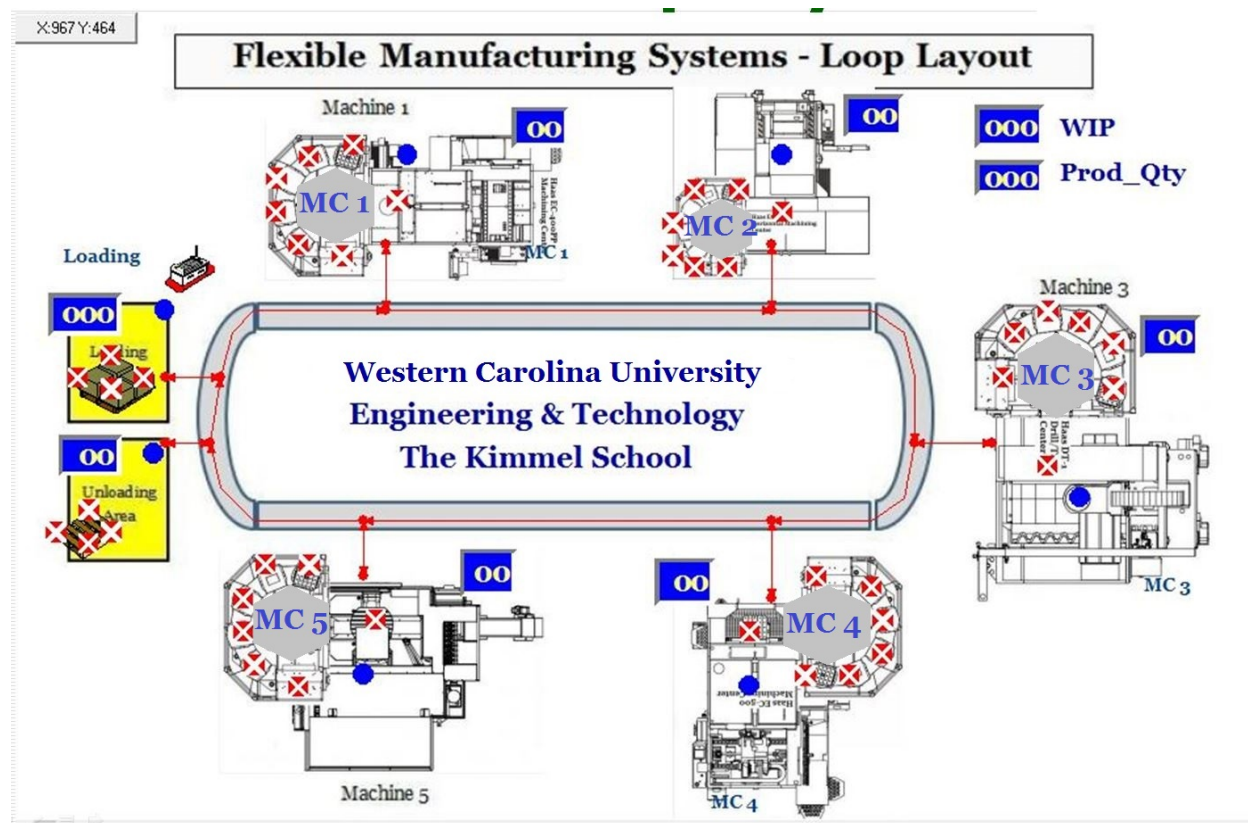


Figure 10 – FMS Loop Layout with Secondary parts handling system at each station to allow

unobstructed flow on the loop (5 MCs, a Load/unload station, and a conveyor system)

Results and Discussion

The performance analysis of FMS loop layout with various resources is presented in this section. The summary of case problem calculations (Average time in system, resource utilizations, number of buffers used etc.) is presented in table 4. A comparison of number of AGVs and buffers utilizations for the proposed system is shown in figure 4 and figure 5 respectively.

Table 4 – Simulation results - Loop layout (No Buffers) General time unit: minutes

Resource: # of AGVs	Simulation Run (hours)	AVG time in Move Logic (min.)	AVG time in Operation (min.)	AVG time Blocked (min.)	AVG time in System (min.)	Total Exits
1	320.22	127.15	97.09	6983.8	7208.04	250 pcs
2	226.57	78.2	97.23	4219.73	4395.16	250 pcs
3	206.24	69.35	97.12	3608.03	3774.5	250 pcs
4	199.14	61.85	97.04	3404.45	3563.34	250 pcs
5	192.34	52.07	97.13	3211.22	3360.42	250 pcs
6	192.34	52.06	97.13	3211.23	3360.42	250 pcs
7	192.34	52.06	97.13	3211.23	3360.42	250 pcs

Note: Layout configuration: Loop; Buffers: No Pallet pool

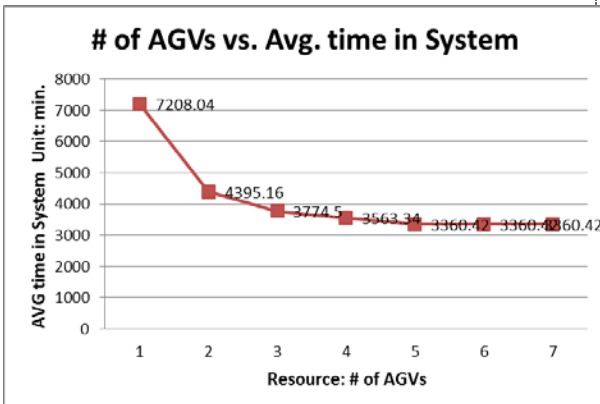


Figure 11 – Average time in System vs. number of AGVs used in Loop Layout configuration without any buffers

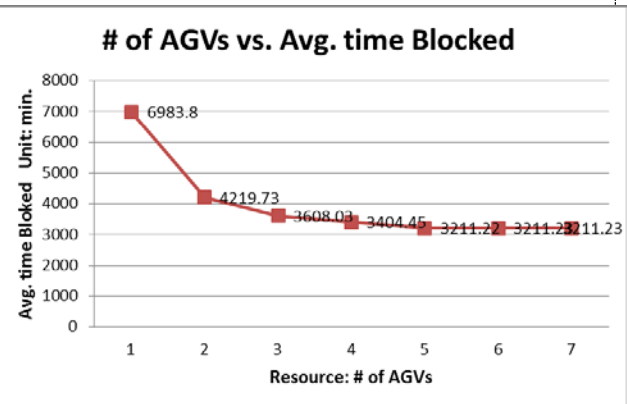


Figure 12 – Average time Blocked vs. number of AGVs used in Loop Layout configuration without any buffers

Performance measures in term of total flow time, average time in system, average time blocked, and throughput were collected from ProModel's output program manager. The data manager provides the students an opportunity to simplify the process of generating and charting graphs and reports (see Figure 14, 15, 16 and 17) and analyzing the output data. Table 10, 11, and 12 provide a summary of the descriptive statistics associate with different resource settings.

Table 5 – Simulation results - Loop layout (6 Buffers) Time unit: minutes

Resource: # of AGVs	Simulation Run (hours)	AVG time in Move Logic (min.)	AVG time in Operation (min.)	AVG time Blocked (min.)	AVG time in System (min.)	Total Exits
1	318.00	1230.87	97.08	6156.46	7484.41	250 pcs
2	157.44	563.87	97.27	1824	2485.14	250 pcs
3	104.48	338.4	97.19	35.27	470.86	250 pcs
4	85.54	83.13	97.13	0	180.26	250 pcs
5	85.43	55.86	97.07	0	152.93	250 pcs
6	85.41	52.20	97.21	0	149.41	250 pcs
7	85.35	52.33	97.14	0	149.47	250 pcs

Note: Layout configuration: Loop; Buffers: 6 (station pallet pool with six 400 mm×400 mm pallets)

The times spent by parts in the system have been used as one of the performance measures of difference resource settings. In the case problem, the following observations were made from the ProModel output viewer.

1. The average time spent by parts in the system has a tendency to decrease with an increase in the number of the AGVs (from 1 to 7). It has been observed that in the first setup, as shown in Table 10, the average time spent by parts and average blocked time are not reduced significantly when the number of the AGVs is increased after four. Figure 10 and 11 shows some of the cases in which a behavior is observed.

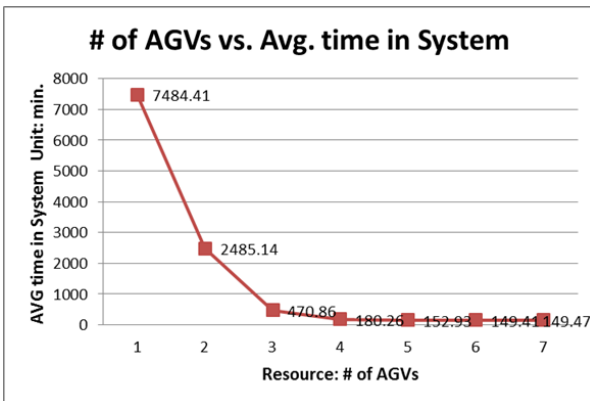


Figure 13 – Average time in System vs. number of AGVs used in Loop Layout configuration with maxi. six buffers

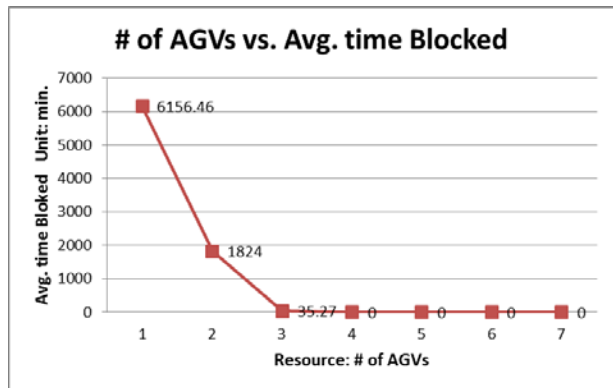


Figure 14 – Average time Blocked vs. number of AGVs used in Loop Layout configuration without maxi. six buffers

2. The case problem was also used to study the effect of a change in the numbers of buffers within the workstations as well. It appears that an increase in the number of buffers (Using one AGV in the system) does not lead to a decrease of the average time spent by

parts in the system and the average blocked time in the system.

Table 6 – Simulation results - Loop layout (1 AGV) Time unit: minutes

Pallet pool # of Buffers	Simulation Run (hours)	AVG time in Move Logic (min.)	AVG time in Operation (min.)	AVG time Blocked (min.)	AVG time in System (min.)	Total Exits
0	320.22	127.15	97.09	6983.8	7208.04	250 pcs
1	341.53	352.2	97.09	7490.39	7939.68	250 pcs
2	285.33	456.17	97.23	5746.98	6300.38	250 pcs
3	319.19	674.03	97.25	6593.71	7364.99	250 pcs
4	318.15	870.12	97.18	6414.52	7381.82	250 pcs
5	317.21	1050.29	97.12	6147.58	7294.99	250 pcs
6	318.02	1230.87	97.08	6156.46	7484.41	250 pcs

Note: Resources: one AGV

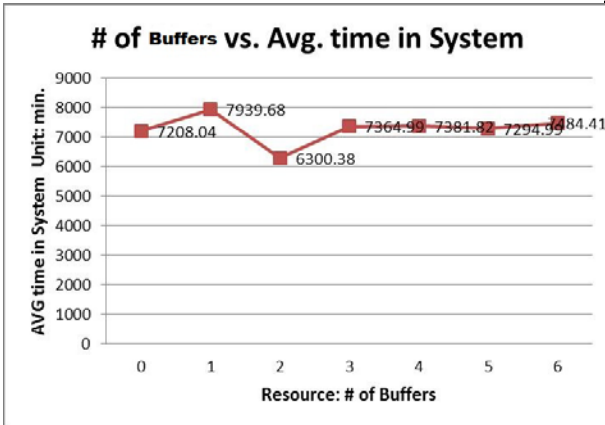


Figure 15 – Average time in System vs. number of AGVs used in Loop Layout configuration with only one buffer

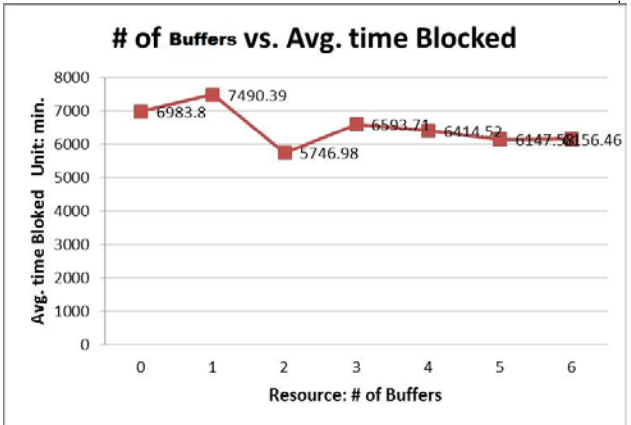


Figure 16 – Average time Blocked vs. number of AGVs used in Loop Layout configuration without only one buffer

- The number of buffers in the workstation becomes a significant factor when the numbers of AGVs increase to four. Detailed simulation runs can conduct for different numbers of buffers in MC pallet pool (See Table 15).

Table 7 – Simulation results - Loop layout (4 AGVs) Time units: minutes

Pallet pool # of Buffers	Simulation Run (hours)	AVG time in Move Logic (min.)	AVG time in Operation (min.)	AVG time Blocked (min.)	AVG time in System (min.)	Total Exits
0	199.14	61.85	97.04	3404.45	3563.34	250 pcs
1	100.17	62.12	97.22	428.45	587.79	250 pcs
2	85.46	81.28	97.23	7.96	186.47	250 pcs
3	85.58	84.04	97.16	0.17	181.37	250 pcs
4	85.54	83.13	97.13	0	180.26	250 pcs
5	85.54	83.13	97.13	0	180.26	250 pcs
6	85.54	83.13	97.13	0	180.26	250 pcs

- Results from simulation runs with four AGVs in the MHS system indicate that the average time spent by parts in the system and the average blocked time have a significant drop when two buffers are added to the workstations. The difference in the time spent by parts corresponding to four AGVs tends to decrease when the number of buffers is increased.

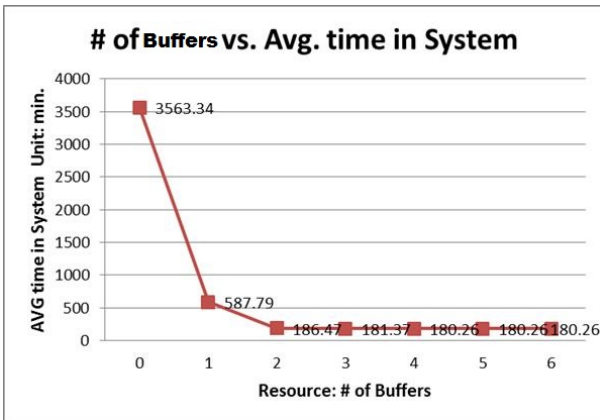


Figure 17 – Average time in System vs. number of AGVs used in Loop Layout configuration with four buffers

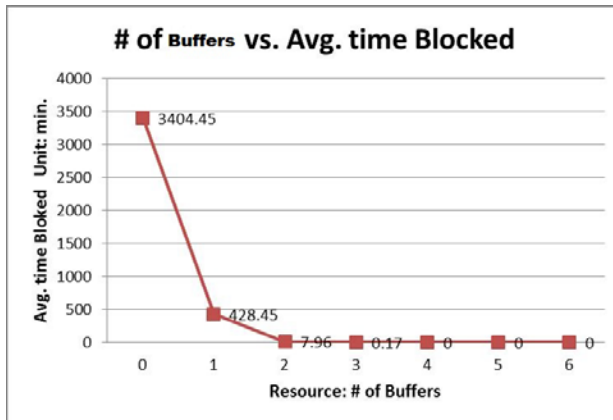


Figure 18 – Average time Blocked vs. number of AGVs used in Loop Layout configuration without four buffers

The results demonstrated in this paper are based on the runs using the PC version of ProModel. This version of ProModel is designed to help students learn simulation and is the same as professional version with some limitations on the size of some features. Models built with the student package may not exceed the following limits: (1) 20 locations, (2) 8 Entity, (3) 8 resource type, (4) 5 Attributes, and 15 Scenario Parameter. Many students have been attracted by, and demonstrated enthusiasm for, working with the visual computer-oriented nature of simulation, but have been impatient working through the details and complexity of the FMS applications.

Student Assessment of Instruction

From table 8 to table 14 were results of ET-642 Student Assessment of Instruction (SAI) taken in spring semester 2014. The results were broken down into the five categories of the Student Assessment of Instruction. With each of the five categories provided in the evolution form, readers can see how many students Strongly Agreed (SA), Agreed (A), Disagreed (D), Strongly Disagreed (SD) or N/A. These qualitative responses were then converted into their numerical equivalents as follows: (1) Strongly Agreed (SA) = 4 points, (2) Agreed (A) = 3 points, (3) Disagreed (D) = 2 points, and (4) Strongly Disagreed (SD) = 1 point. Each table provided the median, mode, standard deviation, the N, and the mean for each question and for the course as a whole.

Table 8 – Student Assessment of Instruction: Organization and Clarity Section

2014 - Spring - Lecture - 4/6-5/2 Survey 201410		Western Carolina University Undergraduate and Graduate							
Course: ET642 80 - Automation Systems		Department: Engr Tech							
Responsible Faculty: Guanghsu Chang		Responses / Expected: 14 / 16 (87.50%)							
		Chang, Guanghsu							
* Standard Course Form Organization and Clarity	Responses		Individual						
	SA	A	D	SD	N	Mean	Med.	Mode	Std Dev
Q1 My instructor is well prepared for class meetings.	8	6	0	0	14	3.6	4	4	.49
Q2 My instructor explains the subject matter clearly.	5	7	2	0	14	3.2	3	3	.67
Q3 My instructor clearly communicates course goals and objectives.	5	8	1	0	14	3.3	3	3	.59
Q4 My instructor answers questions appropriately.	6	7	1	0	14	3.4	3	3	.61
Responses: [SA] Strongly Agree=4 [A] Agree=3 [D] Disagree=2 [SD] Strongly Disagree=1									

Table 9 – Student Assessment of Instruction: Enthusiasm and Intellectual Stimulation

		Chang, Guanghsu							
* Standard Course Form Enthusiasm and Intellectual Stimulation	Responses		Individual						
	SA	A	D	SD	N	Mean	Med.	Mode	Std Dev
Q5 My instructor is enthusiastic about teaching this course.	11	3	0	0	14	3.8	4	4	.41
Q6 My instructor presents the subject in an interesting manner.	6	8	0	0	14	3.4	3	3	.49
Q7 My instructor stimulates my thinking.	7	7	0	0	14	3.5	3.5	3,4	.50
Q8 My instructor motivates me to do my best work.	6	7	1	0	14	3.4	3	3	.61
Responses: [SA] Strongly Agree=4 [A] Agree=3 [D] Disagree=2 [SD] Strongly Disagree=1									

Table 10 – Student Assessment of Instruction: Rapport and Respect

* Standard Course Form Rapport and Respect		Chang, Guanghsu								
		Responses					Individual			Std Dev
		SA	A	D	SD	N	Mean	Med.	Mode	
Q9	My instructor helps students sufficiently with course-related issues.	6	6	2	0	14	3.3	3	3,4	.70
Q10	My instructor is regularly available for consultation.	5	8	0	0	13	3.4	3	3	.49
Q11	My instructor is impartial in dealing with students.	8	5	0	0	13	3.6	4	4	.49
Q12	My instructor respects opinions different from his or her own.	9	4	0	0	13	3.7	4	4	.46
Responses: [SA] Strongly Agree=4 [A] Agree=3 [D] Disagree=2 [SD] Strongly Disagree=1										

Table 11 – Student Assessment of Instruction: Feedback and Accessibility Section

* Standard Course Form Feedback and Accessibility		Chang, Guanghsu								
		Responses					Individual			Std Dev
		SA	A	D	SD	N	Mean	Med.	Mode	
Q13	Assessment methods accurately assess what I have learned in this course.	8	5	1	0	14	3.5	4	4	.63
Q14	Grades are assigned fairly.	10	4	0	0	14	3.7	4	4	.45
Q15	The basis for assigning grades is clearly explained.	7	6	0	0	13	3.5	4	4	.50
Q16	The instructor provides feedback on my progress in the course on a regular basis.	9	4	1	0	14	3.6	4	4	.62
Responses: [SA] Strongly Agree=4 [A] Agree=3 [D] Disagree=2 [SD] Strongly Disagree=1										

Table 12 – Student Assessment of Instruction: Student Perception of Learning

* Standard Course Form Student Perceptions of Learning		Chang, Guanghsu								
		Responses					Individual			Std Dev
		SA	A	D	SD	N	Mean	Med.	Mode	
Q17	My instructor advances my knowledge of course content.	6	8	0	0	14	3.4	3	3	.49
Q18	My instructor promotes my understanding of important conceptual themes.	6	7	1	0	14	3.4	3	3	.61
Q19	My instructor enhances my capacity to communicate effectively about the course subject matter.	6	8	0	0	14	3.4	3	3	.49
Q20	My instructor encourages me to value new viewpoints related to the course.	7	7	0	0	14	3.5	3.5	3,4	.50
Responses: [SA] Strongly Agree=4 [A] Agree=3 [D] Disagree=2 [SD] Strongly Disagree=1										

The SAI also contained two sections with the following open-ended questions: (1) Describe the best aspects of this course, and (2) Describe changes that could be made to improve the course.

Table 13 – Student Assessment of Instruction: The best aspects of this course

<p>Faculty: Chang, Guanghsu</p> <p>Question: Describe the best aspects of this course.</p> <p>Response Rate: 50.00% (7 of 14)</p> <ol style="list-style-type: none">1 Learning something I knew nothing about when I began taking the class. I enjoy learning something new.2 I am learning a whole new subject matter.3 The teacher is very enthusiastic about this course.4 The best aspects of this course is the laid back atmosphere that the class has. Dr. Chang is always in a great mood when he is teaching.5 The instructor clearly understands the topic and concepts. He teaches with a good amount of enthusiasm6 Introduction to new software tools7 Dr. Chang's enthusiasm for these course made the class more enjoyable. The course was also very well structured making it easier to follow lectures.

Table 14 – Student Assessment of Instruction: Changes that could be made to improve the course

<p>Faculty: Chang, Guanghsu</p> <p>Question: Describe changes that could be made to improve the course.</p> <p>Response Rate: 57.14% (8 of 14)</p> <ol style="list-style-type: none">1 I just wish we had more real work case studies more critical thinking.2 Smaller, concise blocks of instruction. The course is taught to quickly and there is no time to go into detail on topics. There is just too much information in one class period to absorb everything. I would suggest a two day a week course instead of one day a week.3 have an on-campus version of the course4 More clarification and a better explanation of the course material.5 I would take more time to slow down and go through the software step by step. When explaining ProModel sometimes I feel that the pace is too fast and there are items that we miss.6 provide some sort of hands-on applications, even if it's just to visit an automated assembly plant. The second case study along with a final project was tedious and probably unnecessary. The homework assignment for Pro model probably would have sufficed but having two projects for the same software was too much.78
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The student evaluations in SAI spring semester 2014 are very important for two reasons. First, I can and do use student assessments to improve my teaching skills. Second, student assessments are used as one of several factors in modifying my teaching materials, course learning outcomes, and quality enhancement plan.

6. Conclusion

In this paper, a case problem of an FMS is presented on the basis of a model given by a local manufacturing company in Asheville. The paper presents the results of a simulation study of flexible manufacturing systems. ProModel simulation package was used for this study since it provides the students sufficient flexibility and a learning-friendly environment to analyze and model flexible manufacturing systems and is a commonly used tool in industry as well as being very similar to many other packages available to industry. The case problem allows the students to conduct performance evaluation of the system under various resources, conditions of AGV availability, different processing times and different layout configurations of FMS just as in practice. In addition to answering specific questions the case problem reinforces many concepts key to the course. Some interesting results have been observed through several simulation runs. The key conclusions from this case problem include:

1. Computer simulation is an excellent tool for FMS performance analysis and evaluation. It provides insight into the complex dynamics of an FMS that cannot be obtained using other analysis techniques. Computer simulation also gives students unlimited freedom to try out different combinations of design parameters for improvement of FMS performance. Furthermore, the results are both visual and quantitative with performance statistics reported on all measures of interest.
2. The simulation presented in this paper confirms that machine utilizations in three different layout configurations increase with an increase in the number of the AGVs. This increase continues to 3 AGV levels after which the utilizations tend to become constant.
3. Incorporating simulation case problem into ET 642 Automation Systems course at Western Carolina University has provided students an opportunity to use a commercial simulation package ProModel and also prepares them to apply what they are learning with the view to providing them a versatile tool and specific application experience in FMS performance improvement.

In summary, the application of simulation in FMS design and operation is expected to continue to grow and evolve in the future. For future research, the computer simulation methods of FMS design and analysis can be expanded to incorporate other FMS design parameters (e.g. choice of scheduling rules, machine breakdown, tool changing, prevention maintenance) and system performance (e.g. AGV traffic deadlock, average block time, transportation cost).

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