ALGORITHM FOR BALANCING PRODUCTION CAPACITIES USING CAPACITY BALANCING MEASURES AND COMPUTER SIMULATION

[1]David STAŠ, [1]Radim LENORT, [1]Pavel WICHER

[1]ŠKODA AUTO University, Mladá Boleslav, Czech Republic, EU,
david.stas@savs.cz, radim.lenort@savs.cz, pavel.wicher@savs.cz

https://doi.org/10.37904/clc.2022.4531

Abstract

The paper deals with the issue of capacity balancing at the operational level of production management. The authors focused on the possibilities of supporting planning and decision-making processes, where they provided planning staff (production planners) with measures to gradually balance the production schedule in relation to the available production capacities. The aim of the paper was to design an algorithm based on the identified capacity balancing measures and a computer simulation model of the operation, which allows to achieve a balanced production schedule.

Keywords: Production capacities, capacity planning and balancing, production schedule, computer simulation

1. INTRODUCTION

In the end, the low level of utilization of production capacities, or their inefficient management, almost always negatively affects the productivity of the production unit, the operation, and the entire company. Efficient use of production capacities and resources generally means in practice the possibility to produce more products or services with the same consumption (time, energy, materials, etc.), which brings companies several assets that increase their competitiveness in a globalized global market [1]. Efficient use of all necessary production resources (material, energy, and human resources) is the primary task of production management to cope with the current complex global situation, when there is a significant disruption to the smooth operation of supply chains due to the consequences of the coronavirus pandemic or the war in Ukraine. The authors of the article address the issue of production scheduling at production facilities with the aim of optimal use of production capacity within operational management. The aim of the paper was to design an algorithm based on the suitable capacity balancing measures and a computer simulation model of the production operation, which allows to achieve a balanced production schedule.

2. METHODOLOGICAL BASIS

2.1. Production capacity

Operational management has been solving the optimal use of production capacities since the very beginning of industrial production. During this period, of course, not only did the tools and approaches to effective management evolve, but so did the very understanding of the concept of production capacity. For example, Malindžák [2] emphasizes the distinction between capacity given by time and capacity given by the amount of production. He considers the neglect of the "time dimension" to be a fundamental mistake, which rather represents size, resp. the current number of units of the device. He considers the confusion of the device's capacity as the instantaneous value of the device's output to be another misinterpretation. Similarly, production capacity is defined, for example, by Borowiecki [3] or Pasieczny [4], which express production capacity as a measure of the ability to create a maximum number of products at a given time (i.e., usually per year), at a given plant (centre or department), corresponding to the valid quality regulations, with optimal use of production equipment and adherence to technological production procedures. According to Muhlemann et al. [5] production capacity is not only the ability to perform specified tasks at a given time, but also the ability to process or perform what the customer requires. In contrast, Waters [6] uses the notion of planned capacity, which expresses the maximum number of products leaving the process under ideal conditions, and the notion of effective capacity, which expresses the maximum production under normal conditions. As Bellino [7] states" an increase in the growth rate can be obtained both by an increase in profits and by an increase in the rate of utilization of production capacity. Capacity planning is the process of determining the production capacity needed by an organization, to make efficient use of production resources and to meet changing demands for its products [8].

2.2. Balancing production capacity

Capacity calculations are carried out to analyse the production system imbalance and bottlenecks in the process at each station and address them well in advance to ensure the smooth flow and thereby increasing the utilization of the resources to the maximum to achieve targets and meet the customer demands on time [8]. The concept for balancing production capacities must consider not only the fulfilment of production order deadlines, but also the possibilities of storage capacities and all relevant factors [9].

3. ALGORITHM FOR BALANCING PRODUCTION CAPACITIES

3.1. The purpose of the algorithm

The expected benefit lies in the support of planning and decision-making processes, where planning staff (production planners) is equipped with appropriate capacity balancing measures and computer simulation model of the production operation to balance the production schedule. A capacity-balanced production schedule is created gradually using proposed measures and the computer simulation model.

3.2. Capacity balancing measures

The design of the algorithm was preceded by the creation of an exhaustive set of specific measures for the elimination of overloaded capacities of production resources. The measures are both intensive and extensive. All measures are divided into two groups – measures related to production requirements and measures related to resource capacity:

I. Measures concerning production requirements:

a. Cooperation – realize the given production operation with external capacities.
b. Production advance in time – however, it can be possible only in case when a computer simulation model works with data about work in progress, which is very difficult in practice.
c. Delay of production in time – according to the reserve for possible shifts in time (= planned date of completion of production - simulated date of completion of production) and utilization of other planned resources in the given technological process.
d. Transfer to another production source (same or different within the alternative technological process) – according to the designation of orders that have an alternative process and the capacity utilization rate of the alternative process.
e. Reduction of production to the warehouse (e.g. without customer orders, reduction of the reserve stock required by the customer…) – do not include these orders or approach them as in point c.

f. Prioritization of production orders (e.g. according to the importance of the customer, the amount of fines, or the relative contribution margin (EUR per min of the workplace)) – postpone all or part of the production order with the lowest priority to a later time.

g. Divide production batches (large production orders) that were created at the MRP level by merging several orders from different customers or one customer who determined the schedule of gradual delivery of partial parts of the order, move those orders or their parts that have a later delivery date.

II. Measures concerning resource capacities:

a. Capacity increase by measures requiring only minimal costs:

- overtime,
- reduced times – e.g. legal breaks by means of staff rotation,
- strengthening the operation of a set of automatic equipment (adjustment, manipulation, maintenance),
- inventory creation in front of a bottleneck (reduction of material unavailability),
- shortening the setup by appropriate alignment of production orders,
- relocation of routine maintenance to non-production times (shifts…),
- placement of a more experienced worker (in the case of a manual workplace, it is a worker who has a higher than standardized performance, in the case of a semi-automatic workplace, it is an acceleration of handling and production operations),
- increasing the performance of production operations by technical measures (e.g. use of another tool, short-term increase at the limit of technical possibilities of the machine).

b. Capacity increase by measures requiring additional costs:

- Inclusion of an additional shift (in case the device does not work in continuous mode, or e.g. weekend).
- Inclusion of additional capacity – increasing the number of workers at the manual workplace or by including a backup machine in production.

3.3. Input data

To verify the above set of measures, it is necessary for the production planner to have a number of input data available. These are part of the company's information systems, production planning and scheduling rules, and output data of the computer simulation model after each simulation run. The list of required input data is as follows:

Product:

- alternative technological processes of production,
- cooperation capacity for each technological process of production and its operation.

Production order:

- size,
- planned date of completion of production,
- reserve for possible shift in time (planned date of production completion minus simulated date of production completion),
- information on whether the order is manufactured in a warehouse,

- information on whether it is a production batch consisting of several customer orders with different fulfilment dates combined at the MRP level.

Customer:

- customer priority (priority of its orders).

Manufacturing source:

- simulated load,
- flexibility (possible short-term increase of capacity by measures requiring only minimal costs),
- work shift distribution,
- backup human resources and production facilities that can increase production capacity.

3.4. Conceptual framework of the algorithm

The essence of operational production planning is the creation of schedules of the entered production always as close as possible to the moment of production with the possibility to gradually refine this production schedule according to the current situation. Such a production schedule must correspond to the updated balances of machine capacities, workers and all currently needed inputs. At the same time, it is necessary to choose such an order of implementation of individual measures so that additional production costs are minimized. In line with these principles, the proposed measures have been arranged in eight logical sequential steps. Their conceptual overview, which determines the priorities for the application of individual measures for dealing with congested capacities of production resources, is as follows:

1) Verify if the congested capacities can be solved / partially solved by simple measures, i.e. compare capacity congestion with the flexibility of the given resources. If this possibility is realistic, then inform the interested workers to apply some of the measures according to point "II. a".
2) Verify if the production order can be transferred to another production source with free capacity (same or different in an alternative technological process). Specifically, apply the measure "I. d “.
3) Verify if it is possible to postpone the production of production orders on an overloaded resource to a later date, i.e. to postpone orders that have a large time reserve and a small utilization of other planned resources (see measure "I. c").
4) Verify if there are stock-produced contracts at the congested source (see measure "I. e") and classify or treat these contracts as in step 3.
5) Verify if there are production batches on the overloaded source and then move over time those sub-customer orders or parts thereof that have a later delivery date (see measure "I. g").
6) Verify if the shortage of congested resources can be addressed by including an additional shift or by including additional production capacity (see measure "II. b").
7) Verify if production orders from an overloaded source can be solved by cooperation, i.e., apply the measure “I. a".
8) Postpone all or part of the lowest priority production order to a later date (see measure I. f).

3.5. Designed algorithm

Based on the measures, the required input data, and the conceptual framework defined above and using a computer simulation model of the operation, a universal algorithm for capacity balancing was designed. The process diagram of the algorithm, which includes the basic implemented activities, decisions, but also the required input data, is shown in **Figure 1**.

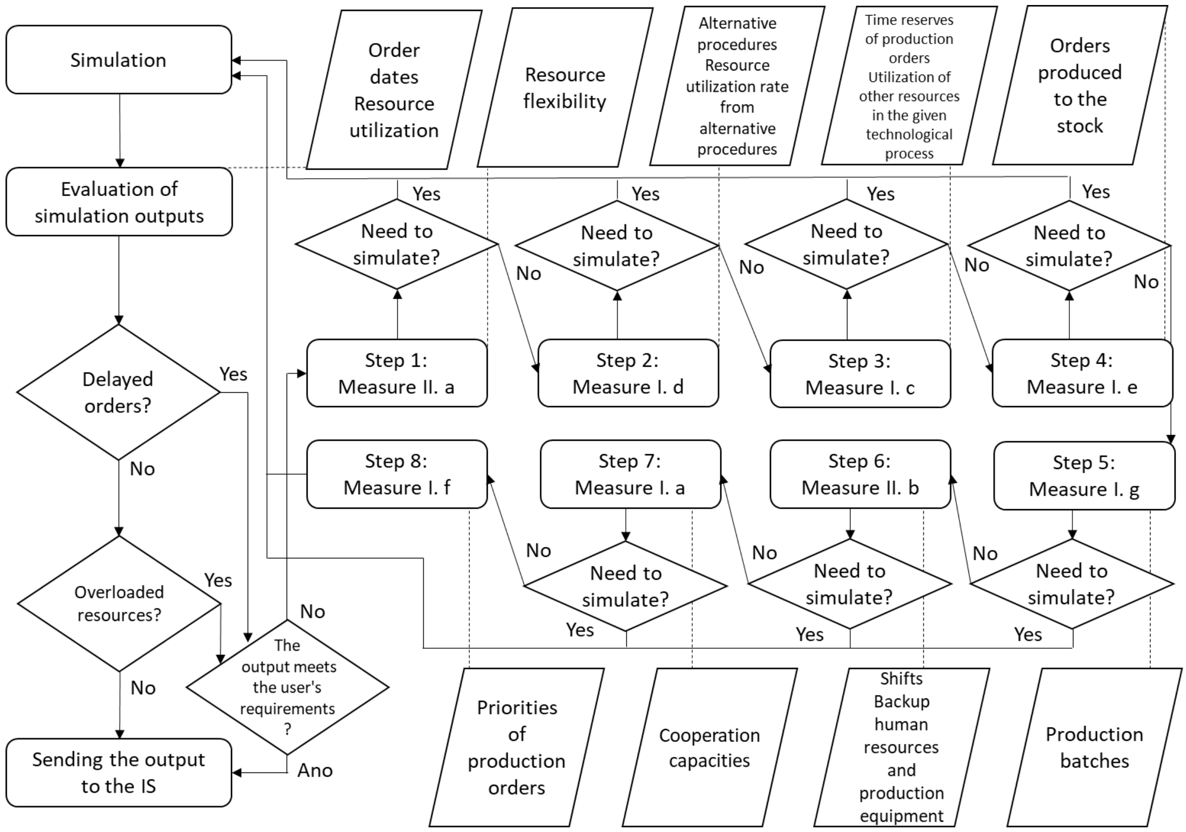

Figure 1 The process diagram of the designed algorithm

The algorithm starts with the implementation of the first simulation run. Based on its results, a process cycle is implemented, including the evaluation of simulation outputs, decision-making on the acceptability of the assessed production schedule and verification of measures for capacity balancing of the production schedule. This cycle is implemented until an acceptable (capacity balanced) production schedule is obtained. Simulation runs can be implemented not only after the end of each cycle (scenarios of a set of possible measures), but also during the partial examination of individual measures within the cycle.

4. CONCLUSION

When implementing the algorithm, it is necessary to consider the fact that operational production planning is always strongly dependent on the type of production, production factors and other production characteristics of a particular production system. For this reason, it is appropriate to concretize the proposed universal algorithm into a simple procedure for production planners, which would allow efficient and fast verification of possible measures for capacity balancing of the assessed production schedule. The aim is to focus on those measures that are relevant to the production system and at the same time to implement the smallest possible number of simulations runs within the computer simulation model.

ACKNOWLEDGEMENTS

The work was supported by the Ministry of Industry and Trade of the Czech Republic as part of the project no. CZ.01.1.02/0.0/0.0/17_107/0012482 "Development of new SW from DYNAMIC FUTURE s.r.o. - Predictive planning applications 4.0".

REFERENCES

[1] MAŠÍN, I., VYTLAČIL, M. *Nové cesty k vyšší produktivitě*. Liberec: Institut průmyslového inženýrství, 2000.

[2] MALINDŽÁK, D. *Production Logistics I*. Kosice: Štroffek Publishing, 1998.

[3] BOROWIECKI, R. et al. *Ekonomika i organizacja przedsiebiorstwa przemyslowego*. Warsaw: PWN, 1990.

[4] PASIECZNY, L., WIECKOWSKI, J. *Ekonomika i organizacja dzialalnosci przemyslowej*. Warsaw: PWN, 1976.

[5] MUHLEMANN, A.P., OAKLAND, J.S., LOCKYER, K.G. *Production and Operations Management*. Pitman ELBS, 1992.

[6] WATERS, C.D.J. *Operations Management: Producing Goods and Services*. Prentice Hall, 2001.

[7] BELLINO, E. *Production, Value and Income Distribution: A Classical-Keynesian Approach*. Routledge, 2021.

[8] CHAKRABARTI, A., ARORA, M. *Industry 4.0 and Advanced Manufacturing: Proceedings of I-4AM 2019*. Springer, 2021.

[9] ROUCOULES, L., PAREDES, M., EYNARD, B., MORER P., C., RIZZI C. *Advances on Mechanics, Design Engineering and Manufacturing III: Proceedings of the International Joint Conference on Mechanics, Design Engineering & Advanced Manufacturing, JCM 2020*. Springer, 2021.