Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 63 (2017) 477 – 482

www.elsevier.com/locate/procedia

The 50th CIRP Conference on Manufacturing Systems

Determining the potential to improve schedule compliance

Andreas Piontek*, Hermann Lödding

Institute for Production Management and Technology of Hamburg University of Technology, Denickestr. 17, 21073 Hamburg, Germany

* Corresponding author. Tel.: +49-40-42878-4734; fax: +49-40-42878-2295. *E-mail address:* Andreas.Piontek@tuhh.de

Abstract

High schedule compliance is very important but rarely achieved in make-to-order productions. Especially when orders are released too late (e. g. due to missing raw material) it is challenging to identify how many orders can still be produced in time. This paper shows how companies can identify their potential to increase schedule compliance by earliest operation due-date sequencing. The simple model shows that five parameters determine the potential to increase schedule compliance through sequencing: the input sequence deviation, the WIP level, the number of operations, planned sequence interchanges in the order throughput, and the number of parallel machines.

Keywords: sequencing, schedule reliability, manufacturing control

1. Introduction

Delivery reliability is the major logistic objective perceived by customers [1]. Naturally, it is necessary to produce on time to achieve a high delivery reliability. Two major factors determine whether orders are produced on time or not: backlog and sequence deviations (see figure 1).

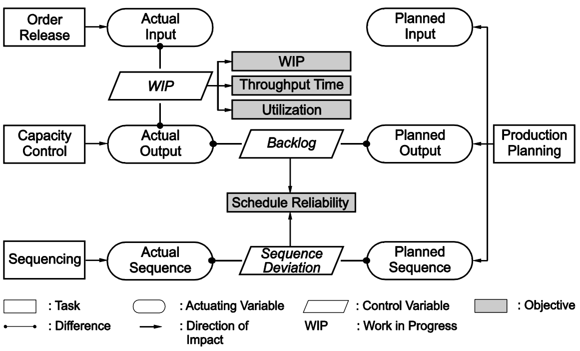

Fig. 1. Manufacturing control model [2]

Both are influenced by the input. When raw material is not available and orders cannot be released on time, a loss in utilization can arise which can result in backlog. But more important is the influence of the order release on sequence deviations. Even if enough orders are released to guarantee the planned utilization, input sequence deviations negatively influence the achievable schedule reliability.

It is well-known, that sequencing influences schedule reliability and that the earliest due date rule supports minimising the maximum lateness on a single machine [3, 4]. While the effect is qualitatively known and proven with simulation experiments [3, 5] simple models that can quantify the effect for complex systems are mostly missing. The model presented in this paper shows how companies can determine which schedule compliance the production can achieve based on present input deviations when sequencing with the earliest-operation-due-date rule.

The paper is structured in five sections. After the introduction, we present the current state of research on which the model described in section three is built upon. Section four evaluates the presented model in simulation runs that show its accuracy. The paper closes with a summary and an outlook in section five.

doi:10.1016/j.procir.2017.03.127

2. Current state of research

2.1 Definitions

Lateness is the deviation between the order's actual and planned end date. Consequently, a negative lateness indicates an early order completion and a positive lateness a late order completion.

Schedule reliability is defined as the number of orders that are manufactured within a defined lateness tolerance divided by all orders [2, 6].

$$SR = \frac{NO \ with \ L_{ll} \leq L \leq L_{ul}}{NO} \quad (1)$$

where SR is the schedule reliability (%), NO the number of orders, L_{ll} the lower limit for permissible lateness (SCD) and L_{ul} the upper limit for permissible lateness (SCD).

Customers perceive late deliveries more negatively than too early deliveries. Therefore the schedule compliance is more customer oriented than the schedule reliability. It is defined as the number of orders that are manufactured with a lateness of zero or smaller than zero divided by all orders [2].

$$SC = \frac{NO \ with \ L \leq 0}{NO} \quad (2)$$

where SC is the schedule compliance (%), NO the number of orders, L the lateness (SCD).

2.2 Partitioning lateness

In analogy to the funnel formula, Yu [6] derived the mean lateness as the ratio between the backlog and the output rate:

$$L_m = \frac{BLO_m}{ROUTO_m} \quad (3)$$

where L_m is the mean lateness (days), BLO_m mean backlog (-), $ROUTO_m$ the mean output rate (orders/SCD).

The equation shows that orders are late on average if a backlog (planned - actual output) develops at a workstation. Naturally, the mean lateness does not reflect the lateness for every single order. Moreover, the influence of sequence deviations is not visible.

It is possible to partition the lateness of an order into backlog-dependent and sequence-dependent lateness [7, 8]. Sequence deviations can cause lateness for single orders. To derive how sequence deviations influence lateness Kuyumcu [7] and Lödding et al. [8] first define the difference between the actual and planned rank as the sequence deviation of an order.

$$SDO_i = rankO_{act,i} - rankO_{plan,i} \quad (4)$$

where SDO_i is the sequence deviation of order i (-), $rankO_{act,i}$ the actual rank in number of orders (-), $rankO_{plan}$, the planned rank in no. of orders (-).

To determine the orders' ranks, the orders are sorted by the completion dates and ranked with consecutive numbers. Consequently, for the planned ranks orders are sequenced by their planned completion date and for the actual rank by their actual completion date accordingly (Table 1).

Table 1. Defining ranks and calculating sequence deviation

Order	$TOUT_{plan}$	$TOUT_{act}$	$rankO_{plan}$	$rankO_{act}$	SDO
A	10	11	1	2	1
B	11	10	2	1	-1
C	12	12	3	3	0

where TOUT is the time of output (days), $rankO_{act}$ the actual rank (-), $rankO_{plan}$ the planned rank (-).

Figure 2 shows how the sequence- and backlog-dependent lateness can be calculated for single orders with simple trigonometry in the throughput diagram. Thus, the sequence-dependent lateness can be calculated by dividing the sequence deviation by the planned output rate ($ROUTO_{plan}$):

$$L_{SD} = \frac{SDO_i}{ROUTO_{plan}} \quad (5)$$

where L_{SD} is the sequence-dependent lateness (days), SDO_i sequence deviation of order I (-), $ROUTO_{plan}$ the planned output rate (orders/SCD).

The backlog dependent lateness follows from the ratio between the backlog at the sequence-dependent output time ($BLO(TOUT_{SD})$) and the actual output rate.

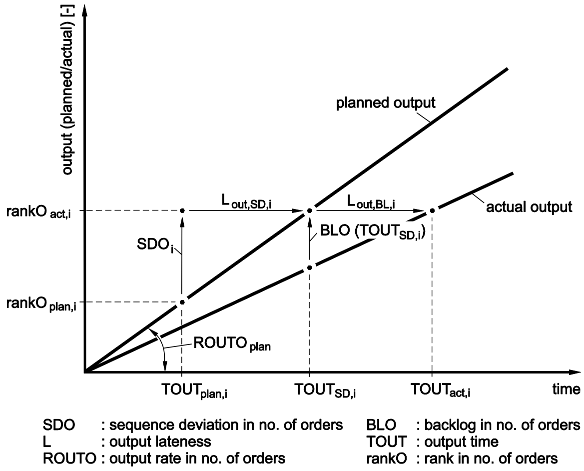

Fig. 2. Determining the sequence- and backlog-dependent lateness [7, 8]

2.3 Determining the minimal sequence deviation for single workstations

Bertsch presented in his dissertation [9] a precise model that shows how lateness can be forecast for different sequencing rules when planned throughput times are constant. In extensive simulation runs, he shows that the complex mathematical model can forecast lateness distributions.