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SIMULATION-BASED LEARNING TOOL FOR FACILITIES DESIGN

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ABSTRACT

This paper describes a tool, LAYSIM, to emphasize to the students the important role of material handling cost in choosing the type of layout; i.e., Product, Jobshop or Group Technology-based layout for a certain set of products. It addresses how through experimentation with LAYSIM students understand and appreciate the manufacturing costs associated with each type of layout. The paper describes the underlying learning model, development of the LAYSIM, the features of LAYSIM and the proposed dissemination technique.

1 INTRODUCTION

Allowing students to experience the practical and realistic situations of their profession has to be the thrust of the curriculum in engineering. The design process is iterative, the analyzer has to go back and forth between the different steps of defining, developing, analyzing, testing, and evaluation until a satisfactory design is obtained. Design is also a creative process of devising a product or a system to meet the ultimate goal of satisfying the customer needs (Steudel 1993). To aid the process of designing, the student has to be provided with enough tools in the form of fundamental concepts, which can be embedded into their minds by using the experiential learning approach. Experiential learning is a pedagogical approach that offers students an opportunity to link classroom theory with practical applications. People learn by many different means, but prefer to gain knowledge and skills through experiential opportunities (Richardson 1994).

Learning tools that are interactive are a cost-effective way of giving several different experiences to a student. Simulation is the art and science of creating a representation of a process or system for the purpose of experimentation and evaluation (Gogg and Mott 1993). It is a powerful analytical tool that can significantly facilitate the problem solving process. The capability of the simulation environment to allow the user to experiment by changing the different parameters is unique, and in the process helps the user discover what additional information is needed to solve the problem. With the increased power of the personal computers and software, simulation - the interactive teaching tool - has a much wider scope in the engineering curriculum.

This paper describes a tool, LAYSIM, to impart to the students the impact of choosing a type of layout; i.e., Product, Jobshop or Group Technology-based layout for a certain set of products on manufacturing costs including material handling cost. The simulation tool developed is meant to be used in introducing the topic of Facilities Design in an engineering or management curriculum. The module is intended to give the students a first-hand experience in understanding the relationship between the type of layout, number of components being manufactured in the factory and the resulting manufacturing costs.

2 LEARNING MODEL

LAYSIM has been developed as a means of providing the students an environment for experimentation with different plant layout options. It presents the students with three different types of plant layouts: 1) Product Layout, 2) Group Technology-based Layout,

Table 1 Layouts used in LAYSIM

Jobshop Layout	Group Technology-Based Layout	Product Layout
2 components		2 components
6 components	6 components	6 components
12 components	12 components	12 components

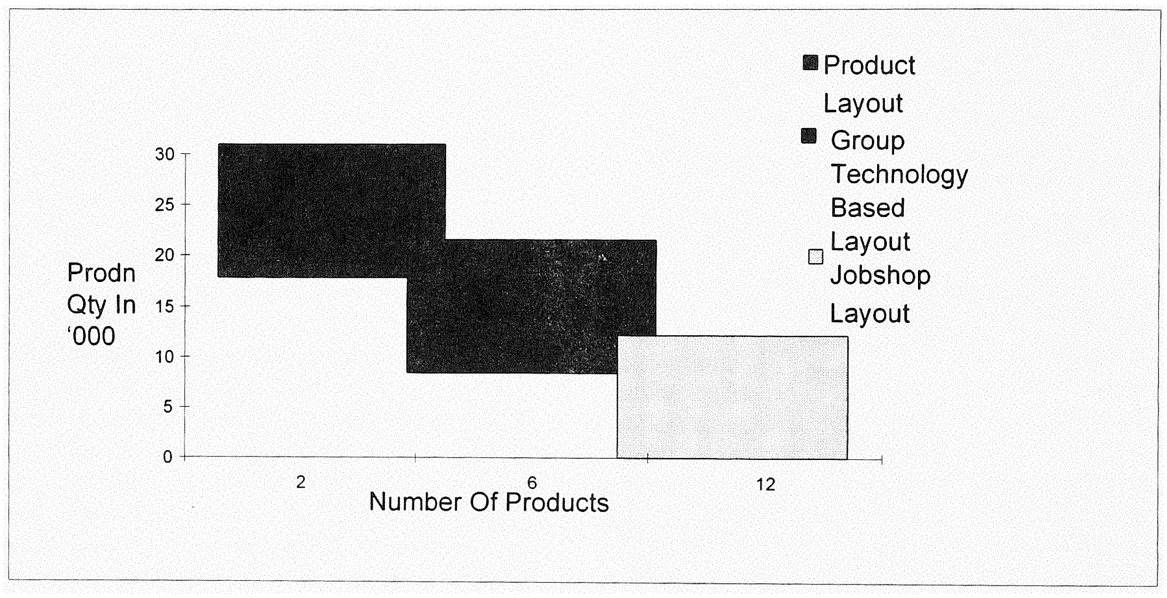

Figure 1 P - Q Chart

3) Jobshop Layout and a common set of products. LAYSIM incorporates eight layouts as shown in the Table 1. The students have an opportunity to compute the material handling costs with each type of layout for different levels of production volume and different number of products. (This is explained in more detail in the next section.)

LAYSIM will enable students to perform the following experiential exercise. They would be able to change certain parameters and perform a number of simulation runs to collect enough data based on which they would be able to construct the P - Q Chart, where P represents the number of products being manufactured in the factory and Q represents the volume of production. For example, one simulation run will be performed for each of the layout types for 2 components with "large" production volumes. The simulation runs would provide the manufacturing costs in each case; the layout type with the least manufacturing costs will be the "preferred layout". A typical P - Q Chart is shown in Figure 1.

The above exercise will enable the students to understand and appreciate the manufacturing costs associated with each type of layout. The layouts and the number of components chosen has been designed in such a way that after going through the exercise the student is able to come up with results which support some of the theory behind the P - Q Chart (Tompkins et al. 1996).

3 DEVELOPMENT OF THE LEARNING TOOL

3.1 Development of Software

ProModel 3.0 was chosen as the simulation software for LAYSIM. ProModel 3.0 is a PC-based software which runs under the Windows environment. This software was chosen because of the following capabilities:

- a run-time model can be made for distributing the module for feedback and dissemination;

- animation of the material handling equipment, material and personnel is possible;
- appropriate icons for production environment such as machines, material handling equipment; etc. are built into the software;
- importing of AutoCAD drawings into the layout background is possible;
- shifts can be defined and assigned, and down-time for machines can be specified;
- global variables can be defined: this is used to compute the manufacturing costs during simulation;
- subroutines can be built: this has been used to make the models interactive; and
- a number of views of different parts of the plant can be defined for the factory layout and can be presented to the user in a defined sequence during the simulation run, or can be used by the user in a random manner;

Multimedia ToolBook 3.0 was chosen as a driver software for LAYSIM. It is possible to run any Windows-based software, such as ProModel, from within Multimedia ToolBook 3.0 and ToolBook can help in building aesthetic screens with buttons for navigating through the module. A sample of the driver screens used in the module are shown in Figures 2 and 3 as seen by the user of the module.

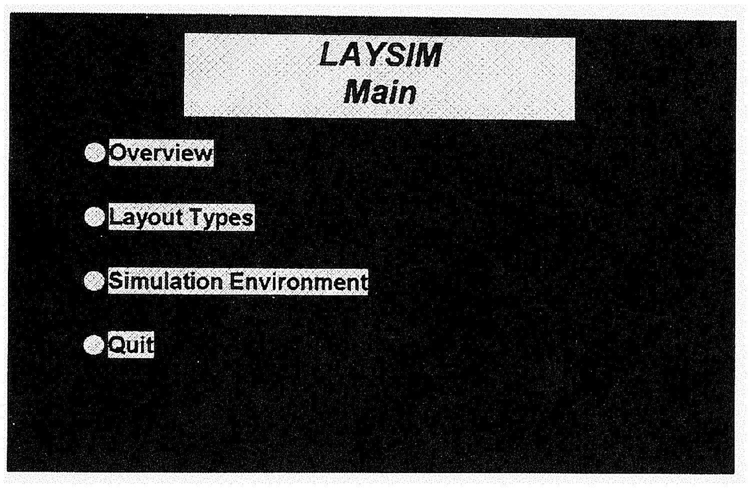

Figure 2 LAYSIM Main Screen

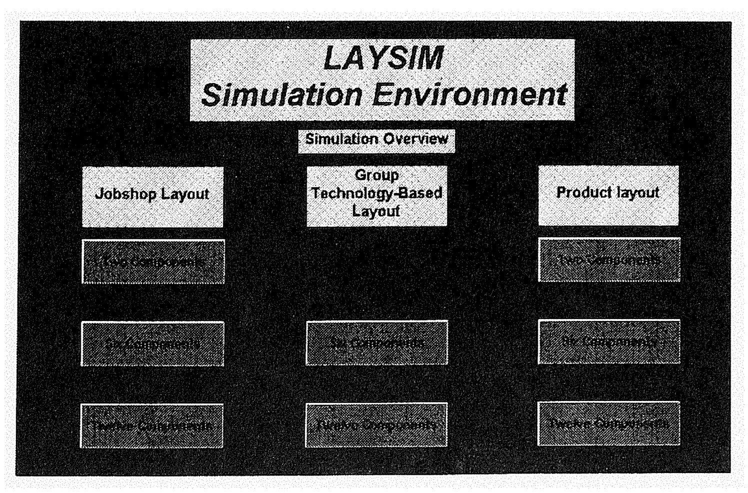

Figure 3 LAYSIM Simulation Environment

The floorplan of the factories used for the simulation model have been built using FactoryCAD which runs on a AutoCAD software platform and provides additional features for developing floorplans. The floorplan includes the boundary walls for the factory, office, break rooms and also the workcenter/machine boundaries as laid out on the floor of the factory. These boundaries are then used as a reference to place the icons of the various machines in ProModel. The layout drawing developed using FactoryCAD is saved as a Windows metafile and then imported into ProModel. A sample of the layout imported into ProModel is shown in Figure 4, and in Figures 5a and 5b is shown the interrelationship of all the software which has been used in developing the learning tool.

TWO-COMPONENT JOBSHOP LAYOUT

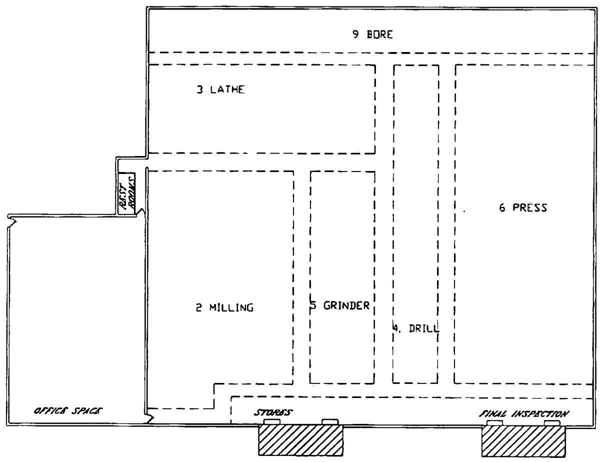

Figure 4 An Example Floorplan in FactoryCAD

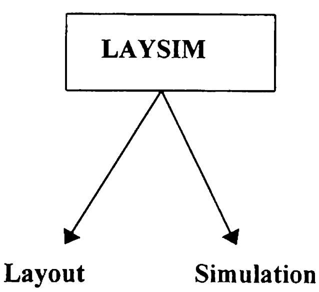

Figure 5a Components of LAYSIM

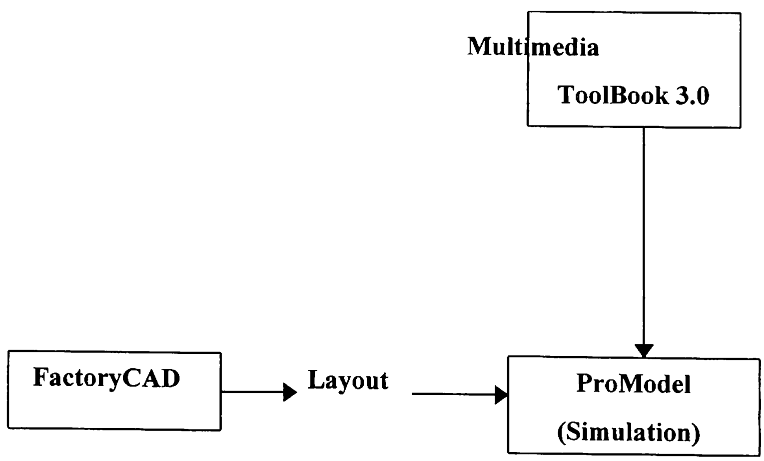

Figure 5b Relationship between FactoryCAD, Multimedia ToolBook and ProModel

Table 2 - Components to be Manufactured

Part No.	Part Name	Wt/Pc in lbs.	Production Routing(process times in minutes)
1	Crank Case	1.1000	1- 2 - 3 - 6 - 4 - 10 (5) (3) (2) (2)
2	Cylinder	0.5000	1 - 3 - 4 - 7 - 10 (2) (1) (0.5)
3	Cylinder Head	0.3000	1 - 3 - 4 - 10 (3) (2)
4	Crankshaft	0.1500	1 - 8 - 3 - 2 - 4 - 10 (0.8) (3) (3) (1)
5	Connecting Rod	0.0750	1 - 5 - 4 - 9 - 4 - 2 - 6 - 4 - 6 - 10 (2) (1) (3) (1) (1) (1) (0.5) (0.5)
6	Outside Bearing	0.0125	1 - 3 - 10 (0.5)
7	Inside Bearing	0.0150	1 - 3 - 10 (0.5)
8	Breather	0.0500	1 - 2 - 4 - 10 (1) (0.5)
9	Cover plate	0.0125	1 - 6 - 10 (0.1)
10	Suction Fitting	0.0125	1 - 3 - 10 (0.3)
11	Discharge Fitting	0.0125	1 - 3 - 2 - 10 (0.3) (0.5)
12	Breather Plate	0.0125	1 - 6 - 10 (0.1)

3.2 Example

A set of compressor components have been chosen for manufacturing in the example factory. These components are listed in Table 2. The table has details on the Weight of the components in pounds and the processing sequence along with the process times. The processing sequence is shown by numbers which represent the machines, the reference for the number representing the machine is found in Table 3.

The machines required for manufacturing the components and the areas per machine are shown in Table 3. Three different choices are possible for moving material. Table 4 provides data for selection of appropriate material handling method.

Table 5 presents the calculation for the calculation for the number of machines and floor space for one of the eight layouts used in LAYSIM. Table 5 is for the 2 component Job Shop case.

Table 3 - Machines and their area requirements

Machine Number	Machine Name	Reqd. Area(Sq. Ft.)
1	Mill	100
2	Lathe	90
3	Drill	50
4	Grinder	100
5	Press	200
6	Hone	45
7	Saw	50
8	Bore	100

Table 4 Material Handling Alternatives

Wt. Of Unit Load (Lbs.)	Method Of Handling	Cost/Move /Ft. Traveled
0 To 25	Manual Handling	$0.010
26 To 500	Walkie Pallet Lift	$0.015
501 And Up	Fork Lift Truck	$0.025

The first step in developing the simulation models was to import the FactoryCAD layout into the ProModel model; the procedure for doing this has already been described earlier. The layout forms a static background for the simulation. The next step is to introduce machine icons in the space allocated in the layout, this is specifying of the locations, beyond that entities, resources, path networks, and processing sequence are specified for running the model. Salient features of the module are described below.

It is possible to define regular shift hours and shift breaks for the full week and save it as a separate file. A number of such shift times can be defined and stored in separate files. These files can then be assigned to the various locations and resources in the simulation model. For the models developed for LAYSIM three different shift files have been created and assigned to different locations and resources.

By defining the distance traveled by the material handling resources and the material handling cost as "global variables" and incrementing their value the material handling cost is dynamically presented on the simulation screen. A few parameters such as the batch size of the components being processed are variable and the user will have an opportunity to specify the value before the simulation run.

The run time model has been made for distributing the tool to get feedback about its effectiveness. The run time model can be used on any personal computer without having the need to buy the simulation software. ProModel 3 has a provision to create a model package which can then be distributed to the users'; the model package consists of the models and ProModel which has to be installed at the users' site before the packaged model can be run. The user, however, cannot modify the model or develop other models.

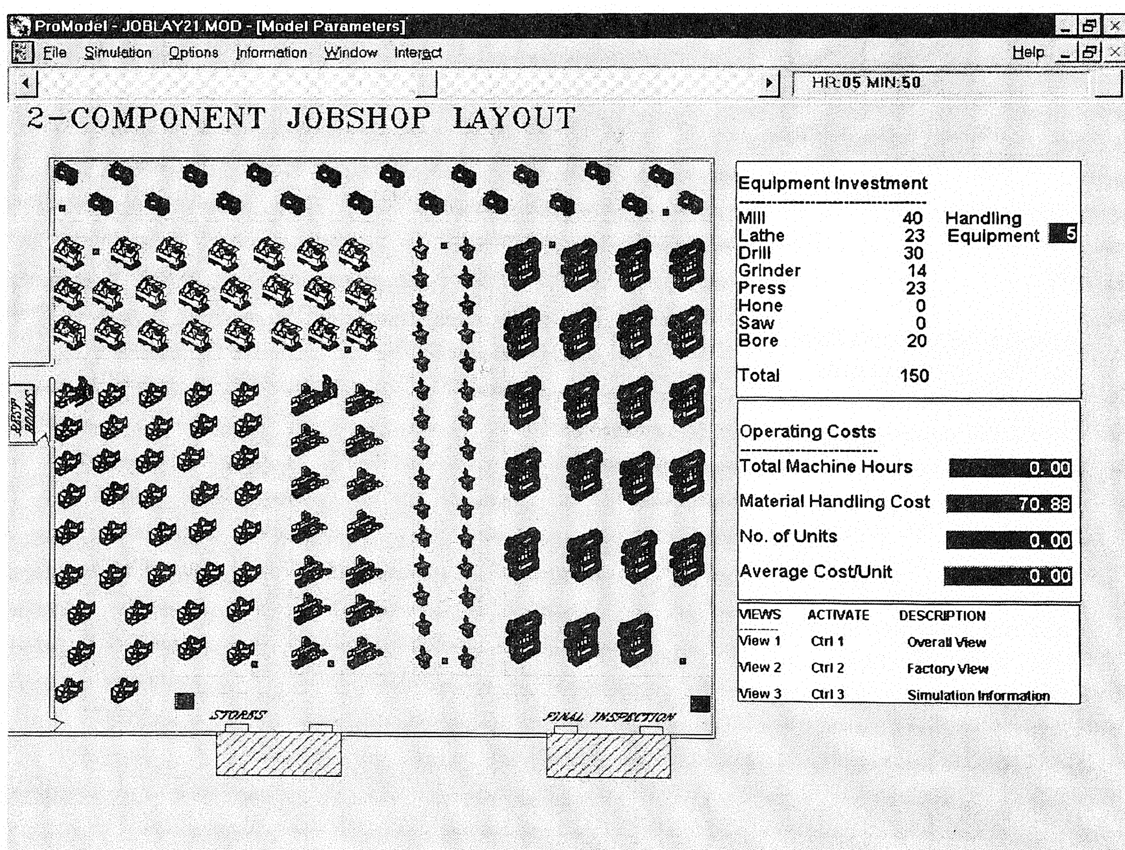

Figure 6 Simulated Environment in ProModel

Table 5 - Calculations For Machine Determination And Space Allocation For Two Component Jobshop Layout

Part # & Name	**No. of Comp. per shift**	**Rough Stores 1**	**Milling 2**	**Lathe 3**	**Drill 4**	**Grinder 5**	**Press 6**	**Hone 7**	**Saw 8**	**Bore 9**	**Final Insp. 10**	**Total Area**
1 Crank Case	2500		12500	7500	5000		5000					
2 Connecting Rod	2500		2500	1250	6250	5000	3750			7500		
Total Minutes Needed		0	15000	8750	11250	5000	8750	0	0	7500	0	
Total No. of Components	5000											
Machines Needed (Total mins./480 mins.)		0	31.25	18.23	23.44	10.41	18.23	0	0	15.63	0	
Efficiency Rate 80%*			39.06	22.79	29.3	13.02	22.79	0	0	19.53	0	
Machines Needed		0	40	23	30	14	23	0	0	20	0	
Area (Sq. Ft.)*		800	5000	2588	1875	1750	5750	0	0	2500	500	20763

* Assumptions:

1. An additional 25% was added to sq. footage required for machines for:
   - Maneuverability (i.e. work-in-process, aisleways, etc.)
   - Storage of parts, tools, misc.

2. 80% Efficiency Rate assumed for all machines

The user is able to see the movement of the material through the various stages of production in the simulated factory. The material is moved from the stores to the first stage of production and from there to the various departments/machines before it is finally routed to the final inspection and then dispatched. A number of different icons are used to identify the components in various stages of production, material handling icons are used to simulate the movement of material between the departments. There is also an indicator for machines in use. All this gives the students a better understanding of the material handling occurring with each type of layout. A sample screen for a model in ProModel shown in Figure 6.

On the simulation screen several different views have been defined. A few of these get activated from within the model during the simulation run to highlight the various regions of the factory and present a better view to the user, a list of these views also appears on the simulation screen with information on accessing these via the keyboard during the simulation.

4 DISSEMINATION

The learning tool discussed here has been developed for the Product Realization Consortium. This consortium is funded by the Technology Reinvestment Program and involves Cornell University, Massachusetts Institute of Technology, Tuskegee University, Worcester Polytechnic Institute, Society of Manufacturing Engineers, and North Carolina A&T State University as partners. The objective of the consortium is to revitalize manufacturing engineering education. One significant task identified by the consortium is the development of appropriate courseware. The courseware developed will be tried at multiple campuses to establish its usefulness.

ACKNOWLEDGMENTS

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