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# Worker flexibility in dual resource constrained (DRC) shops

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# CHAPTER 1

# INTRODUCTION

Today's business environment is becoming increasingly uncertain and dynamic. This trend started in the sixties, and has been accelerated by forces such as globalization, advances in technology, and changed market conditions. To survive in such an environment, a growing number of firms is competing on the basis of variety and timing by broadening their product range, reducing delivery times, and introducing new products to market more frequently. To this end, firms should possess flexible resources in order to provide a quick response to market demands.

This thesis is concerned with one specific flexible resource, human flexibility, which is considered to be an effective means of increasing the responsiveness of a production system. In particular, this thesis concerns worker flexibility in dual resource constrained (DRC) systems. In such a system, the number of workstations exceeds the number of workers, and both workstations and workers represent potential constraints on the system production capacity. It also implies that (some) workers need to be cross-trained and worker transfers between machines are necessary. Many researchers have acknowledged the common occurrence of DRC systems (Treleven 1987, Hottenstein and Browman 1998, Felan and Fry 2001, Zavadlav et al. 1996, Bartholdi and Eisenstein 1996, McClain et al. 2000, Hopp et al. 2004 and Inman et al. 2004). In today's dynamic business environment, DRC systems are widely adopted as a means of providing a large variety of products and offering a quick response to market demands.

A cross-trained workforce is believed to offer several benefits to firms. In general, it helps to respond to unexpected and unbalanced workloads. In this way, it reduces manufacturing lead-times, which in turn leads to lower work-in-process inventory levels and better customer service (e.g. Krajewski et al. 1987, Treleven 1989, Malhotra et al. 1993, and Felan and Fry 2001).

The objective of this thesis is to examine a number of worker flexibility issues in DRC systems, including the level of cross training, the degree of chaining, worker deployment rules, and staffing levels. The level of cross training concerns the extent to which workers should be cross-trained. The degree of chaining focuses on how the cross-trained workers should be allocated. Worker deployment rules determine the direction of worker transfers. Staffing levels indicate the level of workstation redundancy. These worker flexibility issues are examined in two different DRC contexts, a parallel shop, and an assembly line.

## 1.1 Worker flexibility issues

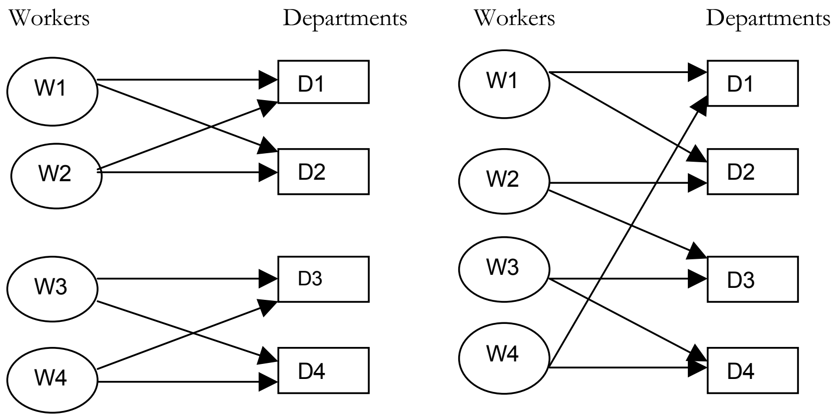
This section elaborates on the two major worker flexibility issues, the level of cross training, and the degree of chaining, which are the main focus of this thesis.

To what extent workers should be cross-trained is the most essential question in worker flexibility decisions. It is widely believed that the increase of cross training improves system performance (Allen 1963, and Treleven 1989). This performance improvement comes at a price. If workers are trained for more stations, they need time to get oriented at new stations, to access information about the job to be performed at the new stations, and to (re-) learn the setup procedures (Malhotra et al.1993, Kher et al.1999, Gunther 1979 and 1981). There seems to be tradeoffs between the benefits of cross training and its associated negative consequences. The optimal level of cross training may be dependent on the magnitude of the impact of these negative consequences.

Chaining is a mathematical concept that originates from graph theory. A chain equals a so-called connected graph. Within the context of a DRC shop, a "chain" can be interpreted as a skill allocation structure, in which a group of workers and workstations are all connected, directly or indirectly, by cross training decisions. Within a chain, a path can be traced from any worker or workstation to any other worker or workstation via the worker and workstation links.

For a better understanding of the chaining concept, an example is given in Figure 1.1. It illustrates two possible ways of skill allocation: (a) two short chains, and (b) one long chain. In the former way, workers are grouped into two subgroups. Within a subgroup, each worker can operate at two workstations, or in other words, workers and workstations are linked together within a subgroup.

However, there is no connection between the two subgroups. In the latter way, each worker maintains a skill overlap with his neighbours. For example, worker 1 can operate at workstations 1 and 2; worker 2, at workstations 2 and 3; worker 3, at workstations 3 and 4; and worker 4, at workstations 4 and 1. In this way, all the workers and workstations are linked together, and form one chain.



(a) Two short chains (b) One long chain

**Figure 1.1 Degree of chaining**

Figure 1.1 also suggests that chaining may have some advantages, in terms of being able to handle fluctuating demands. In configuration (b), workers and workstations are linked to the greatest extent. In fact, all the workers are involved, directly or indirectly, in the case of a sudden rise in demands at any workstation. For example, when workstation 2 is heavily loaded due to an unexpected increase in demands, since workers 4 and 3 cannot work at workstation 2, they cannot participate directly in dealing with the increase of workloads at this particular workstation. However, they may contribute indirectly. Worker 4 may take workloads from worker 1 and worker 3, and worker 3 may take workloads from worker 2, which in turn gives workers 2 and 1 more opportunities to concentrate on the heavily loaded workstation 2. On the contrary, in configuration (a), only workers 1 and 2 will be involved in dealing with the workload increase at workstation 2, whereas workers 3 and 4 cannot participate.

By creating links between workers and workstations, workloads are balanced among workstations through a cascading effect. A chained configuration with limited flexibility was shown to be able to achieve most of the benefits of total flexibility (Jordan and Graves 1995).

## 1.2 DRC contexts

According to the job routing patterns, three different DRC contexts may be distinguished: parallel, job shop, and serial. In a parallel shop, part-types (customers) must visit only one workstation (server) out of a set of non-identical workstations (servers) with different processing times. Each workstation has its own queue of part-types, independent of other workstations. In this way, routings do not contribute to interdependencies among tasks. In a job shop, the number of workstations that a part-type must visit and the order in which they must be visited will differ across part-types. The routing of the jobs thus creates certain interdependency among tasks. Finally, in a serial shop, part-types must visit all workstations in a fixed order (workstation 1, 2, … n), and the job routings generate the most interdependency among tasks. It appears that parallel shops and serial shops represent two extremes of DRC systems in terms of task interdependency, while job shops have a task interdependency level somewhere in between.

Most of previous DRC studies were based on job shops (Treleven 1989). Few studies were based on parallel shops. Nelson (1967 and 1970) and Elvers and Treleven 1985 studied the impact of job routing patterns on the effectiveness of various dispatch rules, and they found out that the rankings of the rules are not significantly affected by the job routings. Hogg et al (1993) examined worker assignment rules in parallel-channel, DRC queuing systems. Jos et al (2004) assess the performance of a group of cross training configurations within three routing structures, a parallel structure, a serial structure, and a job shop structure. Their study indicated that shop contexts have impact on the performance of cross training policies, and thus highlighted the importance of involving contextual factors in worker flexibility decisions.

A number of studies (Hopp et al. 2004 and Inman et al. 2004) addressed worker flexibility issues in serial lines. However, they assumed that two work places are set for one station, and two workers can work at this station at the same time. In fact, a worker has his own home station, and can move to help other workers whenever it is needed. The competition for the available stations is not very intensive. Furthermore, they assumed a big buffer size between stations, which absorbs most of production uncertainties attributable to task time variations. As such, task interdependencies have been largely reduced. As far as we are aware, none of the existing research has addressed worker flexibility issues in a highly task interdependent DRC serial line.

In this thesis, we explore worker flexibility issues in a parallel shop, and in a highly task interdependent DRC assembly line, respectively.

## 1.3 Worker flexibility in a DRC parallel shop

We assume that new part types come into the system at a regular basis, and after being produced for a certain amount, they leave the system. This is represented by an independent variable, part type repetitions, in our study. To be more specific, it refers to the number of lots that are to be produced for a specific part type before it is replaced by a new part type. Each part type will visit only one department once. Workers have to learn production procedures related to the introduction of a new part type, and if they transfer to another department, they start to forget what they have learned about that part type. Furthermore, Workers are different at learning speed. In other words, there are slow and fast learners in the system. First, we examine the impact of part type repetitions and the individual learning patterns on the system performance when workers are trained only for one department, which gives the range of parameters of the model and serves as a base for further analysis. Then we assume that there are only slow learners in the system. Based on this assumption, we investigate how the performance of worker flexibility policies such as the level of cross training and the degree of chaining vary with part type repetitions, in a learning and forgetting environment.

## 1.4 Worker flexibility in a DRC assembly line

In our DRC assembly line, there are more stations than workers. At each station, there is one table, which allows one worker to work on it. The competitions for the shared stations are thus intensive, and one worker may block another one. Between two stations, there is a buffer with size one, which cannot absorb most of the variations in processing time and thus results in high production uncertainties. In such a shop, tasks are highly interdependent. In other words, the execution and outcome of one task affects the execution and outcome of other tasks to a great extent. We argue that, on the one hand, the increase in cross training and chaining may increase assignment opportunities, and workers have less chances of becoming idle. On the other hand, it may increase worker interference, and result in more worker idleness. We examine the effectiveness of the level of cross training, the degree of chaining, worker deployment rule, and station-to-worker ratios. For the evaluation, we use throughput per worker to measure productivity, and we use worker idle rate to explain the differences in throughput.

### 1.5 Overview

This thesis is divided into to two parts: worker flexibility in a DRC parallel shop, and worker flexibility in a DRC assembly line. The first part consists of Chapters 2 and 3, whereas the second part is presented in Chapter 4. Each part mainly consists of three subsections: literature review, methodology, and results. Chapter 5 summarizes the findings of this study, assesses the implications of the research, and concludes with suggestions for further research.