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Modeling the benefits of cross-training to address the nursing shortage

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ABSTRACT

This paper seeks to offer insight into cross training strategies that could be effective in aiding in alleviating the nurse shortage issue and its potential to negatively impact on patient safety and mortality. We develop optimization models to evaluate the benefits of cross-training, in particular chaining practices, on nurse workforce planning under stochastic demand, and determine the optimal allocation of both regular and cross-trained staff at a minimum cost. We demonstrate the benefits of cross-training in terms of a reduction in the total number of nurses required to satisfy demand across multiple departments as well as from an economic (i.e. overall cost savings) perspective, while simultaneously meeting the hospitals service and quality of care requirements. In particular, the results indicate that cross-training strategies could help with optimal utilization of constrained nursing resources and thereby limit the negative implications of the growing nurse shortage crisis.

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1. Introduction

The United States is facing a severe shortage of nurses due to supply side issues. It is projected that by 2020, this number will be approximately 808,000 in terms of registered nurses (Buerhaus et al. 2009). This issue has resulted in patient safety concerns and affected the hospital staff's ability to detect complications in patients, potentially leading to increased patient death rates (Aiken et al., 2002; Stanton, 2004). Research has shown that hospitals with higher nurse to patient ratios have better outcomes in terms of quality of care, patient safety, mortality, etc. (Aiken et al., 2010; Needleman et al., 2006; Stone et al., 2007). Some states have even mandated ratios, which vary based on the hospital department (IHSP, 2001). While there is some evidence to support enforcing specific nurse to patient ratios (Aiken et al., 2010), this is an extreme measure in terms of controlling the planning and deployment of nursing resources and may exacerbate the nursing shortage (Paul and MacDonald, 2013). As well, such a strategy assumes that demand for services and the supply of nurse resources in a hospital behaves in a linear manner, when in fact it is very complex and dynamic in nature (Clancy, 2007).

The effective use of available resources is possible through an accurate estimation of demand at each of these complex units. However, given the nursing shortages observed across hospitals in the US (Domagala and Rowles, 2002; Sarudi, 2000; Hacket et al., 1989), it might not be possible to always have enough supply to meet this demand. One way to mitigate this issue is via cross-training of nurses (Grandinetti, 2000; Tzirides et al., 1991; Wheaton, 1996; Snyder and Nethersole-Chong, 1999). In this paper, we focus on developing optimization models to evaluate the benefits of cross-training, in particular chaining practices (Jordan and Graves, 1995), on nurse workforce planning within a multi-department setup.

Through the optimization models we evaluate total staffing across departments, and determine the optimal allocation of both regular and cross-trained staff at a minimum cost. Further, we consider practical limitations including constraints on total available resources as well as minimum quality as a function of experience levels (worker heterogeneity), demand variability and patient service levels. Finally, given the limitations of exact analytical methods in evaluating the benefits of cross-training policies, we develop an evolutionary optimization based heuristic that yields time efficient high quality solutions regardless of the problem size. Realistic examples featuring Emergency and Surgery Departments demonstrate that when there were no constraints on the maximum number of nurses, cross-training resulted in a lower total number of nurses required for achieving departmental service goals. When such a constraint was imposed, we found that both departments achieved both higher s ervice levels and overall cost savings when cross-training was implemented. Our analysis confirmed that these results hold regardless of the distribution that described the nursing demand. Further, we were able to confirm the directional nature of the above policy implications within a multi-department setup.

2. Literature review

The primary focus of this paper is on evaluating the benefits of cross-training as it applies to hospital settings, which forms the motivation for the extant literature discussed below. First, we

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discuss the generic cross-training literature and then present research specifically related to various hospital departments.

Cross-training is basically a process of determining the skill patterns of a workforce. The skill pattern can range from an extreme, wherein all workers are capable of performing all the tasks involved, to one where each worker is specialized to do only one task. The first scenario is generally referred to as full cross-training whereas the second one is a case of no cross-training. There are also intermediate policies such as chaining (Jordan and Graves, 1995), wherein each worker could have one or more other skills, in addition to their normal skill set that he or she would use for their home department. In this study, we evaluate the benefits of chaining policies in both a two and multi-department setting.

The popularity of cross-training policies stems from its ability to provide flexibility to an organization's workforce. However, it has been shown that this flexibility may be expensive and difficult to maintain (Hopp and Van Oyen, 2004; Inman et al., 2004). Further, cross-trained personnel might not be as efficient as a dedicated workforce. For instance, Karuppan (2006) showed that there is a decrease in the productivity and quality of output when using cross-training. This decrease is attributed to cross-trained workers not being able to exercise or practice their skills as often, and thus causing them to forget basic skills related to their additional tasks. Similar findings have been reported by Chakravarthy and Agnihothri (2005), who show that a slide in the relative efficiency of cross-trained workers when compared to dedicated staff may negate the benefits of a flexible cross-trained workforce. However, in a recent study, Easton (2011), using a two stage stochastic model, presented some new and different results from a cross-training perspective when compared to the prior literature. For example, they demonstrate that cross-training often leads to improved performance when compared to dedicated specialists. In scenarios wherein the cross-trained workforce was less efficient than dedicated specialists, they found that increased cross-training resulted in trade-offs between capacity (i.e. workers with the required skills to meet a specific type of demand) shortages and workforce size, where work force size represents the total number of workers irrespective of their skills.

It should be noted that some of the above experiences presented in the literature that preceded Easton (2011) may not apply in a hospital setting, as the underlying uncertainty is considerably higher than what is experienced in manufacturing or other non-hospital environments. This comparatively smaller uncertainty in non-hospital environments could also explain reduced opportunities for workers to practice their additional skills. Further, the experiences in hospitals who have implemented cross-training policies are similar to the findings presented in Easton (2011). This is evident from the extant literature on cross-training policies applied in hospital environments. For instance, it has been reported that cross-training can improve the quality of care, often by mitigating the impacts of uncertain patient arrivals and absenteeism, by reducing the need for temporary staffing while still maintaining service levels (Inman et al., 2005). In one of the earliest papers, Tzirides et al. (1991) recommend implementing flex teams involving related hospital departments in order to handle random patient census. Wheaton (1996) reports on a successful cross-training program for nurses in the Neuro-critical care unit of the ICU of a particular hospital. Similarly, Snyder and Nethersole-Chong (1999) report on cross-training surgical nurses for the ICU, which not only reduced overtime in the ICU but also boosted morale across the units. Grandinetti (2000) studied care teams, which included implementations of cross-training to, in part, improve staff flexibility. A recent paper that aimed to address the nursing shortage is that of Wright and Bretthauer (2010). The authors focus on scheduling flexibility and efficient use of available nursing resources, which included creating a pool of cross-trained nurses. Their research showed that coordination across departments in implementing flexible scheduling could reduce labor costs as well as overtime and undesirable staff schedules.

However, though there exists literature on the application of cross-training across different hospital departments as detailed above, most do not evaluate the impacts or attempt to model or determine the levels of cross-training. One exception is the paper by Inman et al. (2005), in which the authors used simulations to model different cross-training strategies, such as reciprocal pairs and chaining, to determine the impact on costs resulting from absenteeism and random patient census. In addition, Gnanlet and Gilland (2009) developed a two-stage stochastic programming model to find the optimal level of cross-training and allocation of beds for a pair of hospital units that face random patient census and the resulting demand.

In this paper, given uncertain demand, we determine the optimal allocation of both regular and cross-trained staff to minimize cost considering practical limitations, including constraints on total available resources, while maintaining minimum quality (worker heterogeneity) and patient service levels. Our models extend the literature (for example, Campbell, 1999, Inman et al., 2005) on the effect of demand variability on expected shortage levels and optimal staff allocation decisions by being capable of handling various probability distributions in addition to the normal distribution, as well as incorporating the impacts of the costs of cross-training and temporary staffing. The motivation for inclusion of worker heterogeneity in our models, in addition to its impact on staff costs, is the significant influence it has on productivity rates when considering cross-training policies, as these policies have been shown to have a greater benefit when applied to the best subset of workers (Jordan et al., 2004; Kim and Nembhard, 2010). Similarly, our models consider service levels in our analysis as it not only impacts the number of nurses from a cost and service goals perspective, but also because it has been shown that return on cross-training declines rapidly as customer service levels increase (Robbins et al., 2007). Our models, by considering worker heterogeneity in addition to demand variability, service levels and resource costs, contributes to the general worker productivity related cross-training literature (for example, Brusco and Johns, 1998). Further, the models developed are capable of studying the impact of cross-training on nurse workforce planning in both simple two and multi-department environments. Finally, we develop an evolutionary optimization based heuristic that yields time efficient high quality solutions regardless of the problem size.

3. Methodology

The goal of the proposed model is to evaluate staffing policies for nurses across departments with cross-training. Specifically, we study the chaining problem for two and multi-department setups. The simple two department case is equivalent to full cross-training; however the multi-department setup would be one wherein the first department has cross-trained nurses for the second, the second has cross-trained staff for the third and so on, with the last department in the chain having nurses that are cross-trained for the department at the start of the chain. The rationale behind considering this particular chaining arrangement is that given the complexity of nursing duties within a given department, cross-training across more than two departments is unlikely. This is a valid assumption based on our discussions with hospital staff and evidence available in the extant literature on the disadvantages resulting from excessive cross-training (Inman et al., 2005). Further, this type of chaining has been demonstrated to be cost efficient (Inman et al., 2005). Several key aspects of the staffing problem such as costs, service levels, quality, and constraints on available staff are considered. Before elaborating on the model, we present the following notation in Table 1.

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