

## IMPROVING MANUFACTURING QUALITY IN AUTOMOTIVE INDUSTRY USING DISCRETE EVENT SIMULATION. CASE STUDY

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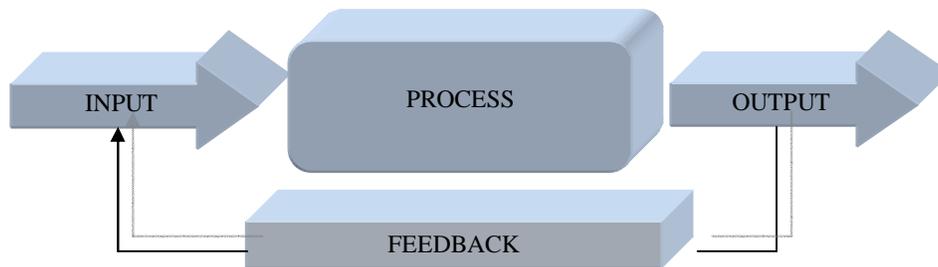
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**Abstract:** Many processes within automotive manufacturing factories are very complicated and expensive. It is very useful to see how these processes will work before really implement them. One of the tools that we can use is process simulation. The objective of this paper is to present how to use process simulation to improve processes and activities for manufacturing in automotive industry and a case study on how process simulation was use before implementing a Statistical Process Control System for manufacturing a vehicle suspension part.

**Keywords:** automotive industry, manufacturing, SPC integrated system

### INTRODUCTION

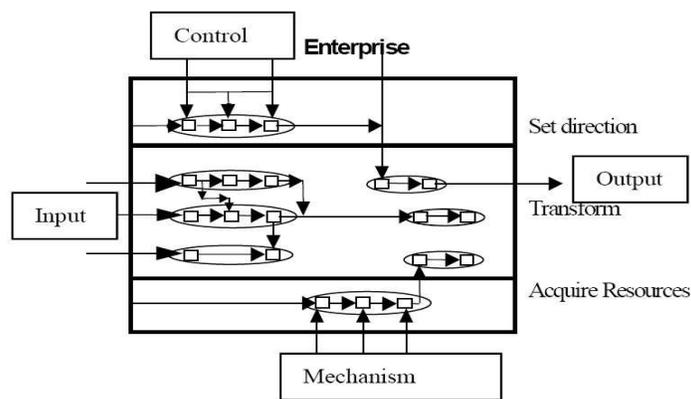
The word process comes from the Latin word “*processus*”, which means progress. A process is a series of activities that provide value to something or someone. To understand the process there must be an understanding of the relation between the activities [1]. The word „process” is defined in many ways. Some of them are: „a series of activities that provide value to something or someone”[2], „a set of interrelated or interacting activities that transforms inputs into outputs.” [3], “a particular course of action intended to achieve a results”[4], “a series of actions, motions, or occurrences” [5]. The structure of a process is presented in figure 1.



**Fig. 1. Basic process structure**

The process approach is a powerful way of organizing and managing how work activities create value. While a more traditional structure organizes and manages work activities vertically by function, with quality problems frequently occurring at the boundaries of the functional departments, the process approach organizes and manages work horizontally the way work activities create customer value.[6] Today organizations became more and more process oriented. A model of a today enterprise is shown in figure 2. Presley et al., propose that business processes may be placed into three categories: (1) those processes which transform external constraints into internal constraints (set direction), (2) those processes which acquire and make ready the required resources, and (3) those processes which use resources to produce enterprise results. By providing categories to organize processes, more holistic enterprise design may be achieved. Figure 1 show activities (boxes) arranged into business processes (ellipses). The business processes are organized into an enterprise represented by the larger box. At this high level of abstraction, the enterprise itself is represented as an activity that takes inputs and transforms them into outputs using available resources under the bounds of a set of constraints.

Frequently the only activities or processes considered in modeling and improvement activities are



those listed as category 3, which transform inputs into products and services. However, it is as important to consider the strategic and acquisition activities in an enterprise. Understanding the different process categories is vital to develop useful representations. Categorizing the different processes helps to ensure that the frequently overlooked categories of setting enterprise direction and acquiring and preparing resources are considered. [7]

**Fig. 2. Enterprise model with process categories**

## PROCESS SIMULATION

The Oxford English Dictionary describes Simulation (Discrete Event Simulation) as: "The technique of imitating the behavior of some situation or system (Economic, Mechanical etc.) by means of an analogous model, situation, or apparatus, either to gain information more conveniently or to train personnel".

A simulation model is essentially a map of a business process. The model also contains information on how the process behaves, including how long each step takes, how often a step is repeated and who is involved.

These data are easily included in the model by filling in the blanks on the computer screen for each model element. For example, each process step has a blank space for the time it takes to perform it.

Once all the relevant data are inputted, the software performs a dynamic analysis in which simulated time is played out in the model. The simulation "engine" keeps track of what is happening in each stage, updating the statistics and status of the model as the condition change.

Simulation provides a statistically based assessment of how the modeled process operates, essentially predicting how a process operates, essentially predicting how a process will perform given the circumstances described by the data.

The one who use software's for process simulation has great benefits because the software provides two tools that help explain how a process operates: animation and a detailed statistical report. The animation is great for seeing overall how things are working. Obvious problems will show themselves here. The detailed statistical report provides key performance metrics, including number of items processed, number of defects or problems, how long customers waited, how busy staffs were and how long things took.

Once the current state has been accurately modeled, the simulation allows managers to create different what if scenarios to test ideas for improving processes. Often this is as simple as varying the data entered for the model elements.

A simulation project provides usually four critical benefits [8]:

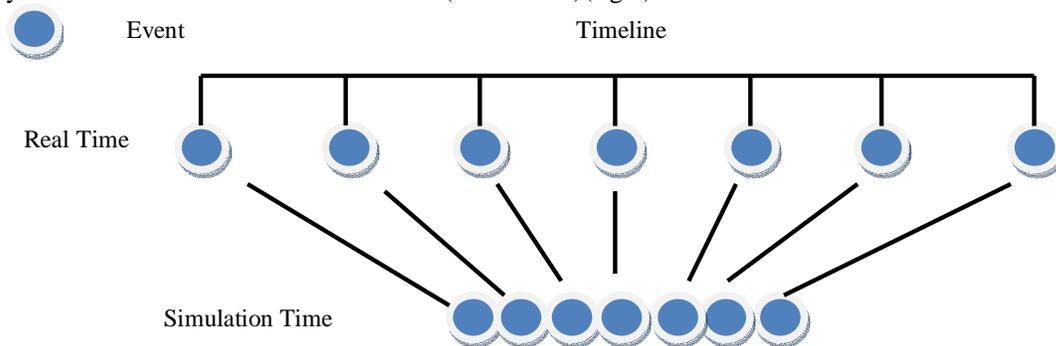
1. Clearer understanding of business;
2. The ability to accurately evaluate current operations;
3. The ability to test ideas for improvement;
4. Powerful communication of the process and your proposed changes.

## DISCRETE EVENT SIMULATION (DES)

The basic idea behind simulation is simple (Doran & Gilbert 1994): We wish to acquire knowledge and reach some informed decisions regarding a real-world system (the business). But the system is not easy to study directly. We therefore proceed indirectly by creating and studying another entity (the simulation model), which is sufficiently similar to the real-world system that we are confident that

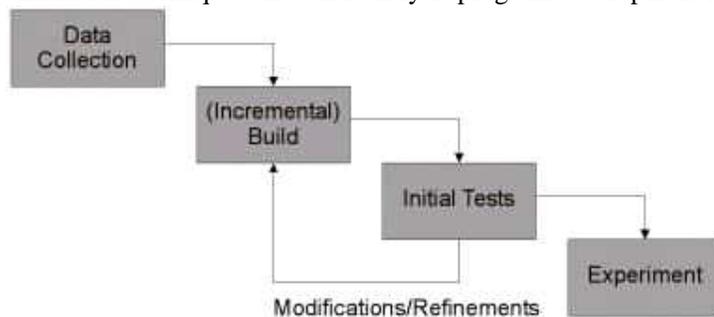
some of what we learn about the model will also be true of the system. Computer-based discrete-event simulation relates to a symbolic representation of processes in ways that can be made persistent, replayed, dynamically analyzed, and reconfigured into alternative scenarios. Simulation models can dynamically model different samples of parameter values such as arrival rates or service intervals, which can assist in discovering process bottlenecks and suitable alternatives. These models can provide a graphical display of process models that can be interactively edited and animated to show process dynamics,[8].

Discrete Event Simulation (DES) concerns the modeling of a system as it evolves over time by representing the changes as separate events. This is the opposite of Continuous Simulation where the system evolves as a continuous function (differential)(fig.3).



**Fig. 3. Discrete Event Simulation**

Well-known examples of Simulation are Flight Simulators, Fleet Management and Business games. However, there are a large number of potential areas for Discrete Event Simulation. One of the main areas currently being explored is in designing new manufacturing areas, especially where high capital investment is involved. For example, if a company wishes to build a new production line, then the line can be first simulated to assess feasibility and efficiency. The diagram below (figure 4) shows the key stages in using Discrete Event Simulation. It can be noted that this bears a strong resemblance to other simulation techniques and other analysis program development methodologies (prototype method).



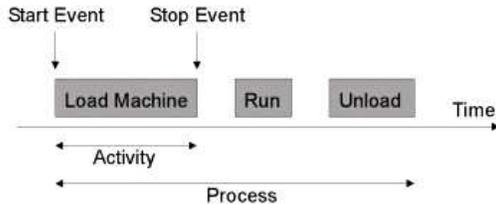
**Fig. 4. The key stages in using Discrete Event Simulation**

Although, discrete event simulation could conceivably be carried out by hand it can be computationally intensive, therefore will invariably involve computers and software. The software could be a high level programming language such as Pascal or a specialized event/data driven application. The five key features found in the software simulation model are:

- Entities – representations of real-life elements e.g. in manufacturing these could be parts of machines;
- Relationships – Link entities together e.g. a part may be processed by a machine;
- Simulation Executive – Responsible for controlling the time advance and executing discrete events;
- Random Number Generator – Helps to simulate different data coming into the simulation model. Important that the random data can be reproduced in different simulation runs;
- Results & Statistics – Important in validating the model and for providing performance measures.

The simulation executive may operate in one of two manners [9]:

- Time Slicing - Advances the model by a fixed amount each time, regardless of the absence of any events to carry out.
- Next Event - Advances the model to the next event to be executed, regardless of the time interval. This method is more efficient than Time Slicing, especially where events are infrequent, but can be confusing when being represented graphically (processes that take different times will appear to happen in the same time frame if the stop event is the next event after the start event).



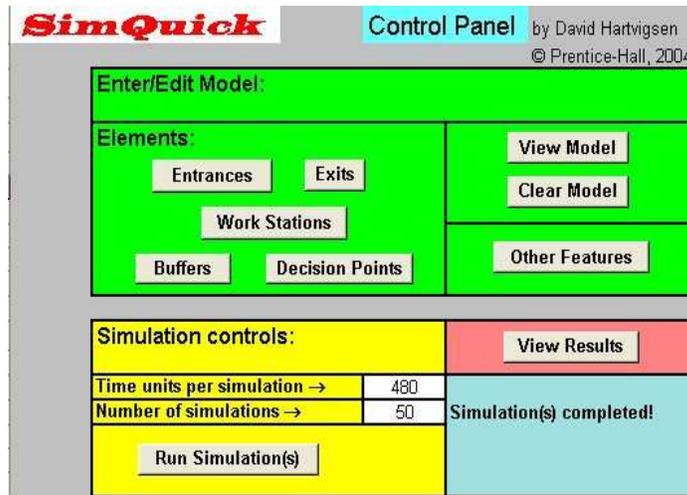
**Fig. 5. The three phases for discrete simulation**

There are also three approaches to describing the discrete simulation (figure 5) [10]:

- Event - This approach describes an instantaneous change, usually from a stop event to a start event. This is the most common one used, easy to understand and efficient and is acceptable to implement;
- Activities - Represents duration. Essentially groups a number of events in order to describe an activity carried out by an entity e.g. a machine loading. This approach is easy to understand and to implement but is not efficient;
- Process - This approach groups activities to describe the life cycle of an entity e.g. a machine. This is less common and more difficult to plan and implement, but is generally thought to be the most efficient.

## TOOLS FOR DISCRETE EVENT SIMULATION

There is a lot of software which can help us to realize process modelling and process simulation. A list of free simulation software can be found on <http://www.topology.org/soft/sim.html>. Some examples of commercial software are: ProModel ([www.promodel.com](http://www.promodel.com)), Scitor Process v3 ([www.scitor.com](http://www.scitor.com)), iGrafx



**Fig. 6. SimQuick interface**

Process  
iGrafx  
Process  
SimQuick  
(<http://www.prenhall.com/hartvigsen>)  
. For the case study we used SimQuick software (fig. 6) which is an Excel application software. SimQuick allows you to perform process simulation within the Excel spreadsheet environment.

There are three basic steps involved in using SimQuick:

1. Conceptually build a model of the process using the building blocks of SimQuick
2. Enter this conceptual model into SimQuick (this is done by filling in tables in a special Excel spreadsheet).
3. Test process improvement ideas on this computer model.

The building blocks in SimQuick are objects, elements, and statistical distributions. Objects typically represent things that move in a process: people, parts in a factory, paperwork, phone calls, e-mail messages, and so on. Elements typically represent things that are stationary in a process. There are five types of elements:

Entrances: This is where objects enter a process. Entrances can represent a loading dock at a warehouse, a door at a store, and so on. You must specify when objects arrive at an Entrance and in what numbers (using a statistical distribution or an explicit “custom” schedule).

Buffers: This is where objects can be stored. Buffers can represent a location in a warehouse or factory

where inventory can be stored, a place where people can stand in line at a post office, a memory location in a computer for e-mail messages, and so on. You must specify how many objects a Buffer can hold.

**Work Stations:** This is where work is performed on objects. Work Stations can represent machines in a factory, cashiers in a store, operators at a call center, computers in a network, and so on. You must specify how long a Work Station works on an object (using a statistical distribution).

**Decision Points:** This is where an object goes in one of two or more (up to 10) directions. Decision Points can represent the outcome of a quality control station, different routings in the processing of a mortgage application, and so on. You must specify a rule for deciding in which direction an object goes (using a statistical distribution).

**Exits:** This is where objects leave a process. Exits can represent a loading dock at a warehouse, a customer buying a product at a store, and so on. You must specify when objects depart from an Exit and in what numbers (using a statistical distribution or an explicit “custom” schedule).

A SimQuick model describes how the objects move between the elements. You have a great deal of freedom in constructing models using the building blocks of SimQuick; hence, you can model a variety of real processes. When a SimQuick simulation begins, a “simulation clock” starts in the computer and runs for the designated duration of the simulation. While this clock is running, a series of events sequentially takes place. There are three types of events in SimQuick: the arrival of objects at an Entrance, the departure of objects from an Exit, and the finish of work on an object at a Work Station. Whenever an event occurs, SimQuick moves objects from element to element as much as possible. SimQuick keeps track of various statistics during the simulation (e.g., the mean inventory at each Buffer) so you can analyze what happened when the simulation is over.

## **CASE STUDY**

The need of integrated manufacturing processes with quality control and support processes is not very new and many companies have reported good results in term of productivity and quality.

COMPA is a Romanian automotive company established in Sibiu, with a good tradition in manufacturing automotive parts for well known companies like Tyssen Krupp Bilstein, Bosch, Honeywell etc.

We have decided to start a project [11] together with COMPA in order to integrate the welding process with measuring and support processes. The following requirements were established:

- controlling the process using SPC methods;
- minimizing systematic factors responsible for process variation;
- acquiring process data for later analysis;
- permanent monitoring for process performance;
- reducing possibility of human error during data acquiring;
- obtaining real time information regarding the process;

Starting from these requirements, the main objective of this project was defined: designing and implementing an integrated SPC system for measuring and monitoring parameters of spare parts to ensure high precision measurement, measuring automatization process and high productivity.

The project was split in three stages:

Stage 1: Research and analysis of the welding processes in order to identify measuring characteristics;

Stage 2: Designing SPC and knowledge transfer;

Stage 3: Prototype building and validation.

To have the whole picture of the project a graphical view of the welding process and SPC system was made (fig. 7) [11]. The entire process was describe in detail using a flow diagrams and different improvement arise. During the whole welding process there are numerous places were a quality measuring must be made. This measurement was made using a 2D coordinate measuring system. The time required for one measurement is around 15 minutes and the main disadvantage of this kind of measurement is that operation needs qualified workers and requires much time.

The solution was to implement an SPC system which gives the following advantages: very fast measuring time, does not require highly qualified workers, it measures all the needed characteristics in one time, all the data from the measurement can be transferred into the computer where can be

processed and forecast analysis can be done. (fig. 8).

Before realizing the measuring system a **simulation** was made [12] to see how the implementation will affect the entire process.

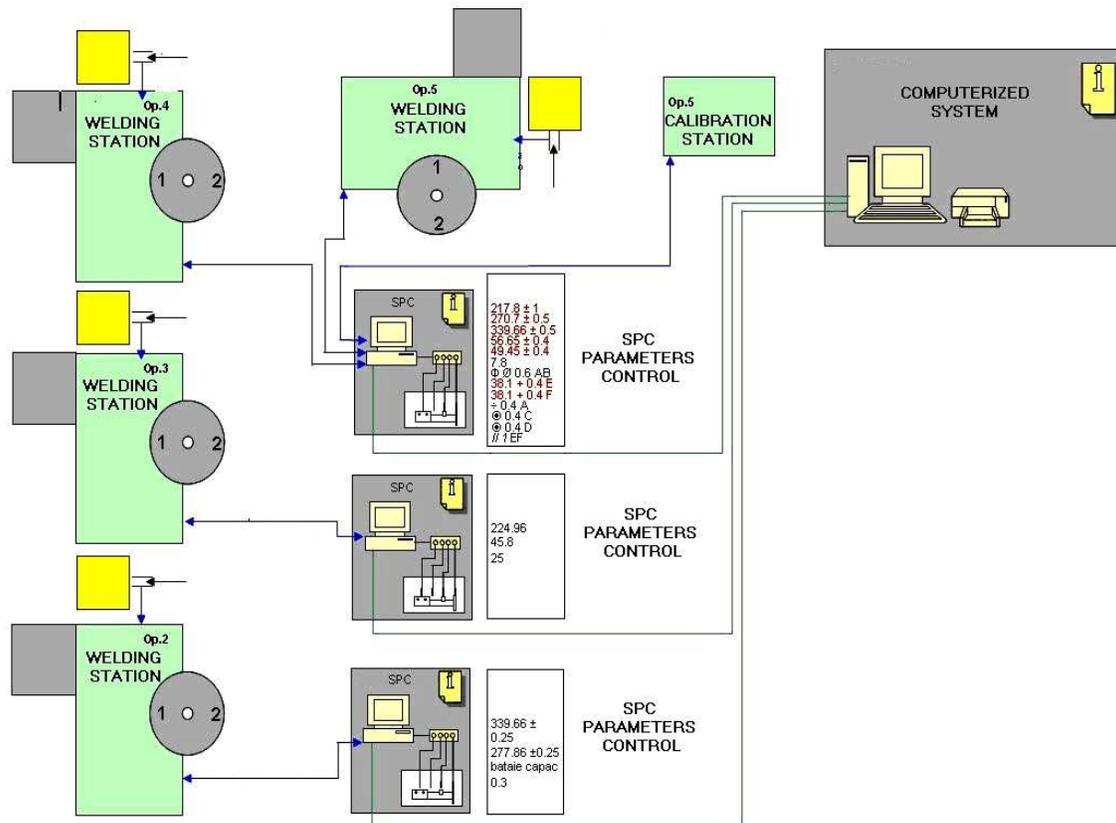


Fig. 7. Computerized system for statistical process control of welding process for strut housing

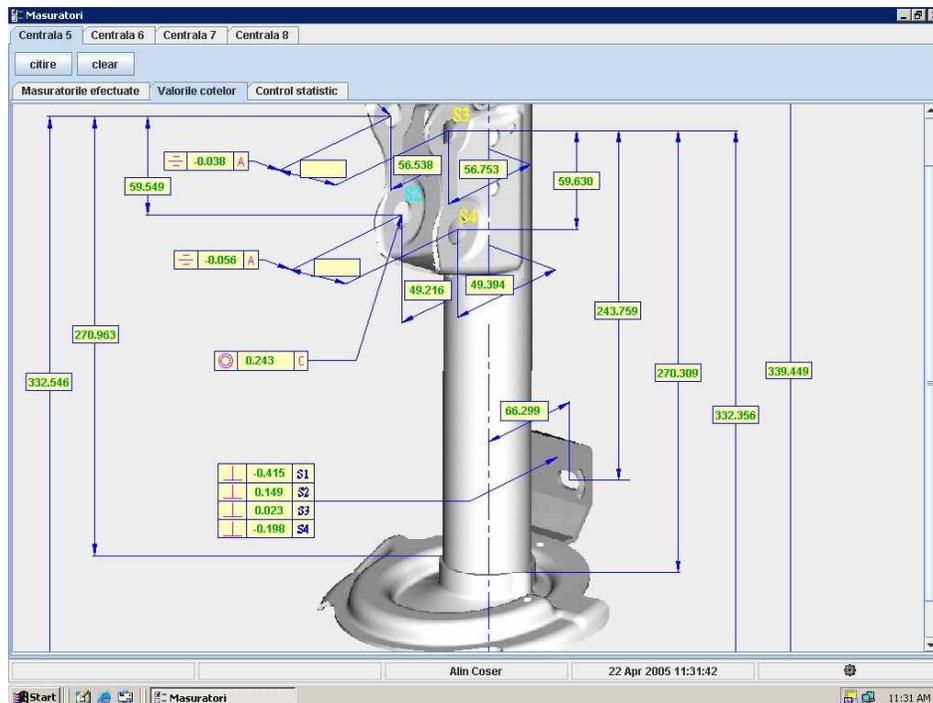


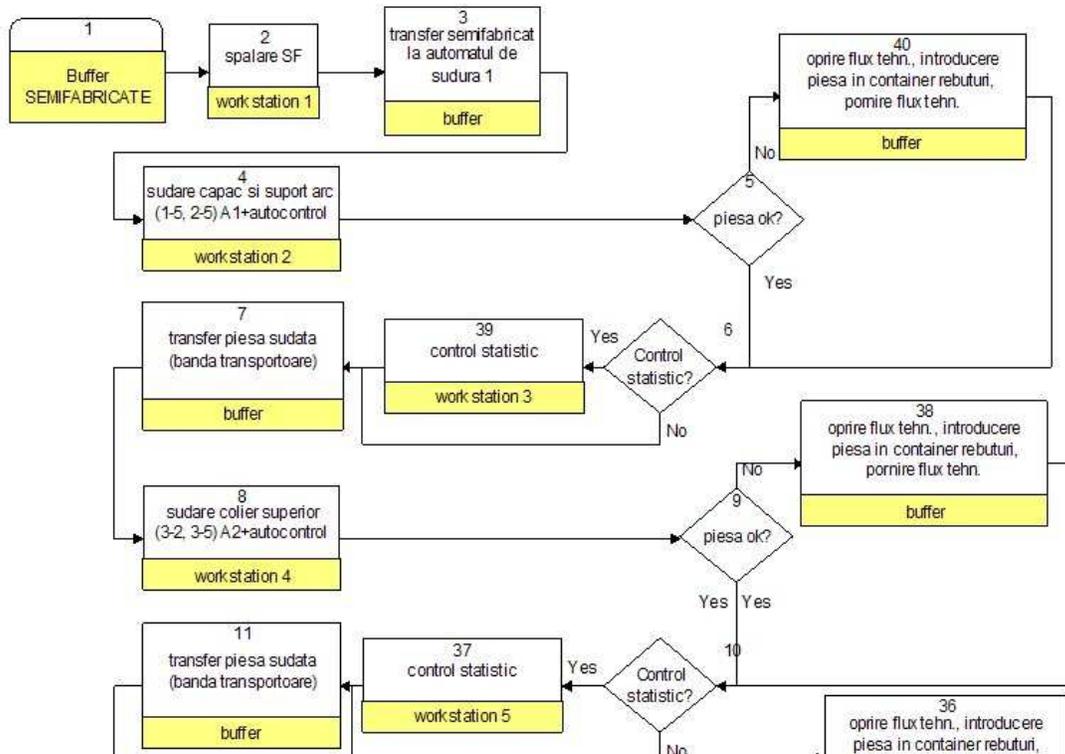
Fig. 8. Measuring using SPC measuring system

## THE SIMULATION

The simulation followed the following steps:

- building the process model;
- collecting the necessary data for the simulation;
- building the simulation model;
- running the simulation model;
- results analyzing and interpretation.

The process model was build after a detailed observation. A part of the process is shown in figure 9.



**Fig. 9. Partial representation of the strut housing welding process**

To build the simulation model the necessary data was collected from each work station. The working time and other specific times were collected and the results were presented (Table 1).

**Table 1. Data collection**

Work Station	WS 1	WS 2	WS 3	WS 4	WS 5	WS 6	WS 7	WS 8	WS 9	WS 10	WS 11	WS 12	WS 13	WS 14
Time [seconds]														
Nor(m,s) m- average s- standard deviation	Nor (819, 121)	Nor (21,3)	Nor (601, 41)	Nor (22,6)	Nor (595, 53)	Nor (21,4)	Nor (599, 41)	Nor (22,2)	Nor (609, 54)	Nor (22,3)	Nor (33,5)	Nor (21,3)	Nor (21,3)	Nor (611, 52)

The simulation model was build and all the data was implemented in the simulation software.(fig. 10)

Simulation controls:			
Time units per simulation →	28800		
Number of simulations →	50		

Work Stations:

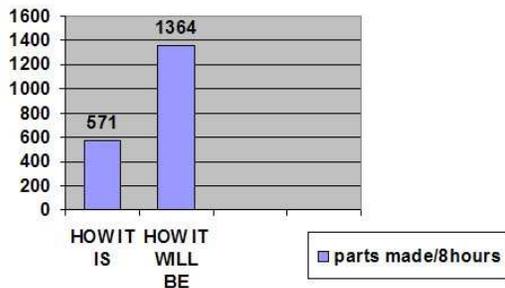
1			
Name →	ws1		
Working time →	Nor(819,121)		
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
buffer3	200		

2			
Name →	ws2		
Working time →	Nor(21,3)		
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
decision5	1		

**Fig. 10. Data implementation using SimQuick software (partial representation)**

The simulation has two stages: process simulation “as it is” and “how it will be”. First stage used real data from the process and in the second stage we implemented estimated data. For each stage the simulation software runs 50 simulations of an 8 hour shift. The results were impressive. For the process “as it is” the final inventory for a shift (8 hours) was 571 realized parts. For the expected process after the implementation of the SPC system the expected final inventory were 1364 realized parts (fig. 11). Even taking in consideration the errors susceptible to be made the results were a strong support for SPC system implementation.



**Fig. 11. Simulation results**

## CONCLUSIONS

Process modeling and simulation using discrete event simulation is a powerful method for all the people involved in designing, running and controlling manufacturing processes. This method can be used also by the people involved in quality assurance processes. It is also a very good way to understand a process and to estimate the behavior of one before spending resources in a real one

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