Case Study

Deploying lean in healthcare: Evaluating information technology effectiveness in U.S. hospital pharmacies

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\textbf{A R T I C L E I N F O}

\textbf{A B S T R A C T}

This case study provides a lens of operation research for evaluating the use of technology on medication distribution systems in U.S. hospital and helps better understand how technologies improve the healthcare operational performance in terms of processing time and cost. We analyze two prescribing technologies, namely no carbon required (NCR) and digital scanning technologies to quantify the advantages of the medication ordering, transcribing, and dispensing process in a multi-hospital health system. With comparison between these two technologies, the statistical analysis results show a significant reduction on process times by adopting digital scanning technology. The results indicated a reduction of 54.5\% in queue time, 32.4\% in order entry time, 76.9\% in outgoing delay time, and 67.7\% in outgoing transit time with the use of digital scanning technology. We also conducted a cost analysis on each of the two technologies, illustrating that the total cost generated by using digital scanning was as low as 37.31\% of that generated by NCR. Lessons learned about how to evaluate IT effectiveness by lean methods are presented for both theoretical and practical perspectives.

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1. Introduction

The medication distribution system in hospitals deals with the high volume of medication transfers from when the medication is dispensed to when it is administered, and physician prescriptions. According to the National Community Pharmacists Association (NCPA)’s report, the number of prescriptions being dispensed in a pharmacy per day in the United States rose, on average, approximately 12\% (from 178 to 201) from 2006 to 2011 (NCPA, 2012). The great challenge that hospitals confront is the long delays on medications and prescriptions in that the demand pressure on them continuously grows. Thus, improving workflow in medication distribution systems to enable pharmacists to allocate their time more effectively is vital to proving a high quality healthcare service and beneficial to patient safety.

To address this, research indicates that many hospitals have adopted technologies to improve their existing operational processes (Agarwal, Gao, DesRoches, & Jha, 2010; Calderia, Serrano, Quaresma, Pedron, & Romao, 2012; Goh, Gao, & Agarwal, 2011). This practice is particularly important for pharmacies. A vast body of research demonstrates that the use of information technologies (IT), such as computerized physician order entry system, has benefits on reducing prescribing errors (e.g., Shawalha et al., 2011) and decreasing dispensing delays in the pharmacy units (e.g., Chuang, Wang, Chen, & Cham, 2012). However, little is known about the actual performance of information technology (IT) effectiveness to be accomplished (e.g., how much time or cost is saved) regarding medication distribution process in hospital pharmacies. Measuring healthcare information system (IS)/IT performance is challenging to IS researchers (Jones, Heaton, Rudin, & Schneider, 2012), because the performance measures used to evaluate the healthcare IT input and output are drawn from administrative data that are short of detail-oriented, detecting information (Jones et al., 2012). This gap is worth researchers to solve in that a quantified performance assessment is critical for hospitals to maintain their service quality (Douglas & Judge, 2001).

Therefore, drawing on the lean methods from operation research filed, time study and cost analysis, the reported cases analyze the two common prescribing technologies used in U.S. hospital pharmacies via comparing their operational time and IT cost spending. In doing so, this case study not only has better chance to deeply understand the effectiveness of IT usage in healthcare, but only
demonstrates the cost and time analysis methods to evaluate IT effectiveness for the practitioners.

2. Research background

2.1. Medication distribution systems in hospital pharmacy

A medication distribution system in hospitals is one of the most complex workflow that consists of prescribing, ordering, transcribing and dispensing medications (Flynn, Barker, & Carnahan, 2003). This system, which involves a number of procedures and a variety of supporting staff, starts from the moment a physician writes the prescription, then goes to the nursing station or any other dispensing station, and ends at the point the medication reaches the patient. The main goal of this system is to ensure that the correct drug is administered in the appropriate dose to patients at the correct time.

The prescribing process is one of the important components in every community or hospital pharmacy due to the widespread use of drug prescription. Pharmacies in hospitals use different prescribing methods. For example, the traditional approach to medication management is handwritten prescriptions, but it is inefficient and error-prone. Illegible or unclear prescriptions result in more than 150 million calls from pharmacists to physicians and nurses, asking for clarification, a time-consuming process that tremendously costs the healthcare providers economic input due to the long operational time each year. Therefore, there is a need for IT usage in hospital pharmacies. In the next sections, we describe some technologies that have been adopted for medication distribution process.

2.2. The use of prescribing technology

Current studies show that many IT tools or systems for prescribing and dispensing practices are available in the market and have the abilities to enhance the accuracy and improve the efficiency of prescribing practices. Indeed, the use of information system (IT) can significantly improve healthcare performance (Karsh, Holden, Alper, & Or, 2006). For example, pharmacists at one U.S. hospital used a computerized prescription order entry system to review all prescriptions, which alerts the prescriber and pharmacist on dosage errors to reduce misinterpretation of prescriptions (Jayawardena et al., 2007). In addition, Wang and Chang (2002) indicated that the introduction of personal digital assistants (PDAs) into prescription system could prevent errors that occurred during the prescription of drugs in a teaching hospital setting.

2.3. Performance measurement of IT effectiveness

Measuring hospital performance is a crucial task for managers within healthcare industry to understand its ability to provide high quality of healthcare service and thus to maintain or seize the competitive advantage (Douglas & Judge, 2001). Handler, Issel, & Turnock, (2001) conceptualized a framework for measuring performance and monitoring public healthcare systems. Yet, their research does not consider the contribution of IT resource utilization to the hospitals.

Of equal importance for pharmacy units is to provide a set of clear criteria to understand the effectiveness of the use of technology. Few studies have been conducted to evaluate the IT effectiveness of medication distribution by a comparison study in order to better understand their effectiveness (Chuang et al., 2012; Cochran & Haynatzki, 2013). For example, Chuang et al. (2012) implemented a new drug storage label system that had important drug items circled (e.g., drug name and packaging dose). Compared to the old drug stage label, the overall drug-dispensing error rate was decreased, and the pharmacists’ degree of satisfaction was increased. Based on the literature, we found that the pharmacy efficiency can be measured by operational time and costs on the target level of inputs that is utilized to achieve the outputs in the drug distribution processes.

3. Case study approach

3.1. Hospital pharmacy selection

This case study was conducted to examine the processing time involved in administering the medication distribution process and its cost at two public hospitals, A and B, in Louisiana, United States. In 2012, Hospital A had approximately 450 licensed inpatient beds and 430,000 outpatient visits, and Hospital B had approximately 250 licensed inpatient beds and 141,000 outpatient visits. The pharmacies at both hospitals were chosen to be involved in this study, as both had different prescribing technologies. The pharmacy at Hospital A used NCR copies for prescribing, and Hospital B used digital scanning technology.

3.2. The use of prescribing technology

The two methods of drug distribution were NCR technology and digital scanning technology in the selected pharmacy, respectively. At Hospital A, the physicians and pharmacists used NCR technology. The NCR technology is where medication orders are written on a “no carbon required” physician order form. The NCR copies have four parts altogether. The first part is the chart copy, in which the physician writes and puts on a patient’s chart. The remaining three copies are the pharmacy copies on which the order is imprinted. Those copies are sent to the pharmacy through a “tubing system” by the unit secretary or nurse for the pharmacists to fill in the prescriptions. Digital scanning technology, on the other hand, was used in Hospital B. The medication orders are scanned by the unit secretaries or nurse. Once the scanning is done, the prescriptions appear on the pharmacy monitor in the order in which the physicians’ orders are, and it allows the pharmacists at order entry to enlarge the image, turn the image, and change the contrast of the image, all which are used to improve readability.

3.3. Data collection

Data was collected over a 2-week period from both hospital pharmacies to determine the time elapsed from when the orders were sent to the pharmacy from the nursing station to the time the medication was sent back to the nursing station from the pharmacy. An investigator can achieve high levels of precision by increasing the sample size. Should there be constraints, because of budgetary limitations or a shortage of time, a proper sample size has to be determined. Eq. (1) was used to calculate the required sample size “n” for estimating the mean. For this data, we set $d = 2$ s; $\sigma$ was estimated to be 9.4 by the sample standard deviation; and the value of critical deviate with a 0.001 $\alpha$ error was 2.326. After calculating, we estimated that the minimum sample size needed for this research was 107 cases of prescription. We collected 107 prescription cases which every individual copy of prescription the physician wrote down as an official copy would be seen as 1 case.

\[
 n = \frac{t_{\alpha/2} \sigma^2}{d^2}
\]  

(1)

where $d =$ desired precision (or maximum error); $t_{\alpha/2} =$ critical deviate for specified reliability $1 - \alpha$; $\sigma =$ population standard deviation.
3.4. Parameter measured

3.4.1. Time study

Time study is a major underpinning of improvement effects in operational research methods, and this technique was used to quantify the time spent on each activity that occurred in the workflow. To compare the two technologies, the following time parameters were studied. Queue time refers to the time spent when the prescription waits in the queue until it is attended or viewed by the pharmacist at the order entry station. In terms of NCR technology, the prescription after the time is stamped is placed in the queue. For digital scanning technology, the prescription starts in the queue as soon as the prescription is scanned. Order entry time refers to the time spent when the pharmacist at the order entry station starts and finishes entering the prescription into the pharmacy information system. In NCR technology, this time starts when the pharmacist picks the prescription and ends after entering the prescription. For digital scanning technology, the timing starts as soon as the prescription image is viewed on the screen and ends when order entry is completed. Outgoing delay time refers to the time spent when the tube enters the system but before it is sent from the pharmacy to the nursing station. Oncoming transit time measures the time a tube spent in traveling from the pharmacy to the nursing station.

3.4.2. Cost analysis

The comparison of cost analysis between NCR technology and digital scanning technology was conducted at Hospitals A and B for a 5-year period. We selected four high cost items that includes time spent by pharmacist, prescription papers, the introductory cost, and paper shredding costs.

Time spent by pharmacist: the following measurement breakdown came from analyzing the tube time spent and filing time spent. Using occurrence sampling and the stopwatch method, these standard times were developed. These results were determined after assuming 15% allowances. Eq. (2) shows the calculation of $T$ (in hours). During the study period, it was found that $X = 500$, $Y = 970$, $A = 10$ s, $B = 2$ s, and $C = 15$ s.

$$ T = \frac{[AX + (B + C)Y]}{3600} \quad (2) $$

where $X =$ average number of incoming tubes per day; $Y =$ average number of order forms per day; $A =$ time to handle tube (in seconds); $B =$ time to punch each order (in seconds); $C =$ time to fill each order (in seconds).

4. Case analysis

After visiting hospital A, we found that the entire process of NCR technology might cause medication delay due to the nature of the process itself. First, medication delay can happen when the tube is not available. If this occurs, the nurse has to call the pharmacy to request a tube and wait for the tube. Once the tube arrives at the nursing station, the prescription is sent to the pharmacy by the nurse. During the transit from the nursing station to the pharmacy, the tube can stop in between because of the traffic (other tubes coming in the system) in the pneumatic tube system to cause another delay. Once the tube reaches the pharmacy, the tube falls at the collecting station and is picked by the medication filling staff who pick the tube only when they are available to fill the medications. Thus, the tube is likely to be left at the collecting station to create new delay when the staff is occupied. The delay can also happen when a pharmacist intends to request a clarification from a nurse before entering the medication information into the system when the nurse is not available.

After visiting hospital B, we found that digital scanning technology provides an instant prioritizing of orders, placing STAT (a medical abbreviation for urgent or rush) orders at the top of the computer queue in red in order to alert the pharmacist. The pharmacist at the order entry workstation pulls up the image and enters it in the pharmacy information system; all order entry functions are performed. When a clarification is needed regarding the order, the pharmacist annotates on the image and scans it back to the nurse and a phone call is made to inform that a clarification is needed. Such a computerized digital scanning of original physician orders eliminates the distortion that is experienced with NCR copies. The important benefit of the digital scanning technology is that it digitally documents the exact time the order is scanned and processed and thus reduces the turn-around time on receiving the order.

In order to deeply understand the effectiveness of two prescribing technologies, the lean methodologies, which are time study and cost analysis were used in this case study as shown in the remainder of this section.

4.1. Time study

The statistical analysis results (see Table 1) show that the digital scanning technology outperformed the NCR technology in all measures. The results of ANOVA found significant differences in times between the NCR technology and the digital scanning technology for the prescription. The benefits of using digital scanning technology in terms of medical processing time are as follows:

- Reduction in the queue time per prescription (654.7 s for using NCR technology versus 297.8 s for using digital scanning technology);
- Reduction in the order entry time per prescription (224.76 s for using NCR technology versus 151.95 s for using digital scanning technology);
- Reduction in the outgoing delay time per prescription (38.23 s for using NCR technology versus 8.83 s for using digital scanning technology);
- Reduction in the outgoing transit time per prescription (129.43 s for using NCR technology versus 41.77 s for using digital scanning technology).

4.2. Cost analysis

Cost analysis was conducted for evaluating the spending between two technologies. The results of cost analysis (see Table 2) showed that cost spending in digital scanning technology was less than in NCR technology. After the calculations of time spent by pharmacist were derived, total inpatient-carbon prescription order handling time was 5 h and 58 min (5.967 h). The cost of having a pharmacist on staff was $54.09 with all benefits. After 5 years this amount totaled $589,027.93. The cost only took place in the old and partial implementations, since the tubing and filing of the carbon prescriptions would be replace by the scanned single prescription form.

For prescription paper of inpatient, the total cost per carbon sheet was $1.00. The hospital ordered 30,000 sheets per month. Over a 5 year analysis the cost was $1,800,000.00. With a full implementation of using digital scanning, the cost would reduce to $0.22 per sheet and this would reduce the 5-year analysis to $396,000.00. On the other hand, the cost of the outpatient prescription order sheet did not change in price. This cost remained at $0.22 per sheet. However, the difference was a standard form used by all clinics. The cost of $41,000, approximate number of sheets used per month, would be $541,200.00 over a 5-year period of time.

The introductory cost for digital scanning technology is purchasing the medication order management system with new servers and stations. This lease would allow for all improvements including software upgrades and 24-h technical support for any maintenance
Table 1

The ANOVA results of each operational time.\(^a,b\)

<table>
<thead>
<tr>
<th>Methods</th>
<th>Queue time</th>
<th>Order entry time</th>
<th>Outgoing delay time</th>
<th>Outgoing transit time</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCR copies (N = 107)</td>
<td>654.70</td>
<td>224.76</td>
<td>38.23</td>
<td>129.43</td>
</tr>
<tr>
<td>Variance</td>
<td>416,300.20</td>
<td>36,621.70</td>
<td>2877.66</td>
<td>6228.03</td>
</tr>
<tr>
<td>Digital scanning (N = 107)</td>
<td>297.81</td>
<td>151.95</td>
<td>8.83</td>
<td>41.77</td>
</tr>
<tr>
<td>Variance</td>
<td>70,475.93</td>
<td>113,018</td>
<td>265.36</td>
<td>87.65</td>
</tr>
<tr>
<td>Time reduction (%)</td>
<td>54.50</td>
<td>32.40</td>
<td>76.90</td>
<td>67.72</td>
</tr>
<tr>
<td>F value</td>
<td>28.78</td>
<td>3.90</td>
<td>22.95</td>
<td>133.82</td>
</tr>
<tr>
<td>p value</td>
<td>0.000(^**)</td>
<td>0.049(^*)</td>
<td>0.000(^**)</td>
<td>0.000(^**)</td>
</tr>
</tbody>
</table>

\(^a\) All tests are two-tailed.  
\(^b\) \(p < .05\)  
\(^*\) \(p < .01\)  
\(^**\) \(p < .001\).

Table 2

The comparison of cost analysis between two technologies.\(^a\)

<table>
<thead>
<tr>
<th>Cost items</th>
<th>NCR technology (Hospital A)</th>
<th>Digital scanning technology (Hospital B)</th>
<th>Cost reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmacist cost</td>
<td>US$589,027.93</td>
<td>US$0.00</td>
<td>100</td>
</tr>
<tr>
<td>(US$54.09 × 5,967 h × 365</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days × 5 years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prescription paper cost</td>
<td>Inpatient: US$1,800,000.00</td>
<td>Inpatient: US$396,000.00</td>
<td>78</td>
</tr>
<tr>
<td>(US$1.00/sheet × 30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheets/month × 60 months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient: US$541,200.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(US$0.22/sheet × 41,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheets/month × 60 months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introductory cost</td>
<td>US$0.00 (No new server and stations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredding cost</td>
<td>US$6334.20</td>
<td>US$54,480.00 (for a server)</td>
<td>−100</td>
</tr>
<tr>
<td>(US$6.102/lb × 1035 lb/month × 60 months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td>US$2,936,562.13</td>
<td>US$1,095,720.00</td>
<td>62.69</td>
</tr>
<tr>
<td>Monthly cost</td>
<td>US$48,942.70</td>
<td>US$18,262.00</td>
<td>62.69</td>
</tr>
</tbody>
</table>

\(^a\) This comparison between two technologies was based on the 5-year period.

and repair. The lease also gave the option to renew after the 5 years and receive a new server. This purchase was for the partial and full implementation only. The cost of the server was US$908.00 per month, totaling US$54,480.00 (one server) over the 5 years. In term of stations, the cost of each station was US$289.00 per month, totaling US$104,040.00 (six stations) over 5 years.

The shedding cost for using NCR technology was generated since Hospital A has confidential files on every patient; they are required to shred all inpatient prescriptions. The cost of shredding was US$0.102 per pound. After the carbon prescription paper was weighed and multiplied by the usage amount, 30,000 sheets per month, the total weight of shredded per month was 1035 lb. Over 5 years, this amount totals US$6334.20. However, for digital scanning technology, this cost would be eliminated. The greatest cost down for digital scanning technology is on the saving of prescription paper (from US$1,800.00 to US$396.00). Finally, our results of this study showed that a reduction of 62.69% in total cost in the use of digital scanning compared with NCR technology.

4.3. Practical implication

This case study provides the following significant insights to healthcare practitioners and researchers.

First, the results of this case indicate that the reduction on queue time (54.5%), order entry time (32.4%), outgoing delay time (76.9%), and outgoing transit time (67.7%) from using digital scanning technology. By using the lean methodologies, we found that such reduction of time only requires a short attention span from pharmacists and nurses, making them more concentrated and more productive on their tasks, preserving the value of the pharmacy, and even opening up opportunities for them to create more value.

Second, hospitals might want to think of a better way to allocate and coordinate their valuable resources. We confirmed the benefits of using the digital scanning technology that not only helped different groups of people handle appropriate tasks, but made the human resource well managed without waste on work force and other resources. Also, we can see from the cost analysis that the cost digital scanning technology generated was only one third (37.31%) of that generated by NCR method.

Finally, as the number of prescriptions received in hospitals continues to grow, it is necessary for careful assessment of the impact of the delivery of healthcare service and the design of prescription system and workflow. This case study elaborates on how the lean methodologies to evaluate technologies adopted in healthcare units and to improve the workflow after adoption. Thus, the value of lean operation is applicable to the healthcare context for the improvement of healthcare service quality.

5. Conclusion

This case study evaluates the effectiveness of prescribing technologies in medication distribution systems in two U.S. hospital pharmacies by using time study and cost analysis. After comparing two technologies, pharmacy productivity and profits were increased through the use of the digital scanning technology. The use of digital scanning technology in the order entry facility improves the turnaround time and cost spending during the medication distribution process. The intangible benefits by using digital scanning technology were also recognized in the medication distribution process, such as offering a more clear understanding of prescription, the increased prescription handling ability, and the enhanced storage capability to prescription
order forms. Finally, this case study believed that by using the lean methodology, it has benefits on identifying the delays in medication distribution systems and further avoided medication errors, which are major problems associated with patient safety in hospitals.

References
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