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Cross-Training Depth and Patient Flow Efficiency: A Stochastic Frontier Analysis of Emergency Departments

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Abstract
This paper examines the relationship between cross-training and patient flow efficiency in emergency department (ED). The paper addresses the issue of enhancing the patient management and ED output with the deeper cross-training of healthcare personnel. It was a cross-sectional study and the mixed-methods approach where both the qualitative and quantitative data were used. Stochastic Frontier Analysis (SFA) established the relationship between the depth in cross training and the efficiency of the flow of patients. Information on 12 months on 15 U.S. EDs in hospitals was used with 1,200 patients' cases studied. The level of cross-training was quantified by the number of roles by which healthcare professionals were trained whereas the efficiency of the patient flow was evaluated with the key performance indicators such as wait times and throughput. The findings indicated that the deeper cross-training, the better the flow of patients within a given ED (beta = 0.25, $p < 0.05$). This paper will bring out the operational advantages of cross training implying that more versatile staffing may lead to an improvement in patient flow. Researchers can study in the future the way in which training cross-patient effects can be longer lasting regarding patient outcomes. Such results provide useful information in enhancing ED operations using cross-training.

Keywords: *Stochastic Frontier Analysis, Flow, The Efficiency of Patients, Cross-Training, The Operations of Healthcare, Emergency Departments.*

Introduction

Emergency departments (EDs) form the essential parts of healthcare systems, and their mandate is to provide urgent medical care to their patients, who usually need urgent care. Nevertheless, EDs across the world are suffering major problems in handling the large number of patients using lean resources. The fact that the number of patients has been growing continuously, and the number of workforce and poor infrastructure are inefficient in-patient care. Slow turnaround times, wait times, and inappropriate staffing are some of the factors which work against the patient experience and the clinical outcomes performance. These issues have even been compounded by the worldwide surge in demand of emergency healthcare because of reasons like aging populations, and even the rising burden of chronic health issues (Benson & Gray, 2021). Cross-training is one of the possible solutions that can help to address these problems as it is a practice of training healthcare professionals to do many jobs in the ED. Cross-training has the potential to increase flexibility in operations, resource allocation, and eventually mitigate cases of bottlenecks in the patient care through imparting staff with skills that can cover a myriad of tasks.

Although cross-training may be leveraged to achieve positive effects, the findings in relation to connecting cross-training practices to the efficiency of ED are significantly absent empirically. Available literature on ED performance has concentrated largely on the number of staffing, process efforts or introduction of technology, but not much has been written on the direct effect of cross-training depth on efficiency of flow in patients. The study conducted by Kuo et al. (2020) discussed the strategies of workforce management in EDs and focused on the resource use but did not cover the effect of cross-training on the processes of engaging patients in care. Benson and Gray (2021) place their studies of staffing practices in EDs and operational readiness in a slightly different context since they are more concerned with staffing concentration, more than with cross training. Patel et al. (2021) provided the information on resource allocation strategies, such as staff optimization but did not directly evaluate the quality of cross-training and its contribution to patient flow enhancement. Our research can be seen as a chance to fill that gap to better understand how cross-training depth (i.e. how many functions ED staff can perform) could affect the efficiency of patient flow with regards to wait time and throughput and the effectiveness of care delivery in general.

The analysis of the current study falls under the framework of resource orchestration theory (Helfat & Peteraf, 2003) that holds that organizations (or firms) would be abto do a better job at realizing more efficiency in their operation by balancing and in some cases maximizing the utilization of human capital. Applied to the theme of healthcare, this theory implies that the idea of improving cross-training can enhance the utilization of healthcare professionals so that they could be more controlled and more effectively allocated as a resource. With the capability to assume many different roles, ED staff can become more dynamic and enable hospitals to respond to the varying patient levels of requirement and minimize patient care delays. The concept of cross-training, therefore, may be interpreted as the measure of achieving enhanced flexibility and capacity of workforce, which results in the enhancement of the patient flow management. The perspective of resource orchestration also underscores the strategic resource management as being key to the realisation of efficiency within an organisation thus, it is the best framework to evaluate the possible advantage of cross-training in EDs.

Hypotheses:

H1: The deeper the cross-training in the field of work, the higher the efficiency of the patient flow in emergency departments. The premise of this hypothesis is that as cross-training of staff members is conducted on as diverse tasks as possible, there is the potential to cope more readily with patient volume and patient requests, and deal more efficiently with the patient flow.

The second hypothesis (H2) is that patients in cross-trained EDs wait less and have increased throughput. Cross-training may also eliminate (or at least minimize) patient bottlenecks, by making the staff more versatile and able to work across all roles. Wait times may be reduced, and patients accommodated per a given unit of time are increased, improving the throughput in the ED.

This element can help healthcare providers overcome the increasing strains on emergency provision through the introduction of the concept of cross-training programs in EDs. This is not just an answer to the demand of flexibility within a highly not very predictable environment, but also a chance to enhance the general efficiency of operations and patient care. With healthcare systems the world over struggling to adequately deal with the rising number of patients, the need

to learn how the concept of cross-training may be used to improve the efficiency of EDs may be one of the key steps in streamlining the delivery of emergency care. In such a way, the current study manages to address the research gap due to a systematic examination of the impacts of cross-training depth on the efficiency of patient flows in EDs, and it also offers profound insights to practitioners and researchers in healthcare operations management.

Literature Review

Cross-training depth: Cross- training depth can be viewed as how many tasks different employees can be trained to do in the event of an emergency department (ED). These may vary in complexity like simple task like triaging or reception patients to diagnosing treatment or administration tasks. The level of cross-training diversity in EDs is inconsistent across organizations based on their priorities, the resources available, and the role of the staff. Through cross-training, employees are able to change roles when required, which has the potential to streamline flexibility and help prevent clogs, especially during busy periods where the patient flow is high (Patel et al., 2021). Cross-trained staff proves to be more effective than others in discharging the dynamic and unstable character of ED workflows and hence, is an excellent tool in enhancing efficiency of operations.

Efficiency of patient flow: Patient flow efficiency is one of the required EDs performance indicators. It denotes the capacity of an ED to cater to and handle patients in a swift and seamless manner, through different phases of care management, that range between initial evaluation, triage, treatment, and release. Wait time, throughput/ number of patients served over a certain period, and the discharge time are the significant metrics employed in the measurement of patient flow efficiency. Minimizing the wait time and maximizing throughput are the main objectives of patient flow improvement in EDs as better patient satisfaction and quality of care are related to these articles (Benson & Gray, 2021). The effective movement of patients does not only maximize the use of resources, but it also eliminates the risk of overcrowding and the delays thereof, both of which may lead to worse clinical outcomes.

Hypothesis Derivation

Cross-training has been highly considered to be a strategy that aids in increasing the flexibility found in ED staffs and this is important in highly fast paced settings where patients are unpredictable in flow. Mass casualty incidents or seasonal increases in the number of patients can lead to limitation of staffing resources in EDs. Such multitasking employees can, in turn, cut down the waiting periods and enhance the service effectiveness within such stressful environments as those described above (Patel et al., 2021).

The studies confirm that the higher staff versatility enhances the flow of patients. According to a study by Kuo et al. (2020), cross-trained EDs showed the possibility of responding to fluctuating patient seats in case of limited resources. EDs will be able to process patients better with this responsiveness which in turn reduces the waiting time and augments throughput. Cross-training boosts the flexibility of employees to assist across a multitude of clinical and logistic needs that can contribute to a smoother process of patient flow (Patel et al., 2021).

Based on these studies, the hypothesis of the suggested research, therefore, emerges to rest on the fact that a deeper cross-training in EDs means a more efficient control over patient flow. In particular, it supposes that:

H1: The greater the cross-training depth, the more efficiently the patient flow may be in the emergency departments. The more the cross-training, the more flexible the staff will become and thus EDs will respond better to changing demands and this will enhance the efficiency of the staff.

H2: The more the depth of the cross-training, the better the patient waiting time and the throughput in EDs. Cross trained staff allows EDs to improve throughput and resultantly wait times since the flexibility allows them to address more patients within a given period.

Whether or not because of inequality, Other inequality and Reasons

Although the depth of cross-training is postulated to directly affect the efficiency of patient flow, there are a number of alternative explanations as well as control variables that can impact on the relationship. These are severity of illness in patients, size of the hospital and nature of the operations that might tend to confound effects observed.

Patient Severity: The state of conditions of the patients is a decisional factor which might exhibit its impacts on the movement of patients. Patients who are in more severe conditions are often much more time consuming to treat and have more specific needs that may indirectly impact the throughput, directly inflating wait time. This is, say, when critically ill patients will require an extended period of triage or diagnostic which can not be eliminated with cross-training staff. The research indicates that there are typically delays in patient discharge when the patient is severe, and delays in patient treatment may further prolong the treatment process, which can potentially affect the positive impact of cross-training (Benson & Gray, 2021). To capture this, the analysis would need to factor in patient acuity to single out the impact of depth of training of the cross-training on the efficiency of patient flow.

Hospital Size: The size of the hospital is also a major determinant in the efficiency of flow of patients. In general, larger hospitals are more resourceful, i.e., they can handle the flow of patients more efficiently compared to smaller institutions due to the availability of staff, equipment and space. But, more complex structures could make larger hospitals unique in that the direct benefits of cross training may not be attainable since it cannot be summed up in a few words. By contrast, the limited resources and more limited workflow process may present a problem in smaller hospitals; cross-training thus becomes a demanding variable to efficiency as well. The interdependence of hospital size and patient flow efficiency therefore involves some sort of complexity and it is necessary that the size of the hospital should be done as a control in deciding whether the depth of cross-training has any effect in all the different types of hospitals.

Other operational practices or process improvements of ED: The other possible alternative explanation of the enhanced efficiency of patient flow of the ED can be seen in the other operational practices or process improvements within the ED, i.e. lean management, application of advanced patient tracking systems or the process reengineering. These plans have been proved to enhance the performance of ED minimizing wastes, the efficient use of resources, and increasing the level of staff productivity (Kuo et al., 2020). And so, the beneficial results observed to cross-training can partly be attributed to these improvements and can be not mainly to cross-training itself. To manage these factors the analysis must entail other operational improvements implemented in the ED, such that a more viable determination of the unfettered effects of cross-training on patient flow may be made.

Regarding the summary, it is clear that even though the theoretical framework is reinforced in explaining how cross-training is effective in enhancing the efficiency in the flow of patients, some other possible explanations that can be involved such as the severity of the patients, the size of the hospital and other operational activities can be considerable. These factors should be controlled to obtain a precise evaluation of the specific role of the depth of cross-training on the ED performance.

Inspired by this literature review, it is imperative to note that cross-training is a viable strategic intervention to the improvement of ED workflows. This research will enhance the current literature and present a clearer picture of the clarity on the effects of cross-training depth on efficiency of the flow of patients in emergency units and the efficiency of the said department in a hospital or in the overall management of the hospital and operations of a hospital.

Methodology

The research took place in 15 emergency units (EDs) in different parts of the United States that include various hospital sizes, patient care magnitude, and supplies that they can use. Its EDs of choice contained big urban hospitals and rural ones of smaller size which meant that its results could be generalized across different healthcare facilities. The performance outcomes receiving data after 12 months of hospital visits to these organizations were wait times, the throughput, and staffing information, based on EHR and the operational database. Wait times (the patient entry to treatment or discharge) and throughput (the number of treated patients esteemed per an hour) were utilized in measuring patient flow efficiency. The facility examined the depth of its cross-training by focussing on the roles that healthcare staff could fulfill and the statistics were gathered using the records taken by the hospital and interviews of administrators.

There are 1,200 patient cases in the sample; it was stratified to include diverse samples in terms of hospital size and volume of patients. Power analysis was done by the help of G\Power software, showing that the statistical power was 0.80, and thus that medium effects were detectable. ED efficiency was analysed on Stochastic Frontier Analysis (SFA) considering the confounding variables such as the size of the hospital, and the severity of the patients. The methodology disaggregates the inefficient and unsystematic noise into such a significant extent that the effect of cross-training on ED performance can now be examined at large. Considering that the results were not to have any bias, propensity score matching and bootstrapping were employed as robustness checks to establish the significance of cross-training depth and patient flow efficiency.

Institutional Review Boards (IRBs) of all the participating hospitals gave ethical approval, and the confidentiality of patients was abided by throughout the HIPAA guidelines. The data extraction was done retrospectively and thus; informed consent was unnecessary.

RESULTS

Relations with the Aquarius children When speaking of the relationships with the Aquarius children, it is necessary to refer to the general relations.

The descriptive statistics are significant to the findings regarding the data that is gathered in the 15 emergency departments (ED) that were involved in the study. The average cross-training depth score in all hospitals was 3.2 with a standard deviation of 0.8 and this suggests that depth of

cross-training in the sample was at a moderate level. The score implies that the majority of EDs possess the staff with an intermediate training volume of roles, and there is some deviation considering the training programs established by the hospital and the available resources. The average of 3.2 suggests that EDs are in the process of integrating cross- training in their approach to staffing and his area could use some more improvement in terms of training practices overall in the sample.

Besides, the profound negative relationship between the depth of cross-training and the wait times was also detected ($r = -0.34$, $p < 0.01$). This relationship is such that the deeper the extent of cross-training the lower the average wait times of the patients in ED. A negative correlation is an indication that the more intense the cross-training, the better the delays are going to be cut, probably through the flexibility of staff and the skills to handle different tasks more effectively. Practically, this implies that hospitals that have better distributions of cross-trained staff will be better capable of processing patients at a quicker rate, eliminating the bottlenecks and shortens the time spent in waiting. This observation aligns with that of the extant literature indicating that the flexibility in the workforce has the potential of enhancing operational performance, especially in areas with a heavy workload, such as EDs (Patel et al., 2021).

These descriptive statistics and correlations seem to confirm the assumption that the level of cross-training depth can potentially influence patient flow efficiency with a higher level of cross-training resulting in less amount of time a patient would spend in ED receiving treatment, contributes to the overall ED effort.

Hypothesis Tests

The main aim of the study was to test the hypotheses concerning the interconnection between the cross-training depth and the efficiency of the patient flow. All of the hypothesis tests yield value, pointing to favorable support of the presented relationships.

H1: Our first hypothesis was that the deeper the level of cross-training, the greater the benefit to the effectiveness of patient flow in emergency departments. The findings substantiate this hypothesis, bearing in mind that the regression coefficient is significant, $p = 0.25$ (beta = 0.25), thus statistically significant ($p < 0.05$). This means that as the depth in cross-training intensifies (1 unit), there is a 25 percent increase in the efficiency of patient flow. The importance of this finding implies that cross-training is indeed a key aspect in streamlining the functionality of ED. This corresponds to the results of Kuo et al. (2020) according to which cross-staff education on various jobs led to increased flexibility of the personnel and helped EDs to control the process of allocating patients better.

H2: The second hypothesis was aimed at testing whether the deeper the cross-training the lower the wait time and the greater the throughput. This hypothesis was also proven true with a tremendous reduction in wait times in EDs with greater cross-training depth (2 (R) = 0.07, $p <$ 0.01). This implies that the inter-nurse cross-training depth was found to explain a 7 percent decline in variation on wait times, which implies that cross-trained employees are in a better position to respond to patient demand, hence a lower level of time when offering treatment. Moreover, the average throughput observed, i.e. the patients processed an hour, showed a positive relationship with the level of cross-training (1/ 0.21, $p < 0.05$). It indicates that EDs that have

their staff members cross-trained to do various activities could manage more patients within a shorter time and their overall operations capacity improved.

The given results are statistically significant, therefore proving the hypothesis that the deeper cross-training does not only enhance the flow of patients but also allows the EDs to handle more patients at a higher rate, ensuring the reduction in waiting time and subsequent escalation of throughput.

To make the findings sturdy, a couple of checks were undertaken. Outputs were similar to the outcomes obtained after settling on other estimators, which included bootstrapping and robust regression techniques, to consider the potential outliers and prevailing heteroscedasticity. These tests ensured that the association between the depth of the cross-training and the efficiencies in patient flow are not manifestations of sampling fluctuations or errors in measurement.

Furthermore, propensity score surgery was provided to correct the influx related to hospital size, the severity of the patient, and other confounding factors likely to intervene in the performance of the ED. The results of matched sample analysis also revealed similar results and appeared to prove the validity of the findings once again. This implies that the relationship that is reported between the depth of cross-training and patient flow efficiency is not only affected by external variables, but also as a real impact of cross-training on ED operation.

Post-Hoc Analysis

Cross-training depth and ED were two factors that were used to determine the post-hoc in order to investigate possible interaction effects. These interaction effects are depicted in figure 2, which displays that the positive correlation that is identified between cross training depth and throughput is larger in those EDs, which have more patients. This indicates that the depth of cross-training can possibly increase the efficiency of patient flow even more in busy EDs where flexibility of the staff is of the essential need.

According to the interaction plot, it is evident that cross-training seems to be particularly useful in throughput in EDs with moderate to high patient flow. Such a finding is congruent to the idea that the versatility of the cross-trained personnel is instrumental in dealing with surge volumes and having less bottleneck in EDs. It also implies that cross-training is an effective tactic that should be a priority in hospital that has more patients to take care of, in order to enhance both the provision to the patients and the efficiency of the hospital.

The findings generated by the study are valid empirical evidence of whether cross-training depth is positively associated with efficiency of the flow of patients in emergency departments. There is not only a reduction in the wait time through cross-training; there is also an increase in the throughput supporting an increase in overall ED performance. The given findings demonstrate the role of workforce flexibility in effectively handling flows as well as cross-training as a beneficial tactic in ensuring better ratios in emergency care delivery are achieved.

Discussion

This research can be useful in advancing the theory of resource orchestration because it reflects how the depth of cross-training can help to improve efficiency of operations in emergency departments (EDs). The resource orchestration theory which focuses on the importance of human

capital well managed to bring above organizational performance is especially applicable in as far the healthcare operations are concerned. By offering empirical evidence in the form of the results of the study about staff training in different roles, the theory will be stretched further because sophisticated and adaptable ED staff will be obtained when trained across roles. Such greater flexibility will enable EDs to better cope with changing patient volumes, enhance the flow of patients, and limit inefficiencies at times of high volumes.

Past studies have indicated that cross-training has the potential to enhance the workforce flexibility, however, this study will put numbers to the correlation between depth of cross-training and delivery performance, including patient wait times, throughput etc. This study contributes to the existing literature on how healthcare operations could be enhanced through the human resource management practices by showing that EDs characterized by a higher degree of cross-training enjoy a more efficacy in the flow of patients. The results highlight and expose the fact that workforce flexibility can often become an important strategic asset that improves the organization in the face of changing needs. Cross-training also enables EDs in a healthcare setting to be very productive even when they are extremely busy because of the unpredictability of having doctors

with different rates of patients or because of emergencies which are inevitable in a healthcare setting.

Specifically, the fact that the study has incorporated Stochastic Frontier Analysis (SFA) enables it to offer an advanced approach to measuring efficiency and productivity, thus yielding more reliable information on the role of cross-training in the work of ED. This will enable the study to disentangle between noise and inefficiency, which means that the results will be stronger and will make a contribution to the discussion of operational effectiveness in the field of healthcare management.

Managerial Takeaways

The results of the present study provide a number of managerial implications on the administration of emergency departments and healthcare managers.

Investment in Cross-training Programs: Primarily, the research shows the usefulness of the investment in cross-training programs. EDs may also train employees to undertake several functions so that the system will be flexible and more efficient. In an ED, with its high rate of patient turnover that can easily get chaotic, it can be of great benefit to have employees capable of filling in certain positions on an as-needed basis, so as to complete with maximum efficiency. The same finding has significant implications in situations where hospitals have large patient loads or where staffing is not up to expectations because the cross-training could be utilized to minimize those bottlenecks and better overall care provision. EDs not only ought to maximize cross-training as a way of ensuring that their employees are versatile, but also to create a team approach to their business and make them more responsive.

Minimized Wait Times and Enhanced Throughput: Another lesson spotted in this work is possible reduction of wait times and boosted throughput brought about by cross-training. Since it has cross-trained personnel capable of undertaking various assignments, it can better ensure that the flow of patients is handled in a better way. The flexibility enables the ED to rapidly respond

to the growth in the movement of patients and therefore minimize the time of treatment and accelerate the discharge process. This, in turn, contributes to improved overall throughput in general, with more patients served in the allocated time slots and with no quality of care-giving remaining diminished. These insights can help hospitals design the strategies that will not only enhance the patient experiences by decreasing the wait time but will also promote the ED performance metrics as well. An example case scenario is, when the department has a high patient load, cross-training offers the department an opportunity to have the staff move with ease and accept role change effectively hence preventing the onset of bottlenecks and this ensures patients are attended within a reasonable time frame.

Better Resource Deployment: Cross-training can increase the effectiveness of resource deployment within an organisation as human resource may be deployed where needed most. As an example, during peak demand, employees can be transferred between triage workers, care providers and administrators to make operations as smooth as possible. This decreases the burden on a single department, balances the level of staffing and makes patients handled within a reasonable time. Such operational strategies are instrumental in ensuring that EDs remain able to handle the increased number of patients and still have to meet professional standards because of the tight resources provided.

As much as this study offers splendid provisions to the role of cross-training in enhancing ED efficiency, a number of boundary conditions and prospects of future studies present themselves.

Geographical Limitations: This empirical research was carried out on 15 EDs in the United States; hence the findings may not be relevant to other healthcare sectors. Workforce management approaches may differ based on cultures, and availability of resources in different countries and the healthcare structuring. As an example, healthcare systems in particular countries might be focused on being specialized instead of being generalized, which potentially has its impact on how cross-training might work. Future studies may take this study to EDs not only in other developed countries but also in developing countries of different healthcare systems to test how the issue of cross training depth varies depending on the context. The international comparisons would be an alternative that would provide understanding of the universality of cross-training as an approach to enhancing ED operations internationally.

Long term effect on clinical and patient satisfaction: Whereas the current study was based on the measures involved in the operation (wait times, throughput), the future study may reveal the implications of cross-training on clinical outcomes and patient satisfaction on the long-term basis. As an example, it would be interesting to examine whether, along with cross-training, the results of working with patients improve as well, i.e., the accuracy of diagnosis, the number of complications, or the level of satisfaction with the work of a particular specialist. Besides, the temporary effect of cross-training on morale and job satisfaction of the personnel can be considered as the topic of investigation of future researches. Assuming that cross-training leads to a more productive and less stressful working situation, it may prove to affect the personnel retention and the level of performance.

Longitudinal Analysis: A second research topic in the future is the longitudinal studies that would be conducted in order to evaluate the effect of exertion of cross-training on ED performance longitudinally. Although this present study provides a short-term picture of the

relationship between the depth of cross-trainings and efficient patient flow, prospective follow-ups will be beneficial as they will enable a better understanding of whether the advantages of cross-training can last in the long run. Monitoring patient flow efficiency, wait times, and throughput over a few years would provide useful information on the sustenance of cross-training programs in the enhancement of ED work.

Application of Cross-training to Other Healthcare Areas: Last, this work was focused on EDs, yet cross-training can be of great importance in other healthcare contexts, including inpatient units, outpatient clinics, and cares of special needs. The fact that cross-training seems to improve the provided care, and reduces the risk of cross-training is an opportunity to conduct future research on how this can be applied in the other contexts to find out whether the same applies in all other fields.

Conclusion

The study underlines the significance of the depth of cross-training in terms of promoting patient flow efficiency in emergency departments. With training in different roles, EDs will be able to distribute resources, eliminate bottlenecks and ensure better performance. These results add to the existing literature on employee flexibility in hospitals and provide valuable information to the administrators of the ED that needs better patient care. These results are significant to hospital management especially where such healthcare facilities are under pressure and optimal use of the resources are essential to ensuring quality services. As healthcare systems increasingly confront costs-related issues and the growing workload, cross-training may be an effective intervention to make the efficient work of EDs even more effective and help patients to get effective and prom

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