KES Transactions on Sustainable Design and Manufacturing I
Sustainable Design and Manufacturing 2014 : pp.256-267 : Paper sdm14-070

Industrial Perceptions of Manufacturing Operations Simulation

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Abstract This paper presents the results of a study conducted within a major automotive company regarding the perceptions of the application of discrete event simulation to manufacturing and assembly operations. The study questioned engineers responsible for running production lines, developers who produce simulations of those lines and factories and academics involved in manufacturing and simulation research. The results show that simulation is widely viewed as a useful tool within the production environment, but there are differences in perspective between, engineers, simulation developers and academic researchers. Generally the engineers tended to show a lack of awareness regarding the effort required to develop a simulation and of what can be produced. It was also found that any lack of production knowledge and/or flaws in data input to models can negatively impact the model's accuracy and reduce the engineers' trust in results. Based on discussions with the parties involved recommendations are made to rectify the situation through improving communications and encourage engineers to work in partnership with simulation team.

1. Introduction

The simulation of manufacturing processes is an important tool for the design, implementation and optimisation of production systems. Recently its use has been emphasised by the need for more sustainable business models within which environmental impact has become a growing concern and a focus across many different enterprises [1]. Due to the benefits and advantages to be gained from simulation, especially those related to the possible cost savings that can be realised by testing situations before implementing them, a wide range of software solutions have been developed over the years. These range from programming languages for simulation (such as Simula), to graphical 2D and 3D simulation development systems (such as Witness). Tools for discrete event simulation have been available for a number of years; the first visual interactive simulation tool (SEE-WHY) was developed for the British Leyland Motor Corporation in the late 1970's [2]. Lanner, the producer of the widely used Witness discrete event simulation system, is able to trace its routes back to this system [3].

Due to the modular "building-block" style in which simulations may be built, many different types of models include the same base elements. These can be customised as needed to represent different situations and behaviours. This means that simulations can easily be built to represent anything from parts moving around an assembly or machining line, to the flow of customers moving through a bank or supermarket. Discrete event simulation software packages are therefore applied across a wide range of sectors, from automotive and manufacturing industries, to supply chain, financial, judicial and medical applications [4]. This range reflects the number of different ways simulation software can be utilised.

Within a manufacturing setting, there are a number of uses for computer aided simulations. Constructing and running simulations of machining and assembly lines can clearly indicate the location and effect of bottlenecks and identify how often machines are blocked or starved and how well labour is utilised. It is also possible to investigate material handling systems in order to find out required timeframes for delivery and the optimised delivery sequences. Recent advances in simulation have expanded the scope of simulation to also include consideration of energy and environmental factors.

Within the automotive engine manufacturing and assembly setting studied for this paper, simulation has often been used for the initial system design phase. It is then applied to look for problems and to find solutions on the line when the plant is in operation. It is also common practice to simulate proposed changes to different parts of different lines to provide the justification that can be used to decide whether or not a proposed change project should advance. The main challenge to the effective use of simulation to produce accurate and reliable results, especially in a manufacturing setting, is that the data used to construct the model must be robust, accurate and reliable. Another concern that seems to be prevalent is the time allotted to the simulation process. Based on the perception that simulations should take very little time to construct and test people often expect results in too short a timeframe. Under these circumstances there is a danger that simulations are manipulated to match the performance of the system under a limited set of conditions. If this is the case a model may initially appear to mimic reality, however, once changes are made it may give unrealistic and incorrect results.

This paper examines how people perceive and make use of manufacturing simulation in an automotive assembly plant setting, especially in relation to the decision making processes used in assembly line change projects. This included looking at matters from the perspective of those producing simulations, engineers and managers that raise projects and ask for simulations, and also asking academics how they thought simulation would be made use of in such a setting.

2. Research Objectives

The aim of this study was to discover how different parties perceive manufacturing simulation within an automotive assembly environment. It identifies and considers various factors from the following perspectives; the engineers developing the simulations, plant managers and engineers working on projects and from academics involved in the work with the chosen manufacturing facility. In addition to investigating the perception of simulation from these different perspectives, this study also examined how well simulation is actually utilised during projects. This involved examining the process by which simulations were initiated, how detailed these requests were in terms of the desired results and whether or not the results were actually exploited once they had been provided to engineers and managers.

The following objectives were therefore set out for the study:

- Objective 1: To discover how accurate and/or realistic different parties believed the simulation produced to be.
- Objective 2: To discover how reliable different parties believed the results provided to be.
- Objective 3: To discover how much engineers and managers knew about the simulation process and consider how this compared to the knowledge of the simulation engineers.
- Objective 4: To discover the types of results engineers and managers believed could be provided as compared to what could actually be provided.
- Objective 5: To investigate the root problems with current methods of simulation and identify those which cause the biggest differences of opinion.
- Objective 6: To identify the most easily rectifiable problems and propose solutions.

Once the study had been completed, results were fed back into the company, in order to be used to improve any problems and issues discovered.

3. Methodology

The work carried out within this study was based on an interpretivist, inductive approach, looking at a small number of cases in a high level of detail, and gaining the opinions of those involved through semi-structured interviews. The research questions shown in Tables 1, 2 and 3 were derived from the aims and objectives that had been set out at the beginning of the study. These were then distributed, through questionnaires, to the three different groups of individuals involved in the study: simulation engineers, plant engineers and managers and academics at Cardiff University. The three questionnaires contained questions that were cross-linked to those given to the other groups in order to gain results that could be compared. In situations where no comparable question was available no question was asked; these are shown as blank in the three tables.

Table 1: Questions for Simulation Developers

1.	Job title
2.	Brief description of role
3.	In what way does simulation relate to your role?
4.	How long would it take you to create, test and run a simulation of a line such as “line A”?
5.	What part of a simulation project takes the longest? (e.g. modelling, data collection, running, analysis)
6.	What type of results can you generate from a simulation?
7.	How realistic/representative do you aim to make a simulation?
8.	Which is more important: realism or speed of creating and running a simulation in order to produce results?
9.	Do you think people take notice of simulation results when making decisions in projects?
10.	Do you think people trust results over their own gut feelings or plans for a project?
11.	-
12.	Do you think simulation is utilised well in the decision making process for projects?
13.	What do you think could be done to improve utilisation of simulation?
14.	What do you think the main problems with using simulation are?
15.	-
16.	-

Table 2: Questions for Plant Engineers and Managers

1.	Job title
2.	Brief description of role
3.	In what way does simulation relate to your role?
4.	How long do you think it would take to create, test and run a simulation of a line such as “line A”?
5.	What part of a simulation project do you think takes the longest? (e.g. modelling, data collection, running, analysis)
6.	What type of results do you think a simulation can give?
7.	How accurate do you think that the simulations produced are?
8.	Would you prefer a reasonably accurate simulation was produced quickly or a very accurate simulation was produced slowly?
9.	Do you think simulation is a worthwhile part of the decision making process in a project?
10.	What would you side with: simulation results or a gut feeling based on experience?
11.	If a simulation showed no improvements as the result of a project but you

thought there would be, would you go ahead?
12. Do you think simulation is utilised well in the decision making process for projects?
13. What do you think could be done to improve utilisation of simulation?
14. What do you think the main problems are with using simulation?
15. How much confidence do you have in results presented to you based on simulations?
16. What would make you trust the results more?

Table 3: Questions for University Academics

1.	Job title
2.	Brief description of role
3.	In what way does simulation relate to your role?
4.	-
5.	-
6.	-
7.	-
8.	What do you think is favoured when creating a simulation: speed of creating the simulation of accuracy?
9.	-
10.	Do you think simulation results are trusted over gut feelings and experience?
11.	-
12.	How well do you think manufacturing simulation is utilised in the decision making process in projects?
13.	-
14.	What do you think are the main problems with simulation that would stop it being used in projects?
15.	How much trust do you think is put in simulation results?
16.	-

4. Results

The qualitative data was collected through either face-to-face or telephone-based interviews and was transformed into quantitative figures where appropriate. Separate analyses were carried out on the resulting qualitative and quantitative figures. Trends and figures that related to the initial aims and objectives were extracted from the data that had been collected. The findings arising from this process were then compared.

4.1 Time to Model (Question 4).

Plant engineers and simulation developers were requested to estimate the time it would require to create, test and run a simulation of one section of a particular production line (that they all had a degree of familiarity with).

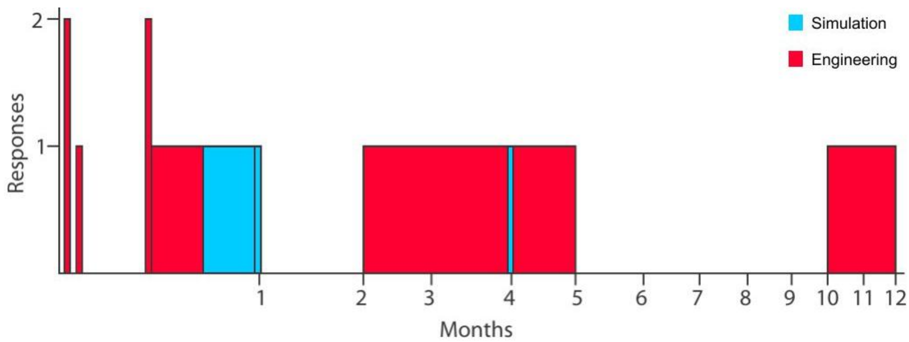

Figure 1: Range of responses to the time to model question

In Figure 1 it can be seen that there is a wide discrepancy between the opinions of those surveyed both with regards to the granularity of the period and the time required. This is particularly true of the plant engineers whose estimates vary from several hours to nearly a year. With results clustered around two main groups, the largest being under one month, with the other being 2-5months.

4.2 Longest stage in simulation process (Question 5).

The engineers and simulation developers were asked what stage of simulation takes the longest. The stages were categorised as: analysis of the production line, creating the simulation model, running the model and data collection (including validation of the model). From the results, shown in Table 4, two of three simulation developers considered analysis or modelling to take the most time.

Table 4: Longest stage in simulation process

	Analysis	Modelling	Running	Data collection
Simulation developers	1 (33.3%)	1 (33.3%)	0	1 (33.3%)
Plant Engineers	0	0	0	7 (100%)

However, all of the plant engineers and one simulation developer considered that data collection is the longest step. This is similar to the assertion made in Trybula [5] that data collection and validation can take up to 40% of the time taken to develop and run a simulation. Of the simulation developers it was the most experienced of the three questioned that identified data collection and validation as most time consuming. This suggests that there is a difference between the perception of how much time it takes to gather data about assembly facilities and reality amongst some simulation developers – potentially due to a lack of familiarity with functioning production lines.

4.3 Perception of Results Simulation Can Deliver (Question 6).

Engineers and simulators were asked what information can be obtained from a simulation of an assembly/production line. Their responses, shown in Table 5, indicated that the engineers as a group are aware of a large number of different types of result that can be delivered by simulation. However, there is no indication of wider awareness of the full scope of what simulation can offer. For example the identification of bottlenecks was recognised by all of the simulation developers but by only one of the seven engineers.

Table 5: Information simulation can provide

	Plant Engineers	Simulation developers
Machine efficiency	2	
Comparison with reality	1	
Cost justification	1	
Graphical range of answers	1	
Bottlenecks	1	3
Blockages	1	
Output by period	2	2
Breakdowns	1	
Platen utilisation	1	
Capacity		1
Experiments run	1	1

4.4 Speed and Realism or Both (Question 8).

All three groups were asked what is most important when creating and running a simulation. As can be seen from Table 6 amongst Plant engineers there is a bias towards realism being the most important factor. One explanation for the lack of distinct preference amongst the simulation developers is that there are potentially two internal ‘customers’ for the simulation; management who want results quickly and engineers who require accuracy so that they can be confident that changes made do improve productivity and/or reduce costs.

In this application cost is especially important as even minor changes to a production line could save or cost thousands of pounds. Another reason may derive from the roles of the members of the simulation team, two of whom are involved in building models (with differing levels of experience) whilst the third is involved in a managerial role (who is of the opinion that speed is most important).

Table 6: Most important factors when creating and using simulations

	Speed	Realism	Both
Plant Engineers	2 (28.6%)	4 (57.1%)	1 (14.3%)
Simulation developers	1 (33.3%)	1 (33.3%)	1 (33.3%)
Academics	0	1 (50%)	1 (50%)
Total	3 (25%)	6 (50%)	3 (25%)

4.5 Perception of simulation accuracy (Question 7).

The Plant engineers and Simulation developers were asked to describe their perception of the reality of simulation. The engineers were specifically asked how accurate they find simulation to be and the simulation developers how accurate they develop their simulations to be.

Table 7: Perception of simulation

Group	Main perceptions of simulation
Engineers	Depends mainly on accuracy of data inputs
	Have experienced correct and completely incorrect simulations
	Overcomplicated and inaccurate
	Tests carried out are not detailed enough
Simulation	Representative of reality
	As detailed as possible

The responses from the plant engineers, shown in Table 7 indicated that there were some negative perceptions and experiences of simulation.

4.6 Is Simulation Worthwhile (Question 9).

Plant engineers and simulation developers were asked if they thought people took notice of simulation results when making decisions in projects, i.e. is it worthwhile. The overall perspective was that it is useful, with 22.2% stating that it “can be useful” and 77.8% agreeing that it is useful (with all simulation developers falling into this category). Perhaps the most interesting aspect of this result is how it contrasts with the perceptions of simulation accuracy, such that even though simulation may have issues with accuracy it is broadly seen as being useful.

4.7 Improving confidence and utilisation (Question 13).

The plant engineers were asked what would help improve confidence in the results produced through simulation and the utilisation of models. There is a clear synergy between the opinions given here, in Table 8 and the perceptions expressed in responses to the question of simulation accuracy shown in Table 7. Responses such as not using corrupt data were seen as directly addressing those concerns.

Table 8: Confidence and utilisation factors

Confidence factors	Utilisation factors
Knowing certain tests had been carried out	Talk through results
More time being taken on data collection	Quantitative and qualitative
Not moving goalpost halfway through	Not too many graphs
More communication during simulation development	Some sections/questions in detail
Comparison to actual data	
Simpler simulations	
Not using corrupt data	

4.8 Results or gut feeling based decision making (Question 10)

All three groups were questioned about whether simulation results or gut feelings (taken to mean intuition) are trusted when it comes to decision making. The results in Table 9 show that the majority of people surveyed have great confidence in simulation results. However, gut feelings do appear to play a role in the decision making process.

Table 9: Results v Gut Feeling

	Results	Gut Feelings
Engineers	6 (66.7%)	3 (33.3%)
Simulation developers	2 (66.7%)	1 (33.3%)
Academics	2 (100%)	0 (0%)
Total	10 (71.4%)	4 (28.6%)

5. Discussion

This section discusses the feedback and opinions expressed by the industrial engineers and simulation developers together with overall findings of the study.

5.1 Improving Utilisation

The feedback from the simulation team suggests that cloud computing technologies maybe an answer to some of the issues they face. Cloud computing could enable the implementation of several of their suggestions namely: the utilisation of network processing power overnight and the use of shared drives. However, the concept of using cloud computing also extends to their desire for there to be ready to use models available in plants, where the models would be available via the cloud. Other suggestions from the simulation team for improving utilisation included having more up to date and accurate models. It was suggested that, currently, the lack of timely communication means that changes can be made to production lines and these are not immediately reflected in the models. The need to continuously update models represented a load on the simulation team that could be offset by increasing the ease of inputting fresh data.

Feedback from the engineers has some synergy with the last of the suggestions from the simulation teams as the industrial engineers require accurate (and hence up to date) models. Their other desires are for increased awareness of the capabilities of simulation and ensuring engineers know how to use and manipulate the models. At the time of this study there seemed no impetus for plant engineers to be trained to update these models, rather than relying of the continued support of the simulation developers.

5.2 Main Problems

The main problem seemingly limiting the greater benefits of simulation resulted from the disconnect between the perception and expectations of what simulation can and does currently deliver. In particular plant engineers were found to assume that a question should be rapidly answered through the use of the simulation. The simulation team often found this to be a difficult requirement to meet, mainly due to the use of the simulation tools which were seen to be time consuming and the models, which were overly complicated. Within this context comments were made that too much detail was required by management.

Plant engineers considered another major problem to be a lack of detailed operational knowledge of the production lines in the developed models. Simulation was seen to be based upon the perceived rather than the actual performance of plant. The requirement that the models reflected more closely the current operational state of such plant was clearly related to the accuracy of the data being used and issues related to the timely collection of data.

5.3 Key findings

Due to the role they play plant engineers and managers can be seen to require greater accuracy from simulation models. To achieve this plant engineers believe that the simulation team should have greater knowledge of lines and make more accurate simulations. However some of the simulation team are more concerned with improving the speed of the modelling process. This represents the most significant difference between engineers and some members of the simulation team. It arises due to the time frame within which the simulation team perceive that they are required to deliver results and the level of detail desired. When asked however engineers say that accuracy is a bigger problem, along with wrong data and limited knowledge of production lines.

Engineers appear to lack knowledge regarding the time taken to produce a simulation and possible results. As the engineers are not familiar with the modelling process they are not aware of the effort required to make a simulation model (in particular a complex model) and what can be achieved through simulation. To reduce this knowledge gap plant engineers want to be shown examples; because engineers are unaware of the capabilities of simulation they would like to be shown specific examples of what can be achieved. This is supported by the opinion given in [6] that it is becoming increasingly important that process owners are fully engaged to ensure that the value of simulation is seen and usage of such techniques is increased

5.4 Recommendations

Following this study several recommendations were made in order to improve the effectiveness of simulation. They all focused around improving communication and cooperation between plant engineers and simulation developers.

- Managers of the plant and simulation team need to be made aware of results and opinions of the other teams as to the role played by simulation.
- More emphasis is needed on relating to the simulation team what the plant engineers really want to see from the simulations.
- A method is needed to integrate engineers into the simulation development process to improve confidence and accuracy. This is best achieved by the allocation of a specific resource (person) to support continuous liaison between the teams.
- Seminars and example sessions should be provided where engineers are shown working simulations and asked for feedback.

6. Conclusions

The study illustrated that although simulation is widely viewed as a useful tool within the industrial environment there are differences in perspective between plant engineers, simulation developers and academic researchers. Engineers and the simulation development team largely work as completely separate teams, which is further exacerbated by differences in geographic location. In this case the simulation developers are a centralised resource used by multiple factories in different locations. Engineers are not aware of how much work goes into producing a simulation of an assembly line, or what can be produced. Similarly the simulation team lack production knowledge, which combined with data input to models affects accuracy and ultimately trust. Improving communications by showing engineers examples simulations and encouraging working in partnership with simulation team will improve accuracy and use of simulations.

Future work could be carried out to discover if there have been any changes made as to how simulation is perceived, carried out, utilised in the period after the recommendations.

7. Acknowledgements

This work was funded by the Knowledge Transfer Partnership (KTP) programme, project number 8270. The authors would like to acknowledge the support of the Advanced Sustainable Manufacturing Technologies (ASTUTE) project, which is part funded from the EU's European Regional Development Fund through the Welsh European Funding Office.

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