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## Worker flexibility in dual resource constrained (DRC) shops

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## CHAPTER 5

### CONCLUSIONS AND DISCUSSION

The objective of this thesis was to gain insight into worker flexibility issues in DRC environments. A number of issues were addressed: the level of cross training, the degree of chaining, the performance of fast and slow learners, worker deployment rules, and staffing levels. These issues were studied in two DRC contexts, a parallel shop, and an assembly line.

In the following sections, we summarize the research presented in this thesis, consider the implications of the results, and discuss its limitations, and finally, provide suggestions for future research.

#### **5.1 Worker flexibility in a DRC parallel shop**

Our study addressed environmental and human aspects in DRC research. Research in the past has tended to examine worker flexibility issues in a context, in which both environmental and human aspects were mostly neglected.

In the present study, environmental aspects were considered by including the frequency of new product introduction as an independent variable. It is operationalized as the number of part type repetitions in our study. It is defined as the number of jobs being produced, from the moment when a part type is introduced into the system until it withdraws from production. It actually represents the product life cycle of a part type. To involve human aspects, learning and forgetting and the individual differences in the learning patterns have been added to the model as design parameters. By including these parameters to a classic DRC model, the reality of the model has been improved in terms of being more dynamic and involving more human aspects. This may be considered to be a relevant contribution to the literature.

Worker flexibility issues such as the level of cross training and the degree of chaining were then investigated in this improved model. In this way, we could understand how these worker flexibility decisions are related to environmental and human aspects.

### **5.1.1 Level of cross training**

With respect to the level of cross training, our results show that the level of cross training is related to environmental dynamics. In particular, it is better to train workers for more skills in a highly dynamic situation, and conversely, in a more stable situation, it is preferable to train workers for fewer skills. Several factors play a role, i.e., the workload fluctuations in a department, the workload balances among departments, and the learning and forgetting costs.

In a highly dynamic situation, i.e., a small number of part type repetitions, a part type will be produced a few times, and then goes out of the system. Consequently, the workload fluctuations in a department are rather volatile. A high level of skills gives workers more possibilities to move among departments, and as such, provides a quick response to the short-term shifts in workload. Though a high level of skills is accompanied with more costs related to learning and forgetting, it seems that in this case, the benefits of additional worker flexibility offset the negative consequences of the increased learning and forgetting costs. As a result, a high level of cross training outperforms in a highly dynamic situation.

In a more stable situation, i.e. a large number of part type repetition, a part type will be produced many times and then leaves the system. Consequently, the fluctuations in workload in a department will be smoother. However, we assumed that a part type will be assigned to only one department, and therefore, the workload balances among departments becomes an important concern. In such a case, a low level of skills, forming a long chain, seems to be able to shift work from a heavily loaded worker to a lightly loaded worker, and in this way, to redistribute workloads among workers, which in turn leads to a better performance. In addition, a low level of cross training incurs lower costs related to learning and forgetting. In the contrary, a high level of skills seems not to offer extra benefits in terms of balancing workloads among departments, and it is associated with higher costs of learning and forgetting. As a result, a low level of skills performs better than a high level of skills in a more stable situation.

Previous studies indicate that when there are learning and forgetting, it is better to limit the level of cross training to avoid the costs of learning and forgetting (Malhotra et al.1993, Kher et al.1999, and Kannan et al. 2004). These studies did not consider the impact of dynamic factors such as the frequency of new product introduction. Our results show that environmental dynamics may have an important impact on cross training policies. When the environment is highly dynamic, a high level of cross training may be needed to contribute to a better performance. In other words, in a highly dynamic situation, generally skilled workers may be appreciated, whereas in a more stable situation, specialized workers may be more beneficial.

A practical implication of these results is that managers should understand that the optimal level of cross training is to some extent contingent upon environmental dynamics. A high level of cross training may not always lead to a better performance.

Certain limitations of this study need to be acknowledged. We assumed a small parallel shop and did not consider job routing. Future research could test our findings in a more complicated job shop for the purpose of generalization.

We did not study control rules in this study. We only selected several most commonly used control rules as fixed parameters in our model. In particular, we chose the decentralized control as ‘when rule’, the longest-idle-time as ‘who rule’, and the longest queue as ‘where rule’. We believe that control rules that aim at facilitating the learning processes and reducing the chances of interruptions may have the potential to improve system performance. Future research may pay attention to these rules.

### **5.1.2 Degree of chaining**

Concerning the degree of chaining, our results indicate that a long chain is always better than short chains. However, the relative advantages of a long chain seem to be strongly related to the degree of environmental dynamics. The relative performance of the short chain configuration versus the long chain configuration presents a U-shape. A long chain is much better in either a highly dynamic or a more stable environment, whereas in an environment in between, its relative advantages decrease to some extent.

As indicated earlier, in a highly dynamic environment, there exist rapid shifts in workload in a department, while in a more stable situation there are more

unbalanced workloads among departments. It seems that these two situations have a higher demand for worker flexibility, and a long chain seem to suit this need better.

The benefits of chaining have proved by many previous studies (Jordan and Graves 1995, Brusco and Johns 1998, Sheikhzadeh et al. 1998, Bokhorst and Slomp 2000, and Slomp and Molleman 2002). Our study contributes to the literature by examining its effectiveness in a variety of dynamic environments. The results suggest that chaining performs well also in a learning and forgetting situation, though the relative advantages of chaining may vary with the degree of environmental dynamics.

The U-shape of short chains implies that learning and forgetting most likely do not have dominant influences on the relative performance between a long chain and short chains. To isolate the effect of learning and forgetting, future research may need first to examine the effectiveness of chaining in a dynamic situation without learning and forgetting, and afterwards, including learning and forgetting to compare the differences. In this way, how learning and forgetting affect the performance of chaining may be better elaborated. We expect that short chains may perform better in a more dynamic situation due to the less interruptions in learning processes. If it is true, the left side of the U-shape will go down and become lower than the right side.

### **5.2 Worker flexibility in a DRC assembly line**

Our study addresses worker flexibility issues in a context, in which tasks are highly interdependent. In particular, we assumed an assembly line, in which there are more stations than machines, there is one assembly table for one station, and there is one small buffer between stations. Due to the constraints in resources, when workers are cross-trained and sharing stations, they may interfere with each other whereby causing starving and blocking, and in turn deteriorate system performance. Our study was based upon a real life case in a Dutch manufacturing firm (Kalk 2005, and van. den. Brink 2005).

Most of DRC research in the past examined worker flexibility issues in a different context, in which tasks are less interdependent due to resource duplications and bigger buffer sizes. Due to the less intensive competition for the shared resources, the increase in cross training and chaining is always helpful

in alleviating bottlenecks and therefore contributes to the improvement in performance.

Our study contributes to the literature by examining worker flexibility issues in a highly task interdependent context, in which the existing findings may not hold for anymore. This research has attempted to illustrate the link between worker flexibility policies and the properties of the context, and that the effectiveness of worker flexibility policies may be contingent upon the degree of task interdependence.

Our results indicate that in a highly task interdependent context, cross training and chaining may entail some negative consequences, such as starving, product blocking, and worker blocking, which in turn counteract their benefits.

Our results show that in a DRC assembly line, as the level of cross training increases, system performance improves in terms of the increase in throughput, the decrease in worker idle rates, and the increase in the number of worker transfers. However, though there are differences in performance between the different levels of cross training, a minimal level of cross training seems sufficient in terms of being able to achieve the most of the benefits of full flexibility.

The impact of chaining on throughput performance seems to be contingent upon the level of skill overlaps. For one skill overlap, a long chain may be valuable, but for multiple skill overlaps, short chains may be preferable. It can be explained as follows.

When there is one skill overlap, in a long chain, each worker forms one skill overlap with his downstream neighbour. This helps to bring products down the line. In our assembly line, workers upstream suffer more from product blocking, while workers downstream experience more starving. When products move more smoothly down the line, both product blocking and starving are alleviated and workers have less chances of becoming idle. In contrary, when are two short chains, one skill overlap between two neighbouring workers is missing in the middle of the line. Products cannot move as smoothly as in the case of a long chain, which results in a higher product blocking and starving rates. Furthermore, in a long chain, more workers are involved in the competitions for the shared stations, which causes more worker blocking. Overall, the decrease in product blocking and starving offsets the increase in worker blocking. This explains that when there is one skill overlap, a long chain gives a better throughput performance.

## Conclusions and discussion

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When there are multiple skill overlaps, in a long chain, more workers share a number of stations as compared with short chains. These workers may work subsequently next to each other, and by the time they complete their tasks, the finished products may not be able to move down the line immediately, which drives up product blocking substantially, especially for the upstream stations. In addition, a long chain has higher worker blocking rates. This explains that when there are multiple skill overlaps, a long chain has a worse throughput performance.

In contrast, the impact of chaining on the number of worker transfers seems not to be dependent upon the level of skill overlaps. A long chain always has a higher number of worker transfers, whereas short chains have a lower number of worker transfers, regardless of the level of skill overlaps. In a long chain, a worker is linked with more workers, his neighbours may move away to their own territories, and as a result, he has more options to move around and realizes more transfers.

A DRC assembly line seems to perform better at a relative high WIP level, which is influenced by the worker deployment rule that puts its priority upstream. If a DRC assembly line has a low WIP level, workers may easily suffer from starving. In such a case, when a product appears on the shared the stations, the starved workers will compete for the only job opportunity, and as a result, one worker gets the job, while others become idle. In other words, starving may drive up worker blocking. This explains that why a DRC assembly line performs better under the worker deployment rule, which aims to create a higher WIP level. However, there is one exception. When workers are trained for the minimal level of skills, and there is no skill overlap, deployment rules do not make any differences in performance due to the limitations in the assignment options.

In general, system performance deteriorates with the decrease of station-to-worker ratio. It implies that as the line gets more crowded, workers interfere more with each other, which eventually drives up worker idle rates.

The impact of worker deployment rules diminishes with the decrease of station-to-worker ratio, as there are less available stations for a worker to choose.

Our findings contribute to team theory by elaborating task interdependence in a DRC assembly line. It is established in the previous literature that task interdependence is affected by shop layout. Our results indicate that chaining, by

involving more workers in the sharing of stations, increases task interdependency, and causes workers blocking each other more frequently.

Our results suggest that managers should understand the relationship between worker flexibility policies and the context in which they operate. In a highly task interdependent situation, the increase in cross training and chaining may not automatically contribute to a better performance. To benefit from cross training and chaining, and to avoid the possibly negative consequences such as starving, product blocking, and worker blocking, the creation of intelligent control rules is desirable, which serves as one of the directions for future research.

In our study, workers may become idle because of three reasons: starving, product blocking, and worker blocking. We believe that these three causes may have different impact on worker stress and frustration. Future research may pay more attention to how workers react to each of these situations.

In a highly dynamic business environment, DRC shops and worker flexibility are widely adopted as an effective means of competition in the market. This research has demonstrated that though worker flexibility is proved to be beneficial in most of the cases, it is most likely not a universal solution and its effectiveness may depend on context.