Simulation-dynamic model of the details manufacturing process in the workshop

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Abstract. The article discusses the construction of the simulation-dynamic model of the manufacturing details process in the workshop. As part of the production process, the workshop prepares workpieces, performs processing operations and packaging of details, as well as controls defective workpieces during processing operations. The model is built, taking into account the percentage of defect probabilities during the operation. It also shows the work process of the enterprise workshop for 8 hours. A model management interface was created, which includes an input interface through which data is entered, as well as an output interface that allow seeing the results of the work done. On the grounds of the conducted experiments, conclusions were drawn regarding the available data, a comparison of the experimental results was carried out, as well as illustrating how the model visualizes changes in the manufacturing process of details in the workshop.

1. Introduction
Simulation modelling is widely used in areas such as industry, transportation, warehousing, construction, economics, engineering [1]. This method of constructing models currently offers a number of possibilities for the analysis of various processes and interactions [2].

The process of manufacturing part is a complex system consisting of many individual elements and relationships that arise during the manufacturing process. The state of the process is characterised by such parameters as time, defect probability, equipment loading, and more. Different manufacturing factors affect the course of the process, leading to a change in the process [3].

For production, it is necessary to rationally use the equipment, organize workers, evaluate the form of organization of the production process, monitor temporary estimates of the full production cycle, and manage warehouse facilities [4, 5].

In these conditions, the value of decisions increases with decreasing time spent on decision making. Therefore, simulation modelling is an effective tool for solving a wide range of production problems [6, 7].

On the basis of data on the manufacturing of details in the workshop, the task of creating a model in the Powersim Studio application was formulated. The model should show the work process of the workshop for 8 hours, determine the relative number of finished and rejected details, as well as the
number of workpieces that did not manage to go through the production cycle in a workday, and their location in the workshop.

2. Model of calculating the efficiency of manufacturing details process in the workshop

There are types of standard objects in the program that are used to build any model in Powersim. Basically, there are five types of objects: levels (stocks), flows (material relationships), auxiliary variables, constants, and relationships. In addition, auxiliary variables can be combined with streams to create “streams with rates” and connections can be subdivided into information links, lag links, and initialization links.

A graphic diagram of a simulation-dynamic model of calculating the level of efficiency of manufacturing details process in the workshop is shown in figure 1.

![Diagram of flows and levels of calculating the level of efficiency of manufacturing details process in the workshop](image)

**Figure 1.** Diagram of flows and levels of calculating the level of efficiency of the manufacturing details process in the workshop.

The model includes seven levels:

- Workpieces.
- Workpieces preparation.
- Detail 1.
- Detail 2.
• Finished workpieces.
• Defect 1.
• Defect 2.

The diagram also has six flows:

• Preparation.
• Operation 1.
• Operation 2.
• Packaging.
• Control 1.
• Control 2.

In addition to the listed flows and levels, the diagram contains constants and auxiliary variables. Their description is presented in table 1.

**Table 1.** Variables used in the diagram of flows and levels of calculation of the level of efficiency of the manufacturing details process in the workshop.

| Name                  | Decryption                           | Value | Units |
|-----------------------|--------------------------------------|-------|-------|
| Count of workpieces   | Number of workpieces                 | 500   | none  |
| T0                    | Workpiece preparation lead time      | 100   | min   |
| T1                    | Operation time 1                     | 20    | min   |
| T2                    | Operation time 2                     | 25    | min   |
| TY                    | Packing lead time                    | 20    | min   |
| TK1                   | Control time 1                       | 20    | min   |
| TK2                   | Control time 2                       | 20    | min   |
| Defect op 1           | Defect probability in operation 1    | 10    | %     |
| Defect op 2           | Defect probability in operation 2    | 20    | %     |

3. **Control interface of a simulation-dynamic model**

Figure 2 shows the control interface of the developed model, which consists of three tables: with initial data, results and workshop details; and two graphs: the first shows the rate of increase of defects in general and in each operation over time, and the second - how many details are in operations 1 and 2 and how many details are produced by the workshop.

4. **Results**

Two simulation experiments were conducted. During each experiment, the production process of manufacturing details in the workshop was recreated according to the initial data indicated below, but with a different number of workpieces that were put into production:

• Count of workpieces – 1) 500; 2) 2 000.
• Preparation – 40 minutes.
• Operation duration 1 – 20 minutes.
• Control duration 1 – 30 minutes.
• Defect probability 1 – 10%.
• Operation duration 2 – 50 minutes.
• Control duration 2 – 20 minutes.
• Defect probability 2 – 20%.
• Packaging – 20 minutes.
Experiment 1.
Within 8 hours of the workday out of 500 workpieces, the workshop manufactured 357 details, 142 workpieces were defective. All workpieces went through the production cycle, there were no workpieces left on the machines.
Figure 3 shows the results of the run.

| Initial data (Counts of workpieces) | 500.00 details |
|-----------------------------------|----------------|
| Operation | Operation duration | Control duration | Defect probability |
| Preparation | 40.00 min | - | - |
| Operation 1 | 20.00 min | 30.00 min | 10.00 % |
| Operation 2 | 50.00 min | 20.00 min | 20.00 % |
| Packaging | 20.00 min | - | - |

| Result | Workshop details |
|FINISHED DETAILS | 357.00 details |
|DEFECT | 142.00 details |

| Operation | Operation 1 | Operation 2 | Preparation |
|-----------|--------------|--------------|--------------|
|Operation 1 | 0.0 details |
|Operation 2 | 0.0 details |
|Preparation | 0.0 details |

Figure 2. Input interface.

Figure 3. The result of the experiment 1 model run.
Experiment 2.

The initial data for the experiment were applied as follows: 2,000 workpieces were put into production; 1,428 details were produced; 571 workpieces will be rejected. At the same time, production did not have time to complete the manufacturing processes of details. 9 details left on the first machine, 4 – on the second machine.

Reception of the following results shown in figure 4.

| Operation   | Operation duration | Control duration | Defect probability |
|-------------|--------------------|------------------|--------------------|
| Preparation | 40,00 min          | -                | -                  |
| Operation 1 | 20,00 min          | 30,00 min        | 10,00 %            |
| Operation 2 | 50,00 min          | 20,00 min        | 20,00 %            |
| Packaging   | 20,00 min          | -                | -                  |

### Figures

- **Figure 4.** The result of model run with modified experiment 2 parameters.

In the course of the final work, a simulation model of the manufacturing details process in the workshop was built using the Powersim program and two simulation experiments were conducted. According to the results of the experiments, it can be concluded that when a large number of workpieces enters production, production will become ineffective. A certain number of details will not have time to go through the production cycle to the end. It was also noted that the machines that perform the operations are most loaded at the beginning of the workday. And by the middle of the day, the machines are completely out of work.

5. Conclusion

Using this model, user can analyze the manufacturing details process at various indicators, the effectiveness of this process, the effectiveness of individual production subsystems. With this model, user can see how many details will be produced for the workday, how many workpieces to be sent as a defect. The developed workshop model can be applied to solve the problem of «bottlenecks» of technological processes and improve the quality of products manufactured by the workshop.

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