# PAMSIM: A PROJECT MANAGEMENT SIMULATOR

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## 1. INTRODUCTION

The purpose of the Project Activity Management Simulator (PAMSIM) is to provide a new means of teaching project analysis and management. An important ingredient of project management is the design and use of project control systems. Traditionally, project management has been taught in one of two ways. One way is the ordinary textbook-lecture-homework approach, in which project management control and analysis functions are treated individually. Another way is the case-study approach in which a real or imagined project is analyzed. Both of these approaches suffer from several weaknesses:

(1) Neither emphasizes the design of project control systems. Rather, analysis is emphasized.
(2) Neither considers the dynamic nature of project environments.
(3) Neither stresses the decisions and their associated repercussions that must continuously and repeatedly be made in a project environment.
(4) The concepts of feedback and corrective action cannot be presented adequately.
(5) The relationship between expected and actual is not clearly understood. The two tend to become synonymous.

A third way of teaching project management is introduced in this paper. This approach complements (not replaces) the traditional textbook-lecture-homework approach by permitting the student to interact with a dynamic simulated project environment. Further, it provides to the participant a means of gaining experience in controlling a project situation, of testing his ideas, and of receiving immediate feedback showing the results of his decisions. The participant literally "closes the loop" in the control system - he is actually part of the adaptive feedback control system. The new approach provides to the administrator a means of portraying and manipulating a simulated project environment and assistance in evaluating participant performance in operating and controlling such a system.

## 2. THE SIMULATION PROGRAM, PAMSIM

PAMSIM is a Fortran IV program which takes decisions relative to project activity and converts them, on a simulated weekly basis, into a set of decisions or orders for the specified activities for the next week of simulation. Within any week, the simulator allows for the occurrence of random events, for example, a "weather delay", independently of the generated random activity time. Using the available control mechanisms of resource leveling and dynamic scheduling, lost time can be gained back. By explicitly accounting for the delays and allowing expediting, the simulator is felt to be more realistic than the traditional PERT method.

The strong points of PAMSIM are:

(1) The design of control functions is interactive with analysis, due to the dynamic mode allowed.
(2) The simulator stresses decision making and its associated repercussions which is realistic of a project environment.
(3) Feedback and corrective action are required.
(4) The difference between expected performance and actual is demonstrated.

Traditional methods of teaching project management cannot offer comparable strengths.

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2.1 INITIALIZING THE PROJECT

The project selected for use should meet these general criteria:

(1) It should be selected from an area such that the interests and/or learning needs of the participants are matched.
(2) It should be large enough in scope to challenge the participants, i.e., decisions should not be obviously easy.
(3) It should be small enough in scope to be completed in the allocated time for the learning process.

Ideally, the participants would be included in the selection of possible projects. They should at least be involved in the breakdown of the project into its activity components. Such an involvement serves to familiarize the participants with the eventual project and provides an insight into the implied interrelationships. Figure 1

| Activity No. | Description |
|---|---|
| 82-84 | Set florescent fixtures (A) |
| 83-84 | Dummy (A) |
| 84-86 | Install ceiling tile (A) |
| 85-86 | Interior paint (A) |
| 86-87 | Tile floors (A) |
| 87-88 | Finish electrical work (A) |
| 87-89 | Set plumbing fixtures (A) |
| 88-89 | Dummy (A) |
| 89-90 | Inside cleaning (A) |
| 90-94 | Install carpets (A) |
| 91-92 | Clean up and grade outside |
| 92-93 | Form and pour exterior concrete |
| 93-94 | Lay asphalt |
| 94-95 | Paint parking spaces |

A PARTIAL LISTING OF ACTIVITIES FOR A PROJECT
Figure 1

is a partial listing of activities for a project dealing with the construction of three professional office buildings.

After the project has been selected, an initialization run is required which provides:

For each activity

(1) The I - J numbers
(2) The PERT time duration estimates
(3) Minimum and Maximum number of men allowed on the activity
(4) Direct labor cost ($/man-day)
(5) Delay possibilities from:
    (a) Weather
    (b) Material shortage
    (c) Equipment trouble
    (d) Labor strikes

For the project

(1) Maximum number of men allowed
(2) Constant overhead ($/week)
(3) Variable overhead (% of direct labor)
(4) Amount of late penalty ($/day) and its start date

Figures 2 and 3 show typical outputs of this initialization phase. Additionally, a standard CPM schedule is generated which may or may not be distributed to the participants, dependent upon the administrator's desire.

2.2 PARTICIPANT DECISIONS

Each team (one or more participants) must plan the scheduling of the project activity. The teams' plans are converted on a simulated weekly basis, into a set of decisions or orders for the activities which they want to be worked during the next week of simulation. For each activity to be worked during the week, a team must turn in a card containing information necessary to identify the activity, indicate the days the activity is to be worked and the resources (number of men) to be assigned.

The objective of the participants is to complete the project with minimum expense. Premium labor can be expended to gain time, but such time gained may be lost to delays. Similarly, using minimum resources extends project time. Tradeoffs are possible and the objective is to make these tradeoffs in an optimal manner.

2.3 COMPUTER ASPECTS

Figure 4, a gross logic flow chart, has been included to provide a graphical summary of the manner in which PAMSIM acts upon the initial data and the participant's decisions to simulate the operation of the project system. The basic structure of the simulator is related to repetitive simulations of successive five-day weeks. Appropriate adjustments can be performed to permit other basic simulation periods.

(1) The first major segment of the simulator is devoted to acceptance and manipulation of the initial data. The usual PERT formulas are utilized to determine both the expected duration and the variance of that duration for each activity. That expected duration, combined with a random number of standard deviations along with the minimum manpower required for the activity, comprise the actual quantity of mandays of work required to complete the activity.

(2) Figures 2 and 3 illustrate both the appearance and the general content of the data provided each participant by the simulator's initialization phase.

(3) Simulation of each week of project activity begins with the determination of when, if at all, random delays from strikes (and their duration),

Project Parameters

| Events Pred | Events Succ | Activity Duration Estimates Opt | M L | Pess | Minimum Manpower Requirements | Maximum Manpower Permitted | Direct Labor Cost Per Man Day |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 3 | 2 | 3 | 4 | 4 | 6 | 100 |
| 2 | 9 | 3 | 4 | 6 | 3 | 5 | 130 |
| 3 | 4 | 3 | 5 | 6 | 5 | 7 | 100 |
| 4 | 5 | 3 | 5 | 7 | 4 | 6 | 130 |
| 4 | 7 | 3 | 5 | 7 | 3 | 4 | 150 |
| 4 | 11 | 2 | 3 | 4 | 2 | 2 | 100 |
| 5 | 6 | 5 | 6 | 8 | 4 | 6 | 120 |
| 5 | 8 | 2 | 2 | 3 | 4 | 6 | 120 |
| 6 | 7 | 6 | 8 | 11 | 4 | 6 | 120 |
| 6 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 12 | 5 | 7 | 8 | 3 | 4 | 150 |
| 8 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 14 | 6 | 7 | 9 | 3 | 4 | 130 |
| 9 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |

TYPICAL INITIALIZATION ACTIVITY REQUIREMENTS
Figure 2

Project Parameters

| Events Pred | Events Succ | Delay Possibilities From Weather | From Materials | From Equipment | By Labor Strikes |
|---|---|---|---|---|---|
| 1 | 2 | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY |
| 2 | 3 | A GOOD CHANCE | VERY UNLIKELY | IT IS POSSIBLE | NO POSSIBILITY |
| 2 | 9 | A GOOD CHANCE | IT IS POSSIBLE | NOT TOO LIKELY | IT IS POSSIBLE |
| 3 | 4 | A GOOD CHANCE | NOT TOO LIKELY | NOT TOO LIKELY | A GOOD CHANCE |
| 4 | 5 | A GOOD CHANCE | IT IS POSSIBLE | NO POSSIBILITY | IT IS POSSIBLE |
| 4 | 7 | A GOOD CHANCE | NOT TOO LIKELY | NO POSSIBILITY | NO POSSIBILITY |
| 4 | 11 | IT IS POSSIBLE | A GOOD CHANCE | NOT TOO LIKELY | A GOOD CHANCE |
| 5 | 6 | A GOOD CHANCE | IT IS POSSIBLE | NO POSSIBILITY | IT IS POSSIBLE |
| 5 | 8 | NO POSSIBILITY | IT IS POSSIBLE | NO POSSIBILITY | IT IS POSSIBLE |
| 6 | 7 | A GOOD CHANCE | IT IS POSSIBLE | NO POSSIBILITY | IT IS POSSIBLE |
| 6 | 10 | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY |
| 7 | 12 | A GOOD CHANCE | NOT TOO LIKELY | NO POSSIBILITY | NO POSSIBILITY |
| 8 | 10 | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY |
| 8 | 14 | NO POSSIBILITY | IT IS POSSIBLE | NO POSSIBILITY | IT IS POSSIBLE |
| 9 | 17 | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY | NO POSSIBILITY |

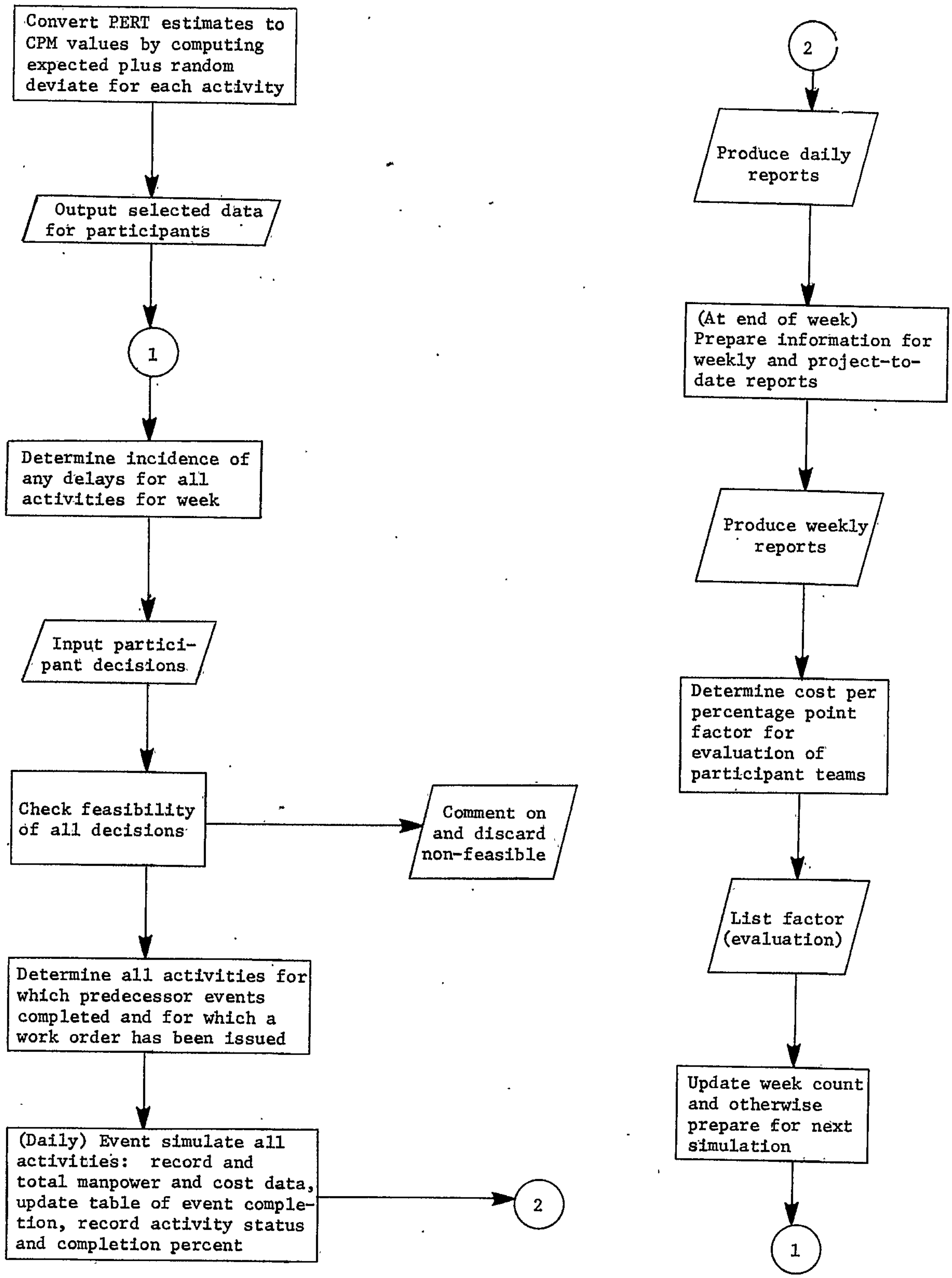
General Items --

Maximum Number of Men Permitted at One Time on Project - 20
Constant Portion of Overhead Charge (In $ Per Week) - 700
Variable Overhead Charge (Percent of Direct Labor Cost) - 70.25

Use of More than Minimum Manpower on a Task Causes a 50 Percent Higher Charge to be Levied for the Extra Personnel.

A Penalty (In $ Per Day) of 50 Starts After the 24th Working Day.

TYPICAL INITIALIZATION OUTPUT
Figure 3




GROSS LOGIC FLOW CHART
Figure 4

adverse weather, material shortage, and/or equipment non-availability will occur. Appropriate notations are made in the decision tables utilized during the actual activity simulation.

(4) Participant work order decisions are accepted as input and checked for certain levels of feasibility. Decisions which are not feasible or violate certain constraints are either corrected or discarded. Appropriate editing comments are also listed to aid in post simulation analysis. Feasibility checks include correct activity I - J number, acceptable activity and project manpower assignments, correct start-to-work dates, etc.

(5) A predecessor event table is generated during the initialization phase. As events are completed, they are "checked off" in that table. When all events which are precedent to another event have been checked off, a flag or notation is made in the pertinent decision tables to permit useful work to be performed on those activities controlled by the subject event.

(6) An event oriented simulation is then performed on each activity which has been scheduled and for which the controlling events have been completed. Cost and manpower use is recorded and the level of completion adjusted. Delayed activities (weather, materials and equipment) have manday completion requirements extended by an equal amount to preclude useless effort from counting toward completion. In cases of delay by strikes, no cost or manpower use is recorded since this expense is not born by the project. Cost and manpower use for activities which have been scheduled but can not be counted as useful because precedent events are not complete, are handled similarly to delays due to weather. A report similar to Figure 5 is prepared at the end of each day's simulation.

(7) At the close of the simulated week, cost summaries are prepared for both the effort during that week and for the project-to-date. A total project completion percentage is determined by comparing total useful effort and total required effort. In addition, an evaluation factor is computed to permit comparison of all participant teams. This factor "Dollars per Percentage Point" is simply the quotient obtained by dividing the total project completion into the total cost. A continuing low factor is desirable. A weekly report, illustrated by Figure 6, comprises the final report from a given run of the simulator.

(8) The cycle of simulation continues after participants analyze their output, adjust their control system, and prepare their next set of decisions.

## 3. CASE STUDIES

### Case I - Enlargement of Football Stadium

This project consisted of 74 activities and 48 events, scheduled over approximately 150 working days. Essentially this project consisted of removing an existing track, excavation to lower the playing field, construction of stadium seats, construction of end zone seats, creation of a central chair-back section, general renovation of existing seats, installation of an artificial turf and the addition of lighting the field.

Nine teams, composed of three participants each, competed among themselves and against the project using the simulator. The results are given in Table I. It is important to note that in this

| Team No. | Finish Date | Total Cost At Completion |
|---|---|---|
| 1 | 151 | $199,795 |
| 2 | 153 (max) | 200,023 |
| 3 | 145 | 212,786 (max) |
| 4 | 151 | 201,137 |
| 5 | 128 (min) | 199,472 |
| 6 | 154 | 194,547 |
| 7 | 137 | 206,973 |
| 8 | 150 | 196,972 |
| 9 | 151 | 193,482 (min) |

ACTUAL PERFORMANCES ON SIMULATION PROJECT: ENLARGEMENT OF FOOTBALL STADIUM
Table 1

project the late penalty did not affect any team. Had there been less slack (or negative slack), the earlier finish teams would have perhaps had more favorable total cost comparisons. The actual spread in completion time was 19.5% while the total cost variation was smaller at 9.9%.

### Case II - Wicklow Professional Center

This project consisted of 148 activities and 95 events with a completion of 100 working days. Three professional office buildings were to be built on a common location. Each was single story, steel shell frame with masonary walls. The similarities of these buildings allowed for many crew dependencies. Nine teams competed against each other using the simulator. Results of this project are given in Table II. The spread on completion was 19.4% while the total cost spread was only 1.9%. All teams incurred late penalty expenses.

| Events | | Work Status | Man Days Used | | Direct Cost | | Percent |
|---|---|---|---|---|---|---|---|
| Pred | Succ | | Today | Cumulative | Today | Cumulative | Completed |
| 1 | 2 | COMPLETED | 0 | 0 | 0 | 0 | 100 |
| 2 | 3 | COMPLETED | 0 | 31 | 0 | 4450 | 100 |
| 2 | 9 | COMPLETED | 0 | 12 | 0 | 2340 | 100 |
| 3 | 4 | COMPLETED | 0 | 35 | 0 | 4000 | 100 |
| 4 | 5 | COMPLETED | 4 | 34 | 240 | 3240 | 100 |
| 4 | 7 | WORKING | 4 | 7 | 675 | 1125 | 46 |
| 4 | 11 | FORCED WORK | 2 | 10 | 400 | 1200 | 90 |
| 5 | 6 | STRIKE DELAY | 0 | 8 | 0 | 960 | 33 |
| 5 | 8 | WEATHER DELAY | 4 | 12 | 480 | 1440 | 90 |
| 6 | 7 | NOT STARTED | 0 | 0 | 0 | 0 | 0 |
| 6 | 10 | NOT STARTED | 0 | 0 | 0 | 0 | 0 |
| 7 | 12 | NOT STARTED | 0 | 0 | 0 | 0 | 0 |
| 8 | 10 | NOT STARTED | 0 | 0 | 0 | 0 | 0 |
| 8 | 14 | NOT STARTED | 3 | 3 | 390 | 390 | 0 |
| 9 | 17 | NOT STARTED | 0 | 0 | 0 | 0 | 0 |

TYPICAL INTERIM OUTPUT
Figure 5

Costs for Week Ending on Day 10 are --

| | |
|---|---|
| Direct Labor | 11145 |
| Overhead | 8529 |
| TOTAL | 19674 |

Cumulative Costs Through Day 10 are --

| | |
|---|---|
| Direct Labor | 19145 |
| Overhead | 14320 |
| Late Penalty | 0 |
| TOTAL | 33465 |

This company is 33.4 percent completed and has expended $33465 as of Day 10. Dollars per percentage point = 1001.91.

TYPICAL INTERIM COST SUMMARY
Figure 6

| Team No. | Finish Date | Total Cost At Completion |
|---|---|---|
| 1 | 129 (max) | $230,370 |
| 2 | 110 | 228,414 |
| 3 | 108 (min) | 226,068 (min) |
| 4 | 122 | 230,362 |
| 5 | 115 | 227,910 |
| 6 | 115 | 228,334 |
| 7 | 125 | 230,374 (max) |
| 8 | 118 | 229,471 |
| 9 | 120 | 229,110 |

ACTUAL PERFORMANCES ON SIMULATION PROJECT:
WICKLOW PROFESSIONAL CENTER
Table II

## 4. CONCLUSION

Experience with the simulator program has been encouraging and educational. Some events which have occurred are:

(1) Good decisions have been "destroyed" by uncontrollable delays.
(2) The original critical path changes.
(3) Time-cost tradeoffs become viable alternatives during the project.
(4) The competitive nature of the participants acts as a stimulus for learning with little formal encouragement.

When PAMSIM is used in the competitive mode among teams, often the participants will use traditional approaches to supplement and aid them in the decision making process. A critical path program with updating is almost always employed. Sometimes the IBM Project Management System* is run in parallel. When this can be done, the PAMSIM program provides the dynamic aspect of the project, yielding the changes over time. Then the participants use the projection capabilities of the traditional tools to help form better decision policies.

It should be emphasized that the use of PAMSIM is not restricted to a team competitive situation. It could be used as a research vehicle, testing alternative decisions, rule or policies against a project environment.

Recalling that the objective of PAMSIM is to provide the participant a near-real environment in which the basic aspects of project management interact, the following excerpts from a team report after 11 weeks of simulation are offered as evidence of PAMSIM's educational values. Somewhat out of context, the participants report "The original computer prepared plan estimate of 130 days is unrealistic. Seven days were saved during the first 37.7% of the project. A manually devised schedule...gives a projected completion time of 104 days. This schedule is better than the computer run schedule because it allows for expediting and judicious planning in order to work at or close to the 15 men per day maximum... Slightly more expediting will be necessary than in the past but, on the other hand, increased project manager experience should slightly reduce the amount of forced labor and over-scheduling costs."

*Project Management System/360, Program Description and Operations Manual (H20-0344-2), International Business Machines Corporation, 1968.

## BIOGRAPHY

Professor Estes received his Ph.D. degree from the School of Industrial Engineering and Management at Oklahoma State University. He taught in the Industrial Engineering Department at Auburn University before returning to Oklahoma State. Teaching interests are in the areas of project management, operations research, engineering economy and facility design. Current research includes the application of modern engineering techniques to the problems of smaller cities and regional units of government. Dr. Estes, for seven years, was employed by Southwestern Bell Telephone Company in various management positions, including project engineering responsibilities. His consulting activities have been in the areas of material handling, facility design and project management.

Professor Herring received his Ph.D. degree from the School of Industrial Engineering and Management at Oklahoma State University while on a National Science Foundation Faculty Fellowship and on leave from Auburn University. Teaching interests include computer sciences, operations research, and industrial simulation. Prior to becoming affiliated with Auburn University in 1965, Dr. Herring was employed at White Sands Missile Range for seven years. His work there dealt with the design, implementation and operations of management control systems. His research interests have dealt with industrial studies and simulation methods.