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## Design of a period batch control planning system for cellular manufacturing

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## Summary

This study aimed at gaining insight into the main factors that have to be taken into account when designing a planning system for the co-ordination between cells in a cellular manufacturing system. In the last decades, the application of cellular manufacturing systems has become increasingly popular, both in production and service industries. The concept is known under various names: team based production, semi-autonomous groups, group technology, and so on. A change towards cellular manufacturing has important consequences for both the design and organization of the production system (lay-out, technology, and the allocation of tasks, responsibility and authority with respect to the transformation process in the system). However, the transformation process has to be planned and controlled in order to obtain the logistical benefits of a change towards cellular manufacturing. In this study, we investigate the consequences of applying cellular manufacturing for the design of a planning system.

Planning systems are responsible for regulating, co-ordinating, and monitoring the flow of work through the production system. In the past, various developments, internal to the firm as well as external to it, have led to changes in these systems. In Chapter One we described the origins of these developments and outlined eight different factors (e.g., changes in the labour market, demand market, available production technology, information systems, planning theory, and so on). The various origins of these changes led us to expect that the change towards cellular manufacturing would have consequences for planning systems as well. The first research question of this study focused on cell co-ordination characteristics. We focussed on multi-stage cellular manufacturing systems, as these systems will have interrelationships between cells.

In order to be able to examine the consequences for planning systems, we chose to restrict our attention to a well-defined planning system that has been proposed and criticized for its suitability for co-ordinating multi-stage cellular manufacturing systems. This is the *basic unicycle Period Batch Control* (PBC) system. The second research question of this thesis concerned the identification of the main factors that distinguish the basic unicycle Period Batch Control system from other planning concepts in providing support for the co-ordination requirements between cells.

The third research question examined the design choices in the basic unicycle PBC system and the relationship to production system design in greater depth. It was interested in the main choices that should be made when designing such a PBC system and the effect of these design choices on system performance.

We performed five case studies in small-batch metal ware production situations. All firms used a multi-stage cellular manufacturing system in their production of parts, although none used the type of PBC system that we examine in this thesis. We identified the relationships

between the cells and the co-ordination mechanisms that were applied in order to cope with the corresponding co-ordination requirements. We made a distinction between three types of relationships between cells: sequential, simultaneous, and latent relationships. The occurrence of sequential and simultaneous types of relationships can actually be observed. Identification of latent relationships can provide insight into alternative arrangements of the other types of relationships between the cells. This may help to improve system performance.

The essential characteristics of the basic unicycle PBC system that we examined are that it is single cycle, single phase, and uses a single offset time for all work orders. This results in a transparent system with an intermittent but predictable goods flow. The periodic nature of the PBC system enables the cells to perform their own detailed planning, while the overall co-ordination of the flows in the system is being performed by the PBC system.

The effectiveness of such a PBC system depends on a number of design choices. We have identified the length of the period  $P$ , the number of stages  $N$ , the throughput time  $T=N \cdot P$ , the definition of the work orders (contents of the stages), and the batching policy (applying overlapping production between successive operations) as the main design choices in a PBC system. These choices depend on the congruity between the production system structure and the planning system. We provided a mixed integer programming model to support decisions about stage contents and a framework that helps to set suitable stage decoupling points.

Literature on PBC system design does not provide clear support for determining appropriate values for these parameters. In order to be able to measure the effect of these design choices, we mathematically modelled the factors that are important in determining the period length  $P$  and a suitable batching strategy. Heuristic solution approaches were developed that provide support in finding an initial configuration of a PBC system. The characteristics of the production system are partially taken into account in these solution approaches.

We developed a simulation modelling approach in order to determine the effect of various configurations of the PBC system on system performance. Literature had shown that these choices do have an effect on the manufacturing throughput time. Our study investigated whether there would be a significant effect if this manufacturing throughput time remained constant. Our simulation used the data structure of a cellular manufacturing system described in literature, which enabled us to perform some validity checks. The simulation analysis revealed that the main factors that should be taken into account in designing a PBC system are the length of the period, number of stages, and the batching strategy. Even if the total throughput time did not change we found that varying the number of stages and the period length, especially on dependability and costs, had a considerable effect.

Designers of planning systems should consider the effect of these design choices on the logistical performance of systems. We have provided a design procedure aimed at improving the congruity between production system design and planning system design. Our approach enables an explicit trade-off between the various design choices to be made.