A METHOD FOR IMPROVEMENT POTENTIAL ASSESSMENT IN A BATCH PLANNING AND SCHEDULING SITUATION

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Abstract

A method is presented for estimating the improvement potential of planning and scheduling in a batch-wise processing company. It involves a characterization of the actual planning and scheduling situation and supports systematic exploration of improvement options and their benefits. Insights gained in two explorative industrial case studies were used to arrive at a robust method that can be applied in a variety of batch process industries. The method is aimed at supporting industrial decision makers in deciding whether to invest in hardware i.e. production and storage capacity, or software i.e. batch scheduling and sequencing, or to focus on information management i.e. customer order acceptance procedures or planning issues like delivery time policy.

Keywords

Planning and Scheduling, Batch Processes, Performance Improvement

Introduction

Integration of planning and scheduling functions is generally expected to contribute to increasing productivity and competitiveness in manufacturing industries. In practice integration often leads to difficult problems for engineers to solve and to expensive automation projects. Such expenses are hard to justify if the benefits resulting from integration cannot be specified beforehand. A benefit analysis of integration projects is generally difficult, but more so for batch processing operations, due to their particular complexity. Even for the scheduling function as such, it is generally very difficult to determine the added value of a change in scheduling policy when compared to a current bottom line (Ovacik, 1997). This is one of the reasons why advanced scheduling algorithms are not widely adopted in industrial practice. The central question of the research work presented here is therefore: How can the improvements derived from changes in production planning and scheduling, and from changes in the production system, be specified and assessed?

Method outline

The method aims for performance assessment of improvement options in a batch planning and scheduling situation when compared to the performance of the actual planning and scheduling situation. The latter is defined by the given batch production system and the given planning and scheduling activities. Two explorative case studies, the first performed in a production plant for food products, the second at a production plant for starch derivatives, provided the basis for the development of a systematic procedure for identifying improvement options and estimating their improvement potential, in relation to a company's strategic objectives. The procedure followed to arrive at an Improvement Potential Assessment (IPA) of identified improvement options, is depicted in Figure 1. The white blocks represent desired information inputs provided by a company. The dark grey blocks represent a predefined framework designed to process this information.

Elements of the procedure

General Model

The General Model serves as a generic framework for defining a planning and scheduling situation. It consists of the elements 'production system', 'planning & scheduling activity' and a 'list of general evaluation parameters'.

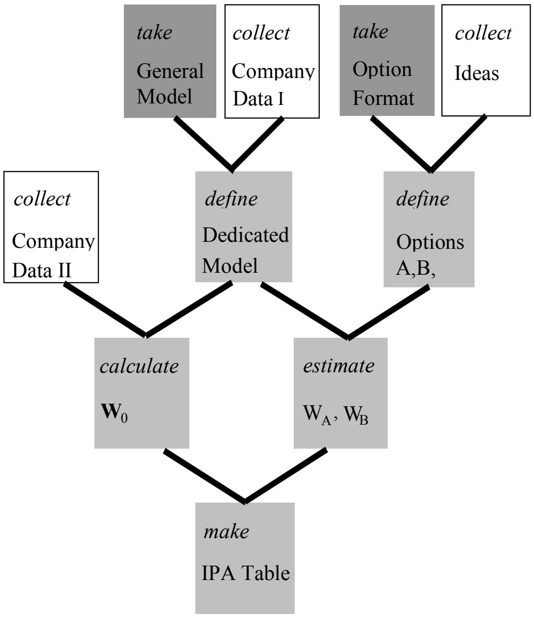

Figure 1. Procedure to derive IPA table

External boundaries must be set before describing the production system. In both case studies the production system was one production line, where the external boundaries contained all production activities within the selected production line, from receiving raw materials to the shipment of the final products. Bottleneck resources are detailed within the specified production system. Raw materials, intermediate products and final products are also specified.

Planning & scheduling activities are defined as one information-processing block, the output of which is the production orders executed by operations. Input is the set of customer orders defined as product demand. Output is generated using objectives, restrictions, rules and algorithms which in industrial practice generally reside 'in the heads' of the planners.

Appropriate evaluation parameters must be selected by a company to reflect its strategic objectives for a quantitative assessment of the actual planning and scheduling situation and its improvement potential. The General Model contains a gross list of evaluation parameters like resource utilization level and delivery reliability for this purpose, and definitions and calculation methods extracted from the literature (Pinedo, 1995).

Company Data I

These data describe the specific production system, process configuration, bottleneck resource capacities, processing times, and the objectives, restrictions, rules and algorithms, work dispatch rules, that apply to a company's planning & scheduling activities. Moreover, the format for production orders and customer orders is specified here. Finally, a company specific selection of evaluation parameters is made with the aid of the general list given by the general model, and the calculation method for the specific company situation is specified for each evaluation parameter.

Dedicated Model

Using Company Data I the General Model is translated into a Dedicated Model that describes the actual company-specific planning & scheduling situation.

Company Data II

These data specify product demand and supply, production orders, the production report and all further data of a system to describe material flows and stocks over a certain past period. The selected historical period, 2 weeks in the first case study, 8 weeks in the second, should be representative of the actual planning and scheduling situation. It should typically cover at least one production cycle and cover a broad range of products manufactured and delivered.

$\mathbf{W}_0$ $(=w_{1,0}, w_{2,0}, w_{3,0}, \ldots)$

Represents calculated values of selected evaluation parameters (w_1,w_2,w_3,..) in the zero situation. The zero situation is described using the Dedicated Model and the Company Data II.

Option Format

The Option Format specifies criteria for the definition of improvement options. Options should state unambiguously what exactly is altered compared to the zero situation. The option format furthermore presents a list of categories of improvement options, which can be used as a checklist to generate ideas.

Ideas

This box represents the ideas generated by the company and by the researchers to improve the actual planning and scheduling situation.

Options A,B,..

The processing of ideas according to the prescribed option format yields a list of options to be assessed for their improvement potential.

$\mathbf{W}_A$, $\mathbf{W}_B$, ..

These are the values of the evaluation parameters that would result from implementing options A, B etc. The aim of the method is to estimate the maximum value changes for each of these parameters, for each individual option. A value change that is desirable indicates true improvement potential.

IPA table

To create the IPA table, we need the values of the evaluation parameters in the zero situation, the options A,B,.. and the effect of each option on the values of the evaluation parameters. The change potentials are derived from Eq. (1):

$$\Delta \mathbf{W}_A = \mathbf{W}_A - \mathbf{W}_0 \quad \text{etc.} \tag{1}$$

Explorative Case Study

In the case study the bottleneck resource unit comprises four identical batch-units with relatively short batch processing times, less than a minute. Production could be regarded as semi-continuous with product dependent changeover times between the runs. The company considered three situation evaluation parameters to be important: utilization level bottleneck resource (w1), delivery time reliability (w2) and net profit (w3).

$$w1 = 100\%\text{*production time/length of period} \tag{2}$$

$$w2 = 100\%\text{*deliveries not late/total deliveries} \tag{3}$$

$$w3 = \text{profits} - \text{extra costs} = \sum q_i{*}p_i - K_1 - K_2 \tag{4}$$

Where

q_i = delivered amount of product i [ton]
p_i = profit of product i [Euro/ton]
K_1 = off-spec costs [Euro]
K_2 = delivery error costs [Euro]

Off-spec costs arise from mistakes at the operational level and were analysed as being little influenced by the planning and scheduling activities. Delivery error costs arise from late deliveries: trucks picking up products have to be paid for extra waiting times. The latter can be influenced by production planning and scheduling activities.

The values of the evaluation parameters in the zero situation were calculated using company data II except for delivery time reliability. The original promised delivery dates appeared not to be registered, only the actual delivery date and the order acceptance date. If an original promised delivery date could not be met, customers were informed about the new delivery date. Whereas the administration system recorded a delivery time reliability of 100%, the planners estimated a value of 90%. Further, analysis of the zero situation showed a significant difference in planned and realized maintenance times of 37.5% which had not been noticed by planning.

The main option (option A) explored was the use of a batch sequencing tool by the planner to help him formulate the production orders. The effect of introducing option A on the utilization level (w1) is based on the activity status of the bottleneck resource in the zero situation. Option A has no influence on the length of the maintenance times or on production stops due to process disturbances. At most only the set-up times and process start-up times can be reduced which turned out to be 4% of the length of the period. Delivery reliability (w2) is expected to be influenced positively by option A. The maximum effect of option A on net profit (w3) is based on the assumptions that (i) the delivery error costs are zero ($K_2 = 0$) and (ii) the extra production time results in extra products which are delivered during the period. Net profit is calculated then as:

$$w_{3,\,A} < \sum q_i{*}p_i + 4\%{*}\langle C\rangle{*}T{*}\langle p\rangle - K_1 \tag{5}$$

Where

$\langle C\rangle$ = mean weighted production capacity [ton/h]
T = length of period [h]
$\langle p\rangle$ = mean weighted product profit [Euro/ton]

Keeping in mind only a fraction of the calculated maximum change potentials will be achievable option A was discarded. The company then decided to focus on more strategic planning options like production on Sunday (option B) and increasing the bottleneck resource capacity by 10% (option C). These strategic options were first evaluated qualitatively (Table 1).

Table 1. IPA Table Case Study

	Situation Evaluation Parameters		
	w_1 [%]	w_2 [%]	w_3 [Euro]
Zero Situation	73	90	100*
Alternative Situations	Value Change		
	$\Delta w1$	Δw_2	Δw_3
Option A	< 4	+	< 6 *
Option B	13	-	+
Option C	0	0	+

* Indicative of a confidential figure

The IPA results prompted development of a system dynamics model for analyzing quantitatively the effects of implementing strategic planning options in the zero situation. This simulation model for the internal supply chain of the production line has been formulated derived from Sterman's (Sterman, 2000) generic model for demonstrating supply chain dynamics (see Figure 2). The model was validated on the basis of aggregated empirical data. In the model physical aspects of the production system as well as working procedures of the company are incorporated. Mean input is a smoothed product order demand function describing an ordered amount of product and its target delivery lead time. Mean outputs are the simulated actual delivery time, delivery reliability, and product inventory level and production rate values in time. Seven options are introduced, defined as changes in the parameter values or model structure, to seek for improvements: (1) longer production run; (2) capacity expansion; (3) reducing time of product change over; (4) reducing safety stock coverage; (5) reducing target delivery time; (6) improving customer order fulfilment; (7) shift towards make-to-order policy. Experimentation with the model indicates that options (4) en (5) have most impact on the mean output parameters.

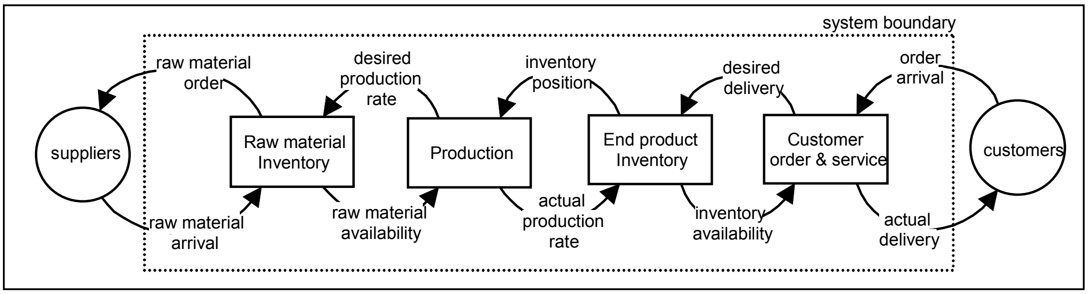

Figure 2. Causal diagram overview of the internal supply chain model

In exploring the policy space for changing the safety stock coverage, the model indicates three critical areas to pay attention to:

(a) The area for policy changes where the side effects are marginal. This is in the range of 0.4-1.1 days of safety stock coverage;
(b) The area where extra inventory is superfluous, i.e. not significantly improving the company performance anymore. This is for safety stock coverage larger than 1.1 days;
(c) The area where further reduction of safety stock coverage will be detrimental to the delivery lead time and delivery reliability. This is for safety stock coverages of less than 0.4 days.

However, the quantitative values for these different areas can not be taken as “hard” true values, but should be more as indication, based on the assumptions in the model.

In exploring the policy space of changing the target delivery lead time, the model gives an important insight: the higher the setting of target delivery lead time, the higher the inventory of end products will be. This is so, because in practice the customers are placing the order each day, and the longer the delivery lead time, the more orders will be accumulated in the backlog. Since there are different product types to produce and different product types ordered by customers, this results in higher inventory level needed to fulfil the orders. The model thus points to the importance of keeping down the target delivery lead time as much as the system allows.

Conclusions and future research

Although the method is still under development, it is promising as a systematic approach to identifying improvement options and their improvement potential in batch production plants. The procedure helps companies to think about the strategic objectives of their planning and scheduling activities and its translation into well-defined and measurable evaluation parameters. It assists industrial decision-makers in identifying trade-offs between different evaluation parameters and in pinpointing the factors that are critical for higher productivity or competitiveness. Another unintended positive effect of the method that appeared during industrial application, is that it helps to break down the information and communication barriers between different departments within a company, such as those often found between operations, planning and sales.

Future research will focus on (i) elaboration of the procedure steps in order to arrive at a method that is transferable to industrial practitioners and unambiguous in its results; (ii) the applicability of the presented simulation model as part of the method to quantify the effect of implementing strategic options in other industrial situations.

The ongoing explorative case studies will be completed and reported. A third case study to validate the method in another industrial batch situation is in preparation.

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