Improving the process of designing route maps in production

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Abstract. The paper describes the method of designing route maps, taking into account the capabilities of the production means, which will improve the efficiency of the technological processes being developed through the planning of resources. The paper presents the data used in the design of the route, as well as the model of interaction with the archive of technological processes. The basic requirements for the implementation of the proposed model at a high-tech instrument-making enterprise are described. The feasibility of using this approach in the framework of the integration of the computer-aided design system information flows for technological preparation of production and manufacturing automation systems is shown. An example of the route formation using the tools developed in the research process.

1. Introduction
The technological route, reflecting the rational sequence of processing parts, is the main part of the technological process in its content [1,2]. The construction of such a route is a technological problem and, therefore, may have several solutions, only one of which will be the most effective and rational one. Currently, there are mechanisms for constructing a technological route in automated systems for technological preparation of production, which are based on the use of templates previously successfully configured for a specific part [1, 3]. As part of the study, one of the objectives of improving management efficiency is to identify such a route, which is the most rational, the result of which will be the most beneficial, both in terms of the minimum resources involved, and in terms of maximum economic benefits.

Petri nets [4,5] are used as a simulation tool as the most visible and universal method for the formalization of simulation models. The use of Petri nets should be limited, since the stated system parameters will lead to a large number of system states and parameter variability. These factors create serious problems in the formation of networks.

The itinerary planning of the route map is carried out basing on the system of technological training design. Each planning unit is presented in the form of a transverse technology of their manufacture in the form of a technological process with a laid route. In this case, the planning units are the final nomenclature of planning and its semi-finished product with \( N^{e_i} \rightarrow N^{v_i} \) transitions from one state to another.

While observing the process of high-tech instrument-making production, it was revealed that, due to unintended circumstances, a part of the technological processes launched in production is subject to adjustment of the technological process [6,7]. This is due to the constant refinement of manufactured
products by developers and designers, as well as in connection with the change of $I_n$, $M$, $R_{Cn}$, $t_{TPn}$, $N_{pj}^e$ resources (figure 1).

![Route map]

_Figure 1_. Model of technological process transition using a route map.

The technological process of $I_{PL}$ detail consists of $O_{al_{PL}}$ technological operations. Each $O_{al_{PL}}$ technological operation is characterized by $H_o = (I_n, R_{Cn}, t_{TPn}, N_{pj}^e)$ set of characteristics, where $I_n$ is the executor of the technological operation (indicating the grade); $R_{Cn}$ is work centre (means of production); $t_{TPn}$ is execution time of the technological operation (processing time includes $t_p$ preparatory time (readjustment) and $t_v$ execution time of the technological operation on the equipment, i.e. $t_{TPn} = t_p + t_v$) is a semi-finished product with a set of characteristics on the current $O_{al_{PL}}$. $O_{al_{PL}}$ state change is the result of the need to change the route which causes the necessity to correct the route map. The interoperability transition parameters are tied to manufactured $I_{PL}$ product nomenclature and the $R_c$ means of production.

In the case of the means of production replacement it is necessary to perform the following actions:

- The operator (designer) will initiate the process of starting the search for alternative $R_c$ work centres for the current part;
- If successful, the current means of production is automatically replaced by a new means of production from the archive of technological processes;
- Description of operations and transitions, time standard are automatically replaced with data from the archive of technological processes;
- If the current part differs from the archival part in its execution and there is no data concerning the current part in the archive, then the participation of the tasksetter and technologist is required to finalize the current transition. With the reappearance of the same parts on the new means of production - the participation of the tasksetter and the technologist is not required.
If the dimensions of the workpieces change (for example, the thickness of the workpiece has increased due to the breakdown of the means of production) the following actions should be taken:

- The operator (designer) has to start the process of searching the transition group for the current part in the archive of technological processes;
- In case of finding transitions the current transition is replaced with a new one (from the technological process archive);
- All Ho characteristics are cleared along the current PLnIО;
- Data from the archive of the technological process is entered into the current operation;
- If the current part differs from the archival one in its execution and there is no data in the archive, then the participation of the tasksetter and technologist is required to finalize the current transition (templates are used in the systems of technological preparation of production). With the reappearance of exactly the same details, redevelopment of the route is not required.

If it is necessary to change the labour intensity, there is the possibility to obtain data from the archive of technological processes. The start time of Oₙₙ₄ technological operation is recorded in route maps.

Thus, it is possible to get a summary report about all the technological operations performed by specific In contractor for the current In detail, taking into account Rcn means of production described in details in Oₙₙ₄.

All the above cases are constantly recurring events that happen during the production process. The groups of transitions collected on the basis of the experience form a basic set (a complex of sets) for using data when building a route, the data of which is stored in the archive of technological processes (figure 2).

![Figure 2. Addressing the process of search for transitions in the archive of technological processes.](image)

Data about the transition of a technological operation is obtained from the archive of the technological process by means of SQL queries [8, 9] (the structured query language) integrated into
the interface of the route design system. After sampling the data is placed in the list. The list is sorted by date in such a way that a later executed transition ($t_f$) with the nearest date is placed first in the queue. Earlier transitions by date of execution, for example, are out next in the list (table 1).

**Table 1. Transition table.**

| Date         | $R_{cn}$ | $t_{TP}$ | $t_f$ | In          |
|--------------|----------|----------|-------|-------------|
| 02.02.2019   | DMU 100  | 0.5      | 0.5   | P Ivanov    |
| 12.12.2018   | DMU 75 R | 0.6      | 0.7   | A Sidorov   |
| 11.10.2018   | DMU 75   | 0.65     | 0.9   | B Novikov   |
| 02.06.2018   | DMU 75   | 0.65     | 1     | P Ivanov    |

On the basis of the received table, it is also possible to generate lists of tasks for a specific performer. If the execution time is $t_f > t_{TP}$, it means that the performer has exceeded the $t_{TP}$ time specified in the norms. The performer with $t_f = t_{TP}$ has the first priority.

The proposed scheme of interaction with the archive of technological processes is an addition to the existing model of interaction organized between the design system and the resource management system [10].

2. Conclusion
The proposed algorithm for designing route maps based on the archive of technological processes allows bringing the process of planning route maps to a real situation, which is characterized by one of the important characteristics, which is the accessibility to the execution of technological operations at the workcentre. The proposed mechanism allows using the data to analyse the speed of technological operations, to assess the work of subordinates, as well as to plan the loading of performers in production.

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