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Flexibility-driven order releases in job-shop production

Hans Corsten*, Ralf Gössinger, Norbert Wolf

Department of Business Administration and Production Management, University of Kaiserslautern, Gottlieb-Daimler-Straβe 42, Kaiserslautern 67663, Germany

Abstract

Overview. The aim of releasing orders is to transfer jobs from the planning stage to the realization stage under consideration of economic objectives. In a job-shop with order driven production, this decision problem is characterized by time-related, open decision fields. In this context, a possible approach to solve this problem lies in considering flexibility as a decision criterion. This procedure also forms the basis of opportunistic coordination. Here, the basic idea is to utilize the inherent flexibility of a production system to compensate negative consequences of unexpected changes of the decision field. The aim of this article is to

- examine the extent in which flexibility aspects are considered in relevant order release models
- specify the principles of opportunistic coordination within the order release planning problem to achieve a flexibility-driven order release, and on this basis
- develop the structure of a decision model to flexibility-driven order release.

Keywords: Order release planning; Flexibility; Opportunistic coordination

1. Basic considerations

1.1. Problem specification

The aim of *order release planning* is to pass orders into the production process under consideration of the given production conditions and the basic objectives. It is located in the transition between the planning activities, prior to the production process, and control activities (see Melnyk and Ragatz, 1989, p. 1082; Zäpfel and Missbauer, 1993, p. 299).

The order release planning proceeds from the assumption of a given production program and order lot size. They are both elements of superior planning problems (see Missbauer, 1998, p. 49). Thus, also the rejection of orders lies outside the scope of the order release planning (see Bergamaschi et al., 1997, p. 401. In order-oriented production, the decision on accepting or rejecting orders takes place on the level of the production program planning (see e.g. Corsten et al., 2001, p. 307; Kingsman et al., 1989, p. 198; Jaikumar and Wassenhove, 1989, p. 62; Philipoom and Fry, 1992, p. 2562). Arriving orders usually pass the three *phases* order preparation (e.g. availability examination), order prioritization (incorporating orders in queues with defined processing sequence), and order triggering (release of an order with the highest priority based on a defined rule) (see Bergamaschi et al., 1997, p. 401; Melnyk and Ragatz, 1989, p. 1082; Park and Bobrowski, 1989, p. 233; Philipoom and Fry, 1992, p. 2559).

The starting point of these considerations forms the *job-shop production* (see Kuhn, 1990, p. 18) usually being used for order-driven single or small batch production. The degrees of freedom of the production process and the relatively high flexibility result from the characteristics of the implemented potential factors of production and the orders to be executed

- *Potential factors of production*: Potential factors can have several alternative processing possibilities. Within a class of potential factors, these alternatives can be overlapping.
- *Orders*: The production plan of an order can be non-linear (e.g. cyclic structure, alternative processing sequences with interchangeable operations). Order conditions (e.g. completion date) can form soft restrictions.

In *order-driven production*, the production system is often characterized by the fact that due to flexibility not all potential factors are combined rigidly. In some cases, only if

* Corresponding author. Tel.: +49-631-205-3756; fax: +49-631-205-3762.
E-mail address: corsten@sozwi.uni-kl.de (H. Corsten).

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orders are available it is possible to combine single potential factors[1] of different factor classes temporarily (e.g. human labor, processing units, tools) having a limitational relationship regarding the order's capacity demand to get a corresponding capacity supply (For this aspect in the context of an order release in flexible manufacturing systems see e.g. Bossert, 1999, p. 69; Chen and Askin, 1990, p. 896; Jaikumar and Wassenhove, 1989, p. 62; Kuhn, 1990, p. 102; Liang and Dutta, 1993, p. 389; Nayak and Acharya, 1998, p. 1811; Shanker and Tzen, 1985, p. 581; Vidyarthi and Tiwari, 2001, p. 958). On the one hand, it has to be considered that a specific combination of potential factors can be utilized not only to execute one order but for all orders requiring the same type of capacity. Besides the choice of an order sequence and a release date, thus, maintaining and changing factor combinations are relevant options of the order release (see Park and Bobrowski, 1989, p. 233). The *economic problem* results from the fact that the impact on success of these options can have conflicting relationships, requiring the selection of a more favorable combination of action alternatives.

The starting position shown is characterized by a time-related, open decision field, i.e. the decision field changes over time and information about these changes are incomplete at the moment of planning (see Schlüchtermann, 1996, p. 2). This openness entails two types of uncertainties:

- regarding the orders, there is uncertainty about the order quantity, the arrival dates and their conditions, and
- regarding the resources, uncertainty results from possible disturbances (see Arzi and Roll, 1993, p. 2195; Cigolini et al., 1998, p. 2938; Hasan and Spearman, 1999, p. 1202; Homem-de-Mello et al., 1999, p. 92; Missbauer, 2002, p. 700; Portioli-Staudacher, 2002, p. 396).

To solve problems in time-related, open decision fields, two possible approaches can be pursued (see Schlüchtermann, 1996, pp. 15, 100 and 103):

- *The construction of a closed decision field*: By setting a planning horizon together with the relevant action alternatives and the data, a decision field is defined neglecting all aspects outside these boundaries and their interdependencies to elements within the decision field.
- *Maintaining the openness of the decision field*: To compensate the negative effects of incomplete information about the changes of the decision field, flexibility is established or maintained, i.e. referring to flexibility as an objective in the selection of action alternatives.

Due to a relatively high flexibility of the planning object, the latter approach is suggested. In this context, it is important to note that the usability of the planning object's flexibility can be limited by the insufficient arrangement of the planning process. Substantial reasons are (see Zelewski, 1998, p. 238):

- the incomplete consideration of action alternatives,
- the insufficient incorporation of flexibility in the objective function, and
- the insufficient reaction capability of the planning process.

In scientific literature, the order release problem is either discussed specifically for job-shop production or in the context of flexible manufacturing systems under the term 'part selection and loading problem' (for an overview of models see e.g. Bossert, 1999, pp. 53, 65). Even though they have a particularly high relevance in flexible manufacturing systems due to the close technical coupling (see e.g. Kuhn, 1990, p. 22), in models referring to job-shop production in general, the details of the factor combination are often abstracted from (Exceptions constitute the so-called dual-resource-constrained-approaches by Fredendall and Melnyk, 1995, p. 1526; Park and Bobrowski, 1989, p. 233, which consider the relationship between machines and operating personnel).

The order release approaches discussed in literature can be systematized (in accordance with Bergamaschi et al., 1997, p. 406; Melnyk and Ragatz, 1989, p. 1083; see also Philipoom et al., 1993, p. 1110. In the context of flexible manufacturing systems see e.g. Kuhn, 1990, p. 54) by different characteristics. The following have effects on flexibility:

- *Release mechanism*: In a *load-oriented* release, the utilization of capacity determines whether orders can be released or not. Is the release *order-oriented*, then release dates are calculated based on the order properties. With respect to a flexibility orientation, it has to be noted that in the context of operative planning, flexibility results from the interaction between capacity demand and capacity supply. Thus, a load-oriented order release is preferred here.
- *Time interval*: While in a *periodic* approach, release decisions are only made in defined time intervals, in a *continuous* order release they can be made at any time. With respect to flexibility aspects, a continuous order release appears to be more suitable (see Stecke and Kim, 1988, p. 8; Stecke and Kim, 1991, p. 56) since fixed time intervals entail restrictions regarding the planning processes' ability to react.
- *Time horizon*: The release mechanism can be either *myopic* or *hyperopic*. In the first case, the decision's effects are only taken into account up to the next decision. In the second case, the system load is considered beyond the next decision. Since in a flexibility-oriented order release establishing and maintaining flexibility are focused, a hyperopic approach is on

[1] Between the potential factors within one factor class, there can be substitutional relationships.