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Title: Multi-objective resource allocation and outpatient appointment scheduling by simulation optimization

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Abstract We consider integrating strategies to increase capacity of outpatient clinics by re-allocating resources and improving patient scheduling in an appointment session. Multiple objectives are considered in minimizing staff overtime, patient waiting time and waiting room congestion. Problem complexity includes patient classes with different flow paths through a multi-phase multi-server queuing system with uncertainties. An iterative 2-phase simulation optimization algorithm is developed. Experiments are designed based on a study of an eye clinic in a public hospital.

[494 characters (no spaces) in 76 words]
MULTI-OBJECTIVE RESOURCE ALLOCATION AND OUTPATIENT APPOINTMENT SCHEDULING BY SIMULATION OPTIMIZATION

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In specialist out-patient services, shortening the access time of patients to the next appointment and the on-site waiting time on the appointment date are typical concern for both patients and the healthcare organization. Several strategies have been adopted by Hospital Authority of Hong Kong to shorten the access time. Access time statistics of new cases for specialist outpatient services in different hospital clusters are published regularly on website. Collaboration between hospital clusters is coordinated centrally to enable patients in clusters of longer access time to be treated in clusters of shorter access time. In some clusters, diverting less serious cases to general outpatient clinics or family medicine specialty clinic has helped to reduce the workload and shorten the access time. Another strategy addressed in the annual plan in 2015-16 \cite{1} is to increase efficiency by developing more efficient service models. This work is motivated in a way to align with this operational strategy. Balancing workload can enhance efficiency to improve resource utilization, help retain manpower currently in shortage while shortening the patient waiting time for heavily loaded resource. To support the Strategic Plan 2012-2017 \cite{2} in developing a fair and transparent resource allocation system, the proposed methodology is rational and easy to comprehend.

The outpatient system operates like a multi-phase, multi-server queuing network serving patient classes with different flow paths and stochastic factors. The problem is divided into two phases as shown in Fig. 1. The first problem is the block appointment scheduling problem, named as Phase II, for a given resource allocation plan. The basic decision variables represent the number of patients in each class scheduled to different time blocks. This problem is embedded within the higher-level resource allocation problem, named as Phase I. The decision variables in Phase I are the number of compatible resource units assigned to perform different treatment procedures (or a combined set).

The multiple objectives common to both Phase I and II problems include average patient waiting time ($Z_1$), average staff overtime ($Z_2$) and congestion (queue length) in the clinic waiting area ($Z_3$). The three objectives are combined into a weighted objective function ($Z$) for the algorithm to find a good \textit{balanced} solution. Alternatively, the weights can be varied systematically to generate multi-objective solutions from which a set of approximate Pareto-efficient solutions can be identified.

The experiments designed are based on information and parameters collected in a joint project with an eye clinic of a local public hospital \cite{3}. To anticipate demand increase, a session quota of 250 and 300 for a 4.5-hour period is tested respectively. Resource flexibility scenarios
are created to examine the impact of the Phase I strategy. Performances are compared with well-known priority rules incorporating either or both types of improvement strategy.

![Flowchart](image.png)

**Fig. 1** Overview of integrated resource allocation and appointment scheduling problem

The contribution of this work includes solving an integrated problem of resource allocation and (block) appointment scheduling, by exploiting the characteristics of scarce manpower in outpatient clinics. When generating a new solution, a balancing criterion based on patient waiting time, different from the traditional concept of load balancing, is applied. The motivation and data came from a real-world specialty outpatient clinic, but could be generalized to other systems operating like a multi-phase, multi-server queuing network with stochastic factors.

**References**

