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Cross-training policies for team cost and robustness

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ABSTRACT

We assess alternative cross-training policies for work-teams considering cost, and levels of cross training. The policies are assessed with respect to their robustness to demand-mix variation and absenteeism coverage. We employ simulation to examine instances where cross training can be used to help meet a fixed demand scenario, and with instances where cross-training can help to meet demand mix variability. Current results indicate that when minimizing cross-training costs, policies related to equalizing the cross-training level among the workforce, may provide improvement in terms of robustness without additional cost. We also assess the effects of some environmental factors, demand mix-coverage, absenteeism coverage, and job-task correlation.

1. Introduction

It is unusual for work units to have known, constant work requirements over anything more than trivially short time horizons. More often demand is uncertain and work teams must be flexible to adapt to these variations. Cross-training is commonly cited means for coping with variable requirements and uncertainties in multi task dynamic work environments. In general, higher levels of cross-training have been shown to create greater flexibility, which is in turn necessary to address demand variability (Easton, 2011). But cross-training generally involves significant costs and consequently, one must be cautious in implementation to avoid overtraining. That is, too much cross training has been shown to lead to performance losses (e.g., Hopp & Van Oyen, 2004). Because of this non-monotone response to additional training, the literature has presented a range of cross-training policies to moderate the relationship between cross-training levels and demand variability.

In attempting to balance the costs and benefits of cross training, there are generally multiple competing objectives that one might consider including job enrichment, worker health and safety, motivating the workforce, and flexibility to deal with absent workers (Bokhorst & Slomp, 2007). However, training costs, learning, cognitive load, scheduling, and demand, all create challenges and add complexity to the decision making process. Determining an appropriate cross-training level for an organization should ideally consider all such relevant issues. In this paper, we focus our efforts on identifying low cost cross-training policies and the robustness of those policies with respect meeting levels of *Demand-Mix Coverage* (DMC) and *Absenteeism Coverage* (AC). We will address instances where cross-training is intended to meet *Fixed Demand* (FD), AC, and DMC along with several environmental variables.

The literature has directly considered the problem of obtaining appropriate cross-training levels under conditions of certainty. For instance, Brusco and Johns (1998) considered several potential cross-training policies in the maintenance service of a paper mill factory, concluding that a skill chaining policy has the ability to aid in workload balancing. Jordan, Inman, and Blumenfeld (2004) conducted several experiments to show that complete skill-chains (i.e., chains that taken together create worker redundancy for all tasks), are critically important, and without which performance may be significantly degraded.

Other research has considered a broader perspective by considering a range of cost factors, including Agnihothri and Mishra (2004) who examined an equipment repair service, wherein travel time and downtime cost were considered. Historical data were used to forecast future requirements. They concluded that full cross-training is sometimes the most cost effective policy in field service operations. Noting that cross training need not be a one-size-fits-all endeavor, Chakravarthy and Agnihothri (2005) modeled the mix between specialist and generalist workers in a service system with two clients and stochastic demand. Also,

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Wirojanagud, Gel, Fowler, and Cardy (2007) considered a semiconductor manufacturing industry in which all workers must be cross-trained.

The consideration of demand coverage has also been considered in some domain specific contexts such as computer science (e.g., Giannikos, 2010), transportation (e.g., Fei & Mahmassani, 2011) and hospitals (Gnanlet & Gilland, 2014a,b). Policies that provide significant outcome flexibility with a limited additional resource flexibility have been reported. Chaining strategies, applied to production lines, have provided outcome flexibility not far from the maximum, with limited cross-training levels (Brusco & Johns, 1998). A *D*-skill chaining pattern assigns workers to *D* adjacent stations. The broader benefits of skill chaining in serial production lines has also been analyzed by Hopp, Tekin, and Oyen (2004). Gong, Wang, and Zhang (2011) studied a U-shaped line, staffed with skill-chained workers with absenteeism, and proposed a policy for cross-training, wherein workloads are balanced by only cross-training them on certain stations. Overall, with modest capacity imbalance and significant variability, the strategies based on skill chaining are particularly robust.

Advantages have also been found in dedicated-specialization schemas, in which some workers have been cross-trained on few to no tasks, and others are highly cross-trained. The so-called cherry-picking strategy assigns workers with excess resource capacity to other workstations to improve line balance with a minimum amount of cross-training (Tekin, Hopp, & van Oyen, 2002). In the current study, we similarly consider absenteeism in the context of cross-training policies, and examine several policies related to cherry-picking approaches, for systems with demand-mix requirements that must be fulfilled in order to examine the issue of robustness across several cross training policies.

We note that when the variability of demand and absences are not taken into account, the value of cross-training policies based on minimum levels of variability may tend to be overestimated, as the tradeoffs between the costs and benefits of additional capacity are not fully explored. For example, Easton (2014) showed that when ignoring the joint variability of attendance and demand, workforce-scheduling models tend to overstate the benefits of cross-training. The current work extends these perspectives by considering alternative team cross-training policies that include both costs and levels of cross training. The policies are assessed with respect to their robustness to demand-mix variation and absenteeism exceeds the forecasts. We posit that this approach corresponds to real needs in defining cross-training and, has not been previously dealt with in the literature.

The main gap in the literature is in investigating how various policies behave in terms of robustness to variations in demand and variations in the workforce. The literature suggests that effects of cross-training policy on meeting uncertain demand depends on context (e.g., Nembhard & Prichanont, 2007). Since our focus is on the robustness of such policies, we will consider straightforward versions of each of the three main types that we consider, and also consider some combined policies in the context of addressing questions of robustness to demand and workforce variation. There have been several studies that have investigated specific contexts. However, it is not known how robust such policies are. For instance, what are the implications of potentially employing a set policy more broadly? Alternately, there are a number of cross training policies that have been put forward in the literature. How generally can such policies be applied across other conditions? The current study presents an approach for addressing these questions, and examines these questions for several specific policies.

To test the dependence on the context of the particular effects analyzed, two environmental factors affecting the relation between cross-training and demand coverture will be considered. The first factor measures the similarity between the tasks to be performed to complete the different jobs. The second factor takes into account the level of demand variability that must be met.

In the remainder of this paper, we present our methodology for policy evaluation in Section 2, followed by the corresponding results and discussion in Section 3. Section 4 concludes the paper with overall findings, limitations, and future research directions.

2. Methodology

The objective of this paper is to assess alternative cross-training policies for a work-team. Cost, equal cross-training, specialized workers and combinations of these policies are considered in scenarios where we use cross-training to first deal with fixed demand, FD and absenteeism coverage, AC, and then secondly to jointly consider demand-mix-coverage, DMC and absenteeism coverage.

To motivate our choice of policies for consideration, we consider broadly, the three main types of policies in the literature, namely, those taking a cost perspective, those directly modulating the cross training level itself, and those considering the workers' perspective. The literature has often focused on addressing questions related to the most effective levels of cross training, across the range, from full specialization to full cross training. For example, Nembhard and Prichanont (2007) show that full cross training imposes a cost that may not be fully recouped by increased flexibility. Similarly, others including van Oyen, Van Gel, and Hopp (2001), Gnanlet and Gilland (2014a,b), Paul and Macdonald (2014), Yang and Gao (2016) have suggested training cost minimization as a possibly valuable approach. Yet, the vast legacy of workforce scheduling suggests specialization as a key policy. This has been directly addressed as a policy choice as well, and may be beneficial in a number of scenarios (e.g., Nembhard and Prichanont (2007)). Another further stream of work focuses more on policies from the workers' perspective, where, for example, an equitable distribution of cross training may be more palatable to the workforce (see e.g., Schwab & Büke, 2014).

Since our focus is on the robustness of such policies, we will consider straightforward versions of each of the three main types that we consider, and also consider some combined policies in the context of addressing questions of robustness to demand and workforce variation.

We note that a full cross-training scenario, in which all workers cross-trained on all tasks exists but is not particularly common in practice, particularly for large work centers, and/or difficult tasks, though it may be practical for smaller work teams or organizations with more limited task sets. There are certainly work teams for which full cross-training is unreasonable. This is most notably the case for high knowledge intensity settings such as airline crews, or surgical teams. Nonetheless, we consider the potential for full cross-training at the other end of this spectrum, where there may be many relatively simple tasks. That is, cases where initial qualification and position allows workers to perform any of the tasks assigned to the team are also numerous, both in manufacturing and service settings. We will also assume that no particular resource constraints will apply, and consequently, the only condition to cover certain demand is that the workers have time enough to complete the tasks.

We consider five cross-training policies to include:

(A) *Minimize cost*, the cross training cost based on the total number of tasks for which workers are trained, with an assumed constant cost across tasks.