PERFORMANCE ENHANCEMENT USING AN EXPERT MECHANISM IN A MANUFACTURING SIMULATOR

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ABSTRACT

The need to include a mechanism that could assist in analysis and performance enhancement of simulation models has been under discussion for a long time. Many simulation packages on the market offer powerful "what-if" evaluation techniques for production planning. However, most of them rely on the user's own experience to interpret the results after each simulation, and anyone without such experience would find it difficult to make reasonable sense of the results before deciding on the next simulation run. This paper describes the use of an expert mechanism that could be integrated into a simulation package to facilitate the process of interpreting and assessing simulation results and in improving performance. It also discusses the need for checking stability of the model before reporting the model as realistic.

INTRODUCTION

Although simulation in manufacturing has traditionally been used for high level capacity planning, there are many other benefits in using simulation. Factory layout, production routing, production mix, and throughput prediction, bottleneck identification, new resources deployment, to name but a few, can all be predicted using simulation. Ben-Arieh , while explaining the need of simulation asserts that in modern manufacturing facility, the available flexibility introduces another degree of flexibility in decision making. The lack of clear understanding of the dynamics and interaction of components of modern manufacturing systems calls for the use of simulation as an essential support tool. Simulation is no more a niche management tool, which can only be afforded by a few, thanks to ever increasing computer power and its affordable price. The advancement in programming and software engineering also means that very clever simulation software has hit the market, with highly configurable user features and powerful animation [Mebrahtu & Lung].

However, these powerful features are generally focused on the front-end of creating a manufacturing model easily and on getting simulation results quickly [Pengen et al]. As a result, massive reports, which include statistics, tables and a lot of raw data are generated, but do not help the user see the connection of these reports to the next appropriate action in a consistent and logical way. Any interpretation and action will depend solely on the user's experience in using simulation. Additionally, limited alternative simulation models could be dealt with in a traditional way but as the possible alternatives increase, conducting a large number of simulation runs becomes time consuming and costly (Morito et al).

Some commercial simulation packages now include some type of integrated optimisation routine, Optimiser in Witness and OptQuest in Delma [Fu et al], for instance. The goal of these routines is to seek improved settings of user-selected system parameters with respect to the performance measure(s) of interest. However, unlike mathematical programming packages, there is no way of knowing that an overall optimum has actually been reached, thus *optimisation* may be a loose word.

The experimental work in this paper illustrates the use of a rule-based algorithm that is integrated with a simulation package to analyse simulation output, assess performance of a production floor, and automatically change the controllable variables within given constraints to enhance performance. Once the stability of the original model is checked, each time the simulation is executed, the rule-based algorithm would interpret and analyse the results, and suggest a suitable action plan for the next iteration for further improving the performance. Such a concept also opens up a huge possibility of running the rule-based simulator remotely across the Internet, hence allowing smaller companies to benefit from simulation.

EXPERIMENTAL MODEL

Base Model

In order to demonstrate how simulation results can be translated into action plans, and how different production scenarios can be compared using performance indices, a case study factory model with limited operation and resource flexibility has been set up as shown in Figure 1. The experiment was based on a company model obtained from the Lanner Group, the software house behind the

WITNESS simulation modelling system. Some operational data have been modified for simplicity.

At the start of the experiment, the case study company experienced a severe backlog in sales orders due to antiquated machinery and poor production planning. Assuming that there was a demand for up to five times of the current product output, a series of simulation runs were set up to evaluate the effect of investing appropriate resources against the possible increase in throughput and benefits.

The model consists of seven main operations. The manufacturing process starts with the stock of bars that come into the saw area stock buffer. The bars are then cut producing 3 blocks from each bar. After sawing, the blocks go to a belt conveyor that transfers the cut bars to the coating operation. The coating machine coats 6 blocks at a time. Once coated the blocks are placed in the staging area adjacent to the inspection station. The inspectors then determine the quality of each block's coating and send it either to hardening, or to the rework buffer. The hardened blocks are then loaded into special fixtures so that four blocks can enter a grinder at once. There are two grinders available with no priorities between them. Once ground, the fixture and the four blocks are placed into an unloading station where the blocks (now valves) are sent to the finished stock areas and the fixtures onto an overhead conveyor. The conveyor puts the fixtures back into the fixture buffer for reuse by the loading machine. Witness was used to model the system.

Model Stability

It is important to ensure that the model is not significantly affected by changing the random number streams. If it does, then the model results cannot be expected to give a solution that would be realistic. The stability of the model was checked by conducting 25 runs with different random number streams for each run and for each element and each corresponding data. This was meant to give the feel that events were following more realistic randomness. Outputs of the 25 runs were recorded and a Cusum (90% confidence) conducted as shown in Figure 2. The mask used is a C2 semi-parabolic mask as defined in BS 5703 part 3. It could be seen from the graph that the data were all between the upper mask and the lower mask, indicating good consistency. A similar stability check was conducted on the last model and it again showed satisfactory stability.

The reason for selecting Cusum charts to check stability is to allow future development of the program to automatically check that the change being proposed will result in a significant improvement. The development process will continue by integrating an 'evolutionary operation' (EVOP) design of experiment system into the program, which will be controlled and monitored by Cusum charts [Walker], until an optimum solution is achieved.

THE RULE-BASED EXPERT MECHANISM

Objectives

The existing system can manufacture around 144 valves every 75 hours. It has been established that the benefits of an increase in throughput by 1 valve can be fully justified for an investment of £250. That is, for each investment of £250, there must be an increase of at least one part. A maximum amount of £75,000 is available to be spent for the investment, which amounts to an equivalent of 300 more valves to justify the spending. The main investment costs expressed in terms of production benefits are shown in Table 1. Each item has been assigned a cost equivalent in parts.

Methodology and Results

As previously described, our main performance index is net profit (or net saving) which is the difference between the increase in throughput and the investment (expressed in terms of equivalent parts). The main rules used include the techniques of Theory of Constraints and line balancing backed by concurrent monitoring of investment. It involves mainly identifying bottlenecks and blockages that are used as the basis for actions to be taken in each sequential simulation run.

Witness as an object link embedding (OLE) automation server could be controlled by Visual Basic (VB) which is an OLE controller [Lanner Group]. Relevant input/output data to Witness as well as running of Witness could be controlled with VB (with some assistance from Excel). Therefore, using VB to develop the expert mechanism was ideal. The simulator uses data displayed in Excel but controlled by VB, runs the model and generates output. The expert mechanism receives the relevant output data from the simulator, manipulates the data, assesses model performance and generates recommended changes for the next run. The iteration goes on until a limiting factor is reached, at which point the result would be output.

Eleven simulation runs were conducted with the summary of results shown in Figure 3. The results indicate that all except runs 4 and 7 could be justified for their respective investments. Models 10 and 8 showed the better net savings, with model 10 significantly favoured both in savings and its throughput in view of rectifying the current problems of the company.

CONCLUSION

Although the model is limited in many respects, it highlighted the basic concept of integrating an optimising element to a manufacturing simulator for automatic results analysis and performance enhancement. Various performance assessment methods such as throughput, inventory level, machine utilisation and investment can be incorporated into future experiments to make the system more versatile for a wider spectrum of simulation scenario. The proposed concept can handle a mix of different production objectives whereby users can set target figures with each objective, and the system will iterate until those targets are met within specified allowance.

In an ever growing popularity of the Internet, making the system WEB compliant is another goal in future research. When fully developed, it is possible that registered users from remote sites can use the system by providing required inputs to the simulator, target objectives, constraints of scenarios, plus other necessary details required to build and run a totally customised model on the net. The simulation system will then run continuously at the host web site until the targets and constraints are satisfied. The remote user can then view the optimised results and the accompanying conditions. This concept of **A**pplication-**O**n-**D**emand (AOD) has yet to be materialised but has great potential in allowing smaller firms to benefit from specialised application software such as manufacturing simulation, with the consent of the software suppliers.

REFERENCES

Ben-Arieh, 1986, *A Knowledge-based system for Simulation and Control of FMS*, p 287-295, IFS Publications Ltd.

BS 5703 Part 3 (1981)

Fu M C et al, 2000, "Integrating Optimisation and Simulation: Research and Practice*", Proceedings of the 2000 Winter Simulation Conference*, p610-617,

Mebrahtu M, Lung A, 2001, "Prediction of Shop floor Performance using a flexible manufacturing simulator ", *World Manufacturing Congress 2001*, ICSC-NAISO Academic Press.

Morito S, Koida J et al, 1999, "Simulation-based constraint generation with applications to optimisation of logistic system design", *Proceedings of the 1999 Winter Simulation Conference*, Edited by Farrington, Nembhard, Sturrock & Evans.

Lanner Group, *OLE Automation in Witness*, *Witness 2002 on-line*, Lanner Group, 2002.

Pengen C D, Shannon R E, Sadowski R P, 1990*, Introduction to Simulation*, Mc Graw-Hill.

Schormann F, Perera T, 1998, "Model representation methods in simulation of manufacturing systems", p292-296, *International Conference on Simulation 98*, York University, UK.

Walker R W, 2002, "Evolutionary Operation (EVOP) Evaluated by Cusum Charts", *Conference paper at World Manufacturing Congress,* ISBN 3-906454-28-2.

Witness training course notes from Lanner Group, 1998

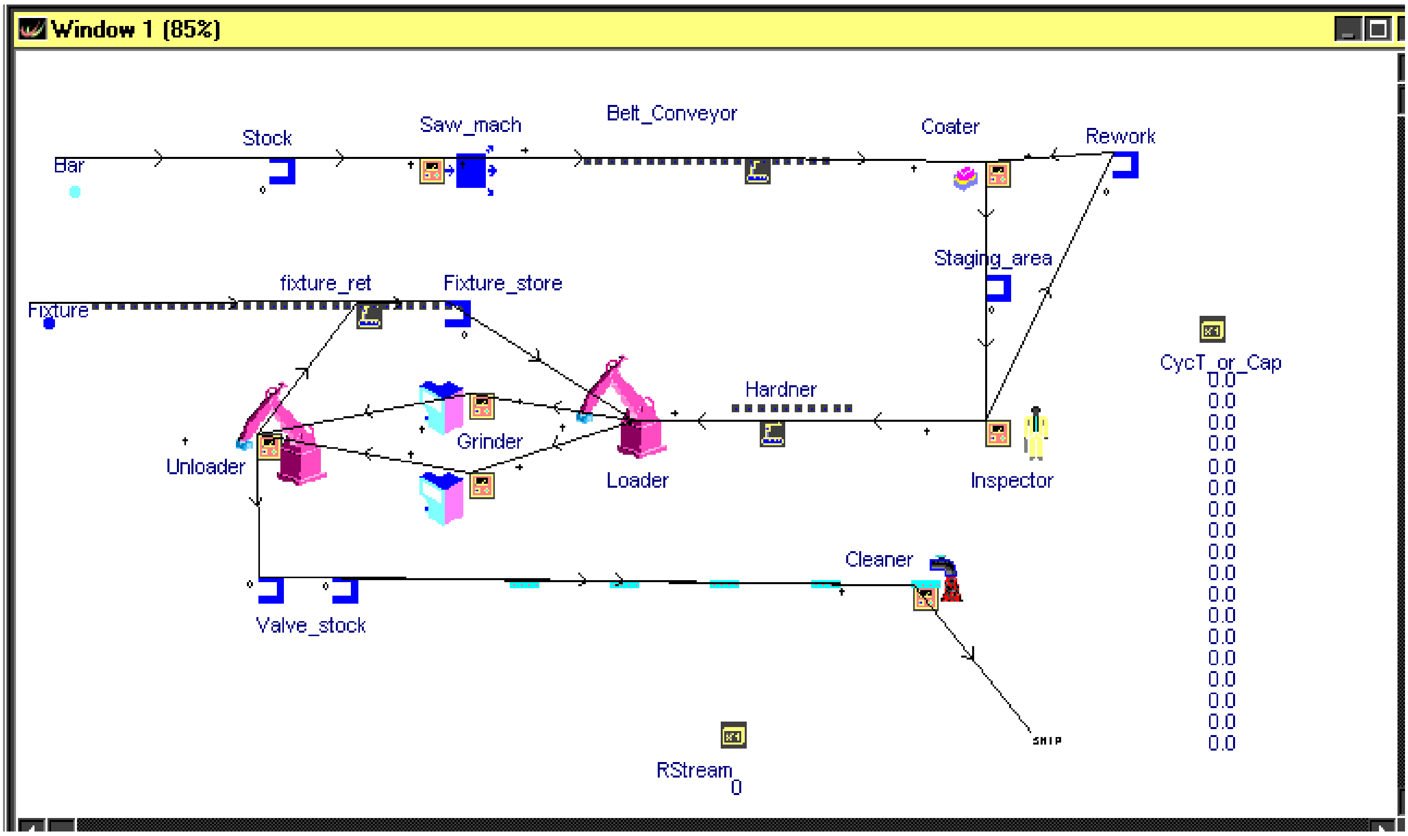


Figure 1 – The simulation model used in the experiment

Element	**INVESTMENT COST-EQUIVALENT IN PARTS**		
	New Element	**Decrease cycle time by 10%**	**Decrease set-up time by 10%**
Buffers	0.2		
Saw_machine	100	10	20
Conveyor		10	
Coating machine		24	
Inspector	80	24	
Hardener (Furnace)		24	
Loader/ Unloader	64		
Grinder	200	40	
Cleaner	40		

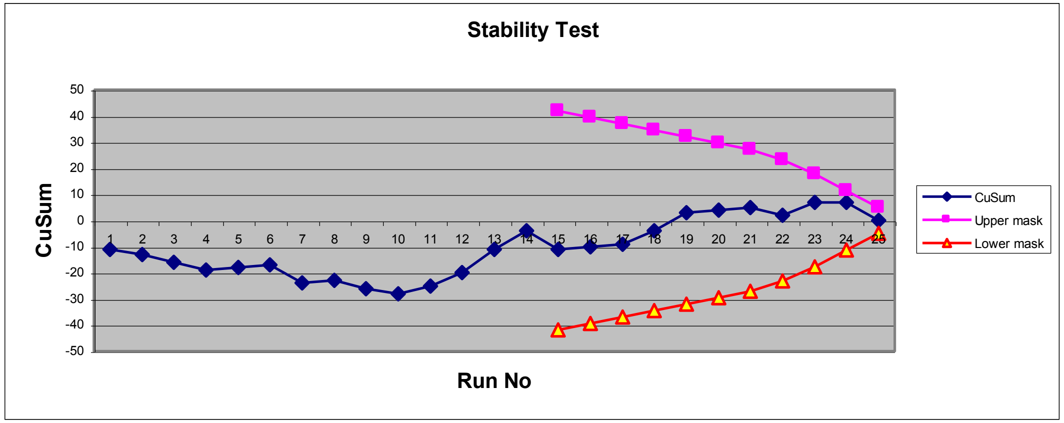
Table 1 - Possible Costs for Investment

Run No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Valves, x	136	145	144	144	148	148	140	148	144	145	150	152	156	154	140	148	148	152	154	148	148	144	152	147	140
x-T	-11	-2	-3	-3	1	1	-7	1	-3	-2	3	5	9	7	-7	1	1	5	7	1	1	-3	5	0	-7
CuSum	-11	-13	-16	-19	-18	-17	-24	-23	-26	-28	-25	-20	-11	-4	-11	-10	-9	-4	3	4	5	2	7	7	0
Upper mask															41.86	39.4	36.93	34.47	32.01	29.55	27.08	23.14	17.73	11.33	4.924
Lower mask															-41.9	-39.4	-36.9	-34.5	-32	-29.5	-27.1	-23.1	-17.7	-11.3	-4.9

Target, T	147
StdDev	4.924

Ctrl Factors	8.5	8.0	7.5	7.0	6.5	6.0	5.5	4.7	3.6	2.3	1.0

Figure 2. Stability Test (CuSum Test) Initial model



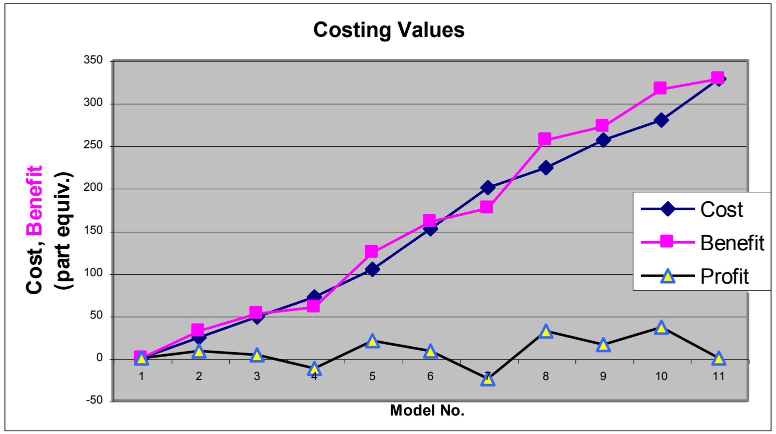


Figure 3. Simulation Results and Costing

Model No.	1	2	3	4	5	6	7	8	9	10	11
Valves shipped	136	168	188	196	260	296	312	392	408	452	464
Cost	0	24	48	72	104	152	200	224	256	280	328
Benefit (increase in parts)	0	32	52	60	124	160	176	256	272	316	328
Profit (Saving)	0	8	4	-12	20	8	-24	32	16	36	0