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Applicability aspects of workload control in job shop production

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Chapter 6 Conclusions

6.1 General conclusions

The main objective of this thesis is to add to the workload control (WLC) concept in order to be better able to cope with several specific characteristics of job shop production (JSP). This objective is pursued by elaborating on *three themes*:

The *first theme*, based on the more general need to explore the applicability of WLC, is set out in Chapter 2. A framework is developed to gain a systematic and quick impression of the applicability of WLC. This framework is especially intended for the earliest selection stage in the introduction of the control concept. Therefore, the framework can be applied without an extensive quantitative analysis of the shop floor characteristics. It is shown in Chapter 2 that the applicability of the WLC concept increases as the variability becomes larger, indicated by increased inter-arrival time fluctuations, due date differences, processing time variability, routing sequence and routing length variability. Also routing flexibility may contribute to the applicability of WLC. It is concluded that, in particular, assembly operations and sequence dependent set up times may cause problems when applying WLC.

The framework has been tested in a medium-sized enterprise, where the potential attractiveness of WLC has been demonstrated as well as the barriers to the introduction of the concept. As an indirect effect, the use of the framework has provided the management of the company with insights in the way in which the shop floor has currently been controlled.

The *second* and *third theme* focus on two specific aspects of JSP environments, briefly described as: (a) the limited possibilities to generate shop floor data, and (b) the interchangeability of machines. The second theme is set out in Chapter 3, the third in the Chapters 4 and 5. The Tables 6.1 and 6.2 sum up the main conclusions with respect to the second and third theme, respectively. This is done in terms of 'implications for WLC decisions' and 'performance implications'. On the one hand an overview of alternative adaptations to the WLC concept ('implications for WLC decisions') is given. On the other hand, the related 'performance implications' are presented, which are based on the simulation studies as described in the Chapters 3 to 5.

Table 6.1 Limited possibilities to generate shop floor data

Implications for WLC decisions	<ul style="list-style-type: none"> ◆ The calculation of workloads per capacity group, necessary to release orders from the pool to the shop floor, has to be adjusted to the availability of shop floor data. Traditional approaches require either feedback after each completed operation, or make no use of order progress information except for the completion of the full orders. The adjustments presented in this thesis are based on the feedback generated when orders move from one production unit (PU) to another.
Performance implications	<ul style="list-style-type: none"> ◆ The use of order progress information per PU leads to large performance improvements compared to the approaches that only make use of the completion moment of full orders to generate shop floor data. ◆ Using additional shop floor data (e.g. by feedback at the end of each operation) rather than feedback per PU leads to marginal performance improvements. ◆ The performance differences between the above discussed alternatives vanish as workload norms become looser.

Table 6.2 Interchangeability of machines

Implications for WLC decisions	<ul style="list-style-type: none"> ◆ Within WLC capacity groups have to be defined to calculate the workloads, which forms the basis of the release decision. At order release, a combination of one workload and one workload norm is considered per capacity group. (Semi-) interchangeable machines allow for alternatives in the formation of capacity groups: several machines can be grouped into the same capacity group, but they can also each be considered as individual capacity groups. ◆ For (semi-)interchangeable machines routing decision rules, i.e. rules that decide on what machine an order will be carried out, have to be embedded into the WLC concept. Particularly, a choice should be made between taking the routing decision at order release (centrally) or at dispatching (locally on the shop floor).
Performance implications	<ul style="list-style-type: none"> ◆ If more capacity groups are distinguished during order release (i.e. less machines are selected per capacity group), then it is possible to balance the workload more precisely among the machines on the shop floor to prevent their over- or underload (balancing effect). The more precisely the workload can be balanced at order release, the better the overall performance that can be realised. ◆ The routing decision should be postponed as long as possible to realise the best performances. This especially holds for highly interchangeable machines. ◆ A larger degree of interchangeability always leads to better performance, independent of the level of workload control. ◆ The balancing effect diminishes as workload norms become looser, which means that a decision on the formation of capacity groups becomes less important.

6.2 Discussion

In this thesis a framework has been developed that allows to perform quick scans with respect to the applicability of WLC. Moreover, it has been demonstrated how to improve shop floor performance by adapting the WLC concept to more specific needs of JSP; control alternatives and performance implications are discussed in detail. This final section provides some guidelines for future research. The guidelines are based on a discussion of the assumptions made in this thesis.

- *Framework*: The framework presented in Chapter 2 is especially designed for gaining a systematic and quick impression of the applicability of WLC during the earliest selection stage in the introduction of a control concept. Future research may focus on the support of later stages in the selection and implementation of a control concept as specified in Chapter 2.
- *Small and medium-sized enterprises (SMEs)*: Chapter 3 elaborates on the limited possibilities to generate shop floor data and the consequences for WLC. Adaptations to WLC release methods are presented, which can handle a limited availability of shop floor data. Future research could focus on coping with inaccurate or delayed shop floor data.
- *Alternative Machines*: The non-interchangeable, semi-interchangeable and completely interchangeable machines modelled in the Chapters 4 and 5 show identical operational characteristics (e.g. operation processing time). Further, the same amount of products has to be operated on each of the alternative machines. Less balanced scenarios (e.g. different operational characteristics or different utilisation of machines) might be more common. Presumably, the type of decisions and alternatives regarding the embedding of these types of machine characteristics into WLC will not substantially change, but the routing and the grouping decision rules themselves will ask for several adaptations.
- *Order release*: Order release is crucial within the WLC concept in order to control the work in progress on the shop floor. Decisions such as order acceptance or capacity adjustments are also facilitated by the WLC concept but not considered within this thesis. However, the aspects of JSP environments described in this thesis, the generation of shop floor data and the interchangeability of machines, might also affect the order acceptance and capacity adjustment decisions within WLC. Analysing those decisions with respect to the specific characteristics of JSP might contribute to the applicability of WLC.

- *Parameter setting*: The simulation experiments, independent from the selected control alternatives, ask for a well-considered setting of the WLC control parameters: especially the workload norms per capacity group influence performance. Even with capacity groups containing only single machines in a pure and balanced job shop, it is not trivial to find ‘good’ workload norms. It becomes even more difficult to find those norms in situations where, for instance, several machines are grouped into a capacity group, and/or the machines show different operational characteristics. This research presents some guidelines on the selection of appropriate norms. However, it is not yet possible to derive the best functioning norms analytically.

WLC is a shop floor control concept that fits in with the requirements of many SMEs in the make-to-order sector. Still, many applicability aspects have to be researched. This thesis provides a starting point. There is a clear need for future research that combines theoretical studies (which aim for a good understanding of the mechanisms that influence the applicability of WLC) with empirical studies (which focus on the implementation of WLC).