Method for Optimization Production Systems by Computer Aided Modeling and Simulation

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Abstract* – Computer aided simulation can be defined as imitating the operations of various kinds of real-world facilities or processes, the process of designing a mathematical-logical model of a real system and experimenting with the model. Simulation does not been study the shop floor in terms of individual elements only, but the system as a whole considering the relationships and interactions between different types of lots, resources, operators and work rules. Because simulation models are dynamic, they take into account dispatching rules, batching, priorities and shift effects. This paper aims at identification and implementation of the most economic method to optimize the production flow of an assembly line, that the assembly line is modeled, and simulated using the Witness software. Witness provides an animated display of the model and with its simulation program; it is possible to run very large and complex. The paper also discusses the development of an informatics product for an automatic display of the daily production rate of the assembly line in a defined time. To achieve a simulation there is no single method recommended, but any simulation should be a proper representative model of the system (obviously mathematical models could also be considered). So, the main problem of obtaining a proper simulation is the problem of creating a realistic model.

***Keywords:* modeling; simulation; assembly line; optimization; Witness Software.**

I. INTRODUCTION

In today's highly competitive globalized market, manufacturers have to improve their manufacturing performance continuously in order to sustain their competitive advantage [1]. Modern manufacturing enterprises are facing increasing pressure to improve their responsiveness to 21st century market dynamics, due to customer expectations for shorter delivery lead times, greater agility, improved quality and reduced costs [2]. To characterize the impact of changing parameters on system performance, simulation has been widely used as a decision support for modeling, analysis, and design of systems. Thus, when direct measurement of the system parameters is inconvenient, simulation provides the means for observing the behavior of a system over time [3].

Specific fields of application of computer-assisted techniques are found mainly in systems modeling [4]. The recent trend of global software development enables large-scale software systems to be developed in a geographically distributed environment, which imposes a number of challenges on software trustworthiness [5].

Over the past few decades, computer simulation software, together with statistical analysis techniques have evolved to give decision makers tools equal to the task. Simulation uses a model to develop conclusions providing insight on the behavior of real-world elements being studied. Computer simulation uses the same concept but requires the model to be created through computer programming. Computer simulation can be classified as a branch applied mathematics. The use of computer simulation increased due to availability of computing power and improvements in programming languages. Added to this are inherent difficulties or even impossibilities to accurately describe complex real world systems using analytical or purely mathematical models. For these reasons, a tool that can represent these complexities accurately is required [6].

The advances in computing power and memory over the last decade have opened up the possibility of optimizing simulation models [7]. A model is a conceptual or mathematical representation of a phenomenon, usually conceptualized as a system. It provides an idealized framework for logical reasoning, mathematical or computational evaluation as well as hypothesis testing. The value of a model depends on its usefulness for a given purpose and not its sophistication. Simple models can be more useful than models which incorporate many processes, especially when data are limited [8].

II. THEORETICAL NOTIONS ON UNDERSTANDING AND PROPER USE OF WITNESS SOFTWARE

Identification methods for modeling and simulating production systems involve the use of computer-aided simulation program. Manufacturing simulation for the purpose of performance analysis follows three main steps:

- Acquiring relevant data such as details of resources, parts, working rules, etc.;
- Modeling the required system, simulating, validating and getting simulated results;
- Analyzing the results and experimenting with model changes and assess their effects.

To drive the simulation was used random variables designed to overcome our lack of detailed knowledge of how the system will operate in practice. The random variable selected was drawn from a given distribution function e.g. normal, exponential, etc. This means that no two simulation runs will be the same so a large number of repeat runs will be required to give an adequate level of precision. It is also needed to select the appropriate distribution from either real data obtained from observations or a distribution that has been shown to be suitable from past experience. The selection of an inappropriate distribution or inaccurate parameters for the correct distribution (e.g. σ) can lead to faulty models that result in either too much or too little capital investment in a project, as a system that is modeled as unreliable will under estimate its capacity.

The procedure for starting-up is to simulate the system from zero transactions up to a given number and to repeat this process a given number of times. To study the shutdown of a system is set to simulate from a steady state and run until there are no further transactions to process and the completion recorded. Again the simulation would need to be repeated a number of times. The number of simulation runs required must be calculated to give the accuracy required from the study. Steady state is when the system has been running long enough to make the effects from start-up negligible.

When simulating a new or modified system a number of alternative models should be constructed and compared. Witness uses discrete-event simulation that steps through time, processing events in order. An event is a change of state within the model. Events may occur at the same time but each event will occur separately in the model. There are many different aspects to this software; however, the system used for the software package has many similarities to Microsoft Windows.

There are 3 steps in building a model:

- Define – the major elements that will form the „building blocks” of the model;
- Display – these elements to form a „pictorial” representation of the model;
- Detail – the characteristics of each element; for example, the parts that enter the machine, the cycle time of the machine, any labor needed, where the parts go on leaving the machine.

The basic designer elements are parts, buffers, machines and labor. A number of shifts can be used with a model to observe interactions and each main shift can be made up of sub-shifts, for example sub-shift day can be used to make the main shift week. Only main shift can be applied to elements like labor and machines. All times are entered in minutes.

To finely tune the behavior of the model, it may specify actions which are executed whenever a machine starts its cycle, finishes its cycle, breaks down, or finishes repair. When two or more elements compete for labor or parts Witness allows you to set the priority to determine which element receives the resource first [9].

III. CASE STUDY: MODELING AND SIMULATION OF AN ASSEMBLY LINE

In this paper, a case study based on a printed circuit board assembly has been analyzed for modeling and simulating an assembly line, and determining the most economical method of optimizing the production flow.

The objectives followed in this study are:

- Identify the existing bottlenecks in the assembly line and their removal;
- Identification of equipment with the highest load and reduce the load capacity to ensure production flow;
- Determining the expected daily output and identifies the most economical method to increase the daily output to 1800 parts;
- Achievement an informatics product of automatic display the daily production made on the assembly line.

All the assembly operations shown on the attached flow chart assemble on to a PCB which arrives as required as an individual. The line runs for 7.5 hours per day (450 minutes or 27.000 seconds), is fully automatic and two people are employed to repair the machines and carry out the rework operation.

Following the testing process are obtained 15% ship and 85% rework, and after rework process result 90% ship and 10% scrap.

There are three suppliers of parts for the line and they supply:

- R1, R2, and R3 in batches of 500 at intervals with a uniform distribution between 10.000 and 12.000 (166,66 and 200 minutes);
- C1, C2 and C3 in batches of 500 at intervals with a uniform distribution between 10.000 and 12000 (166,66 and 200 minutes);
- IC1 and IC2 in batches of 1000 at intervals with a uniform distribution between 19.000 and 21.000 (316,66 and 350 minutes).

To build the assembly line model it is required that data entered into the Witness to be as real and as accurate possible. Introduction of unreal data leads to incorrect results and thus cannot identify solutions to optimize the assembly line.

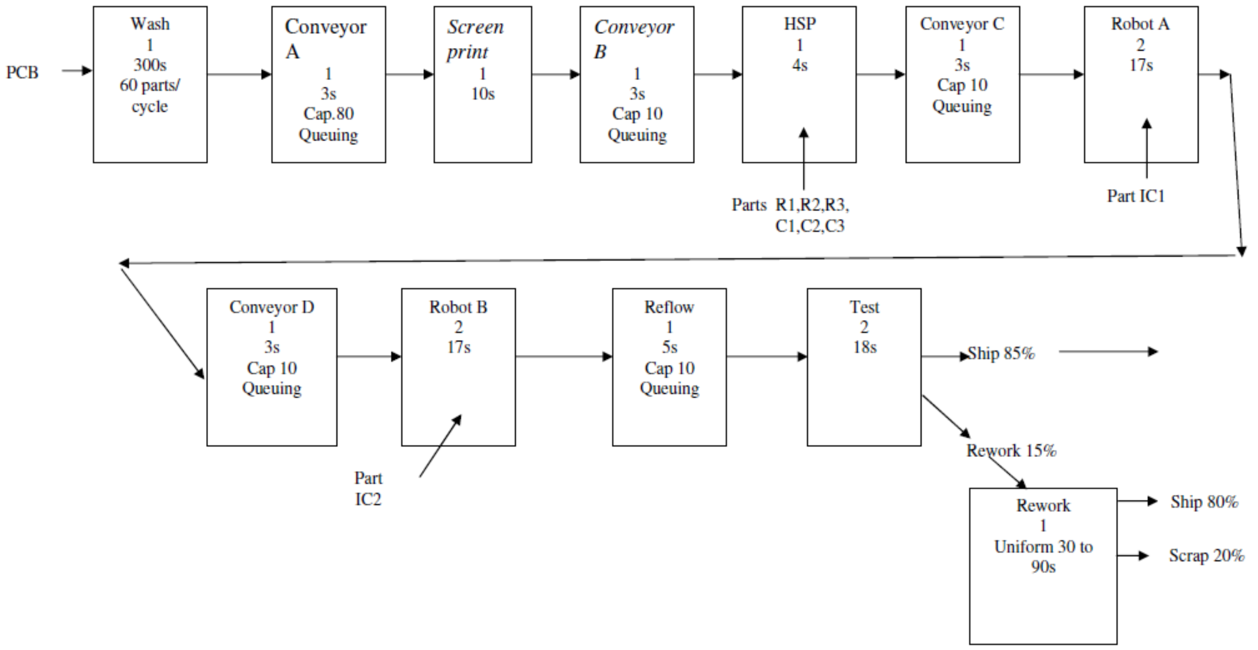

Fig. 1. Assembly line layout [9]

Necessary changes costs to identifying the optimization method of assembly line, refers to:

- Purchase a new washing machines: 50.000 £;
- A new conveyor with 2 seconds cycle time and capacity of 100 pieces: 20.000 £;
- A new machine type Screenprinter: 50.000 £;
- Three conveyors with 2 seconds cycle time and capacity of 20 pieces: 15.000 £;
- Three conveyors with 2 seconds cycle time and capacity of 50 pieces: 20 000 £;
- A new machine type HSP: 100.000 £;
- Purchase of tow robots: 80.000 £;
- A new O reflow machine: 60.000 £;
- A new test machine: 50.000 £;
- A rework station: 20000 £;
- Improved component delivery with guaranteed delivery: 1 £;
- Introduction of new intermediate buffers: 1.000 £ per buffers;
- Reduce delivery period: no cost;
- Purchase labor: 20.000 £ / person.

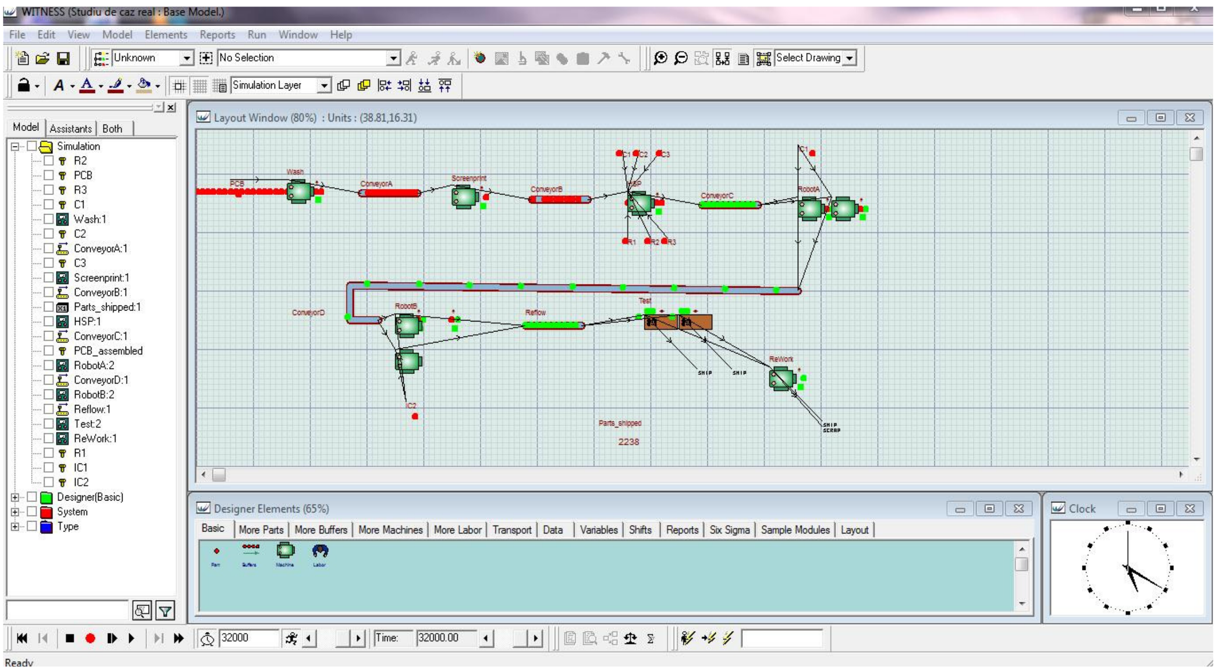

Fig. 2. Modeled and simulated PCB assembly line in Witness Software

After building the model in Witness, it was run for 7,5 hours, respectively 27.000 min, for a period of 5.000 min.

After completing the simulation process, it was observed that Screenprint has the larger load and the production line locks at HSP machine, resulting a production of 2.207 pieces.

TABLE 1. Statistical report on machines operation

Name	Idle[%]	Busy[%]	Blocked[%]	No. of Operations
Wash machine	0.00	42.15	57.85	37
Machine Screenprint	0.00	84.33	15.67	2277
Machine type HSP	4.84	33.76	61.4	2279
Robot A (1)	0.16	71.73	28.1	1139
Robot A (2)	0.16	71.72	28.09	1139
Robot B (1)	0.00	71.73	28.27	1139
Robot B (2)	0.00	71.72	28.2	1139
Test machine (1)	0.58	76.67	22.75	1150
Test machine (2)	0.32	75.22	24.46	1128
Reflow machine	21.26	78.74	0.00	369

After several repeated simulations, it was found out that the most economical method to increase daily production would be through introducing of new intermediate buffers with a capacity of 1.500 pieces (BR1, BR2, BR3, BC1, BC2 and BC3) and, 2.000 pieces (BIC1 and BIC2).

After introduction of the new buffers, it was found out that reduction of Screenprint machine loading with 16.69% and elimination the HSP machine blockage, finally resulting in a throughput of 1.804 finished parts. Costs on optimization the assembly line are 8.000 £.

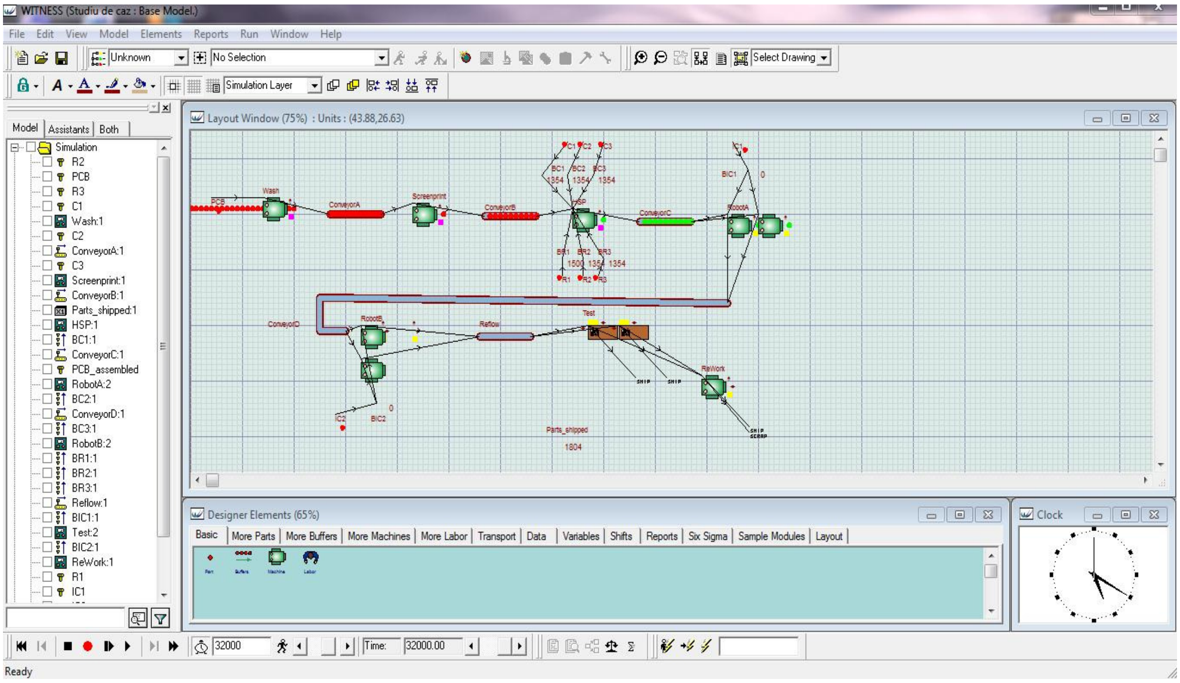

Fig. 3. Optimization of assembly line

TABLE 2. Statistical report on machines operation after optimization

Name	Idle[%]	Busy[%]	Blocked[%]	No. of Operations
Wash machine	0.00	34.44	65.56	31
Machine Screenprint	0.00	67.64	26.74	1827
Machine type HSP	40.42	26.96	26.58	1820
Robot A (1)	40.8	56.62	1.35	900
Robot A (2)	40.76	57.86	1.38	919
Robot B (1)	37.86	57.89	3.4	920
Robot B (2)	37.79	57.03	3.45	906
Test machine (1)	34.3	60.85	4.85	913
Test machine (2)	34.41	61.63	3.97	925
Reflow machine	64.71	35.29	0.00	318

As a method of automatically displaying the daily production made on the assembly line in a certain period of time, has been identified the possibility of achievement an informatics product.

The informatics product of automatic display the daily production made on the assembly line, received the name of parts which are made on assembly line, namely PCB.

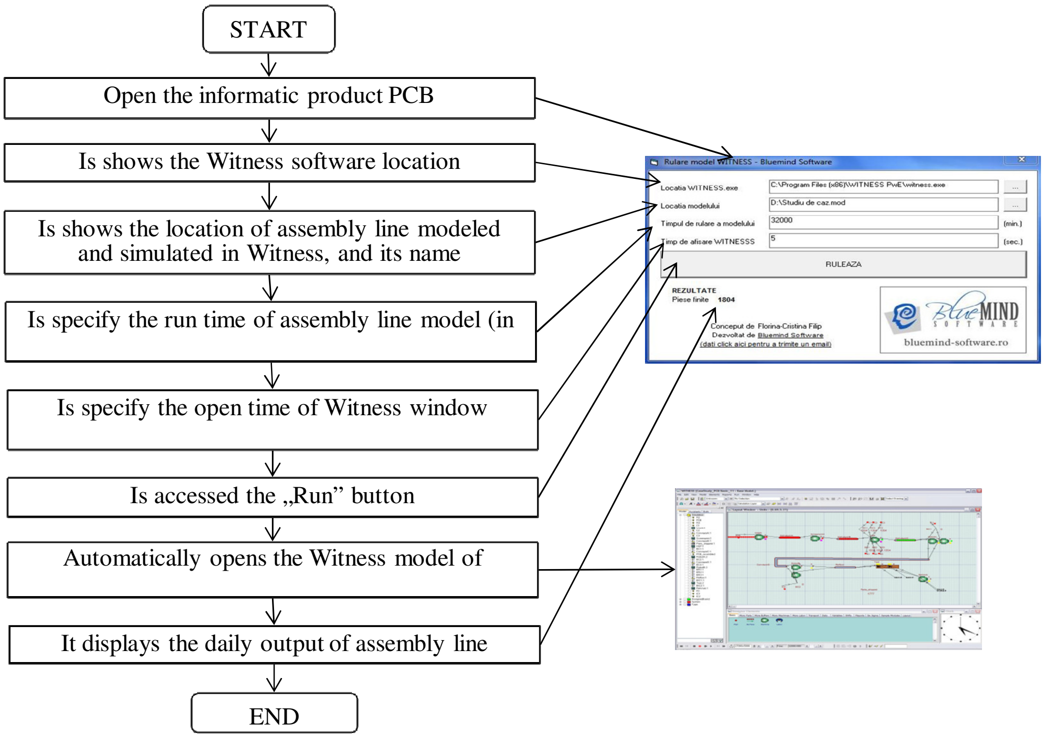

Fig. 4. Logical diagram of informatics product PCB

By achievement this informatics product was followed to get automatically the finished parts number made on the assembly line modeled and simulated in Witness software (fig. 3). PCB informatics product was developed using Visual Basic (fig. 5).

Fig. 5. Informatics product PCB

After completing entry data, by clicking on the "Run Witness" button, the model opens in Witness Software (depending on how many seconds have been indicated in "Waiting time after loading program" section) and then in "Number of finished parts" section is automatically displayed the production performed on the assembly line production in a period of time.

IV. CONCLUSIONS

Due to the emergence and improvement of electronic computers, simulation is now widely used in scientific research and design, being a technique that involves the use of mathematical and logical models that describe the behavior of a real system over a period of time and requires the use of electronic computer. Modeling complex systems such as production systems is a difficult task and as such, requires a simple and effective way to facilitate the simulation process. Simulation process is a representation based on models used to design, develop, analyze and optimize production systems, and most of the times provides for users, accurate design information and helps to find the maximum point of the performance process.

In industrial companies, production systems simulation is a very important tool because it allows system behavior to be prepared and tested. Simulation provides a low cost, a fast and reliable analysis tool. To reduce time and cost involved in achieving a product from conceptualization to production, more and more companies continue to develop advanced software, which costs less and for most industrial companies, time and efficiency are critical and essential. In recent years, modeling and simulation process has gained importance and provides designers the conception of new systems, enabling the quantification and observation of system behaviors. If the system is a production line, an operating room or emergency response, the simulation can be used to study and compare alternative designs or troubleshoot existing systems.

Reasons to using simulation techniques in industrial practice:

- Lack of mathematical formulations (formalized phenomena) that are concise and complete for the problem or meeting some difficulty in resolving whether the model exist;
- Simulation may be the only possible way of experimentation when using the real system is impossible (due to high cost);
- In time, simulation allows complete control of system analysis, allowing the development of phenomena, which leads to conclusions that otherwise, could not be known. This aspect of simulation is particularly usefully in scientific research or in assessing the behavior of technological equipment operation.

Simulation is one of the techniques available to study large and complex systems, is a collection of methods and applications designed to mimic the actual behavior of production systems. Today, there are many simulation tools available that can model all kinds of systems, regardless of their complexity. However, in terms of user, models can be created using the mechanism supplied by simulation facilities.

The most economic method identified in this work to optimize production flow, was the introduction of new intermediate buffers for the reduction of Screenprint machine loading and elimination of the HSP machine blockage.

The results from this applied study performed in this work, have led to data analysis and to identify a way for developing an automatic display method of daily production obtained on the assembly line, modeled and simulated in Witness. Thus, it has helped to identify the possibility to achieve an informatics product for the PCB assembly that can control the run and automatically display the number of finished parts madeon the assembly line with the model that was built in Witness Software.

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