Research Article

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Simulation of the Use of the Material Handling Equipment in the Operation Process

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Abstract: The article presents the simulation model and simulation experiments aimed at the rationalisation of bottle necks in operations in terms of the capacity utilisation of the material handling equipment, in particular, six conveyance lines. The models and experiments were designed in the Tecnomatix simulation environment which facilitates the modelling of even more complex systems. The simulation model visualises the material flow within the production process comprising individual technological operations and workplaces. The model was used to perform simulation experiments with adjusted production times and added or removed workplaces. The presented article also contains the graphs of the utilised capacity of the machinery and operators. The obtained experimental results suggesting the partial or complete elimination of the accumulation of unfinished products.

Keywords: operation, simulation, model

1 Introduction

Prompt responses of accomplishments to various customer requirements, shortening delivery times, as well as on-time deliveries of required materials create the competition among companies and uncertainty on the market. Therefore, companies begin to offer not only high-quality products, but also comprehensive service packages [1]. Such service packages also include simulations of the effects of various decisions in a simulation model to evaluate production capacities, duration of operations, and other necessary production parameters. Companies operating in different sectors of the economy are more and more commonly using IT solutions to optimize logistic systems by improving the handling of materials and performance parameters [2–4]. The use of simulation software products facilitates the identification of the expected result within a short period of time without any change in, or an intervention with the production process [5]. The analysis of the literature with a particular focus on applications in manufacturing provides paper [6]. The literature is classified into three general classes of manufacturing system design, manufacturing system operation, and simulation language/package development. Simulation was defined as a research method by many authors [7–10]. Simulation may also be understood as the numerical method applying complex probability dynamic systems through experiments performed by using a computer model. The importance of the simulation consists in the reorganisation of a company aimed at increasing the efficiency of the company structure, re-engineering the technological and all business processes, restructuring the production program, and in the need for a considerable improvement of the production and business processes [11]. Optimisation of the production processes may be carried out by planning the production operations in a certain time [12], improving the production process at the execution level [13], or by applying special approaches aimed at improving the production efficiency [14].

The purpose of the presented research was to create an appropriate simulation model. Simulation experiments were aimed to remove idle times of the lines and thus to facilitate the smooth flow of the production transport and handling processes.

The aim of the article is creation a simulation model and conduction some experiments for rationalisation of narrow spaces in operations in terms of the capacity utilization of the material handling equipment.

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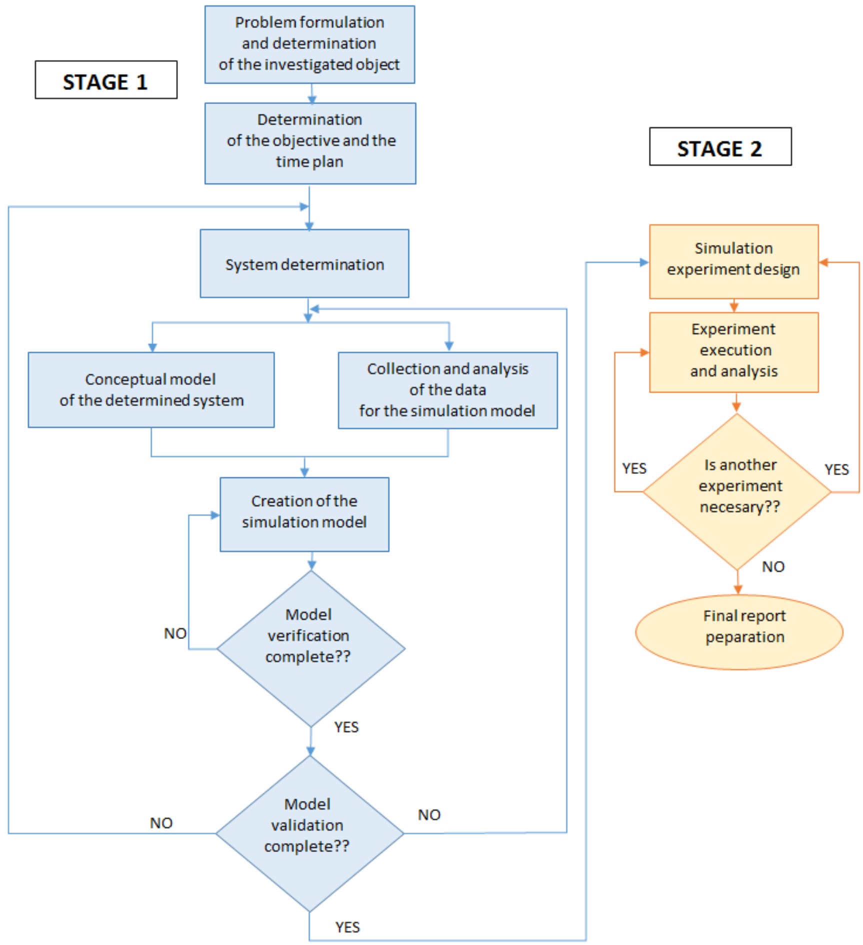

Figure 1: Simulation model creation process.

2 Material and methods

2.1 Problem formulation

The aim of the research was to create a model on the basis of the analysis of the existing production times at workplaces and the number of employees engaged from the beginning of the production, through the controlling, up to the packing. The purpose of the simulation experiments was aimed to eliminate idle times of the line and to utilise optimally machinery equipment.

2.2 Description of the experiment and methods

The simulation experiments were done on the basis of changing of the input parameters.

The production process scheme contains the recorded events that occurred during the simulation process. The created model facilitated the subsequent revision of the events, execution of analyses, evaluations, comparisons of alternatives, and optimisation. The results may be implemented in real-life practice later. There are plenty of software products suitable for this purpose, such as WITNESS [15], Cosirob, Arena, Delmia, INTALA, Factor AIM, Cosimir, EXTEND and many more [16].

2.3 Creation of the model

The creation of the simulation model consisted of several steps so-called the simulation model creation methodology. The model creation itself is comprised in two stages; the simulation model designing and execution of experiments. The life cycle of the simulation model is described in Figure 1.

The critical stage of the modelling is the first stage, *i.e.*, the familiarisation with the production, individual elements and relations. It is very important to determine the

Table 1: Defined input data of the production process.

Production factor	Description
NC programs	Numerical control programs for the execution of operations in machining centres (or work centres or accumulation centres).
Time schedules	Time schedules for the execution of operations over time.
Technological/Operational sheets	Documents containing technological and operational data.
Data about sources	Data about all sources in the production system.
Resources	Required physical resources for the production process.
Human resources	Required human resources for the production process.
Machining parts	Machining parts (or working parts or assembly parts) in the production process.
Energy	All kinds of the required energy.

objective of the simulation. The objective should be determined on the basis of the questions like: Where are the bottle necks in the production area? What are the reasons for long lasting times? Why are the costs higher? Will the order deadline be adhered to?

The following stage is the creation of the simulation model in which the experiments will be performed with the goal to improve the system. Understanding of the researched system, especially the relations among the entities and systems, represents the basis for the correctly performed simulation.

3 Results and discussion

3.1 Analysis and collection of the input parameters of the model

The creation of the simulation model requires the input parameters listed in Table 1. The effects of the input parameters were researched in the production process of selected automotive company. Most frequently, they were the time parameters because the changes are made in time [13].

Simulation programs are classified by their functions. There are simulation programs for robotised workplaces and for the material flow simulation. The correct selection of a simulation program determines the efficiency of the simulation.

The simulation model was created in the Tecnomatix simulation program as a tool for the comprehensive portfolio of digital simulations of the production process. According to Siderska, it is a tool for the discrete simulation. It is suitable for the creation of digital models of the production. It examines and optimises the system performance [17]. It enables the simulation model designing, verification, and subsequent application in the production process. This simulation program (Figure 2) includes the Plant Simulation.

3.2 Production line characteristics

The production line was divided into two basic sections. The production itself starts by loading the material onto the line by using a cart. Products are transported along the production line to individual stations, *i.e.* workplaces. In order to monitor the assembly process, the carts are equipped with the so-called Mobby memory while they are moving through the line. This memory monitors the entire production process and the product crossing through the particular stations. In case of a failure, it sends the error message to the repair station. Each production station is equipped with a recording head. The production is started with manual loading and unloading of the material onto the conveyance lines. When the line parameters are adjusted, the material is only supplemented. Individual parts are passing through the entire production; they represent the product itself. The formalised scheme of the technological operations sequence of the production process in is illustrated in Figure 3.

The Line Section 1 is the area where nine basic technological operations were carried out, with 8 operators working at particular workplaces. The production starts with loading a batch on a line cart, then it continues to the gradual assembly of the product. The Line Section 1 also includes the repair station where the product is forwarded in the case of a failure. Finally, the semi-finished products pass through the section where the determined parameters are measured and then to the interconnecting belt. From this belt the semi-finished products are passed to the Line Section 2 or were placed on a pallet, for future pro-

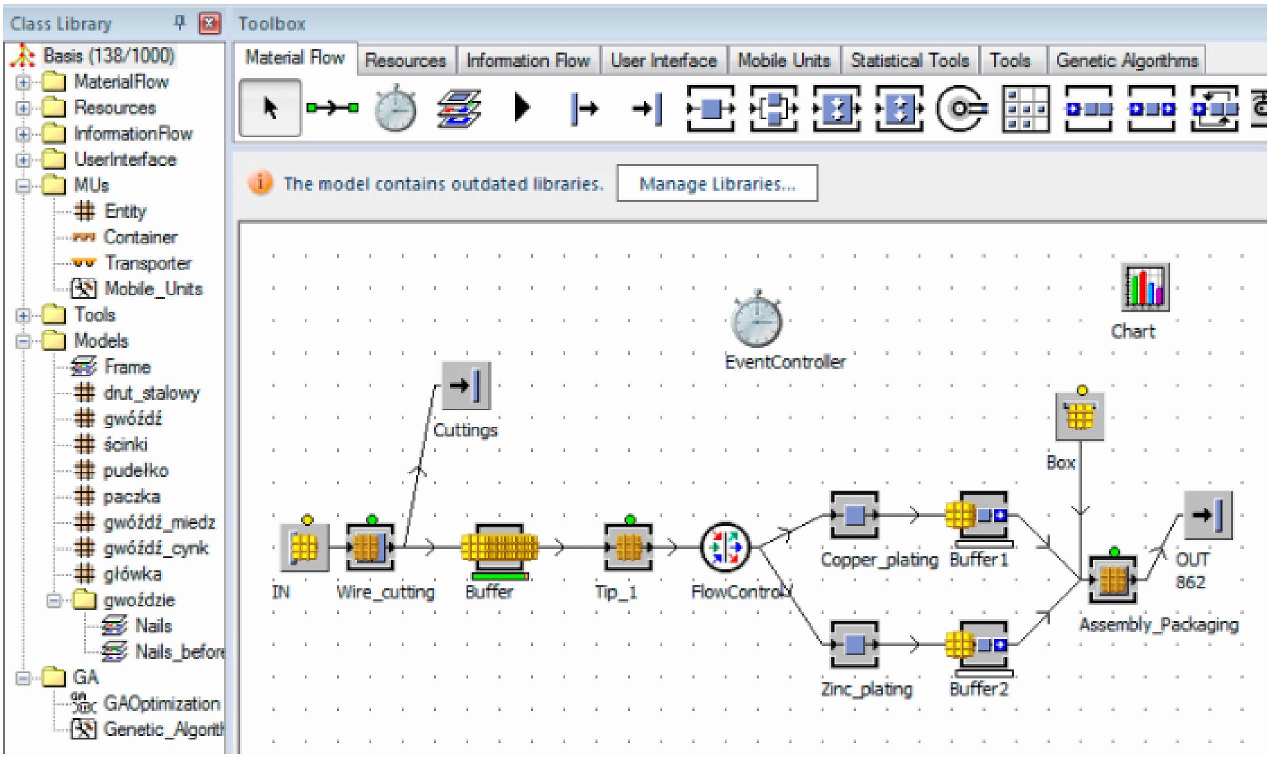

Figure 2: Example of production process designed using Tecnomatix Plant Simulation [17].

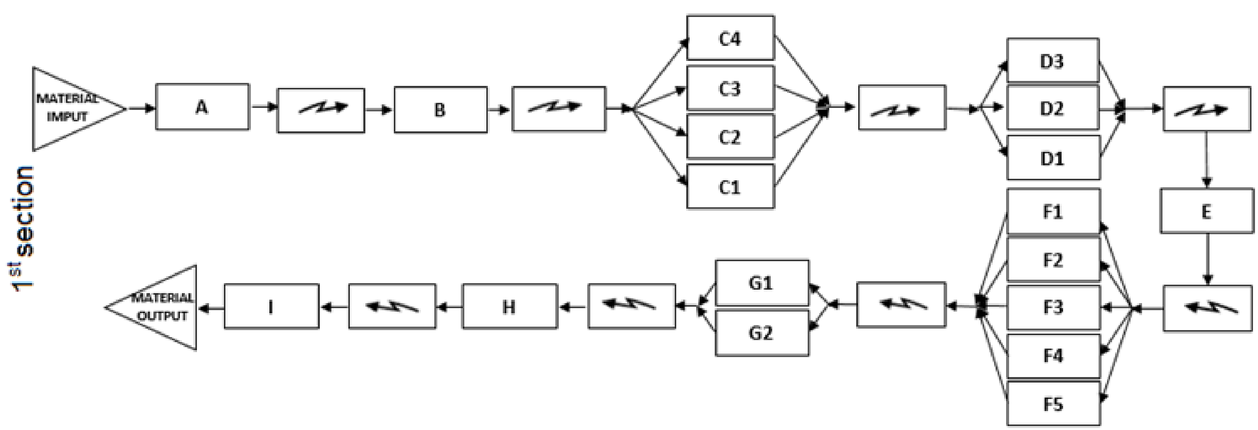

Figure 3: The formalised scheme of the production process.

cessing. The number of operations, operation times, and the number of operators at both lines are listed in Table 2.

3.3 Simulation model of the line

Tecnomatix simulation program environment was used for the simulation model of the line. This model depicts the production process and the passage of products through particular technological operations designated as Operations A – I. The created model of the Line Section 1 is shown in Figure 4.

After the simulation of the existing state of technological operations in the created model (Figure 4), there were visible critical operations, accumulation of unfinished products (entities) after Operations A and B, at the entry to Operation D, and before the entry to Operation E; this may be also seen in Figure 5 showing the capacity utilisation of individual operations.

Figure 5 shows that the first two operations are significantly blocked. The first operation represents 45% of the

Table 2: Timelines of technological operations in the Line Sections 1.

OPERATIONS	1st section of line	
	Operation time	Number of operators
A - Loading of steel coils on roller conveyors	15.0	1
B - The introduction of the coil into production	13.0	0
C - Unwinding of coils using unwinders	14.0	0
D - Punching of trays and transporting by vacuum conveyors	18.0	3
E - Pressing of trays and their transport by gravity conveyors	20.0	0
F - Can body pressing	35.0	0
G - Application of internal and external varnish	13.0	2
H - Forming the neck of can	8.0	0
I - Quality control of cans	2.0	0

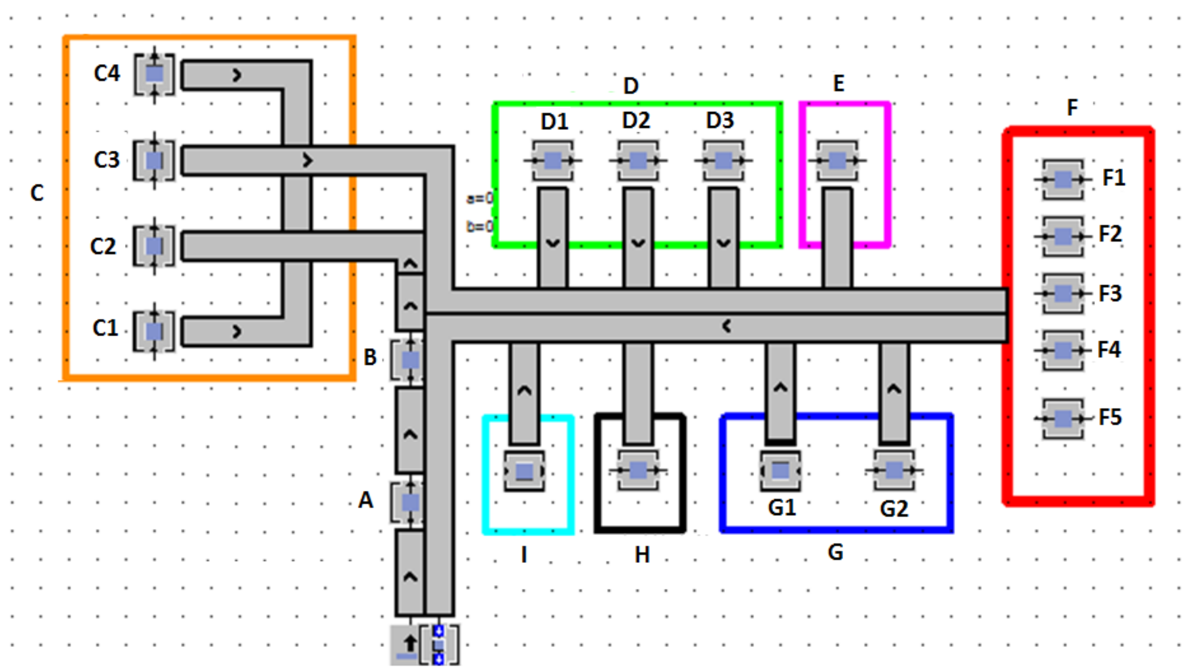

Figure 4: Simulation model of the line in Tecnomatix.

total simulated time. The station was blocked up to 55% of the total time. Operation B ran in 37% and the remaining 63% of time represented the blockage of this operation. Operation C was performed on 4 identical equipment (C1, C2, C3, and C4). Each of them worked only in 17% of the total simulated time and the remaining 83% of the time represented idle times. Operation E represented 99% of the simulated time. Other technological operations represented on average 24% of the simulated time. It was possible to identify critical sites of the entire process, *i.e.* the accumulation of unfinished products before Operations B, C, and E on the basis of the simulation.

These findings indicate the need to optimize of the performance of these technological operations. This may be achieved, for example, by reducing the times of selected operations, if the production technology allows such a reduction. Another way, how to achieve this, is to add an equipment at critical sites in order to eliminate the bottle neck.

Therefore, several experiments were done with the above described model. They were aimed at eliminating the accumulation of unfinished products at critical sites. Figure 6 presents the results of the capacity utilisation for particular operations in the experiment in which the times of technological Operations A, B, and G were changed. The

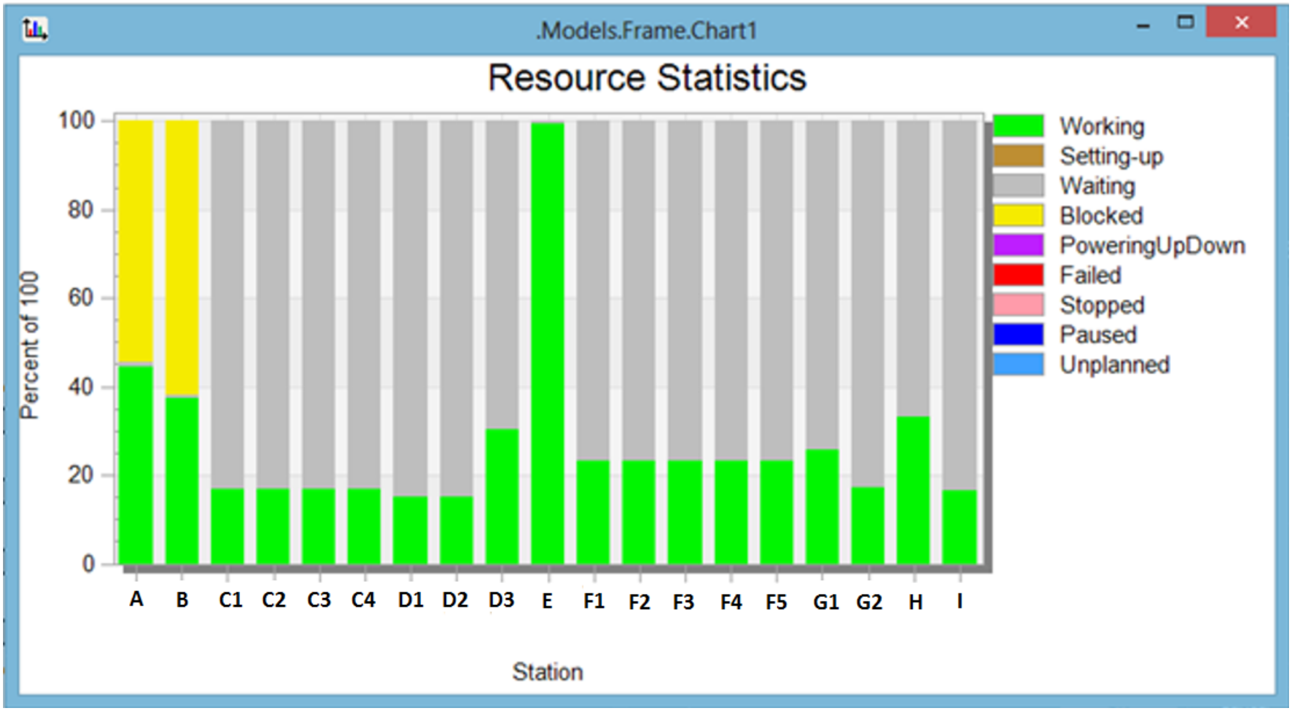

Figure 5: Capacity utilisation (time utilisation of technological operations) - existing situation.

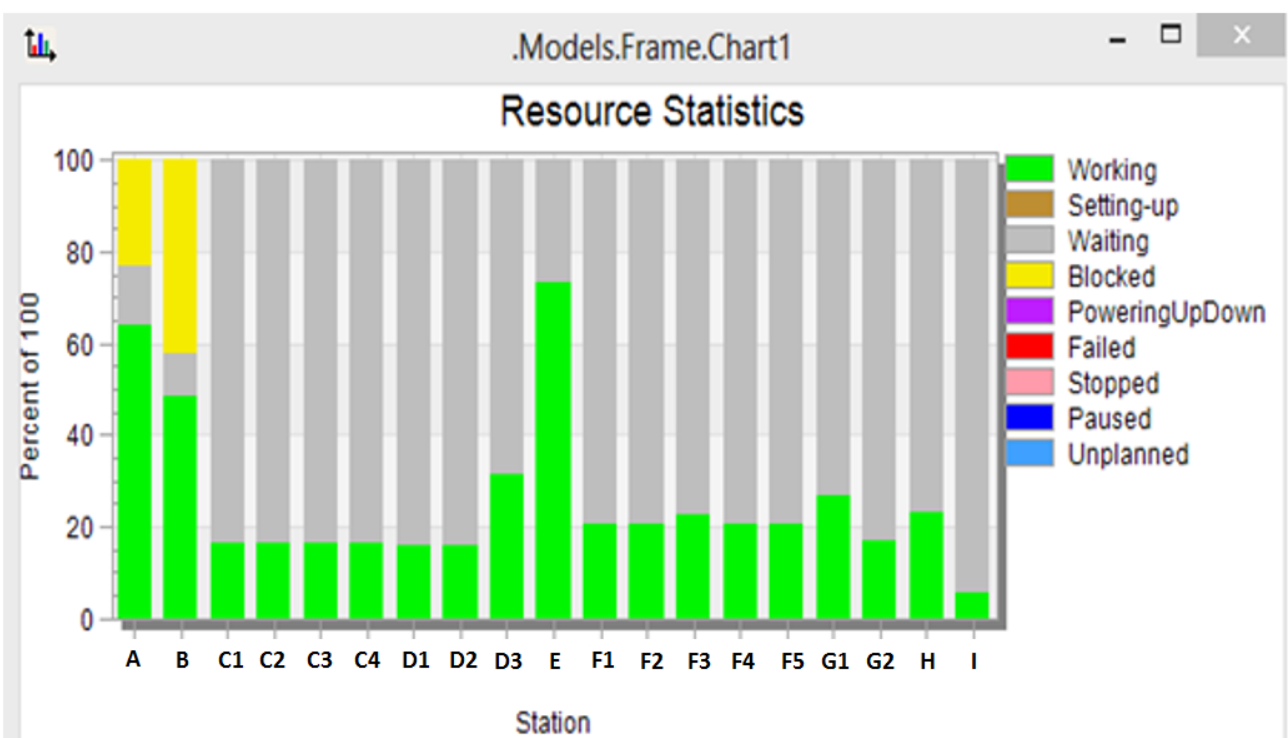

Figure 6: Capacity utilisation (time utilisation of technological operations) – experiment.

production times of these operations were decreased in 2 seconds and the time of the technological Operation C was reduced in 4 seconds (acceptable change).

Figure 6 shows the changes in comparison to Figure 5. The technological Operation A was performed in 65% of the total simulated time; 12% of the simulated time represented idle time (waiting); and there was the blockage of entities 23% of the simulated time. The execution of the technological Operation B represented 49% of the total simulated time; 10% represented idle time (waiting); and there was the blockage of entities 41% of the simulated time. Also the execution of Operation C represented n 17% of the simulated time and the remaining 83% represented the idle time (waiting). The technological operation E represented 70% of the simulated time and 30% represented the idle time. In this case, other technological operations represented on average 21% of the simulated time.

4 Conclusion

The article discusses some scenarios regarding the simulation modeling and experiments focused on streamlining the bottlenecks in operations in terms of the capacity utilization in the context of material handling equipment when implementing Tecnomatix simulation software.

The production process timelines confirmed certain irregularities in terms of the duration percentages of individual technological operations. For example, the machining and assembly operations represented approximately 5% of the total duration of the production process. The placement of physical sources in preparatory operations or waiting prior to the follow-up operations during the adjusting times, and transport and handling represented approximately 95%.

The obtained results allow to conclude the discussion that the reduction of the times of selected technological operations resulted in the following:

- Increased production rate of the operations;
- Reduced amounts of accumulated unfinished products after the Operations A and B (this was not completely eliminated);
- Reduced production rate of Operation G (in this case a 29% decreasing) and increased idle times up to 30%; this had a negative effect on the performance of the entire production line.

Not only this experiment, but also other performed experiments brought the conclusion suggesting that the partial or complete elimination of the accumulation of unfinished products which, however, resulted in lower output of Operation G, reduced average times of several technological operations below 20% of the simulated time, especially G, H, and I (end operations), when compared to the baseline status.

The optimal setting of the production line remains to be open for the future and will be subjected to further research.

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