AN ANALYSIS OF MANUFACTURING SIMULATION SOFTWARE

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ABSTRACT

As a management tool Simulation Software deserves greater analysis from both an academic and industrial viewpoint. A comparative study of three packages was carried out from a 'first time' user approach. This allowed the ease of use and package features to be assessed using a simple theoretical benchmark manufacturing process. To back the use of these packages an objective survey on simulation use and package features was carried out within the manufacturing industry. This identified the use of simulation software, it's applicability and perception of user requirements thereby proposing an ideal package.

INTRODUCTION

The use of simulation software in the manufacturing industry, as a tool assisting process and system development and analysis, is a subject which receives little journal coverage out with sales orientated package case studies. To understand the slow uptake [1] of manufacturing simulation software it was decided to carry out an analysis of the current software available with a view to determining the requirements of the ideal manufacturing simulation package.

A survey of the Scottish manufacturing industry was carried out, aimed at the identification and use of simulation software as well as the perception of package requirements. Industry is, after all, the main user of such software and valuable information regarding their needs must be assessed.

The objective was to develop the model of a simple theoretical benchmark manufacturing process on three simulation packages. This was undertaken without prior knowledge of the package operation in order that the user friendliness could be assessed along with the representation of the model and the statistical output features.

The packages were then compared without bias and their outputs assessed with a static mathematical model, commonly used to analyse manufacturing systems in a spreadsheet form.

The study aimed to demonstrate the development required to make simulation a beneficial tool, outlining it's role in manufacturing development.

SURVEY ON CURRENT SIMULATION USAGE

Aims of survey

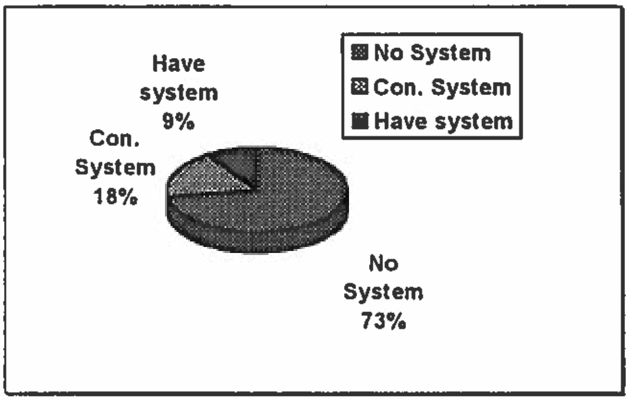
To enable the current use and the regard for simulation in manufacturing industry to be assessed, a survey of production companies in Scotland was undertaken. The aim of the survey was to address the following areas:

1. Is simulation used before implementation of changes to manufacturing systems?
2. What simulation packages are utilised and at what level (Major system change to minor rescheduling change)?
3. Who is involved with the simulation used (in-house engineers, management, production engineers, external consultants)?
4. Reasons for not using simulation (System costs, Development costs, lack of skilled personnel, lack of knowledge in this area, not considered necessary).

Target Companies

It was decided to survey companies in Scotland alone as it was felt locality and previous links with may be beneficial in provoking a positive response to the questionnaire.

Summary of Results



The survey demonstrated the slow uptake for simulation software in the Scottish manufacturing industry. The majority of companies had not given consideration to investment in simulation as a management tool. The feedback would suggested the reasons for this as being:

1. Lack of information,
2. Current system operates to requirements,
3. Use of external consultants in production management.

Where companies had considered a system but decided against the use of simulation the reasons given were:

1. Not deemed necessary in high volume environment which was unlikely to require change,
2. Available systems not suitable,
3. System and training costs outweighed any perceived benefits.

Case Studies

Several case studies were conducted on companies which were found to be using manufacturing simulation systems in their production planning and management. This allowed a more flexible approach to the assessment of simulation use in Industry than that possible by questionnaire alone.

The introduction of simulation in the companies involved differed broadly. In one instance simulation was introduced by an industrial engineer who had used the package in a previous company. In another, a year long study into simulation use, the companies expectations of simulation and the benefits to be achieved was carried out.

It was found that in production systems where simulation was being utilised, most were electromechanical assembly lines operating on a Kanban basis. The main usage of the packages were in the management of the production lines. The production team would assess solutions to manufacturing problems and use the simulation package to demonstrate the solutions. These included the following areas:

1. Analysing work output during overtime,
2. Assessing optimum staffing levels,
3. Throughput time v production time,
4. Increase production capacity.

The case studies highlighted the problems involved with the current simulation packages both in the development of the simulation model and in the actual benefits to be obtained using simulation.

STUDY OF SIMULATION PACKAGES

Modelling of the Manufacturing Process

In this study a manufacturing cell consisting of three machine types producing two differing parts shall be considered. Firstly the physical aspects of the cell should be examined. It should be evident that the hypothetical cell contains factors that would not be present in an operational cell. It would be unlikely that a cell of such size should utilise an Automated Guided Vehicle (AGV) and the product mix would be limited to two. These divergence's from reality have been used to display the necessary characteristics while keeping the cell simple. For the sake of demonstration purposes the AGV has been included and restricting the product mix to two shall produce sufficient results to be analysed.

A schematic of the cell is given in Figure 1.

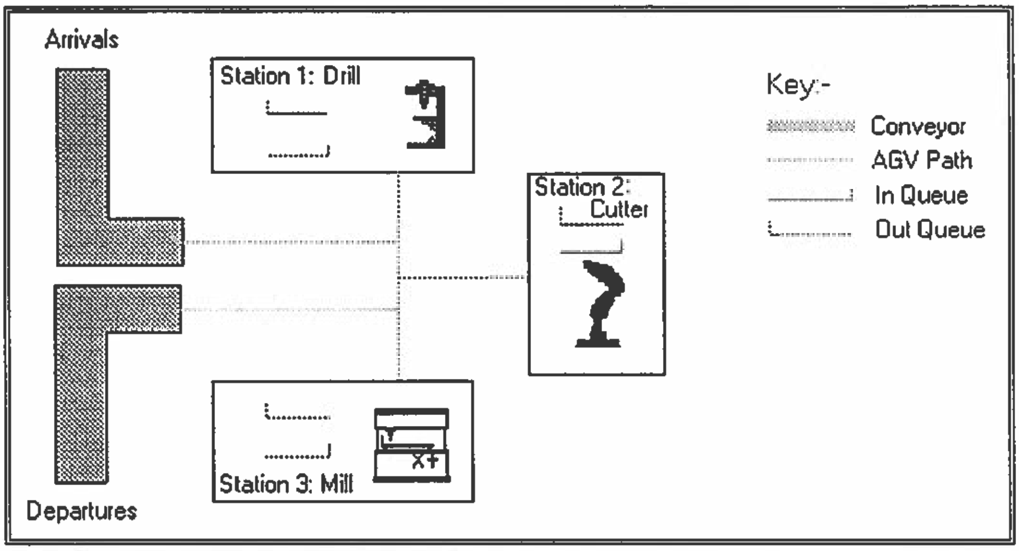


Figure 1 Diagram of Manufacturing Cell

Each station contains a machine, incoming queue and out going queue. The raw materials for the two part types shall arrive from out with the system by the conveyor. Part A shall require three operations in the sequence of Station 1, Station 2 followed by Station 3. Part B shall follow the sequence Station 2, Station 1 then Station 3. An AGV shall be employed to transport and transfer the parts between the stations and conveyors.

On arrival at the system the part shall be assessed to determine the part type and from this the sequence of operations required. The AGV shall be requested to transport the part to the first operation where it shall join the incoming queue. When the machine is available it shall operate on the part. On completion the part shall be passed to the outgoing queue and a request made to the AGV for transportation to the next operation in the sequence. When all operations are complete the part shall be transported to the depart conveyor where it shall leave the system. It will be assumed that the part arrival rate is known along with the machine service times. These are given in Table 1 and Table 2.

Table 1 Part Characteristics

Type	Arrival Rate	Operation Sequence
Part A	5/hour	1-2-3
Part B	5/hour	2-1-3

Table 2 Machine Details

	Type	Part A	Part B
Machine 1	Drill	10/hr	12/hr
Machine 2	Cutter	14/hr	8/hr
Machine 3	Mill	9/hr	12/hr

Simulation Packages to be studied

Simulation software was used to model the manufacturing system given below. Three packages were available for consideration, Package A, Package B and Package C. The packages were assessed from a 'first time' user approach, with no reference to package handbooks. On-line help and examples supplied with the package were used for guidelines. This was to enable the user friendliness and the familiarisation with the package to be determined as this can indicate a package's acceptability to the user.

Mathematical Modelling

It was found from the case studies that static spreadsheet analysis [2] was being used to analyse manufacturing systems in preference to simulation software. A mathematical model shall be used to demonstrate the results obtained from an analysis of the manufacturing system. The equations used are given in table 1 and follow the accepted queuing theory [3].

Table 3 Analysis Equations

	Workstation	Queue
Work in Progress	$L = \frac{\rho}{1-\rho}$	$L_q = \frac{\rho^2}{1-\rho}$
Throughput Time	$W = \frac{1}{\mu(1-\rho)}$	$W_q = \frac{\rho}{\mu(1-\rho)}$

The above equations can now be used to determine the operational characteristics of the workstations in the Manufacturing system given in Figure 1.

RESULTS

In the situation of a hypothetical model used to demonstrate the development facilities of the software packages, there is little to be gained from analysis of results as there is no problem to solve. Of interest, however, is the differences in results when modelling the same system using different packages and mathematical modelling.

Chart 1 Queue Length

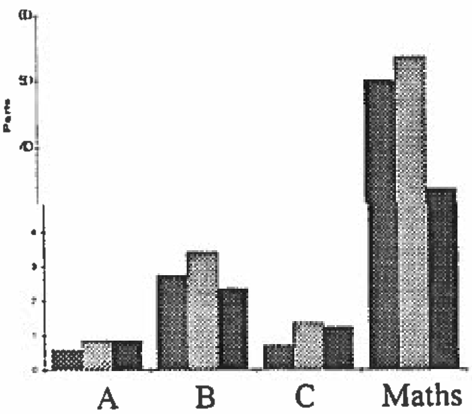


Chart 2 Throughput Time

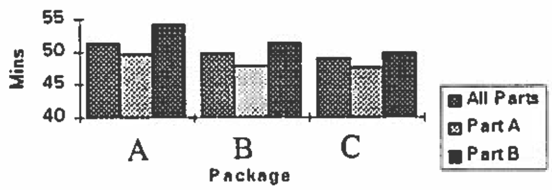
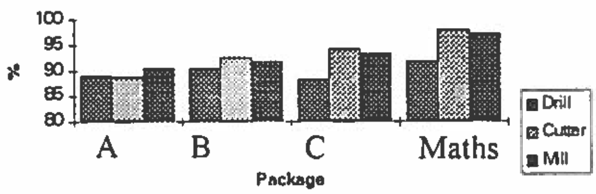


Chart 3 Machine Utilisation



Comments on Results

On the whole there is little difference in the results obtained from the various simulations, with the exception of the mathematical study. The overall throughput time for Package C is approximately 2 minutes less than the Package A and Package B figures. The reason for this stems from the direct transfer of parts between the machines as opposed to AGV transfer, thus giving shorter transfer times. Of note, however, is the somewhat unrealistic values of the mathematical model. This is a result of the system being close to saturation point and becoming unstable. The arrival rates of 10 parts per hour are very near to the service rates of between 10.18 and 10.9 parts per hour. It is interesting to note that an increase in the service rates by 1 part per hour would result in the statistics given in Table 4 Mathematical Results. This is a result of a more stable system.

Table 4 Mathematical Results

		Service		Utilisation		WIP		Throughput	
	λ'	Old	New	Old	New	Old	New	Old	New
Station 1	10	10.9	11.9	0.917	0.84	11.04	5.25	1.1	0.52
Station 2	10	10.18	11.18	0.98	0.89	54.6	8.09	5.46	0.8
Station 3	10	10.28	11.28	0.972	0.88	34.7	7.33	3.47	0.73

The results of the simulation were obtained from a replicated time of 8 hours, representative of a normal working shift. The results of a longer run period may be worth considering to see if the system stabilised to that of the mathematical model. It can be seen from the Package B Queue length/time graph during animation that the queue length, while averaging at approximately three parts, is continually rising up to the eight hour point, finishing at five parts. A longer run would indicate at what point stability is achieved.

ANALYTICAL RESULTS OF PACKAGES.

Package A

The following features stand out in the Package A.

Pros:

1. Quick to model very simple cell with no animation and little detail.
2. Ability to model without animation if required.

Cons:

1. Three separate development programs required to produce animated model.
2. No software links between development programs.
3. Blocks and Elements data editors are cumbersome.
4. Five separate compilation stages required to run animation after simple data change.
5. A data change may require amendment to all Blocks, Elements and animation files.
6. Cinema package complex in the layout of animation features.

The main problem with the Package A came from the development of the model in three separate programs and environments. As there were no software links between the programs all variable names and resource numbers had to be listed separately. In effect to produce a model effectively it was necessary to design the model on paper and then transfer to the package.

The editors of the blocks and elements files presented problems. After accessing an Element field menu and entering data the Escape key is used to back out. Accessing a field in error and Escaping out will result in an empty data field being added. This error cannot be detected until the program link stage. This problem is more to do with the age of the package (released in 1987).

Another problem with the development was the compilation of the files. The Model file and the Elements file are both compiled separately then linked together to produce the simulation data for the Package A program. The Package A animation program then requires to be run with the layout file and the Package A program file. This procedure has to be repeated for every time a change is made to the model or elements file.

The animation development suffers from a two stage development of the animated picture. Each resource picture is drawn and placed. Layers of logic then have to be added to the picture to define the movements of the parts. Again the logic icons have to be numbered corresponding to the Model and Elements files. It is quite simple to erroneously enter a number, with no indication of an error.

Package B

The following features of the Package B package are notable.

Pros:

1. Graphic development makes model easy to visualise (good drawing package).
2. Resource picture and animation logic linked.
3. All modelling carried out on the one screen.
4. Displaying of graphs etc. on screen during simulation.
5. Transportation simple to represent.

Cons:

1. Revalidating Entire model after change.
2. Requirement for additional blocks to complete model.
3. Set up of statistical reports complex.

The graphical development environment makes use of high resolution drawing to represent the manufacturing system and its resources. This leads to good representation during animation. The model development task is eased by the use of menus to access resource data with fields such as resource names having pull down menus containing all resource names. This along with a single development environment eases the model building stage by eliminating the need for multiple resource definition as in Package A. The single environment simplifies the process of changing the model as all data can be accessed from the same screen.

The movement of parts through resources is modelled in a simple manner with each resource defining the mode of transport in and out. All possible methods are given in the menus.

The draw back of model development with Package B is not all the data attributed to a resource is attached to the picture icon of the resource. It is necessary to include additional detail blocks to the resource picture.

The validation of the Package B model is carried out in a single stage before running the simulation. To change data at this stage however still requires the animation to be stopped and the model to be revalidated before beginning the simulation.

Displaying statistics on the screen is a simple process of placing a graph and linking it to the variable. Outputting statistics requires each variable to be referenced to a user specified data file. While this allows the Package B output processor to generate useful graphics, The files should be referenced automatically allowing simple selection of the graphic results required.

Package C

Pros:

1. Windows environment.
2. Simple model building.
3. All element detail contained under element icon.
4. Change of data during simulation.
5. Interactive debugging.

Cons:

1. Complex modelling of transportation.
2. Input/Output rules editor.

Package C makes full use of the Microsoft Windows operating system. This presents a very user friendly front for the package as most users will have previous Windows experience. This also allows for several screens to be displayed at once.

The use of predefined icons allows for rapid model development and with all the element data contained under the one icon, gives a less cluttered look to the development screen than Package B.

One of the most useful features of the Package C is the ability to change model data during simulation. The animation is paused, the data change made and the animation is continued from that point. This in conjunction with the interactive debugging window, commenting on all simulation actions provide an excellent debugging environment.

The method of describing the transportation of parts involved complex rules to express part transfer. The use of tracks to determine transfer was far more complex than Package B's use of the AGV. The tracks linked one resource to the next and transfer rules were required for each track section. The tracks could only have one direction, making all sections of AGV movements requiring two tracks. Parts were pushed onto a track, then carried by an AGV dedicated to that track. The route was depicted by transfers from track to track, finally being pushed from the track to the destination station. As demonstrated by Package B this function is much simpler when described in terms of the AGV.

IDEAL SIMULATION PACKAGE

The important criteria of Manufacturing Simulation Software are given as ease of use, efficiency, typical physical elements and performance measures [4]. The following list represents the characteristics of an ideal simulation package as derived from experiences with the three packages of this study:

1. Windows Based (Package C).
2. Icon based development (Package C).
3. Common resource library (Package A, Package B, Package C).
4. All resource information on menus behind icons (Package B, Package C).
5. Menu driven transfer definition (Package B).
6. Data change possible from simulation run (Package C).
7. Graphical Statistics representation an screen (Package B, Package C).
8. Auto-generated output statistics (Package C).

With Windows effectively standardising the graphical interface of software packages, and most computer users already familiar to it, a windows based package is a definite requirement.

A development environment that provides a single icon per resource with all detailed information contained under that icon simplifies the building of the model process. As all data concerning that element is on the one menu it is less likely that attributes shall be forgotten or lost during a change.

All packages contained the ability to create resource libraries. This is essential in a commercial environment where a library of all machine data etc. can be created, allowing instant access to a resource and its characteristics.

One of the problems with Package C was the transportation of parts through the system. Package B made use of Transport In and Transport Out menus to assist this. With Package C it was required to write transfer rules describing the system operation. The menu driven form allows the transfer of parts to be defined using standardised procedures.

The running of the animated simulation should show clearly what is happening within the system. The use of animation allows the flow of parts and state of resources to be depicted. In order to gain greater understanding during the animation the inclusion of graphs giving a running account of statistics is necessary. Concurrent graphical analysis allows problems to be determined during the simulation run and corrective action taken. This leads to the useful point of making changes to the model during simulation. If a model requires change, the effects of that change can be seen with immediate effect and compared with the previous situation.

CONCLUSIONS

Package A is now seven years old and this study has reflected this in its unfriendly environment and complex model building routines. This package is still in use today with the University of Derby reporting a consultancy interest in the package.

The introduction of Package B, effectively giving Package A a friendlier model development environment, shall be welcomed by Package A users. Similar terminology is used and the basic structure of the development is the same. Unfortunately the separate defining of model entities and animation details was also brought over from Package A.

Package C, with its single icon per resource, does not have this problem. The model development is therefore quicker and geared towards producing results as quickly as possible. Of the three packages it fulfilled more of the ideal requirements. While it is not the place of this study to recommend a package, as this is reliant on the individual situation, Package C should never the less be one for consideration.

MANAGEMENT IMPLICATIONS ON THE USE OF SIMULATION IN INDUSTRY.

It would seem that given the results of the survey simulation has been, to a certain degree, disregarded by the manufacturing industry. While large companies such as British Aerospace and AT&T make use of simulation, It does not seem to be favoured by the smaller production company. One of the reasons for this is simulation has been seen as a complex operation, requiring expert knowledge, which contributes little to the decision processes in manufacturing development.

The adoption of this stance is well founded when examining packages such as Package A and previous simulation programming languages. The simulation of a manufacturing system would require a software engineer to develop the program and it would be unlikely that one could be found in a small production company. The need to bring in consultants or contract engineers would lead to increased costs and project time. There is also the problem of an outsider not fully understanding the system or indeed the problem itself.

As can be seen from case studies [5,6], there is a role for simulation in the manufacturing industry. The use of simulation has resulted in financial savings for Massey Fergusson when introducing new plant. A 33% increase in output was achieved at 3M when simulation was used to analyse their system. It is the outdated view of simulation packages which has to be targeted.

With the development of graphical interfaces for simulation software and much emphasis being placed on 'user friendly' attributes, simulation is now available in a form which is readily accessible for non-software oriented engineers. Package C has been developed with the manufacturing engineer in mind, using the terminology of the manufacturing process as opposed to the software process.

It is quite true to say simulation contributes little to the decision process. It was estimated at AT&T simulation accounted for 10% of the problem solving time spent on a project. What has to be considered at the outset of a project is what role simulation shall play and the expected benefits of using simulation.

Simulation is a tool and, as with every tool, it has a dedicated task. It is no good tightening a screw with a spanner. It is therefore imperative to fully understand the problem in hand before deciding if simulation is a viable catalyst to a solution.

It should be noted that simulating a problem area does not provide a miraculous solution. Simulation is an analysis tool which provides data upon which a solution decision can be based.

This is an area of much misunderstanding which generally results in simulation being disregarded as an effective tool. Consider an engineer analysing a system which has an inherent problem. It is decided to simulate the system and find a solution. The system is modelled with time being spent gathering data on the system and constructing the model. After the simulation run the engineer is no further forward. Simulating a problem system also simulates the problem. It is a this stage that the engineer gives up having achieved no solution from the simulation run. In fact this is just the initial stage of the problem solving process. Simulation of possible solutions developed by the engineer should be carried out and analysed along with the problem to find the suitable solution.

It is hoped that an increase in the education of simulation shall filter through to manufacturing companies. At present most of the papers on simulation in manufacturing journals are sales case studies. While this raises the profile of simulation it does not always provide an objective view point. It may be a matter for the educational institutions to provide a more impartial perspective on the use of current simulation software.

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