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Applicability aspects of workload control in job shop production

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Summary

The term Job Shop Production (JSP) describes a manufacturing environment that produces piece goods in small batches. It is a common manufacturing environment in small and medium-sized enterprises (SMEs). The incoming orders often differ in the number of ordered products, their design, process characteristics (for example, routeings, operation processing times, and set up times), or urgency. Because of this variation the control of the material flows in this type of companies is extremely complex. It can hardly be predicted how the production orders will be divided across the machines in future periods. A high demand on machines and varying production orders cause long waiting times of orders on the shop floor. The direct consequence is that lead times are long and unreliable, whereas nowadays short and reliable delivery times are required.

Workload Control (WLC) methods are intended to realise a good logistical performance in JSP. These methods aim at controlling the workload on the shop floor (expressed in hours) for the different capacities (e.g. machines). In this context, a core decision is taken entailing the release of production orders to the shop floor. The orders are not sent to the shop floor immediately, but are collected in a so-called 'order pool'. The collected orders are assessed periodically for release to the shop floor. A suitable order can be released as long as a maximum workload per capacity group is not exceeded. This order release method guarantees reliable throughput times and a stable and controllable situation at the shop floor.

This thesis aims at adding to the existing workload control methods to be better able to cope with several specific aspects of JSP. The research is subdivided in three themes: the general applicability of WLC in JSP, the adjustment of WLC to the restricted availability of information, and the adaptation of WLC to semi-interchangeable machines.

The *first theme* is based on the need of SMEs for an instrument to make initial decisions about the selection of a production planning and control concept, especially WLC, without exhaustive data collection.

The elaboration of this theme starts from a description of both the inherent WLC characteristics and the relevant JSP characteristics. In order to determine 'best fit' areas in the applicability of WLC, the functional relationships between WLC and JSP characteristics are identified. Taking the incoming order flow as point of departure to identify the dominant JSP characteristics, four aspects have been studied: order arrivals, due dates, operations, and routeings. From these aspects, twelve indicators have been deducted. These indicators are averages of e.g. routeing length and variances in e.g. operation processing times. Also routeing aspects, such as the

assembly structure or routeing sequence variability, are considered. These indicators form the basis of a framework which has been developed. By determining the indicator values in terms of ‘high’ and ‘low’, it can be determined which specific JSP characteristics are suitable for the introduction of WLC. In addition, possible obstacles can be detected.

The framework shows that the applicability of WLC increases as the variability becomes larger, indicated by increased inter-arrival time fluctuations, due date differences, processing times variability, routeing sequence and routeing length variability. Also routeing flexibility may contribute to the applicability of WLC. However, dominant assembly operations and sequence dependent set up times may cause problems when applying WLC. The framework has been tested in a medium-sized enterprise. The required data were easily and rapidly available. Applying the framework showed that the company was suitable for the introduction of WLC. As the company was forced by the framework to look systematically at its own production environment, it was possible, as a side effect, to initiate steps that could further improve logistical performance.

Theme two deals with the limited possibilities of generating shop floor data in JSP and the possibilities to cope with these limitations within WLC. Regarding WLC it is for the release of orders to the shop floor necessary to know the current position of each order on the shop floor at the moment of the (periodic) release decision. To gather this information it is required to register each finished operation. Though sufficient information and communication technologies (ICT) are available allowing SMEs to generate the required shop floor data, this situation is not very common in practice.

In a previous method to handle the limited availability of shop floor data, only two information feedback points (FBPs) are used, namely the moment of order release and that of order completion. These two FBPs are available in each company. Unfortunately, this method leads to weak logistical performance. Often, within SMEs there are more ‘natural’ FBPs than just order release and order completion. Even smaller job shops are often divided into sub-departments. Orders moving from one sub-department to another are then registered anyway, for example for reasons of cost calculations, to register the daily output, or to make productivity surveys. This makes it possible to determine the actual position of each order relative to the sub-departments.

In this thesis adaptations to WLC are developed that allow for diminishing the need for information regarding order release to a limited number of ‘natural’ FBPs. Particularly the way in which the workload is calculated has to be adjusted to the limited availability of shop floor data. These adaptations link up closely with existing WLC methods to calculate workloads. The outcomes of simulation experiments show

that it is possible to realise a good performance with a limited number of FBPs. Additional FBPs always lead to further performance improvements, but the marginal contribution strongly decreases. This makes it attractive to use a limited number of 'natural' FBPs.

Theme three has originated from the necessity to adapt WLC to the specific machine characteristics within JSP. For the same type of operations there can be several machines available. These machines may have different degrees of interchangeability. This means that, sometimes they can be used for processing the same set of orders. However these sets may also not overlap at all, or only partly.

Within WLC order release is an important control element. During order release one workload norm per capacity group is distinguished. A capacity group can contain a single machine as well as a group of (semi-)interchangeable machines. In that context, it is important to make an explicit decision with regard to which machines are grouped into the same capacity group. Apart from the necessity of a grouping decision, the presence of interchangeable machines requires a routeing decision. A routeing decision stipulates on which specific machine an operation is performed. Routeing decisions can be taken at several moments in the planning process, for example at order release or on the shop floor.

In this thesis alternatives to the routeing and grouping decision are analysed. The impact of the different alternatives on the logistical performance is quantified by the use of the outcomes of simulation experiments.

On the basis of earlier insights it is to be expected that, as soon as more capacity groups are distinguished (less machines per capacity group), the workload can be divided in a better way among the machines. The simulation results confirm that the use of a more detailed capacity overview improves the overall performance, provided that proper workload norm levels are chosen.

In addition, it can be expected that, in order to make the proper decision with respect to the actual state of the machines (e.g. idle/busy), it might be an attractive option to postpone the routeing decision as long as possible. The last possibility to take a routeing decision is just before an order has to be processed by one of the alternative machines. This may prevent an order to be left waiting in front of one machine, while another machine remains idle. The expected waiting time reduction is also known as 'pooling synergy effect'. Simulation results confirm these analyses. The results show that the pooling synergy effect occurs independently of the chosen workload norm level, thus with infinite norms as well as with very strict ones.

The simulation results also make clear that the different performance effects, resulting from the routeing and the grouping decision, do in fact cumulate. The best logistical performance can be reached, if a late routeing decision is combined with a grouping decision that defines one single machine per capacity group. However, a

preliminary routeing choice as part of the order release decision - making it possible to assign the workload contribution of an order to a capacity group - might be reconsidered when the final routeing decision on the shop floor is made.

Moreover, the results show that the different effects on performance mainly depend on the degree of interchangeability. If the degree of interchangeability is high, the 'pooling synergy effect' is the strongest. This implies that the routeing decision should be postponed as long as possible, whereas the thorough balancing of workloads across machines becomes less important. If there is a low degree of interchangeability, it is the other way around. It is possible to take 'early' routeing decisions, as long as workload balancing at order release is supported by distinguishing separate capacity groups.

Elaborating on the different themes has led, as intended, to new knowledge about the applicability of WLC in SMEs and, as a result, the possibilities have been increased to apply this concept in different company environments. The framework, developed in *theme one*, facilitates in a structured way the understanding of the relationships between the production environment and the applicability of WLC. *Theme two* and *three* shed light on fundamental decisions within WLC. These decisions are necessary to attune WLC to specific aspects of JSP. Necessary adaptations to the WLC concept have been developed, and different control alternatives and concomitant performance effects have been discussed in detail. Future research, which will combine theoretical studies (which aim at a good understanding of the mechanisms that influence the applicability of WLC) with empirical studies (which focus on the implementation of WLC), should allow SMEs to further improve their logistical performance.