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DECISION SUPPORT SYSTEM IN THE MAKE TO ORDER MANUFACTURING SYSTEM

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ABSTRACT

Current methods for estimating the cost and time are based on decomposing the product into elements, followed by cost estimation of each element and summing of the other costs. As element, we can consider a product component, a manufacturing process component or an activity component. To estimate the cost for each element, its features that are closely related to cost or time are used. With a few exceptions, the estimation methods lead to estimation without a mathematic model describing the relation between cost or time and the element’s features. Moreover, these methods have a slight adaptation capacity to different specific situations because the information that is provided in order to make estimations is general and does not adapt to a specific case.

Therefore, in this paper, the cost and time will be estimated by a set of appropriate techniques which are based on neural modeling and k-nearest neighbor regression. Each of these techniques cover, a range of specific cases.

KEYWORDS: manufacturing system, neural network technique, k-nearest neighbor regression, cost estimation

1. LITERATURE REVIEW

Today, the procedure of responding to an enquiry is approached as a multistage-multicriteria decision-making process. The most common support for this process is to develop an appropriate decision support system (DSS). In this kind of decision-making structure, the initial decision is to determine whether to accept or not the order based on a prescreening process.

Gharehgozli et al. [1] present a comprehensive decision-making structure composed of two phases and dedicated to manage the incoming orders. The incoming orders are checked in the first phase for acceptance based on their due dates. In this purpose, they apply the backward method proposed by Kingsman and Hendry [2] and calculate the completion date, the earliest release date and the latest release date of the orders. In the second phase, the accepted orders are ranked according to a multiple criteria decision-making (MCDM) methodology, which combines two

techniques, the analytical hierarchy process (AHP) and the technique for order performance by similarity to the ideal solution (TOPSIS). The ranked orders are then finally accepted based on manufacturing system capacity. Xiong et al [3] propose a decision support system (DSS) approach that helps SMEs to make appropriate responses to customer enquiries. There are three phases in the workflow for processing enquiries. Oduoza and Xiong [4] showed that none of the existing decision support systems had the capability to instantly relate customer enquiries, during the enquiry stage, with capacity, process capability, inventory, potential profit to be derived and material requirement planning. Ebadian et al [5] propose a new comprehensive decision structure for the order entry stage in order to improve the production planning framework in MTO environments, by taking into account all affected parties of the supply chain: customers, the MTO company, suppliers and

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subcontractors. Ebben et al. [6] investigated the importance of the workload based order acceptance method in over-demanded job shop environments. Their approaches integrate order acceptance and resource capacity loading. Herbots et al. [7] investigate dynamic order acceptance and capacity planning under limited regular and non-regular resources aiming to maximize the profits of the accepted projects within a finite planning horizon. Ivanescu et al [8] investigated the selectivity property of two acceptance policies. The first uses simulated annealing techniques and an empirically determined slack to estimate the realized makespan of an order set. The second uses regression techniques to estimate the realized makespan. Slotnick [9] presents a literature overview of researches regarding order acceptance and scheduling. The author considers that taxonomy of research in order acceptance and scheduling includes single/multiple machines and deterministic/stochastic approach. The objectives are maximum profit, maximum thruput, maximum value of accepted orders, minimum cost, maximum percent of time utilization, and net present value.

2. EARNING POWER

As novelty, we propose the earning power (EP) as performance criterion, for better representing the manufacturing system goal. It is both synthetic (because it reflects the essential motivation of manufacturing process) and compliant with the most important five performance aspects selected by researchers after their importance, namely profitability, conformance to specifications, customer satisfaction, return on investment and materials/overhead cost.

By definition, earning power is the operating income divided by total assets. Operating income is the income resulting from a firm primary business operations, excluding extraordinary income and expenses. It gives a more accurate picture of firm profitability than the gross income.

By asset we mean something that an entity has acquired or purchased, and has money value (its cost, book value, market value, or residual value). An asset can be *a)* something physical, such as cash, machinery, inventory, land, and building; *b)* an enforceable claim against others, such as accounts receivable; *c)* a right, such as copyright, patent, trademark or an assumption, such as goodwill.

For the calculation of earning power, the cost, time, asset, and price must be estimated.

Earning power is defined at operation, job, order, or manufacturing system level [10].

3. METHOD ALGORITHM

The eight steps of the method algorithm are:

I. Breakdown of the current enquiry

In this first step, each enquiry is considered as a potential order, even if a decision regarding its acceptance has not been made yet. To take such a decision, this potential order is processed for enabling to generate its network routings.

Processing consists in identifying all the alternatives regarding order decomposition in jobs and operations. Each operation is defined so that it can be accomplished by using one of the manufacturing system resources. Definition includes the resource that will be used and the product status before and after the operation execution. The result is the routings network diagram of the order, associated with the definitions of all operations.

Fig. 1 shows the routings network diagram of the order *i*, which consists in two jobs: job *i1* having three routings and job *i2* having two routings. The routings network diagram is associated with the definitions of all operations that appear in the five routings, namely 7 operations related to job *i1* and 3 operations related to job *j2*.

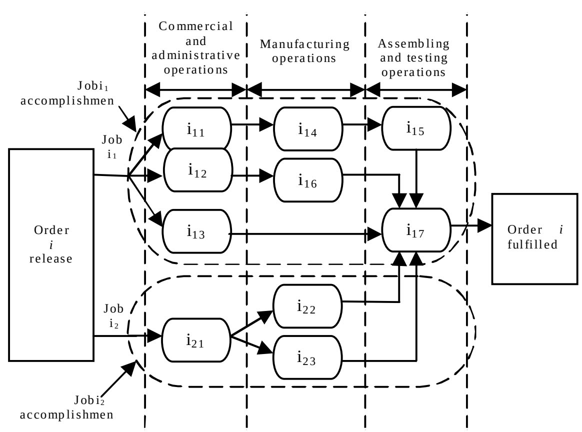

Fig. 1 Diagram of the order *i* routings network

II. Featuring the order routings network operations

For every manufacturing system resource, a set of features was a priori and definitively established. These features represent the potential input variables of the model, which describes every operation that such a resource will perform. During this stage, for each operation that appears in the routings network diagram of the current order, the values of the corresponding set of features are established, based on the operation definition.

III. Modeling the network operations

This step consists in modeling the order routings operations, by using a proper technique (such as for example neural modeling). For every manufacturing system resource, one of these modeling techniques was a priori and definitively selected. Each operation is modeled by using the resource of the previously selected technique. As model output variables are considered the cost, the time, the earning power, and the asset (the same for all the operations) while the input variables are selected from the resource's set of features, in order to obtain the best operation model. In addition, a resource-dedicated dataset containing the resource past experience is permanently updated by registering the actual data resulted after completion of the current performed operation. Depending on the modeling technique, some data are extracted from this dataset. Finally, the order routings network, associated with the cost, time, earning power, and asset models of all operations, are obtained and placed in a portfolio.

IV. Batching the orders flow

For concurrent order processing, the orders existing in portfolio are grouped periodically, this way forming the current batch of orders. Only the enquiries found in the portfolio are considered for batching. They are either newcomers or returnees. Batching rule can be *i) the* first N_e enquiries, while the others are postponed, or *ii)* all enquiries found in portfolio. Period size is set according to orders flow and the due dates. Depending on company policy, the batching can take place either at certain dates or at regular intervals.

V. Orders fullfilment simulation

The current batch of orders is analyzed in order to divide the orders in three groups: accepted, rejected, and returned to portfolio. In this purpose, for each order, the earning power is firstly evaluated by using the operations models prepared at step *III*. The orders belonging to current batch are further ranked according to their earning power values. Then, one or several order groups are prepared. Such a group order contains those orders, which could be accepted; the orders that are not included in the group will be either rejected or returned back to portfolio.

Orders grouping algorithm contains two generic actions, namely the group making up and the performance evaluation. For making up a group, successively, in decreasing order of the earning power value, the acceptance of each order is simulated, by taking into account the resources available workload and the due date of each included order. The performance criterion is the earning power, evaluated at the level of the entire manufacturing system and for the whole current period. Restrictions are the orders due dates.

The prepared orders groups (i.e. their content and performance) are finally transmitted to the management, for making a decision at the next step.

Figs. 2 and 3 show an example of the scheduling diagram before and after simulation.

For the before simulation case (Fig. 4), let us consider the moment when the precedent period is finished and a new batch of orders is coming for simulation. In progress are remained two orders, namely order *1* with the four jobs *11; 12; 13; 14* and due date *DD1*=21, and order *2* with the two jobs *21; 22* and due date *DD2*=19. The workload of the six workstations, namely *F,R,S,T,G,* and *A* can be seen in the diagram.

On the other hand, the new batch of orders consists in the accomplishment of four orders, namely orders *3, 4, 5,* and *6*, before the following due dates: *DD3*=29, *DD4*= 22, *DD5*=28, and *DD6*=23.

Taking into account the order *3* routings network, it was established that the maximum earning power could be obtained when this order consists in jobs *31; 32; 33*, which can be accomplished by completion of the operations shown in the diagram. Similarly, the jobs and their operations, corresponding to orders 4, 5, and 6 were established. The maximum values of the earning power (EP) for the four new orders (namely *EP3*=3.432; *EP4*=3.336; *EP5*=2.568; *EP6*=2.542), as well as their ranking are shown in the diagram.

VI. Decision making on current batch

Two alternatives were highlighted as result of the previous step. According to the first alternative, orders *3* and *5* are accepted, while orders *2* and *4* are rejected. According to the second, order *3* is accepted, orders *2* and *4* are rejected while order *5* is returned to portfolio (for being included in the next batch of orders). The first alternative has been adopted because, inter alia, the earning power, evaluated at the level of the entire manufacturing system and for the whole current period, is higher (*EP*=2.952). The scheduling diagram, resulting from simulation of this alternative, is shown in Fig. 3.

VII. Optimal dispatching of the orders fulfillment

The pool of orders consists in orders *1, 2, 3,* and *5*, as a consequence of the previous step. Their operations should be fulfilled according to the scheduling diagram shown in Fig. 3.

4. DECISIONAL SUPPORT SYSTEM OF THE NEW METHOD

The four generic decision-making actions that make up the method decisional support system are the following: order routings networking, online modeling, reactive scheduling, and optimal programming of the manufacturing system resources.

Order routing networking is an action performed by specialists knowing the manufacturing system capabilities. Currently, there are no adequate solutions for performing this action automatically. However, the facilities offered by current CAPP systems can be considered as support.

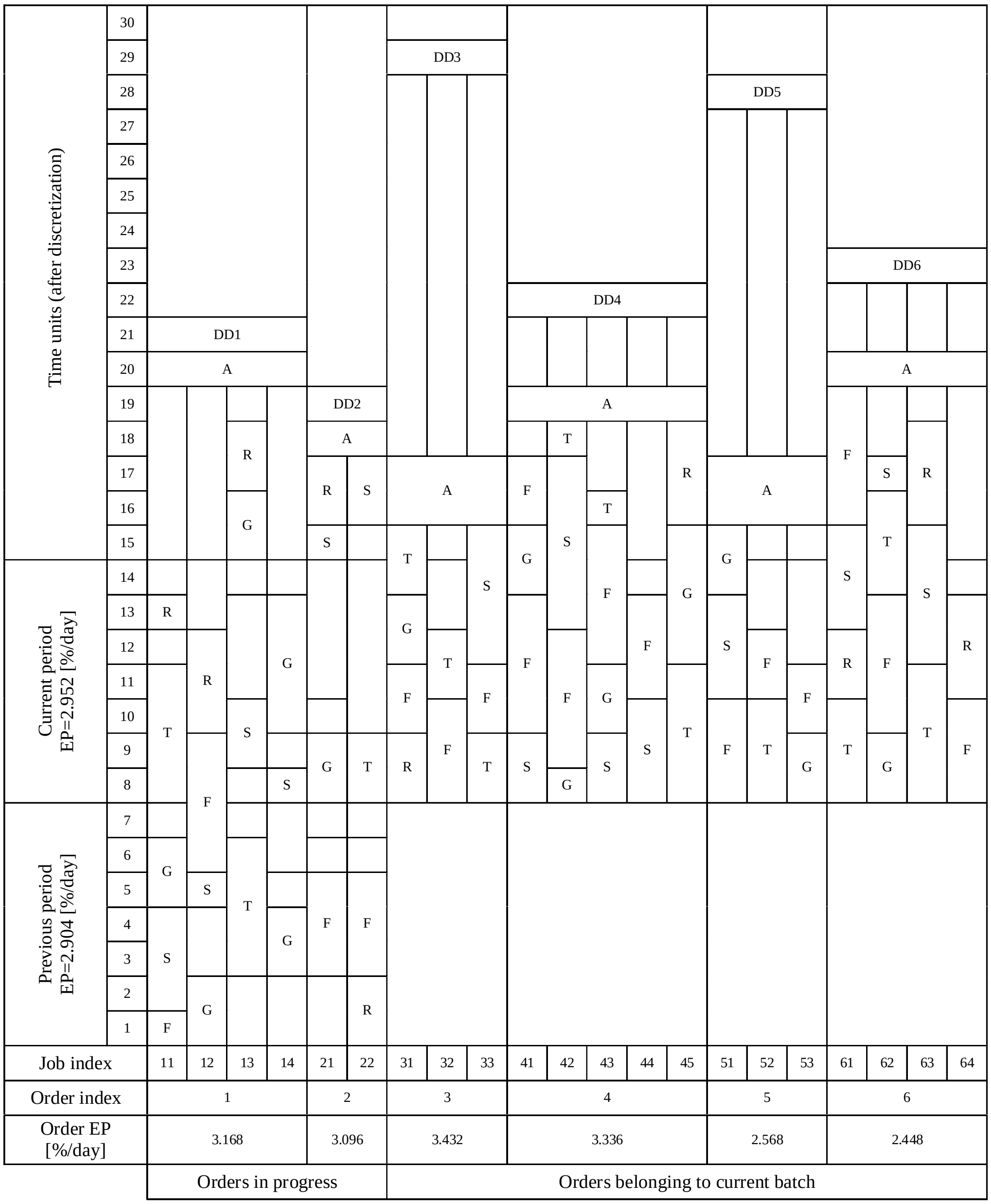

Fig. 2 Scheduling diagram - before simulation case
F – milling, R – grinding, S – turning, T – thermal treatment, G – drilling, A – assembling

Conversely, *online modeling* can be

performed automatically if a software implemented the modeling algorithm. The algorithm should be specific to each resource. In addition, it should include the data obtained from monitoring and management of the resources operation.

Reactive scheduling is an action with a strong general nature. It appears in two of the eight steps of the method, namely steps *VI* and *VII*. In addition, this action appears many times.

Therefore, although it could be performed manually, when the number of operations is small, however, it is preferable to use an appropriate software.

Optimal programming of the manufacturing system resources is performed mainly when issuing the part-program for each operation. In particular, when a CAM system is used, the subroutine for calculating the cutting parameters can implement the algorithm of this action.

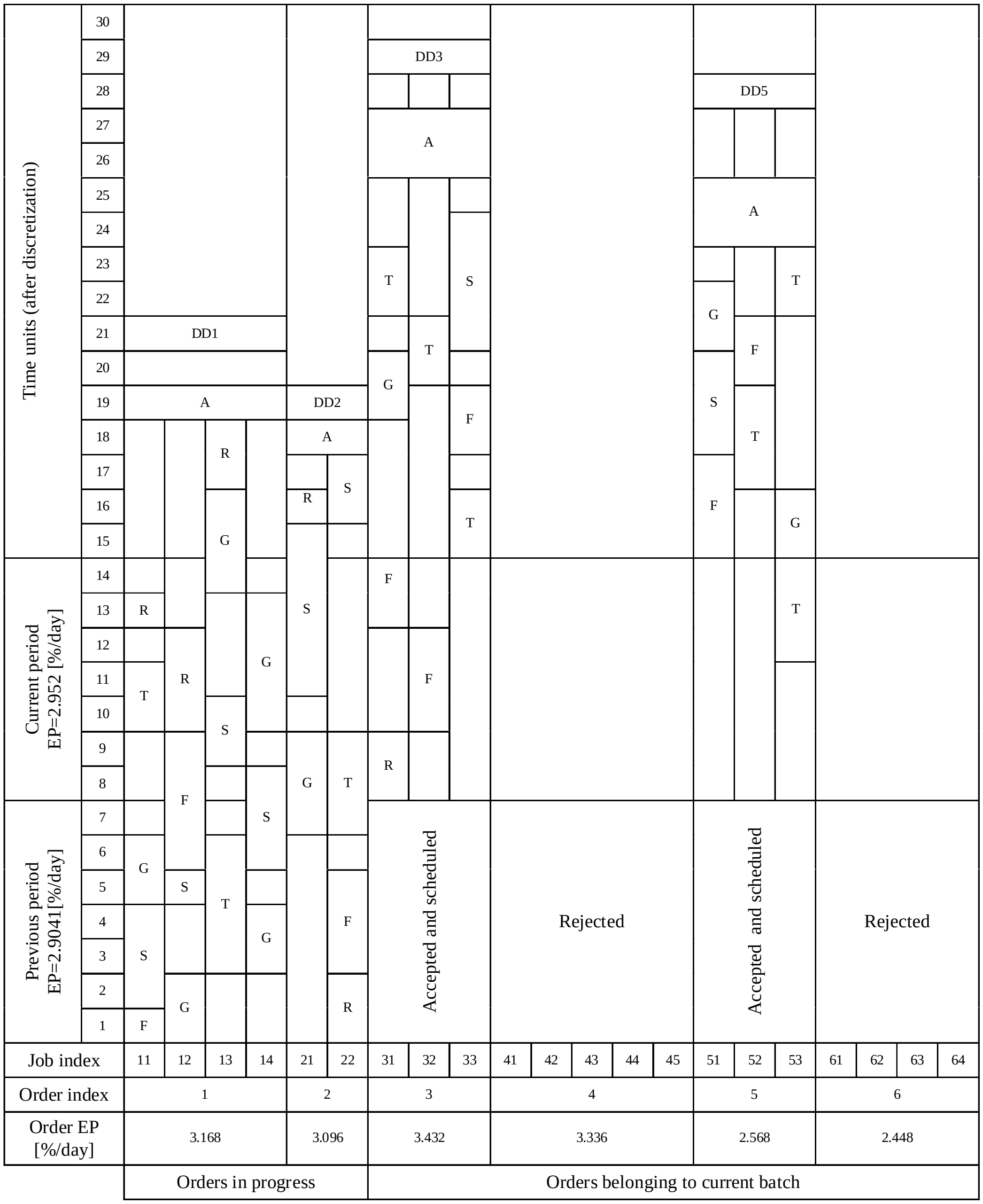

Fig. 3 Scheduling diagram - after simulation case
F – milling, R – grinding, S – turning, T – thermal treatment, G – drilling, A - assembling

5. CONCLUSIONS

This paper aims to develop a method for control of the MTO manufacturing systems in accordance with the present market dynamics.

In order to survive in a complex and unpredictable environment, MTO manufacturing system must be able to react rapidly in terms of favorable market position. Acquiring and maintaining this capacity is the most difficult because it involves many endogenous and exogenous factors and the process is continuous, dynamic, and difficult to predict.

In this paper we present the four generic decision-making actions that make up the method decisional support system. These actions are the following: order routings networking, online modeling, reactive scheduling, and optimal programming of the manufacturing system resources. A decisional support system approach is presented for managing enquiries for manufacturing systems at the customer enquiry stage.

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