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FORMULATION OF A SEQUENCING PROBLEM IN A MIXED-MODEL PRODUCTION SYSTEM

In the paper the problem of production orders sequencing in a mixed-model production system is considered. The authors present the design of the system and production orders, manufactured in the system. Model of the system consists of an input buffer and an assembly line with a given number of stations. The system is presented in a simplified manner, which provides the ability to compare it (under certain assumptions) with a real system. A virtual model of the mixed-model production system has been created. The main objective is to verify the correct operation of the prepared simulation model and the possibility of generating of input data and acquisition of output data in a mixed-model production system. The question is whether such model can be used to simulate the operation of a mixed-model production system in a manner that represents the outcome of a real system.

1. INTRODUCTION

The objective of an enterprise is to provide a short lead time of the product and the quick response to rapidly emerging demand for a variety of products in various types. In addition, it is important to make the best use of production capacity at companies disposal, and in recent times it is one of the most important objectives in the management of production domain. This objective determines costs of production, and thus the competitive position among other companies on the market.

An example of such activities are the mixed-model production systems, specific mainly to automotive industry companies, where at the same resources along a section of an assembly line a range of products in different versions are manufactured. Other examples of applicable fields are not determined by an industry branch, yet by the type of production system implemented in the company. Therefore mixed-model production systems may be observed in all companies that produce various products in multiple versions on the same resources, especially on assembly lines (e.g. aircraft industry).

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On the assembly lines variable products versions, differing in colour, version of the engine and additional equipment installed are assembled. Along with the differences between the products and/or different versions of the equipment the assembly time varies.

One of the problems that arises in such systems is the appropriate utilization of the resources and employees on the assembly line. Currently, in the case of differences in the assembly time, assembly line takt time can be extended and adapted to the version of the product with the highest labour-consumption. However, this leads to the outage of resources/employees in a situation where there is a version characterized by a lower labour-consumption. On the other hand, shorter takt time leads to frequent line stoppages. Since none of these solutions are satisfying, such organization of the flow of the products on an assembly line (production orders sequence) which will provide the employee sufficient time to perform all assembly operations resulting from the planned production program with a high level of resources utilization at the same time is searched.

The problem of production orders scheduling often appears in the literature in terms of production planning, however, it is found mainly for job shop systems [3],[4],[5],[11]. In the case of flow shop, especially assembly lines, discussion over the problem of scheduling is rare and usually based on a certain company, appropriately matched to specific production system, hence not characterized by the versatility of application [6]. In the case of assembly lines authors focus primarily on the problem of line balancing [7],[8],[9] meaning distribution of operations on a fixed number of stations, or determining the appropriate number of resources on line to maximize line efficiency while minimizing costs.

In the paper a part of the assembly production system, consisting of an input buffer, from which the orders are sent to the assembly and an assembly line where the final assembly of products is carried out is presented. The main objective of this study is to verify the correct operation of the prepared simulation model and to validate the possibility of generating of input data and acquisition of output data.

2. MIXED-MODEL PRODUCTION SYSTEM

2.1. SYSTEM DEFINITION

Model of the system consists of an input buffer and the assembly line with a given number of resources. Model is presented in a simplified manner, yet under certain assumptions, the ability to compare it with a real system is provided.

Given is a production system $S=\{B_w, M_i\}$. The production system consists of an input buffer B_w, w = 1, ..., n, where n - the number of lines in the input buffer, to which the products flow down from the previous department and resources M_i comprising the assembly line, with i = 1, ... , m, where m - number of resources. The purpose of the input buffer, acting in accordance to the FIFO rule, is to store all orders before admitting them to final assembly. The input buffer is organized in three lines, each of which has a defined capacity. The control processes are performed both at the entrance to the buffer, where a decision is made on which buffer line should an order be addressed, and at the exit from the buffer, where in turn a decision is made which order (from the buffer at any given time, at least a few different orders can be picked up) is to be sent to the assembly line [10].

With the use of the transport system, before the entrance to the buffer, and just after an exit from it, there is a possibility to send the production order to the so-called bypass (part of the transport system, which moves the order back to the entrance of the input buffer, using a system for transporting empty slings), if for a certain reason a production order cannot be admitted to enter the input buffer or assembly line.

The assembly line is adapted to simultaneously manufacture certain number of different products in several versions depending on the specification requested by the customer, and therefore must have an adequate flexibility. Due to the organization of production, during the assembly process pre-sets are not possible on the resources. Only exchange (swap) of tools required to install specific components is permissible, with the proviso that they must be situated in a place, to which the worker has a quick access. The automation of assembly line is limited to a few selected tools such as automatic wrenches. The assembly line consists of several resources called stations. There are also subassembly lines on which components are assembled into modules, in turn mounted on the main assembly line (e.g., dashboard, doors). It is assumed, that the parts from subassembly lines are always on time in an appropriate spot on the main assembly line and hence are not included it in the main model.

The assembly line is specified by a takt time. Each station must timely complete all assembly operations because the line is in constant motion and after flowing to the subsequent stations it is not possible to return to the unfinished operations. In case of failures the line can be stopped, however it generates significant losses to whole company.

2.2. PRODUCTION ORDERS

On the assembly line production orders $Z = \{P_s^e\}$ with P - products, where s = 1, ..., 3 - number of products, and where e = 1 ... 4 - the number of versions, are assembled. Due to market requirements, the number of possible versions is proportional to the number of additional features and their variations. Options that have the greatest impact on the time required for assembly processes at different stations have been chosen. In general, produced versions can be divided into more and less labour-consuming. It is assumed that the version number 2 requires the standard assembly time, version number 1 requires shorter assembly time than version number 2, and versions number 3 and 4 require longer time than the standard version with appropriate values. In order not to exceed the allowable takt time, individual production orders should be admitted for the assembly in such way, to provide sufficient time for each station to install components. Therefore, it is required to determine the correct sequence of orders for assembly. The place, which is the most appropriate for that, is the exit from the input buffer, just before the assembly line.

2.3. SYSTEM DESIGN

The proposed model is implemented in the Enterprise Dynamics simulation software environment and simulation activities are carried out.

Assumptions:

- Number of products and their versions is given,
- Takt time is given,
- Operation times are given,
- It is possible to temporarily exceed the takt time at selected stations,
- Assembly line in the event of a significant exceed of a takt time may be stopped,
- Components from subassembly lines are always at the right time at main assembly stations,
- Going back to previously uncompleted operations is not possible,
- All tools and components required for the assembly process are at the right stations on time,
- Resources failures are not taken into account,
- In the lack of the feasibility to execute particular order (too much load on the respective stations due to the admission of the previous orders for execution), it can be re-sent to the entrance of the input buffer via bypass.

3. SIMULATION MODEL

For the model of production flow presented in the previous section, simplified model consisting of model of production order and a model of system simulation models, necessary to carry out experimental research on the method of sequencing product variants has been prepared. The process of creation of the model is not the main objective of this paper and it has been not described thoroughly. The constructed model is presented in Fig 1.

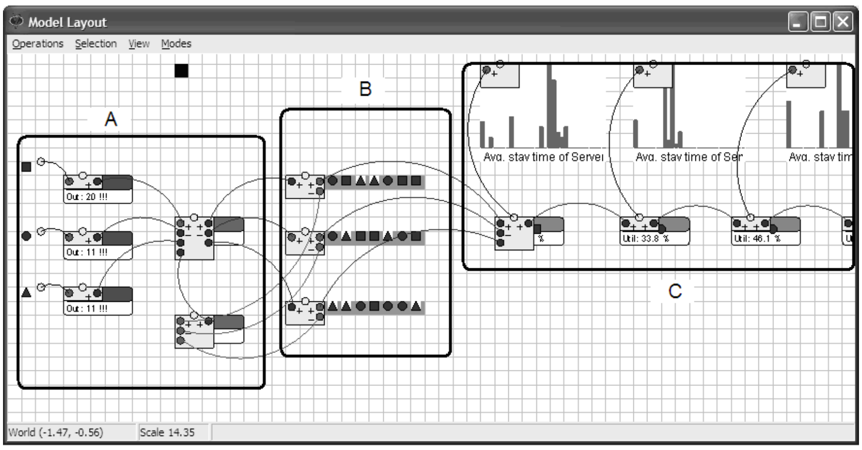

Fig. 1. The initial production flow simulation model

The model consists of three main parts (labelled A, B and C in Fig. 1). The first part of the model (A) contains the elements responsible for the generation of products in different versions, which then feed the main lines of the input buffer. In this section the parameters for each element of model are defined. The parameters contain statistical distributions and functions responsible for:

– products appearance probability at the entrance of the input buffer,
– different versions of the product appearance probability,
– directing of a version of the product to the appropriate line of the input buffer,
– frequency and number of generated input products,
– storing information in storage media attached to the products, concerning the operating parameters for each assembly station.

Listed parameters and functions responsible for generating individual data are implemented using an internal Enterprise Dynamics system language - 4DScript. A sample sheet with defined functions has been shown in Fig. 2. Such a parameterization method allows quick modification of 4DScript language features for statistical models that describe the behaviour of the model.

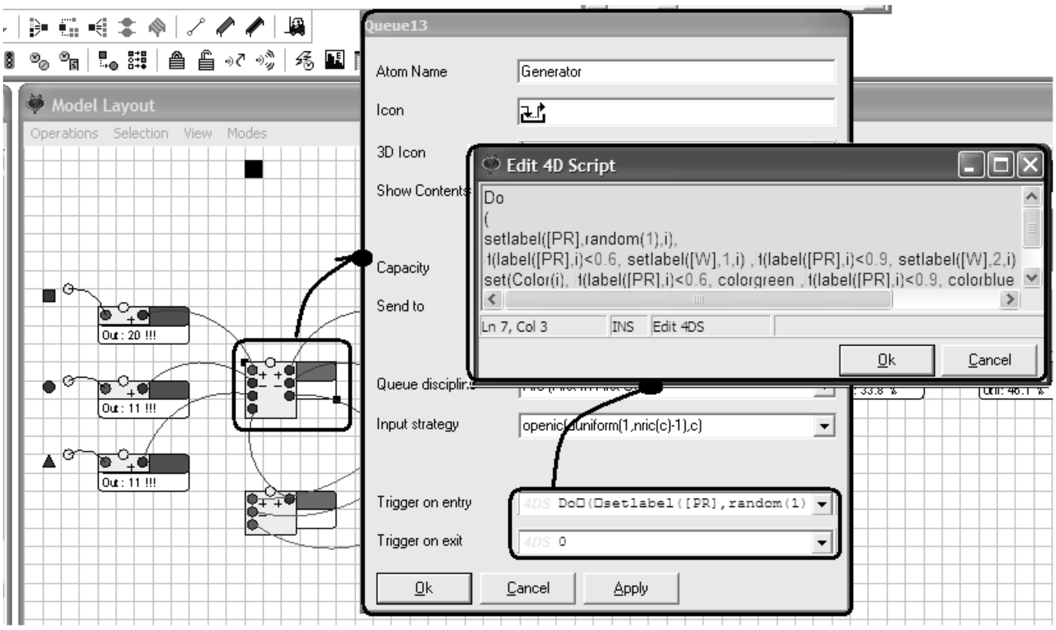

Fig. 2. Simulation model parameterization

Subsequent part of the model (labelled B in Fig. 1), contains the main input buffer components. Also, for this part of the model, control parameters including queuing strategy (LIFO, FIFO, RANDOM) of products in lines and sequence of sending the products from the line to assembly stations located in Zone C are defined. The sequence will result directly from scheduling algorithms adopted to the simulation experiments that are a key research subject in solving research problem described in this paper.

The last part of the model is a set of assembly stations (labelled C in Fig. 1), for which the main parameter is labour-consumption defined for each version at each station. In this part of the model elements responsible for the acquisition of the necessary data for later analysis of the results for the experiments are placed. It is possible to quickly change the recorded parameters of the production system.

At this stage of the research, a number of simulations, for the random data have been executed. The main objective is to verify only working correctness of the prepared simulation model and the ability of generation of input data and acquisition of output data. The model of the production system during the simulation is presented in Fig. 3.

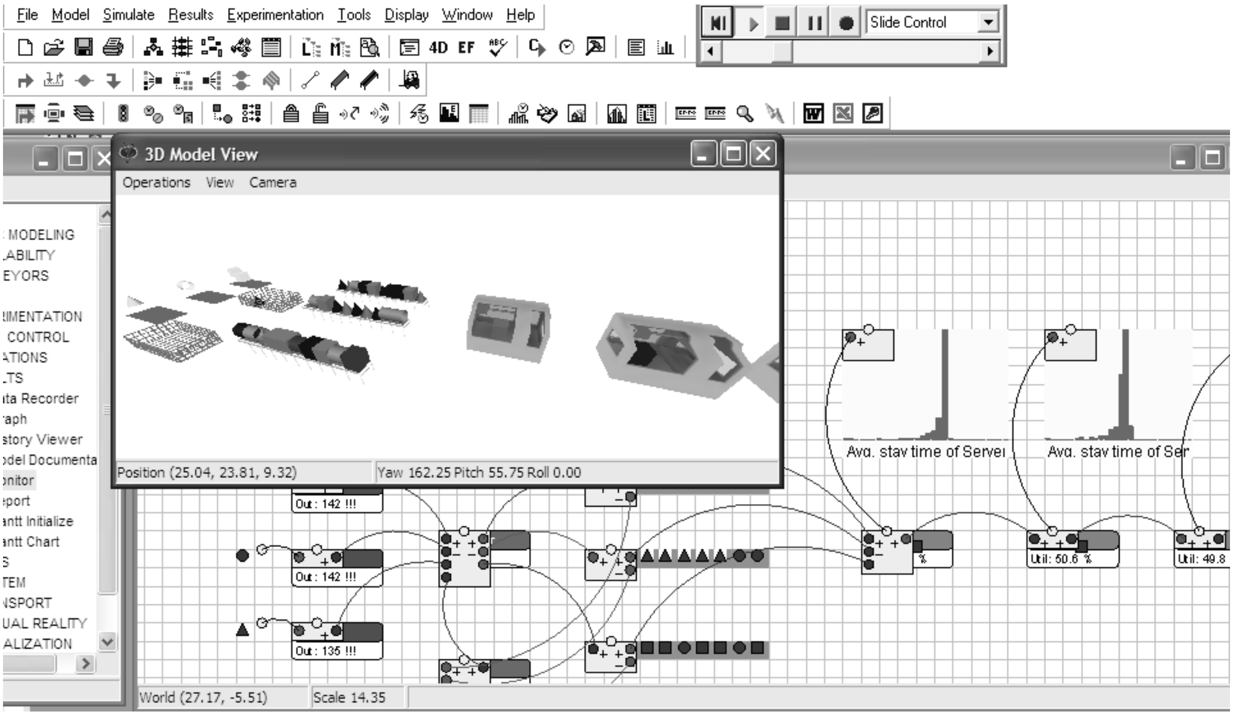

Fig. 3. Implementation of simulation experiment

After conducting several simulations proposed simulation model is working properly. The main objective of this study has been completed. The correct operation of the prepared simulation model has been verified and generating of input data and acquisition of output data is possible.

4. SUMMARY

The paper presents simulation of operation of a simplified virtual mixed-model production system. Simulation experiments has been conducted for random data, in order to verify the correct operation of the prepared simulation model and the ability of generation of input data and acquisition of output data. Proposed model has been verified and meets the objective of the study. In the future research a simulation of the system with data that adequately represents the operation of a real automotive company system is planned. Also tests concerning the influence of a particular sequence of orders admitted for the assembly will be performed. With the ability to modify the system, it will be possible to simulate and analyse the results of different combinations of input data (frequency of occurrence of the relevant types of products, modification of orders sequence in the input buffer, etc.).

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