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THEORETICAL APPROACH FOR THE CONTROL OF THE MAKE TO ORDER MANUFACTURING SYSTEM Part 1

Assoc. Prof. Ghelase Daniela
Assoc. Prof. Daschievici Luiza
“Dunarea de Jos” University of Galati

ABSTRACT

In practice, decisions on acceptance of order and production planning are often considered separately. Sales Department is responsible for accepting orders, while the production department in charge of production plans for implementation of orders accepted. Acceptance decisions are often made without involving the control of the production department or incomplete information on the basis of available production capacity. The paper is a review of make-to-order (MTO) manufacturing system control.

KEYWORDS: control of manufacturing system, order acceptance, MTO manufacturing system

1. INTRODUCTION

Manufacturing companies differ in how they respond to customs’demands. Some, called make-to-stock (MTS) companies, anticipate customer needs, producing series standard products, and deliver the products when customer order occurs. At these companies, all given products are usually used for general purpose, and therefore does not cover the exact customer needs. The estimated delivery periods required by customers can be easily observed. On the other hand, as there is repetitive production, the products can be manufactured on manufacturing systems as a single production line. Therefore, manufacturing systems (and even workstations forming these manufacturing systems), are product dedicated. Changing a product that one MTS manufacturing system performs is time consuming. In additions, inventory costs are high.

Others, called make-to-order (MTO) companies, start the manufacturing process only after the order content was acknowledged and accepted. Compared to MTS companies, these have a better responsiveness, because they can deliver products more varied and even customized. As a result, customer’s requirements are fully satisfied and inventory costs are low. However, these advantages can be realized only if the lead times can be reduced enough so that the delivery period required by the customers is respected. In additions, MTO manufacturing must be job shop and its workstations must be process dedicated.

Lately, the problem of developing a system that offers advantages to both approaches has emerged.

S. Hemmati and M. Rabbani [1], who propose a hybrid MTS/MTO production system, report one solution: a portion of the production system operates as a MTS system and makes certain products, and the other one operates as a MTO system and makes other products. Moreover, some products will be first partially manufactured in MTS mode, reaching the semi-finished product. In this state, the products are kept in stock until the arrival of the customer’s order. Then, product manufacturing continues in the MTO mode, until its delivery. The point where there is a shift from a mode to another is called order penetration point in the production line. A proper combination of MTO and MTS can exploit the advantages of the lower inventory, short delivery time, and good responsiveness. The authors present a decision-making structure to determine the appropriate position of the order penetration point for different products in a manufacturing system. In this way, you can use to a greater extend the advantages of both types of manufacturing systems. However, the disadvantages remain unchanged.

Other researchers try to solve the problem by improving one of the two systems. Since the high inventory and low responsiveness of the MTS manufacturing system are hard to improve, most researchers propose improvement of MTO manufacturing system, considering that it is easier to have sufficiently reduced disadvantages. In this paper, this approach will be considered.

In order to implement this approach, we believe that production process consists in carrying out the following general activities:

a) cost and time estimation,

b) price and due date quotation,

c) manufacturing process planning (where manufacturing operations are established, including workstations that will run, execution order of operations, and requirements for proper performance for each operation),

d) production process scheduling (which establishes the moments of time when all workstations will perform these operations),

e) production process dispatching (correcting deviations from schedule), and

f) manufacturing process control (correcting deviations from plan).

These activities can be grouped into two stages, namely: order entry stage, which is completed or not with an order acceptance, and order fulfillment stage, which is completed with product delivery. Then, upon studying each activity, we propose solutions for improvement of MTO manufacturing system, in order to increase performance.

The customer enquiry stage has a strong impact on the production workload of small and medium enterprises (SMEs). At this stage, customer enquiries are to be transferred to customer orders and planned for in the next production run. If a firm cannot achieve enough customer orders, its production capacity would be underutilized, and waste occurs. A key objective for SMEs is to maximize profits and minimize waste while processing customer requirements. Generally, such a decision will endeavor to accept or maybe reject an enquiry and could even attempt to negotiate with customers in order to protect the interest of both parties. This process, if not carefully handled, could affect a firm's credibility and reliability on the market. Customer enquiries therefore play a major role in the business and operations of enterprises, and for SMEs, it is often difficult manage in a proper manner this essential part of their business.

Analyzing the results reported in the literature, we obtain the following picture:

2. COST AND TIME ESTIMATION

Garcia-Crespo et al [2] present the principal cost and price estimation methods, implemented both in a conventional and knowledge-based manner. This study is based on another review conducted by Niazi et al. [3], where were added proposals of other authors. The methods are grouped into two categories: intuitive, analogical, parametric, and analytic methods.

Intuitive methods are based on knowledge from previous experience and can be saved as rules, decision trees, judgments, etc. which are used later for estimation. These methods can appear as case-based methodology or decision support systems. Analogical methods are based on the similarity between the new product and past cases. These methods include: regression analysis, artificial neural networks, and case-based reasoning. Parametric methods are based on the definition of cost as a parametric function of different product variables. The parameters used in the definition of a parametric method do not necessarily have to describe the product as complex as possible. It is important that these methods do not require large amounts of knowledge about the product, and they are also fast.

Analytical methods are based on the product decomposition into elements. Each of them is closely linked to a specific manufacturing process, thus we can estimate the cost. The total cost is calculated as a sum of all components costs. Depending on the type of elements, these methods are broken down into operation-based, tolerance-based, based on the product features, and activity-based. Among the conclusions of this paper one can hold that the idea that the combination of several estimation methods is a good approach, because none of the methods can cover in a satisfactory manner all cases occurring in practice.

Shehab and Abdalla [4] see that little effort was made in cost modelling at the early stage of the entire product development cycle, and as most of the knowledge-based systems for product cost modelling were mainframe based, they were expensive, and required a long learning curve. More, they lack the material selection capability, and some aspects of the product life cycle such as the assembly stage were not considered. To overcome this, they propose an intelligent knowledge-based system, which, additionaly provides an environment that assists inexperienced users in estimating the manufacturing cost. It advises users on how to eliminate design and manufacturing related conflicts that may arise during the product development cycle. According to the proposed system, an initial process planning is needed including generation and selection of machining processes, their sequence, and their machining parameters. Cost modelling consists of a feature-based CAD system, material selection, process / machine selection, a user interface, and cost estimation techniques.

The Designer designs the product CAD model, specifies all its features, and attributes. The data resulted are used to compute the machining time for each feature. Furthermore, to compute the manufacturing cost the data required is the manufacturing time and the unit time cost of the assigned machine. Set-up times are rendered from machining handbooks. The total manufacturing cost is computed by adding the machining cost, material cost, set-up and changeover costs.

Sometimes developing a knowledge-based cost evaluation system is approached in connection with plug-and-play concept, in order to achieve high portability. Therefore, Ko et al. [5] present an embedded system that by a USB port connects to a host computer and allow for cost estimation of molded parts. It consists of a knowledge-base, knowledge processing units and server service unit for user interactions. Knowledge needed to develop part of your software system is colleted from literature and human experts.

Starting from activity-based costing (ABC) approach, H'mida et al.[6] introduce the new concept of cost entity, defined as a cost aggregation associated with resources consumed by an activity. Fundamental to this association is the homogeneity of the resources, thus they can find a driver to control the cost entity. Homogeneous resources mean they are stable and interdependent. Stable means that the imputation rate (e.g. Euro/min) of each resource does not change according to the product. Interdependent means that the resources are consumed in the same proportion whatever the product that uses them. In order to estimate the cost of an activity, it is broken into components becoming smaller until homogeneity condition is satisfied. The final objective is establishing a tight link between technical variables (or manufacturing features) and economic variables (modelled as cost entities). Out of illustrative manufacturing example present, we can see that in order to satisfy homogeneity condition, the cost entities should be small and in a large number. This adversely affects the efficiency of the method, especially in the case of small batch production.

A group of researchers [7-9] developed a semi-analytical method. According to this method, in a first stage, the analogical approach is used to search for analogies between the shapes to be machined. For each feature parameter, the system generates a process to be used and consequently a model of machining time. In the second stage, by using the analytic approach, the cutting time is determined.

They have applied this method to develop a cost estimation system of manufacturing dies [7,8]. According to the developed system, the whole problem is divided into a number of sub-problems. Every die is decomposed into cavities that represent a group of complex machining features. The analogical approach is used to search for analogies between the shapes to be machined before grouping them into complex machining features. For each feature parameter, the system generates a process to be used and a model of machining time. Next, the analytic approach is used to determine the machining time either by removal rates of metal units for rough operation or from the finishing operation surface or by both production ways. Once the machining time is determined, the system calculates the total of machining cost by multiplying the total machining time by the hourly production cost.

Although, they applied the method for computer-aided cost estimation of weld operations [9]. In this application it is presented a method to reduce any gaps as regard the estimated costs in comparison with the actual costs. The cause of these gaps can be operators training, mastering of welding processes in the workshop, following a solution for planning method changing, equipment aging etc. To remedy such a problem, the authors propose a continuous adjusting of the model parameters (efficiency operator, efficiency process, difficulty coefficient, complexity index, etc.).

Nagahanumaiah et al. [10] propose a cost model based on the notion of cost drivers and cost modifiers.

Cost drivers are the core and cavity features and depend on geometry and machining time. The relative cost for feature manufacturing (basic mold cost) is established based on past experience. This requires sufficient mold design and available cost data.

Cost modifiers depend on complexity, and can be customized using a quality function. These include parting surface complexity, presence of side cores, surface finish and texture, ejector mechanism and die material. Their values are also based on experience and are expressed as a percentage of the basic mold cost. To set these values, the authors propose the quality function deployment approach. According to this approach, the user must identify the different tooling parameters (parting surface complexity, surface finish, etc.) and to assess their impact by considering basic mold cost as a reference.

Researchers propose an analytical method for the processes studied and modelled very well, such as turning. Gara et al. [11] when referring to NC turning of complex profiles give an example of this. To reduce the complexity of analytical models of cost and time, authors propose a simple method for determining the machined length, the average work piece diameter, and the optimum number of passes.

Sanjay Sharma [12] notes that the change in value of production rate causes the change of production cost per unit. Thus, if the manufacturing rate is varied, then the cost will change, both of change in manufacturing time, and because the cost per unit of time variation. To account for this effect of variation of production rate, cost models are modified accordingly. Note that the author considers that the variation of production rates may be the effect of the perturbations of the production process but also a deliberate action to optimize the process.

Denkena et al. [13] present a quotation costing model, based analytic cost functions combined with a rule-based approach. These functions are developed with the help of technical principles instead of using past data, while the experiences of the employees are expressed in rules. This model is applied in case of pressure die casting moulds. According to the proposed model, firstly the mould geometry, bill of material, and process plans are rule-based determined depending on the geometry of casting part. Then, for each component and operation, the amount of work, time and cost are determined based on the analytic cost functions.

Similarly, Masel et al. [14] present a rule-based cost estimation system that can be applied during the preliminary design of a part. It provides an accurate estimate of the volume of an axisymmetric forging based on the part’s geometry. Key idea is that the volume of the forging is one of the most significant cost drivers in the manufacture of axisymmetric parts because the amount of material affects both the material cost and the processing cost.

Li et al. [15] propose an analogy based estimation system, which allows, given a new project, the system to retrieve similar projects from its historical project database and to derive the cost prediction from the similar projects. The novelty is that, in order to refine the retrieved solution into the target solution, it is used an artificial neural network, that adjusts nonlinearly the retrieved solution. Unlike the linear adjustment mechanisms, this is with learning ability and incorporating categorical features. The artificial neural network training is based also on historical project database.

Mittas et al. [16] propose that resulting from application of cost estimation by analogy method to be improved by iterative application of bagging method. This means that in the first stage, has to be extracted a user-predefined large number of bootstrap samples from the original data set. Then, for each one of the samples, estimation is obtained using the estimation by analogy method. The mean of all estimations gives the final prediction for the cost value. In the second stage, the dependent variable is replaced by the residuals of the first stage, where as the independent variables remain the same. They obtain a second estimation. The iterations of the algorithm are continued until a stoppage criterion is met.

Caputo and Pelagagge [17] analyze cost estimation performance compared to parametric models and artificial neural networks, both built from historical data. With the aim of considering a significant application context, reference has been made to the production of large-sized pressure vessels for the chemical process industry. They concluded that in this application, the two methods outperformed the manual estimation method, even when a limited database of historical cases is available and that, in this peculiar context, artificial neural network seemed preferable, thanks to the superior mapping capability.

Javier de Cos et al. [18] analyzed in a comparative manner using the projection pursuit method, the local polynomial approach, and the adaptive neural networks method the performance that can estimate the cost of production of some ring parts that form the part of the turbine building. The best results were obtained when estimating the cost by artificial neural network.

Kutschenreiter-Praszkiewicz [19] presents an application of neural network for time per unit determination. The case considered is a small lot production of the tooth wheels. The motivation of considering this case is in small lot production, the machine setup parameters are set by an operator who works on the machine tool, basied on the technical documentation and his experience, and therefore can not be known at the time of calculation. The neural network use for time per unit prediction can be applied where data from past experience are registered in the IT system. In addition, the neural network can be applied for time consumption prediction for a group of similar elements for which the same framework machining is applied.

Currently, on machining processes, the time a tool passes through a programmed trajectory is estimated by dividing the entire tool path length by the programmed feed rate. There is a big difference (from 211% to 1244%) between estimate and real process time, because the feed rate is not always constant, due to numerical control limitations. This difference is even greater as tool trajectory is more complicated. Coelho et al. [20] study this aspect for milling free-form geometries applying high feed rate and proposes a method to reduce the difference between estimate and real time. The method considers a variable called machine response time, which characterizes the real CNC machine’s capacity to move in high feed rates. Machine response time is a global performance feature, which can be obtained by carrying out a simple test. However, the key idea that can be retained in this work is that, when estimating the time, particular behavior of a distinct tool cannot be neglected.

Di Angelo et al. [21] propose neural modelling for build time and its driving factors for estimating time to a group of rapid prototyping technology (fused deposition modelling, stereo lithography, selective laser sintering, laminated object manufactured, multi-jet modelling, three-dimensional printing, electron beam sintering, selective laser melting). The neural network must be trained with real known data related to the build times of a given set of objects that are manufactured with assigned technologies. The training set of samples should be representative of the correlation between each factor and the corresponding build time components. In other words, during the training phase, sufficient knowledge should be transferred into the neural network.

3. PRICE AND DUE DATE QUOTATION

Most of the times, due date quotation is the capacity driven and orientated towards the integration of the due date setting with the capacity planning. On the other hand, the analysis of the system workload is carried out at an aggregate level from a temporal viewpoint. An example is given by Corti et al [22] who proposed a model aiming at supporting decision makers when they have to verify the feasibility of the due date (DD) required by a potential customer. The model is composed of two modules. The first module adopts a capacity-driven approach to assess the feasibility of a certain due date (either proposed by the customer or by the company). The capacity availability is verified with reference to each resource (selected from those used to browse the order set routings under discussion at the current time) and to a reasonable horizon of time. The proposed (DD) can be accepted, only if some capacity adjustments are allowed, or infeasible. A distinguishing feature of the presented model is the ‘‘what if’’ analysis, which allows for the robustness of the obtained (DD) quotation to be verified. The basic idea of the robustness analysis is to find out what combinations of orders could make invalid the first module appraisal. Since the number of all possible combinations of orders increases with the number of orders, it could be very expensive to exhaustively test all of them. This is why a possible selection procedure based on the probability values is proposed.

Zorzini et al [23] present an empirical analysis regarding the managerial practices supporting capacity and delivery time management in the capital goods sector. Analysis is based on a sample of 15 Italian manufacturers. Results of the analysis show that some approaches on capacity and delivery time management seem to be more suitable to specific industrial contexts. For example, the detailed workload-based analysis and the integrated approach for DD setting seem to be mostly adopted when high delivery time performance must be guaranteed and production flexibility options are scarcely available. Moreover, the results suggest that improving cross-functional communication among the departments involved could lead to better performance.

Sometimes, the manufacturer has the ability to charge different prices to different customers in order to influence demand, reject orders, and set lead-times or due-dates for accepted orders. Charnsirisakskul et al. [24] present decision models, which integrate pricing and production decisions. Through numerical analyses they show that price and lead-times flexibilities are, in general, complementary and that price flexibility is useful in all environments.

4. CONCLUSION

In conclusion, all techniques presented in the literature lead to determining a specific value, unique to these three variables. Therefore, during negotiations possible alternatives can be identified with difficulty. If instead of fixed values the negotiator would have models to describe the relation between DD, price and time, on the one hand, and the negotiation process variables, as the intensity of manufacturing, it would be possible to identify possible alternatives and immediate evaluations for each alternative.

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