Outpatient pharmacy optimization using system simulation

Zhang Dana, He Xiaolib*, Deng Weiru, Wang Li, He Yue

*a Business School of Sichuan University, No.29 Wangjiang Road, Chengdu, Sichuan, 610064, China
b West China Hospital of Sichuan University, No.13 Guoxue Lane, Chengdu, Sichuan, 610041, China

Abstract

Pharmacy is the last department for outpatient in hospital, the efficiency of which is directly associated with patient satisfaction and reputation of the entire hospital. The aim of the study is to improve the efficiency of queuing system of outpatient pharmacy based on queuing simulation method. After stimulating suitable models for the current situation, then changes of the number of queues have been made to see if there is any improvement in system efficiency. Results showed that single-queue multi-window pattern is not only much more balanced to assign prescriptions to each window, but also make human resources well used.

1. Introduction

Outpatient pharmacy, an important part in the complex system of hospital, has direct effects on patient satisfaction and hospital reputation. Due to the big number of people in China, limited resources and unpredictable demand, the phenomenon of ‘three long, one short’ is prominent in China, which means the time of registration, waiting for consultation and getting drugs is long while the actual consultation time is short. Patients may easily get tired and impatient when queuing too long for drugs before leaving hospital. Meanwhile, with the improvement of consumer rights protection awareness and the increasingly fierce competition among hospitals, the idea of patient oriented has become every hospital in China focusing on. So study on outpatient pharmacy is important in many aspects, and it’s one of the modern scientific management research objectives.

Cecilia Bernsten et al. [1] conducted an international, comparative analysis of remuneration models for pharmaceutical professional services and founded out that remuneration models differed in the way that pharmacists were paid for professional services beyond dispensing medicines. Adam P. Bress et al. [2]
described the rationale and the benefits of an international Advanced Pharmacy Practice Experience (APPE), provided strategies and lessons learned from the Australia experience, and outlined the benefits and challenges that were encountered by the students during their advanced pharmacy experience. William R. Doucette et al. [3] conducted mail surveys to collect information about practice setting, prescription volume and staffing from 1847 licensed U.S. pharmacists. Many pharmacies reported that some aspects of their practice have changed, such as collecting patient information and documenting care. Few reported changes in asking patients to pay for pharmacy services. Judith A. Singleton and Lisa M. Nissen [4] highlighted the hypercompetitive nature of the current pharmacy landscape in Australia and gave suggestions about strategies of making pharmacy more competitive. In Mc Dowell A L’s research [5], a weighted scoring system was used to select a pharmacy layout redesign. Xiu-Min L I et al. [6], the data of patients’ and pharmacists’ satisfaction to workflow of outpatient pharmacy were collected by questionnaires, and then analyzed statistically. Hattingh H L [7] pointed out that in the design of pharmacy layout, it is also important to consider patients privacy.

There are many studies focusing on pharmacy management based on strategies, surveys, data mining method and so on. Few of them proposed approaches for pharmacy queuing system [8-9]. We chose outpatient pharmacy of West China Hospital of Sichuan University to work on, and then used simulation method to find out suitable model in the present situation after conducting surveys in hospital pharmacy. Changes of queuing pattern were made, and at last we analyzed the results of different simulation models.

The remainder of this study is organized as follows. Section 2 gives a general review of related literature. In section 3, we introduce the method we used. Section 4 contains detailed steps, results and our suggestions. Finally, section 5 presents the conclusions and future research directions.

2. Literature Review

In outpatient pharmacy, there are many things needed attention. Xiaoqin Wei et al. [10] analyzed medicine management of the hospital pharmacy, prescription dispensing process of outpatient pharmacy and hospital pharmacy as well as pharmacy layout. They studied various packages of drugs and sorting characteristics, analyzed the applicability of sorting technology and equipment which is currently used at home and abroad. Emmett D et al. [11] paid attention to the fact that compared to most general merchandise stores, pharmacies were more concerned about safety and security issues due to the nature of their products, and they discussed these aspects as well as the physical and professional environments of retail pharmacies that influence the perceptions of customers and how these varied whether chain, independent, or hospital pharmacies. In the study of Spry C W et al. [12], in order to help hospitals make decisions about staffing and work scheduling a simulation model was created to analyze the impact of alternate work schedules. Reynolds M et al. [13] presented the findings of a discrete event simulation study of the hospital pharmacy outpatient dispensing systems at two London hospitals, and their findings were being used to support business cases for changes in staffing levels and skill-mix in response to changes in workload. Like what said in [14], it is possible to use hi-tech methods to adjust pharmacy layout to improve its efficiency, and with many factors to consider, the good way to find the best layout is using queue theory and simulation method as well used in other management of pharmacy efficiency.

Though queue theory and simulation method were popularly used in many aspects, but there were only few studies on pharmacy queuing system based on queue theory and simulation method. Zixian Liu [15] researched the service process reengineering of outpatient pharmacy based on BPR, and explained how to use the flow-reengineering theory in hospital outpatient service pharmacy service management. Liu Y et al. [16] took 200 outpatients as samples for investigation about their evaluation on the queuing for medicine, and the results were given single-factor analysis of variance. Queuing method was employed to compare patients’ mean waiting time between single-row multi-window and multi-row multi-window so as to optimize the queuing rule. Day T E et al. [17] improved pharmaceutical services provided by the call center, by using queueing theory and
discrete event dynamic simulation to analyze incoming telephone traffic to the help desk, which indicates us to combine queue theory and simulation together to solve the problem of pharmacy layout.

To sum up, the number of studies on the application of simulation to outpatient pharmacy queuing problem is very limited, while queue theory and simulation method has been widely used in many layout problems. The objective of this study is to improve the efficiency of queuing system of outpatient pharmacy based on queuing simulation method.

3. Methods

Queuing problem refers to things, people and information flow in the flow process need to queue for services due to the lack of service provided. Queuing problem exists widely in production systems, logistics systems and services systems. In the queuing problem, the service intervals of people arrival time, length of service and the number of people in the queue systems are not known in advance, but a random occurrence. Consumers, servers, arrival rules, queue pattern, queue rules, in rules, service rules make up a queue system. Factors to evaluate queue system are average waiting time, average length of queue, average utilization of servers and length of busy time.

Simulation is one of the most effective solutions to solve queuing problems. It is also known as system simulation, which is at first modeled the system, and then test the model to do further studies. The simulation includes three basic elements, namely object system, system models, simulation models, and three basic activities, namely, system modeling, simulation modeling, simulation experiments.

Because of the complexity of simulation system, a method commonly used is based on a computer simulation model to reproduce the real system, which was then illustrated by mathematical methods and figures, while the relevant data analysis and solutions to the system problem are also complete. So the system simulation is often called computer simulation. The simulation software we used in this paper is Flexsim 6.0.

4. Methods and Results

4.1. Settings

We chose outpatient pharmacy of West China Hospital of Sichuan University to study on. Patients in West China Hospital would have a medical card which recorded a variety of patient information, and it was also a voucher of payment. After consultation, doctors would give prescriptions directly in information system, and patients took their medical cards to pay the fees without any prescriptions. As soon as the payment completed, outpatient pharmacy information system would receive prescriptions that was then made up by pharmacy staff. There were 29 windows in outpatient pharmacy, not all available to patients, the openness of which was depended on the number of prescriptions at different periods of time. Each window was divided into two parts, so there were two kinds of people in charge of one window. The receptionist was responsible for dispensing medicines, while the pharmacist made up prescriptions. According to that situation, we got basic parameters for simulation based on queuing theory, which was shown as follows.

a. number of opened windows $n_0$
b. number of pharmacists making up prescriptions $n_1$
c. number of dispensers $n_2$
d. distribution of prescriptions at different periods
e. distribution of pharmacist working time
f. distribution of dispenser working time

We got values of the first three parameters by observation and consultation, and knew the last three by statistical analysis after collecting large quantity of data.
4.2. Data Collection and Analysis

First of all, we needed to determine the busiest weekday and its busiest period, for practical significance, to simulate. We collected number of prescriptions from Jan, 14th 2013 (Monday) to Jan, 20th 2013 (Sunday), the general distribution of which was shown in figure 1. There were many patients visiting West China Hospital, but no great difference in number of prescriptions of every week, according to pharmacy staff’s introduction. The number of prescriptions from Monday to Thursday was almost the same, while significant decrease in Friday, Saturday and Sunday. So we chose prescriptions of Monday to simulate.

![Fig. 1. number of prescriptions from Jan, 14th 2013 to Jan, 20th 2013](image)

Then we analyzed number of prescriptions at different periods on Monday. As shown in figure 2, there were two peak values in the morning and afternoon respectively. Period with most prescriptions was 10:00am to 12:00am, and 2:00pm to 3:00pm followed behind.

![Fig. 2. number of prescriptions at different periods on Monday](image)

In order to get the distribution of prescriptions, we considered pay time as the time prescriptions arrived at pharmacy information system, for the reason that it was impossible to record the arrival time by hands when prescriptions transferred fast in information system.

We found it that prescription arrival time at different periods on Monday didn’t obey any regular distribution after analyzing data extracted from hospital information system. So before stimulating in Flexism 6.0, prescription arrival schedule shown in table 1 was regarded as their arrival distribution.

<table>
<thead>
<tr>
<th>ArrivalTime(s)</th>
<th>ItemName</th>
<th>ItemType</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Arrival135</td>
<td>103</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival136</td>
<td>105</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival137</td>
<td>107</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival138</td>
<td>123</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival139</td>
<td>124</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival140</td>
<td>129</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>Arrival141</td>
<td>131</td>
<td>Prescription</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Dispenser service capability didn’t relate much to the difference of periods, so no period-divided analysis was conducted to measure their service capabilities. In the process of simulation, the article assumed that each dispenser had the same service capability, and was independent from each other. After analyzing 335 samples in SPSS 12.0, the result showed their service capabilities obeyed normal distribution with the mean of 38.73 and variance of 35.67. Similarly, pharmacist working time was also normally distributed on the basis of analysis of 344 samples in SPSS 12.0. The mean was 46.46, and the variance was 28.9. So the values of basic parameters for simulation were given in table 2.

Table 2. Values of basic parameters

<table>
<thead>
<tr>
<th>Number of opened windows $n_0$</th>
<th>Number of pharmacists $n_1$</th>
<th>Number of dispensers $n_2$</th>
<th>Distribution of prescriptions at different periods</th>
<th>Distribution of pharmacist working time</th>
<th>Distribution of dispenser working time</th>
</tr>
</thead>
<tbody>
<tr>
<td>29(change over time)</td>
<td>The same as $n_0$</td>
<td>The same as $n_0$</td>
<td>Prescription arrival schedule</td>
<td>Normal(46.56,28.9)</td>
<td>Normal(38.73,35.67)</td>
</tr>
</tbody>
</table>

After getting familiar with the process of West China Hospital outpatient pharmacy, we also learned from pharmacy staff that after the payment was completed, information system would automatically send prescriptions to windows with the least queuing patients. The process flow chart was shown in figure 3. In order to analyze the influence of service process on the entire pharmacy service system, and find out its problems, the article firstly simulated the original divided-period service process in Flexsim 6.0. The period was from 10:00am to 12:00am when 29 windows were all open, and the time unit was second. After setting up simulation parameters and running the model for a few times, we got evaluation index values shown in table 3.

Table 3. Result of original service process simulation model

<table>
<thead>
<tr>
<th>Average waiting time (s)</th>
<th>Average number of prescriptions for pharmacists</th>
<th>Average number of prescriptions for dispensers</th>
<th>Average dispenser serving time (s)</th>
<th>Utilization of dispensing section (%)</th>
<th>Average pharmacist serving time(s)</th>
<th>Utilization of reception (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>552.6</td>
<td>3.6</td>
<td>2.4</td>
<td>46.9</td>
<td>84.2</td>
<td>39.5</td>
<td>74.5</td>
</tr>
</tbody>
</table>
According to the statistical analysis of actual samples collected before, the average time of making up prescriptions and dispensing was 46.5s and 38.7s respectively, while in simulation model that was 46.9s and 39.5s. The average length of stay was about 10 minutes due to our survey, and 552.6s, which was 9.2 minutes in simulation model. By comparison, there was quite small difference in the result of actual statistical analysis and simulation results. Therefore, the simulation model could effectively, feasibly reflect service process of West China Hospital.

As could be seen from figure 4 and 5, the number of prescriptions assigned to each window was imbalance and volatile, which made some of the windows have many patients waiting in a queue, while other windows were idle, so the total efficiency of service process was low, and patients needed waiting for a long time before getting drugs. Therefore, as the last part of patients staying in outpatient, pharmacy should pay much attention to decreasing patient waiting time and satisfying them.

The reason why the utilization of windows was quite different was that there were too many windows and too many queues. So the article proposed the idea of single-queue and multi-window. Firstly, divide the windows into several groups. Each group got only one queue. Prescriptions would be sent to available windows, so patients needed to wait only when all the windows of that group were busy. Each group adopted single-queue multi-window queuing pattern, while multi-queue multi-window pattern among groups. The proposed service process was shown in figure 6.
In order to solve the problems of multi-queue multi-window pattern, we proposed new plans to improve the original service process, and used simulation method to compare the performance of each plan. As shown in figure 6, windows needed to be divided into groups firstly. So considering practice and feasibility, there were 5 plans proposed below.

**Plan a.** Divide 29 windows into 5 groups. The first 4 groups had 6 windows each, and the fifth got 5 windows.

**Plan b.** Divide 29 windows into 4 groups. Each group got 8 windows except group 2 with 7 windows.

**Plan c.** Divide 29 windows into 3 groups. The first two groups got 10 windows, and the third group had 9 windows.

**Plan d.** Divide 29 windows into 2 groups. One contained 15 windows, and the other one got 14 windows.

**Plan e.** Only one group with 29 windows in service process.

<table>
<thead>
<tr>
<th>Plan</th>
<th>Average waiting time (s)</th>
<th>Average number of prescriptions for pharmacists</th>
<th>Average number of prescriptions for dispensers</th>
<th>Average dispenser serving time (s)</th>
<th>Utilization of dispensing section (%)</th>
<th>Average pharmacist serving time(s)</th>
<th>Utilization of reception (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>552.6</td>
<td>3.6</td>
<td>2.4</td>
<td>46.9</td>
<td>84.2</td>
<td>39.5</td>
<td>74.5</td>
</tr>
<tr>
<td>Plan a</td>
<td>549.5</td>
<td>3.3</td>
<td>2.1</td>
<td>45.8</td>
<td>83.7</td>
<td>38.7</td>
<td>73.9</td>
</tr>
<tr>
<td>Plan b</td>
<td>537.6</td>
<td>3.4</td>
<td>1.9</td>
<td>45.2</td>
<td>82.9</td>
<td>38.3</td>
<td>73.2</td>
</tr>
<tr>
<td>Plan c</td>
<td>523.2</td>
<td>3.0</td>
<td>2.0</td>
<td>44.9</td>
<td>82.1</td>
<td>37.8</td>
<td>73.0</td>
</tr>
<tr>
<td>Plan d</td>
<td>517.1</td>
<td>2.8</td>
<td>1.9</td>
<td>44.2</td>
<td>81.8</td>
<td>37.1</td>
<td>72.8</td>
</tr>
<tr>
<td>Plan e</td>
<td>512.8</td>
<td>2.7</td>
<td>1.8</td>
<td>44.1</td>
<td>81.4</td>
<td>37.0</td>
<td>72.6</td>
</tr>
</tbody>
</table>

Table 4 showed results of original service process and 5 proposed plans in Flexsim 6.0 from 10:00 am to 12:00 am. 5 plans performed better than the original one in the busiest period. The average waiting time in original service process was 552.6s, while plan e got result of 512.8s, which indicated that plan e could decrease waiting time up to 0.7 minutes.
For the background, the average service time of each window was less than the original one, and plan e got the least service time of 44.1s, which meant that an average dispensing time per prescription was 44.1s, 2.8s shorter than the original service process. Meanwhile, the utilization of plan e 81.4%, less than 84.2% of the original one, indicated that labor intensity decreased. But with excessive prescriptions, pharmacists backstage labor intensity was still very large, which needed further study.

For the reception, plan e got the shortest service time 37s. In other words, time to dispense and explain drug usage was about 37 seconds, which was shortened by 2.5s compared to the original service process. Meanwhile, the utilization was improved from 72.6% to 74.5%. It was consistent with the actual situation that reception area was less busy than the background.

Therefore, choosing plan e, single-queue multi-window pattern, could improve efficiency of the entire outpatient pharmacy system, and reduce patient waiting time, while reducing internal pharmacy staff labor intensity.

As shown in figure 7 and figure 8, if single-queue multi-window pattern was adopted, it would not only be much more balanced to assign prescriptions to each window, but also made human resources well used, which improved efficiency of the entire pharmacy. So single-queue multi-window pattern was the best solution to queuing problem of outpatient pharmacy.

In the outpatient pharmacy of West China Hospital, the number of prescriptions varies every day. It may lead to waste of resources if all windows are open but prescriptions are few. Hospital managers has recognized it, and implemented a solution that different windows open in different periods, but the number of opened windows is only empirically determined.

Under the current resources and facilities, we simulated all periods in single-queue multi-server queuing system, and gave the most reasonable numbers of opened windows due to our simulation results shown in table 5.
Table 5. Simulation results of plan e in different periods

<table>
<thead>
<tr>
<th>Period</th>
<th>The number of prescriptions for pharmacists</th>
<th>The number of opened windows in original system</th>
<th>Suggested number of opened windows</th>
<th>Average waiting time</th>
<th>Average number of prescriptions for pharmacists</th>
<th>Average number of prescriptions for dispensers</th>
<th>Utilization of dispensing section (%)</th>
<th>Utilization of reception (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30-9:00</td>
<td>1001</td>
<td>13</td>
<td>13</td>
<td>498.8</td>
<td>1.6</td>
<td>1.3</td>
<td>79.3</td>
<td>71.7</td>
</tr>
<tr>
<td>9:00-10:00</td>
<td>1890</td>
<td>29</td>
<td>21</td>
<td>507.7</td>
<td>2.1</td>
<td>1.6</td>
<td>80.7</td>
<td>72.1</td>
</tr>
<tr>
<td>10:00-12:00</td>
<td>4310</td>
<td>29</td>
<td>29</td>
<td>512.8</td>
<td>2.7</td>
<td>1.8</td>
<td>81.4</td>
<td>72.6</td>
</tr>
<tr>
<td>12:00-13:00</td>
<td>1303</td>
<td>29</td>
<td>16</td>
<td>503.4</td>
<td>3.0</td>
<td>2.0</td>
<td>82.1</td>
<td>73.2</td>
</tr>
<tr>
<td>13:00-14:00</td>
<td>1740</td>
<td>29</td>
<td>21</td>
<td>506.5</td>
<td>2.3</td>
<td>1.6</td>
<td>81.3</td>
<td>72.4</td>
</tr>
<tr>
<td>14:00-16:00</td>
<td>3826</td>
<td>29</td>
<td>29</td>
<td>510.9</td>
<td>2.5</td>
<td>1.7</td>
<td>80.9</td>
<td>71.3</td>
</tr>
<tr>
<td>16:00-17:00</td>
<td>1033</td>
<td>24</td>
<td>17</td>
<td>489.7</td>
<td>1.9</td>
<td>1.2</td>
<td>78.7</td>
<td>70.9</td>
</tr>
<tr>
<td>17:00-18:00</td>
<td>390</td>
<td>9</td>
<td>9</td>
<td>320.9</td>
<td>1.2</td>
<td>0.9</td>
<td>76.4</td>
<td>70.0</td>
</tr>
</tbody>
</table>

5. Conclusions

This paper firstly conducted in-depth research of hospital pharmacy to extract the basic parameters for preparation of pharmacy system simulation, and ran the original service process modeling. The simulation results comparing with the statistical results showed that the model was effective, and after analysis of simulation results, we found that the influential problem of pharmacy system was the unbalance of prescriptions assigned to different windows which was caused by the multi-queue multi-server queuing pattern. Then according to the existing problems, we proposed a solution that was to divide windows in groups, and the newly arrived prescription would be assigned to the shortest group. After comparing different plans, we found out that single-queue multi-server queuing pattern could improve the operating efficiency of the pharmacy, and shorten the patient waiting time as well as the labor intensity of the window staff balance, thus reduce labor intensity and improve patient satisfaction. Finally, we simulated all periods of single-queue multi-server queuing pattern, and gave the suggested number of opened windows.

This paper innovatively divided windows into groups to simulate, on the other hand, there was much further work needed to do. We only took the efficiency of the outpatient pharmacy and how to balance service intensity of pharmacists into account, not considering the pressure of hospital information system after changing the queuing pattern, the difficulties of implementation, and whether patients would like to change the queuing pattern, and the cost problem also needs more study.

Acknowledgements

The authors acknowledge the financial support of the Major Program of the National Natural Science Foundation of China, research on resource scheduling optimization in medical service, project No. 71131006, and the National Natural Science Foundation of China, research on hospital resource planning and control optimization based on patients’ needs, project No. 71172197. The paper is also supported by the Fundamental Research Funds for the Central Universities (Philosophy and Social Sciences) of Sichuan University, study on evaluation and optimization strategy of public hospital outpatient service quality based on patient satisfaction, skqy201208.
References


