Cross Training in Serial Production With Process Characteristics and Operational Factors

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Abstract—**Worker multifunctionality has been recognized as a tool for enhancing system flexibility and performance. This paper investigates the impacts of worker multifunctionality in a heterogeneous serial production system in the presence of individual differences in experiential learning and forgetting. The tradeoffs of multifunctionality and cross training are examined in conjunction with several process characteristics and operational decisions including staffing level, system bottleneck position, task similarity degree, and worker rotation interval. The results show the relationships between the preferred level of worker multifunctionality and both process characteristics and operational decisions. In several cases, minimum multifunctionality and short worker rotation intervals provide improved system performance. Additionally, process characteristics, such as the position of the system bottleneck and the degree of task similarity, have impacts on individual learning–forgetting behaviors and, subsequently, on decisions relating to multifunctionality levels and system performance.**

Index Terms—**Cross training, experiential learning, forgetting, multifunctionality, productivity, simulation, worker heterogeneity.**

I. Introduction

IN ORDER to meet the challenges of worldwide competitiveness, organizations must be able to provide products and services with equal or better value than their competitors. Moreover, there is a need to respond rapidly and effectively to the changes in the marketplace. As product life-cycles shorten, production systems must be able to effectively operate and switch among different types of products. Many organizations are moving toward greater flexibility in all the stages of production in order to provide the customers with greater product variety in less time. Creating a multifunctional workforce is one response to form a flexible organization in order to meet these market challenges.

Introducing worker multifunctionality (also referred to as cross training) may act as a buffer against uncertainties and the variation in workforce supply such as an increase in the rate of periodic product revision, absenteeism, and job rotation [1], [17], [26], [27], [31], [32]. From the managerial perspective, various concerns arise from the potential lost output and increased training costs when workers operate on multiple workstations and spend significant time in the learning process. Several researchers have illustrated the importance of empirical investigation of learning and forgetting distributions (e.g., [14], [21], and [26]). However, quantitative studies of multifunctionality and crosstraining incorporating individual learning and forgetting behaviors are relatively sparse. Several studies have been based on individual steady-state performance, where workers maintain a constant productivity level over time. Another stream of work has been based on assumed experimental conditions of learning and/or forgetting at an organizational level, where all the workers on the shop floor have the same performance level (e.g., [12], [13], [15], and [17]).

In this paper, we use a heterogeneous workforce based on an empirically determined distribution of learning and forgetting in manufacturing to study the effects of worker multifunctionality in conjunction with several process characteristics and operating decisions in flow-line systems. This research aims to provide information to managers and researchers to mitigate productivity losses due to frequent task learning, and to better understand how multifunctionality affects system performance in a dynamic workplace. More specifically, this will inform managers in setting worker multifunctionality levels and correspondingly, cross-training levels based on several important process characteristics. Section II provides a review of previous related studies beginning with studies of worker multifunctionality based on individual steady-state performance (i.e., no learning–forgetting effect), followed by a discussion of studies of workforce multifunctionality with learning and forgetting.

II. Previous Research

The subject of creating a multiskilled workforce has been extensively investigated in the traditional manufacturing job shop environment, based on the assumption of steady-state productivity (e.g., [18], [24], [25], [27], and [28]). In a job shop constrained by both workers and machines, Molleman and Slomp [18] suggested that the distribution of redundancy and the distribution of multifunctionality had significant impacts on the product makespan and the total production time, where *redundancy* refers to the number of workers capable of performing a task, and *multifunctionality* refers to the number of tasks for which each worker is trained. Their finding indicated that introducing worker redundancy helped to decrease the negative impact of system variation such as worker absenteeism. Moreover, their paper showed that uniform skill distribution, where all workers are equally trained on the same number of tasks, resulted in shorter product makespan.

The benefit of uniform skill distribution becomes more significant when absenteeism is high. With variation in worker absenteeism and demand, Slomp and Molleman [27], [28] examined the effects of cross-training policies on team performance,

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