Systems Simulation for Complex Managerial Problems

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ABSTRACT: *Managing any industrial system in day-to-day operation is usually a complex resource allocation problem. This complexity, always present in real life systems, makes the application of analytical tools as problem solvers questionable in many instances. In this paper simulation technique is proposed as an analysis tool that proved to be an adequate, effective and economically efficient problem solver in the case of resource allocation and utilisation for a number of industrial systems. The implementations described in the paper were developed using SLAMSYSTEM modelling environment.*

Keywords: Systems analysis, modelling, simulation.

INTRODUCTION

Systems have grown in complexity over the years mainly due to the increased striving for performance enhancing combined with a greater degree of uncertainty and imprecision in system's external and internal environments. Analytical models that are developed to deal with this complexity often can not cope with the various modelling problems at hand. In this paper, simulation modelling approach is proposed as an alternative or additional problem solving tool in such cases. It is shown that simulation can be an adequate, effective, and economically efficient problem solver for a number of managerial problems such as resource allocation, utilization and scheduling in the area of performance enhancement for complex manufacturing systems.

TO SIMULATE OR NOT TO SIMULATE

Simulation in the broad sense has been defined as an activity whereby one can draw conclusions about the bahaviour of a given system by studying the behaviour of a corresponding model whose cause-and-effect relationships are the same as (or similar to) those of the original (Harrell and Tumay 1997).

Simulation uses a computer program to actually mimic casual events and the consequent actions in a system. As put by Banks and Carson (1984) simulation involves the generation of an artificial history of a system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system.

The use of simulation by manufacturing and service industry sectors is rapidly increasing. Whether the application concerns material handling, storage and control systems, automation of a manufacturing system, resource allocation, or mechanisation of a distribution centre, simulation modelling is being used to test design and operation procedures of systems to enhance their performance. Simulation is no longer considered as the "last resort" tool but more as a powerful technique to analyse real-life problems. There are many specific reasons for that. Probably the most important one is that:

Simulation Modelling can be Applied to the Whole Life Cycle of a Typical Industrial Systems Project

Probably one of the most important advantages of simulation modelling is its adaptability. It can be easily applied concurrently to all project stages as the project evolves. The stages usually involve (i) concept design, (ii) detailed design, (iii) implementation, and (iv) operation. Using simulation models developed concurrently with each stage we can (Banks and Gibson 1989):

- understand basic system operation at the concept design level,
- select the best concept to proceed with to the detailed design,
- test all proposed operating and control procedures,

- test the impact of all design changes made during the implementation stage,
- test the impact of all proposed changes during the operation stage,
- predict necessary changes in the system operation to follow the envisaged changes in the external and internal environments of the system.

Examples and case studies of the above nature can be easily multiplied (Naylor at al. 1996, Witte et al. 1994). They show very clearly why simulation is more and more often chosen as an analysis and decision support tool. They also justify our attempt to use computer simulation as a tool for solving various problems for a number of companies in The Hunter, New South Wales, Australia.

A question that is often overlooked but should be asked is as follows: Is simulation modelling the right tool for the problem? The following may be good guidelines to consider before selecting simulation as a tool (Banks and Gibson 1997).

Do not simulate when:

- the problem can be solved using common sense analysis,
- the problem can be solved analytically,
- it's easier to change or perform direct experiment on the real system,
- the cost of the simulation exceeds possible savings,
- there are not proper resources available for the project,
- there is not enough time for the model results to be useful,
- there is no data - not even estimates,
- the model can not be verified or validated,
- project expectations can not be met,
- the system's behaviour is too complex or can't be defined.

Modelling Tool and Modelling Process

For our modelling purposes SLAMSYSTEM and AWESIM simulation environment has been used (Pritsker 1995, Pritsker and O'Reilly 1999). SLAMSYSTEM provides a simulation language that allows alternative approaches to modelling by easily altering parameters so that many variations of a system can be analysed. It permits network, discrete event, and continuous modelling perspectives, or any combination of the three, to be used in developing a single simulation model.

SLAMSYSTEM also supports both graphical and textural modes of programming. The graphical mode makes program design and debugging easier and quicker, whereas the textural mode is used for specific instructions. The software can easily convert between either mode as it is written. It also has the ability to allow the modeller to insert C language sub-routines where required.

SLAMSYSTEM creates entities and sends them through networks (or paths) which consists of activities and branching that allows the modeller to represent both the physical and decision making processes of the system that is modelled. The entities can have attributes assigned to them to allow for conditional branching. Resources can be used to control the entity utilization's and the program to control specific details can use system variables. Also, a number of probability distribution functions that allow reality to be represented more closely are supported.

SLAMSYSTEM simulation platform has been successfully applied in a modelling process of a number of different areas such as civil construction (Wales and AbouRizk 1996), maintenance (Szczerbicki and White 1998), organ transplantation policy (Pritsker 1995), mine operation (Charlton and Szczerbicki 1999) or manufacturing (Witte et al. 1994) just to name a few.

Model Verification and Validation

Each modelling process should include two very important steps: model verification and validation. Verification is defined as a comparison of the conceptual model with the computer model.

Validation is determining whether the model reflects reality It is extremely important since the basis of simulation is the substitution of the computer model for the real system.

After our simulation programs modelling operations at various companies based in The Hunter have been developed and implemented, they have been tested for correctness and accuracy. Well established verification scheme was used (Sargent 1998). All simulation functions that were included have been tested using simple entity flow tests to determine if they work properly. Then each simulation model was executed under different straightforward conditions to determine if the computer program and its implementations were correct. The bottom-up dynamic testing strategy was used. First, program modules representing systems decomposition were tested. Then, the overall model was run with a number of TRACE options to include in the testing process the values obtained during the program execution.

Our models were also validated and their satisfactory accuracy with the study objectives was determined. The techniques presented in (Sargent 1998), i.e. event validity, face validity, and historical data validation have been used for validation of all modules as well as of overall models.

Only after simulation models are verified and validated the analysts can start experimentation phase. Experimentation is where the real benefit comes in a simulation project. By conducting "what-if" analysis with the model, the analyst gains understanding of the behaviour of the system under varying conditions.

CASE STUDIES: SIMULATION MODELLING FOR PERFORMANCE ENHANCEMENT

A number of modelling and simulation projects have been run in the Hunter region in collaboration with local industries. The companies involved included Hunter Hospital, BHP, Airborne Australia, Tyton Conveyers, and Wambo Mine just to name a few. The complexity of each single problem was such that the application of traditional analytical tools was not possible. For illustrative purposes we follow with two brief case studies: open-cut mine operation and steel manufacturing.

Managing Open-Cut Mine Operation

Open-cut mining is carried out on the surface in which large strips of overburden are removed to expose the coal seam. The overburden is removed by using a variety of techniques, which include blasting, front-end loaders, shovels, trucks and draglines. Open-cut mining offers many advantages over underground mining. It is usually quicker and less labour intensive and can offer a higher degree of safety than underground mining and as such is more cost-effective.

One of the key areas in the running of the open-cut mine is resource management, in particular manning. By creating a model and its simulation it is possible to see what effects resource management decisions will have on the output of the mine. Given the variability of the overburden on the top seam, a model would help to estimate the mine output over a longer period of time, e.g. for six to twelve months.

More explicitly, the modelling purposes for this case were articulated as the following:

- provide a tool for help with resource management policy decisions,
- provide a tool for estimating output from the mine given a variable overburden level on the top seam,
- provide a set of parameters to be of help in the day to day management of the mine.

Details of the modelling process involved as well as detailed model description for this case are included in Charlton and Szczerbicki (1999). This presentation focuses on the results obtained. However, for the sake of completeness, some general model description is included first.

The open-cut mine operates a dragline, trucks, shovels and front-end loaders for the removal of overburden. Coal removal is contracted to an outside company. There are three coal seams mined in the open-cut (from the top they are: SEAM A, SEAM B, and SEAM C - see Figure 1.).

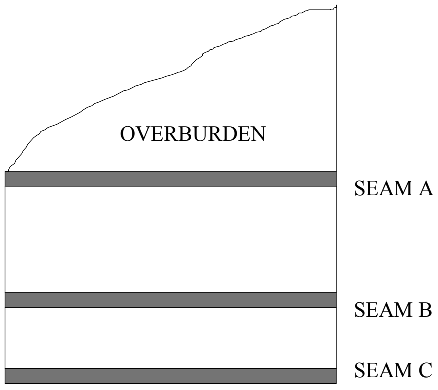

Figure 1: Coal seams configuration

Each seam is approximately 2.0 m thick and covered by overburden. The overburden on the top seam (SEAM A) varies in depth from approximately 0 to 30 m with an average of 15 m. The other two seams are more consistent in thickness being 26 m and 12 m respectively. The policies that management may choose when deciding which of the three coal seams will have priority when allocating the operators and equipment can have a large impact on the output of the coal mine. Thus the model of the coal mine was developed and then re-run several times, each run testing a different policy and recording the output of the mine for comparison.

All seams required similar modelling processes. For example, SEAM C modelling steps included the following:

Step 1 The entities arriving at SEAM C will wait until resources representing a drilling rig and two operators are available.

Step 2 The next step is the dragline operation. Again two await nodes are required for both the dragline and for two operators.

Step 3 As there is 1.0 meter of overburden remaining to be removed a 'clean up' operation is the next step.

Step 4 Once all the overburden has been removed the coal is then extracted by the 'dozer rip coal' operation.

All other seams were modelled using similar steps. For detailed description of these steps and the simulation programming code involved see Charlton and Szczerbicki (1999).

Simulation Runs and Results

In all simulation runs the main areas of interest are the number of entities exiting the system per coal seam and the resource utilisation, particularly the resource OPERATOR that models the real human operators employed in the mine.

The difference between the total number of entities exiting the system from run to run is also of particular interest. In all cases each entity represented approximately 10,000 tons of coal.

As there are 3 coal seams (A, B, and C) there are, theoretically, six possible priority sequences in which resources can be allocated to the seams. However, because of the physical configuration of the real life system some sequences can not happen in reality.

Two sequences were of special interest for the mine management and thus simulation was run for the following seam priorities:

1) Seam C, Seam B and Seam A
2) Seam B, Seam C and Seam A

For each run and each seam statistics for entity observations were gathered. Based on these observations we were able to show that the B-C-A sequence was better mining configuration allowing for larger coal output as well as better resources utilization. Over a 10 year operation of the mine, the above sequence would result in savings in the range of millions of tons of coal.

Managing Steel Processing

The focus of this case study is on the system represented by further processing area of a bar mill in steel manufacturing process. Further processing utilises various resources (equipment, labour, energy) to process bar length and coil products and represents one of the last stages in steel manufacturing sequence.

Further processing area includes the following activities (for detailed description of this activities see Murakami and Szczerbicki (1997)).

- WH (Warehousing),
- MR2 (Inspection),
- RE2 (Reinspection),
- BCL (Bar Classify),
- ST3 (Straight Press),
- CPR (Coil Press).

SLAMSYSTEM network model was developed to depict the logic of the steel flow in the further processing area. The model includes all activities that influence the functioning of the system under study. The manufacturer needed a modelling and decision support tool to analyse and solve the following problems:

- Determine ways to reduce the lead times for the further processing in order to reach a dispatching performance of 95% within 1 week.
- Improve the current rolling sequence as to reach the targeted lead time and dispatching performance.
- Find the optimum number of operators working at the further processing stations.

Simulation Results

The model was run using data supplied by the Planning Department of the manufacturer for whom the study was conducted. The main results were provided in histograms describing dispatching performance for all activities areas included in further processing, i.e. warehousing, inspection, classification and pressing. In Figure 2 below, the results for BCL (Bar Classify) are shown as an example. A 7 day lead time is highlighted.

```
                           **HISTOGRAM NUMBER 2**
                                TIME AT BCL
OBS  RELA   UPPER
FREQ FREQ  CELL LIM 0        20        40        60        80       100
                    +    +    +    +    +    +    +    +    +    +    +
  0  .000  .000E+00 +                                                 +
  8  .195  .100E+01 +**********                                       +
  8  .195  .200E+01 +**********         C                             +
 11  .268  .300E+01 +*************                   C                +
  8  .195  .400E+01 +**********                                C      +
  5  .122  .500E+01 +******                                          C+
  1  .024  .600E+01 +*                                                C
  0  .000  .700E+01 +                                                 C
  0  .000    INF    +                                                 C
---                 +    +    +    +    +    +    +    +    +    +    +
 41                 0        20        40        60        80       100
```

Figure 2: Dispatching performance for Bar Classify area

The summary of simulation results included in similar histograms for all activities areas is presented in Table 1.

Table 1. Summary of simulation results with a 7 day lead time.

Activity area	Dispatching Performance
MR2	85%
CPR	93%
BCL	100%
ST3	93%
WH	100%

The results in Table 1 clearly show the bottleneck (station MR2) which performs well below the targeted 95%. A number of "what if" scenarios were run and conditions for increased performance for this particular area were found. Also, the overall performance of the system was studied and the recommendations to improve it included:

1) changes in the rolling sequence,
2) changes in the allocation of operators.

CONCLUSION

In the paper simulation modelling environment was presented and recommended as a decision support platform for enhancing managerial performance in complex systems. An open-cut coal mine operation and steel processing were presented as illustrative case studies. The problems faced were of sequencing and resource allocation nature. The complexity of the real life system made the application of analytical tools as problem solvers impossible. Simulation technique proved to be an adequate, effective and economically efficient problem solver in such cases.

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