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Discrete Event Simulation Output Data-Handling System in an Automotive Manufacturing Plant

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Abstract

Discrete Event Simulation is a comprehensive tool for the analysis and design of manufacturing systems. Over the years, considerable efforts to improve simulation processes have been made. One step in these efforts is the standardisation of the output data through the development of an appropriate system which presents the results in a standardised way. This paper presents the results of a survey based on simulation projects undertaken in the automotive industry. In addition, it presents the implementation of an automated output data-handling system which aims to simplify the project's documentation task for the simulation engineers and make the results more accessible for other stakeholders.

Keywords: Discrete Event Simulation, Manufacturing, Output Data-Handling System;

1. Introduction

Discrete Event Simulation (DES) can facilitate a deeper understanding of a production system and thereby improve the knowledge about it. One benefit is that DES can help a company reduce costs and accelerate production [1]. However, the efficiency of an engineering process involves the effective transfer or generation of information. This implies that the right information is made available in the right format at the right time. A survey conducted by a Swedish consultant company, which works with DES, has concluded that in order to take full advantage of DES, there is a need for an automatic generated data-handling system which presents the appropriate data to the different stakeholders [2, 3].

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This conclusion is supported by several researchers who maintain that DES has different issues which can be improved. One of the obstacles that can still be found in DES usage concerns the data management, for example, the output data documentation process when the same type of DES studies are performed [4, 5]. In many companies, there is no supporting framework between engineers and the documentation process. Therefore, the creation of a standardised process which presents the relevant output data in the correct format at the right place could contribute to improving the repetitive output data documentation and presentation task [5-7].

Two main requirements regarding output data management can be identified:

1. Standardised reports make the simulation results more accessible for those stakeholders who do not have any or little knowledge about DES. Standardisation will also improve the quality of the reports since all relevant data will be included.
2. The generation of output data reports should be automated. This, in turn, will improve the efficiency in simulation projects and reduce lead times.

This study emerged from the fact that in the automotive manufacturing plant studied, as well as in many other manufacturing companies, the engineers who work with DES tools request and deliver a large number of Key Performance Indicators (KPIs). As a consequence, it is difficult to present the simulation results in a standardised way. Therefore, this paper presents the development of an automated output data-handling system based on the standardisation of the documentation process and its relevant output data derived from a survey conducted at a manufacturing plant. Accordingly, the approach aims to lead to a more efficient and standardised DES output data management process within the manufacturing industry.

2. Literature review

2.1. Key performance Indicators (KPIs)

KPIs are measures used to determine various process performance factors within different organisations and industries. In the manufacturing industry, various types of KPIs are studied, assessed and interpreted by experts, in order to measure a production line's progress according to objectives previously set by a company [8]. This study was based on the most relevant KPIs used to assess the output data of DES projects carried out at a manufacturing plant.

2.2. Standardisation

Standardised work is one of the most important lean tools. In production engineering, standardisation is a continuous process. For decades, the simulation community has tried to generate new approaches to standardise the simulation procedures. This includes the standardisation of data management procedures which are a requirement in the manufacturing industry [7, 9, 10].

Standardised documentation procedures improve efficiency through the standardisation of DES data. The implementation of standardised methods of data management within DES will reduce the time required for project processes as well as facilitate the analysis task, which implies reducing the cost of the overall project. In other words, the standardisation of the analysis of simulation reports could facilitate the decision-making task. Therefore, the use of a standardised data structure, which allows the exchange of data between engineers and other stakeholders, will increase the availability of the data [7, 11, 12].

2.3. DES output data management issue

As DES models become more complex, they also become more detailed and cover increasing amounts of data for analysis. Consequently, due to the continuous increase in size and complexity of DES data, improving the efficiency of its management has become a key aspect [3, 13].

In most manufacturing companies, simulation analysis is carried out by specialised engineers, such as the model builder or another engineer in the simulation team. However, it is often necessary to explain and present this kind of analysis to several stakeholders who may lack expertise in DES, statistics, etc., [3, 7, 10].

As shown in Figure1, in terms of DES output data, the data and information can be divided into two groups: the information sender and the information receivers. The information sender is the simulation model required to send the right output data that enables the analysis and presentation of the results in an appropriate format. Accordingly, the information receivers are the stakeholders that require the output data in a standardised and correct format. Therefore, one of the main issues within DES output data management is ensuring that this specific data, which is derived from the model, is used, understood and presented to a variety of output data receivers. These receivers can include the simulation team, production line responsible/managers, stakeholders/clients, or any other query user interested in it.

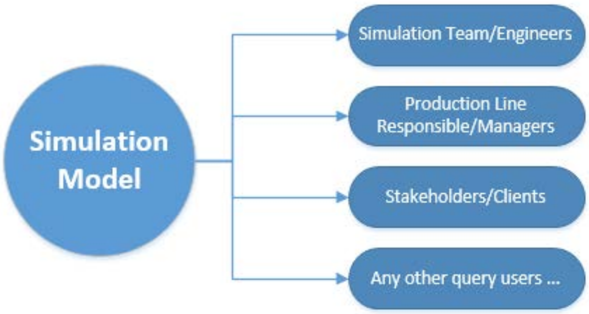

Fig. 1. Output data sources.

As previously mentioned, the output data of a simulation model must satisfy the requirements of different receivers, therefore, improving the efficiency of its management can be a complex task. In order to approach this issue, different strategies can be implemented. In this study, the chosen strategy implies that data should be generated in clusters that can be easily categorised according to different scenarios. This would enable the key results of experiments to be stored in a less complex structure. Therefore, the output data of a model must be related to one or several different DES scenarios, in order to facilitate the clustering task. The different scenarios defined can be used by a range of clients within a repetitive simulation environment [3, 10, 12-14].

In pursuing to eliminate the barriers between output data receivers (or working groups) and improving the efficiency of the repetitive documentation task, a structured process could provide the set of relevant KPIs according to the needs to be assessed. This could be accomplished by developing an application for the storage and presentation of the relevant data. Since most of the DES software applications support the exchange of data by using, e.g., MS-Excel and XML format files, a structured output data report could be generated automatically, by using an implemented algorithm, in an external and simpler, widely used data processor [6, 15].

3. DES output data and its related scenarios

Based on a survey study, conducted by Barrera-Diaz et al.[5], of 23 DES projects performed over four years at an automotive manufacturing plant, it was possible to identify a number of scenarios that were commonly carried out. The scenarios were identified on the basis of the objectives of each project.

The results of the study include the scenarios and their related output data, as shown in Table 1, extracted from the conducted interviews and the project documents studied.

Table 1. Scenarios and related output data. [5]

		Related Output Data							
Simulation Projects	Frequency	THP	WIP	LT	CT	OEE	Utilization	Optimization Data	Specific Data
System Design	1	X	X	X	X	X	X		X
Bottleneck Analysis	3	X	X	X	X	X	X		X
New layout, Add Machines etc	3	X	X	X	X	X	X		X
SPC Frequency	2	X	X	X	X	X	X		X
Singlespindle vs Doublespindle	2	X	X	X	X	X	X		X
Different Strategies/Configurations	5	X	X	X	X	X	X		X
Batch Sizes Optimization	2						X	X	X
Introduce New Variants	2	X	X	X	X	X	X		X
Buffers Optimization	2						X	X	X
Different Suppliers	1	X	X	X	X	X	X		X
Total of Projects Studied	**23**								

The relevant output data is marked with an “X”, the KPIs according to each scenario. The KPIs included were THP-Throughput per Hour, WIP-Work in Process, LT-Lead Time, CT-Cycle Time, OEE-Overall Equipment Effectiveness, Utilization, Optimization Data, and Specific Data. The Red Cross in the “Specific Data” column represents some extra KPIs that may need to be included in order to improve the understanding of the results. Additionally, the “Frequency” column shows how often the scenarios were identified among the projects included in the study [5].

A short description of some of the scenarios follows:

- **Bottleneck Analysis:** A bottleneck is a constraint in a supply chain and refers to the operation or operations that require the most time to process the resources. A bottleneck has a significant impact on the THP of a manufacturing supply chain; it therefore needs to be analysed in order to identify eventual improvements that can ensure an increase of the THP and the cash flow [16].
- **Statistical Process Control (SPC) Frequency:** This scenario addresses a standard method used to control quality within manufacturing processes. The system performance will depend on this statistical process and, in order to improve it, the quality data must be evaluated during the manufacturing process [17].
- **Batch Sizes Optimization:** This process has a major impact on production. It calculates the optimal batch quantity of a variant, in order to improve the efficiency of the production processes. The process can lead to a reduction of the WIP and the manufacturing LT [18].
- **Buffers Optimization:** Buffer allocation problems can play an important role in the overall performance of manufacturing systems. Acquiring knowledge regarding how to optimally allocate capacity to a buffer is important. As in batch size optimization, buffer capacity optimization is related to the desired system performance [19].

3.1. Scenarios Classification

The previously determined scenarios were categorised into three different groups of projects whose aim was the standardisation of the reporting task, based on the type of results and main objectives of the projects, see Figure 2. The groups are: Evaluation/Assessment projects, Optimization projects, and Special Cases projects.

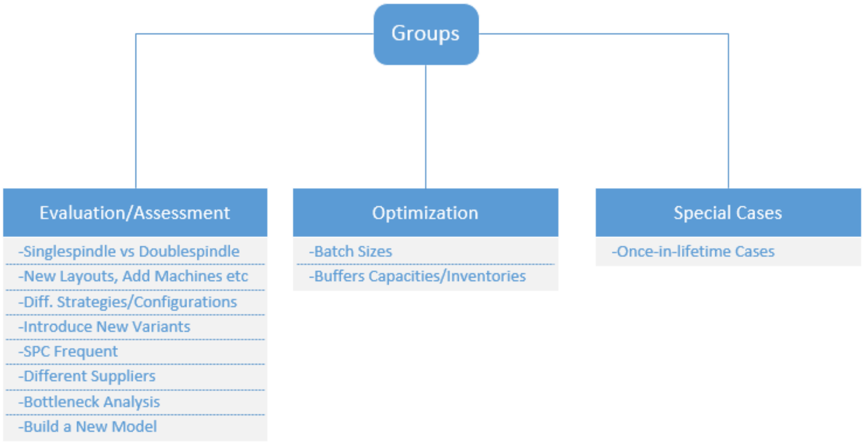

Fig. 2. Classification groups of DES scenarios.

The scenarios in the Evaluation/Assessment group evaluate or assess different simulation cases within a production system. Their aim is to identify the case in which the system performs better. Therefore, the relevant results from these scenarios are based on the system performance (THP; WIP, LT, CT, OEE, Utilization of Operations and Buffers, and Specific Data if required).

In order to evaluate a large number of different configurations, the individual testing of which is not practical, the Optimization scenarios are aided by an optimization tool. This group creates a report using the obtained results and specific data which varies depending on the optimization goal. Therefore, the relevant results regarding this group are compounded by the optimization results.

Special Cases category is the most open group, in terms of relevant results. Since the scenarios included in this group are considered as once-in-a-lifetime cases, there is no relation between their relevant results as it occurs in the other two groups. Therefore, the relevant results regarding this group are specific for the individual simulation project.

4. Output data-handling system

In accordance with the simulation engineers at the manufacturing plant and taking into account the need of a standard process during the output data documentation task of DES projects, specifications for the creation of a standard report were established. It is important to note that the specifications were defined according to the findings described in sections 2 and 3, and the feedback obtained from the simulation engineers regarding the data organisation in the manufacturing plant.

Figure 3 illustrates the methodology used in this project.

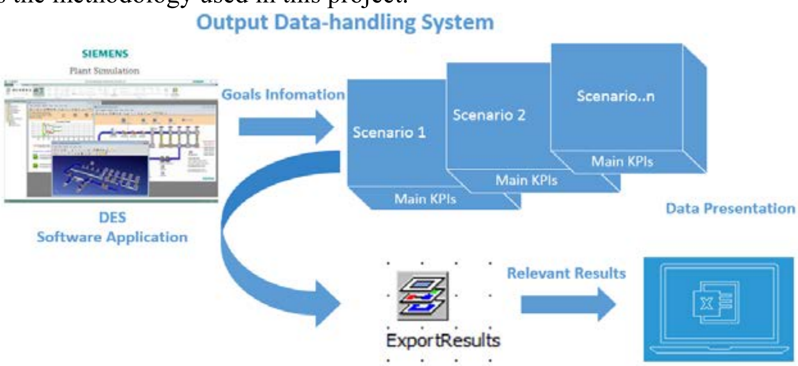

Fig. 3. Overview of implemented methodology.

Due to the easy access of MS Excel by people from the organisation and the possibility to automatically plot charts with the imported data, this format was chosen to present the output data obtained from the simulation experiments. Plant Simulation [20] is a DES software application used in the manufacturing plant where the data-handling system was implemented. First, the scenario and its relevant output data are identified. Then, by means of the implemented "ExportResults" object, the required data is automatically identified, collected, processed and exported. This object was developed and stored in the class library of Plant Simulation. In order to use the object, the developer just needs to drop it in the model of the project. It is important to mention that the data-handling system implemented was only validated under the systematic way of executing a DES project in the studied manufacturing plant. Thus, in order for it to be used in different organisations, new validations need to be performed.

4.1. Implementation

In an effort to present the output data from different types of DES projects in a standardised and consistent manner, a report template that includes several sheets was designed and implemented. The different sheets are:

- **General Information,** which specifies project name, dates, department, current state, assumptions, and objectives.
- **Experiments,** which explain and clarify the planned experiments.
- **Results** sheet covers part of the data described in Table 1 (THP, LT, WIP, CT, and OEE). In order to gain a better understanding of how accurate the values obtained are, THP, LT and WIP will show the standard deviation. In addition, THP will also show minimum and maximum values among the total number of observations. Figure 4.

	THP (Parts/Hours)	THP STAND. DEV.	THP MIN	THP MAX	LT (DD:HH:MM:SS)	LT STAND DEV	WIP (Parts)	WIP STAND DEV	CT (DD:HH:MM:SS)	OEETHPGoal (%)	OEE
Exp 1	44,46666667	0,383469179	40,1546465	40,9583333	04:47:53	536,5334825	351	25,06797181	86,58764736	90	0,755833
Exp 2	45,50833333	1,753571535	45,1666667	45,9916667	04:16:39	1412,870402	397	46,14383292	91,79250045	90	0,706354

... Input Experiments | Relevant_Results | Box Plot | Utilization | Specific Data | Optimization Settings and Dat ...

DD(Days):HH(Hours):MM(Minutes):SS(Seconds)

Fig. 4. Results sheet.

- **Box Plot** sheet for THP facilitates the analysis and allows the clients/stakeholders to make better decisions. Based on this chart, it is possible to find out if the distribution is skewed and if there are unexpected observations in the experiments. In addition, it simplifies the comparison among the different experiments when they consist of many observations[21]. The left part of Figure 5 shows the appearance of the boxplot in the template. The upper right part of the figure illustrates how a standard box plot is built. Finally, the lower right part of the figure presents the format of the data imported into the template. This data is automatically processed in the simulation software and exported in the format shown. The template automatically creates the chart with the help of a MACRO programmed in Visual Basic.

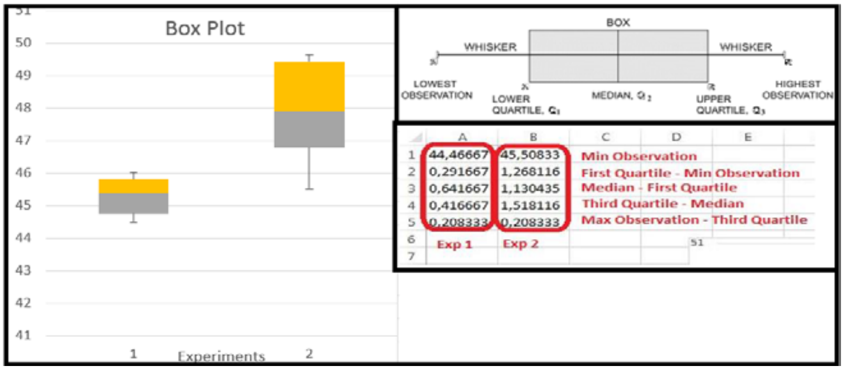

Fig. 5. Box Plot. [21]

- **Utilization** is one of the most important and widely used KPIs. The chart describes the utilization of the resources (X axis), providing the proportion of time (in percentage) that a resource is working, loading, unloading, changing the tool, setting up, stopped, failing, paused, starved or blocked [22]. As with the box plot sheet, the data is processed and exported by the implemented system in the required format. Therefore, the template is configured to automatically create the chart with the data imported from Plant Simulation. It also displays the exact percentage of time, when the pointer is placed over each colour in the chart, shown in Figure 6.

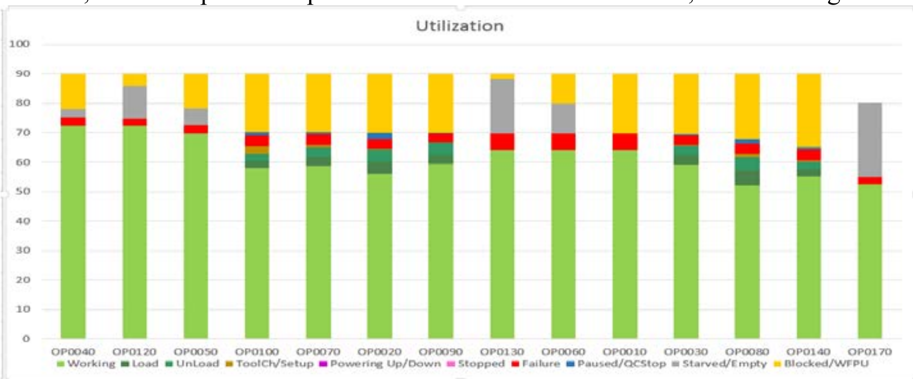

Fig. 6. Utilization chart.

- **Optimization Settings and Data** sheet must be on the report only when the optimization tool is used showing the settings and the obtained data.
- **Specific Data** sheet appears when the engineers decide to analyse data that is not included in the relevant results sheet. Consequently, this extra data is automatically placed in the specific data sheet.
- **Conclusions** sheet is used by the engineers to explain the results obtained from the project and to draw their conclusions.

5. Acceptance Interviews

In order to evaluate the implemented output data-handling system, a number of interviews were conducted. A key factor for the success of the system is its acceptance by the clients who will use it. Therefore, three different clients were interviewed for the purpose of assessing and validating the standardisation of the data. However, since the size of the sample was only three clients, more interviews need to be conducted in order to obtain more comprehensive feedback. The questionnaire for the interviews consisted of the following six questions, of which the first four were graded on a scale from 1 to 6, (1=totally disagree, 6=totally agree), see Figure 7:

Question 1: I found the data and information easily accessible.
Question 2: I found the structure clear in order to find the information.
Question 3: I found the report easy to understand.
Question 4: All the information required is in the report.
Question 5: If applicable, what information is missing?
Question 6: How can the report be improved?

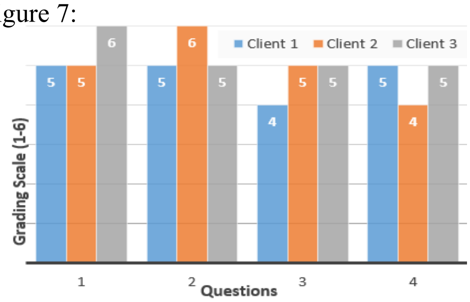

Fig. 7. Results from the first four questions.

In summary, the responses from the clients were positive, see Figure 7:
- Question 1 shows that the data is easily accessible.
- Question 2 indicates that the chosen structure for the report is helpful in finding the required information. A logical and understandable structure is an important factor, in order to quickly find the required data.
- Question 3, they found the report easy to understand from a technical point of view.
- Question 4 indicates that the report has no missing information and, consequently,

Question 5 was not applicable. With regard to question 6, a recommendation from one of the clients was to place the data from the input experiments sheet and the relevant results sheet together. However, the information from those sheets was separated, in order to gain a more simplified structure that contained no overloaded information sheets.

6. Conclusions

In summary, this project has studied and implemented an approach in which the management and documentation of DES output data was standardized in order to facilitate, speed up and support the decision-making task within an automotive manufacturing plant. Firstly, it can be concluded that a standardised output data management process is a key aspect in reducing wasted time and accelerating the documentation task within DES projects. Consequently, a study on the standardisation of the management of the output data from DES projects at a manufacturing plant was initiated. In order to contribute to the standardisation of this process, an investigation of the key output data from different DES projects was performed. The results obtained led to the implementation of an automated output data-handling system that extracts the key results from the different types of scenarios. From the outcomes of the performed interviews, it can be concluded that the output data-handling system generates a standardised report of the simulation results, which covers the required data for the analysis of DES projects. The results of the interviews also indicate a high acceptance for the proposed solution. In addition, the implemented output-data handling system has being further developed and used within the manufacturing plant. Besides the use of this system in an automotive manufacturing plant, the system could also be a valuable addition in other manufacturing companies which use DES to develop and improve their production systems.

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