Application of Queueing Model for Manpower Optimisation in Outpatient Pharmacy – A Statistical Approach to Optimise Medication Dispensing and Prescription Reviewing

Tiew Wen Jun, Changi General Hospital

Singapore Healthcare Management 2023

Changi General Hospital
SingHealth

Introduction

Manpower constraints has been a constant issue faced by pharmacy, and the situation is worsened by the recent expansion of services (e.g. Medication Delivery Service) and workforce attrition. There is a compelling need to optimise the existing manpower to maintain service standards and ensure staff are not overworked. A statistical method known as the M/M/c queueing model is applied to provide an objective mean to:

1. Optimise manpower allocation at specific time points for dispensing of medications and prescription reviewing
2. Achieve waiting time target to improve patient experience
3. Ensure even workload distribution to protect staff well-being

Methodology

M/M/c QUEUEING MODEL

ARRIVAL RATE
No. of patients/ prescriptions per min

WAITING TIME & SERVICE LEVEL TARGET
Dispensing: 80% less than 30mins
Reviewing: 80% less than 15mins

REVIEWING SERVICE TIME
Average time required to review one prescription

DISPENSING SERVICE TIME
Average time required to dispense one prescription

$$P_w = \frac{\frac{A^N}{N!}\frac{N}{N-A}}{\left(\sum_{i=0}^{N-1}\frac{A^i}{i!}\right) + \frac{A^N}{N!}\frac{N}{N-A}}$$

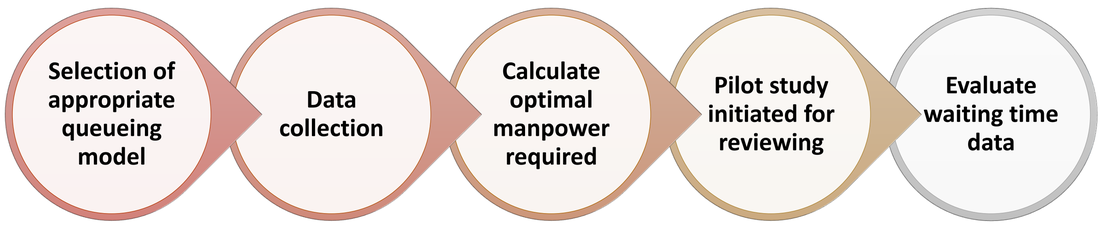
where
P_w = probability that a patient waits
A = traffic intensity for dispensing/reviewing
N = no. of dispensers/reviewers available

Characteristics of the M/M/c queueing model
1. Poisson distribution for arrival process
2. Exponential distribution for service time
3. Single queue, multiple dispensers/reviewers
4. No abandonment by the patients (i.e. patients have infinite patience time)
5. The queue capacity can be finite or infinite
6. Because there are no abandonments, the number of dispensers/reviewers must be greater than the offered load for the queue to be stable and reach steady state

Figure 1: Parameters and characteristics of the M/M/c queueing model

The M/M/c queueing model is appropriate for outpatient pharmacy in Changi General Hospital (CGH) as the dynamic dispensing and reviewing landscape fulfils the criteria outlined in Figure 1. The optimal manpower required to cope with the load at specific time points throughout the day can be calculated using the model.

PDSA Cycle 1



A two week pilot study was first carried out for reviewing to evaluate the effectiveness and feasibility of this initiative. The reviewing process was selected because manpower requirements were lower and the environment was more controlled as compared to dispensing. The % waiting time less than 15mins improved significantly from 73.2% to 86.5% even though the total manpower hours rostered daily was relatively similar at 36hrs/day pre- and post-implementation.

PDSA Cycle 2

The positive results in PDSA cycle 1 motivated the outpatient pharmacy to fully implement this initiative for both dispensing and reviewing from 01-Jan-22 onwards. Pharmacy staff were rostered in accordance to calculations by the queueing model. However, slight deviations in manpower allocation from the model prediction is unavoidable due to overall manpower shortage and staff absence from work due to various reasons (e.g. sick leave, on course), hence adjustments were made daily to fulfil operational needs. Data will be collected for one year post-implementation to determine the sustainability of results. This statistical method to optimise manpower can potentially be spread to other pharmacies in CGH.

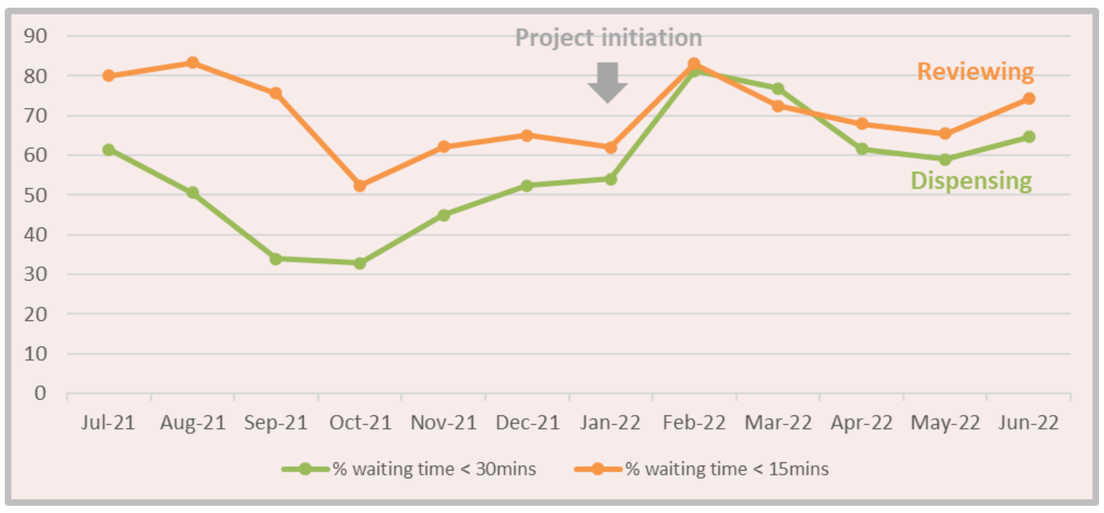
Results and Discussion

Data on arrival rate for dispensing and reviewing were extracted from 1queue and Pharmacy Management System respectively. Waiting time and service level target for dispensing and reviewing is 80% less than 30mins and 15mins respectively, which are the key performance indicators set by pharmacy. Time motion studies were carried out to determine the average service time for dispensing and reviewing, which is 9.82mins/prescription and 2.32mins/prescription respectively.

Time	No. of dispensers required	No. of reviewers required
8:30-9AM	3	1
9-10AM	7	3
10-11AM	11	6
11-12PM	15	6
12-1PM	14	4
1-2PM	11	2
2-3PM	9	5
3-4PM	12	6
4-5PM	14	4
5-6PM	12	2
6-7PM	4	1

Figure 2: Manpower calculations for dispensing and reviewing using queueing model

Data was collected on weekdays for nine months from Apr 2021 to Dec 2021 to determine the optimal manpower required for dispensing and reviewing at 60mins interval during the pharmacy operating hours from 8:30am to 7:00pm (Figure 2).



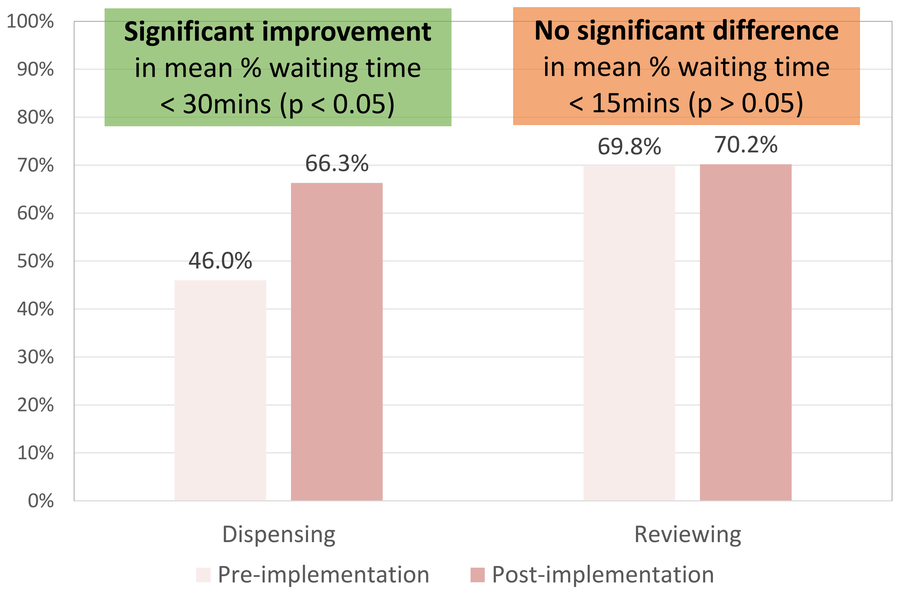


Figure 3: Comparison of waiting time results pre- and post-implementation

Waiting time results for dispensing and reviewing are compared six months pre- and post-implementation from Jul-21 to Dec-21 and Jan-22 to Jun-22 respectively. There are no significant differences in the weekday average number of patients served for dispensing and prescriptions for reviewing ($p > 0.05$).

The service level target of 80% was not met due to overall manpower shortage to fulfil the requirements of the optimised model. In addition, intangible factors such as workflow changes and staff competency levels may be confounders and not accounted for. Manpower required for other duties in the pharmacy (e.g. packing, restocking) has to be considered as a balance measure, in order to fulfil operational needs. However, the results do show that the queueing model is promising in providing a robust solution for manpower allocation in pharmacy through statistical means.

Conclusion

The application of the M/M/c queueing model is a step forward in helping to achieve waiting time targets for dispensing and reviewing at the outpatient pharmacy. This statistical method ensures optimal manpower allocation in accordance to the workload, which is especially important for staff well-being given the limited manpower in pharmacy. The limitation is that when the manpower available on a specific day falls below a certain threshold, the model becomes ineffective in achieving the desired outcomes. Nevertheless, this model revolutionises the way organisations can plan their manpower, especially when the queueing environment is dynamic. The next step is to link this model to an algorithm which can predict manpower requirement in relation to the daily clinic patient load. This can help to determine manpower requirement even more accurately on a day-to-day basis as the variability in patient load may be masked when using average values.