AN APPOINTMENT ORDER OUTPATIENT SCHEDULING SYSTEM THAT IMPROVES OUTPATIENT EXPERIENCE

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Abstract

Patient wait time and access to care have long been a recognized problem in modern outpatient healthcare delivery systems. Despite all the efforts to develop appointment rules and policies, the problem of long patient waits persists. Regardless of the reasons, the fact remains that there are few implemented models for effective scheduling that consider patient wait times, physician idle time, overtime, ancillary service time, as well as individual no-show rate, and are generalized sufficiently to accommodate a variety of outpatient clinic settings. The goal of this research is to improve the quality and efficiency of healthcare delivery by developing a patient scheduling system that meets the clinical policies without overbooking while using an innovative 'wait ratio' concept, a patient arrival schedule from the physician schedule accounting for ancillary services, an evidence-based predictive model of no-show probability for individual patient, and a model-supported dynamic overbooking policy to reduce the negative impact of no-shows. This research provides a step-by-step method for implementation of a scheduling model in outpatient clinics. Consequently, this research will improve the outpatient experience for both patients and medical providers, increase patient access to care, and ultimately enhance the quality of care.

Learning Objectives

The learning objectives are:

1. Understand the fundamental reasons and shortcomings of the current scheduling systems.
2. Define an effective patient central scheduling model that meets the clinic policies.
3. Develop and extend the proposed model to consider ancillary services.
4. Learn and evaluate the implementation of the proposed model.
5. Develop an overbooking policy to reduce the negative impact of no-shows.

Introduction

Patient wait time and access to care have long been the recognized problems in modern outpatient health care delivery systems. As competition has increased for limited health care dollars, efforts have been made to increase efficiency and reduce costs, yet only limited gains have been made in terms of reducing patient wait time and improving patient access to care. Ironically, one of the main strategies to decrease cost has been to shift traditionally inpatient services to an outpatient setting, which tremendously increases the burden on outpatient facilities to efficiently manage health care delivery. Due to the increasing outpatient clinics, patient wait and access to care have become two of most critical measurements for patients to choose their physicians. However, limited progress has been made in the systematic improvement of patient wait and access to care, maybe because most facilities have focused more on the efficient scheduling of provider time since perceivably they have a higher value than the patients' time. The overbooking and shorter scheduled treatment time interval policies are the typical approaches used to prevent physicians from idling. The unrealistic estimation of treatment time intervals at present is mostly of clinics that are still in a physician-centric environment. In this study, even one minute off from an estimation of a treatment time interval will have significant compounding effects to patient waiting. In addition, the inaccurate definitions of appointment time verses arrival time, or inadequate definition of what is included in physician treatment time, evidently increases patient wait time and decreases patient access to care. There is no clear delineation between the physician schedule and the patient arrival schedule. Cayirli and Veral (2003) conducted an extensive review of the literature on scheduling. They concluded the limitations on appointment rules are mainly the lack of implementation and a generalized model that reflects reality. This paper provides an effective scheduling method that considers patient wait time, physician idle time, overtime, ancillary service time, as well as individual no-show probability to improve healthcare delivery by reducing patient wait time and improving patient access to care.

This paper consists of methods for defining schedule time interval for the development of a physician schedule, accounting for ancillary services to develop a patient arrival schedule, and incorporating overbooking to reduce the negative impact of patient no-shows.

General Modeling of Patient Flow

The general model for patient flow in and out of outpatient clinics has been developed by many researchers such as Ho and Lau (1992). Let T_i be physician service time for patient *i*, X be the scheduled time interval, S_i be the scheduled starting time for patient *i*, F_i be the finish time for patient *i*, A_i be the actual starting time for patient *i*, W_i be the wait time for patient *i*, and P_i be the physician idle time waiting for patient *i*. A graphical example for patient flow is demonstrated in Figure 1.

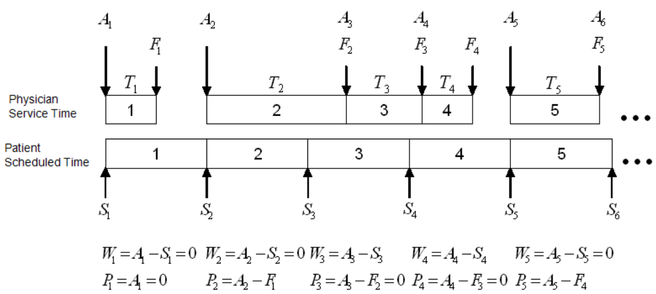

Figure 1. General patient flow

Then the average patient wait time, $\overline{W}$, and the average physician idle time, $\overline{P}$, can be calculated. This general model is used as a basis for our simulation model.

Physician Schedule Development

A successful appointment system should minimize patient delays while fully utilizing medical resources. However, there is a tradeoff in that reducing patient wait time may increase physician idle time and vice versa. Hence, this paper proposes a 'wait ratio' approach that balances patient wait time and physician idle time. This allows us to determine the treatment time interval of each visit type for a given 'wait ratio'. Determining the treatment time intervals across different visit types by the same 'wait ratio' is to ensure every patient is treated equally in terms of waiting. The best scheduled time interval is defined as the maximum scheduled time interval for each visit type that satisfies medical and clinic constraints. Let $X = \mu + d\sigma$, mean μ and standard deviation σ are the parameters of treatment time T_i. *d* is the number of standard deviation away from the mean. The Wait Ratio, *R*, is defined as the degree to which average patient wait time $(\overline{W})$ exceeds *R* physician idle time $(\overline{P})$; $\overline{W}/\overline{P} = R$. The goal is to find the optimal *R* that satisfies the clinic constraints. Once the optimal wait ratio (R^*) is reached, then the optimal time interval (X^*) can also be calculated for each visit type.

To assure that our model does reflect actual clinic operations, certain constraints need to be considered in generating the optimal time interval for each visit type. The proposed model does not aim at forcing the clinic setting to fit the solution, but rather aims at fully utilizing the available resources and capacity to achieve the best solution. The clinical constraints are used to determine a ratio to replace conventional cost ratios, in large part because physicians tend to overestimate the cost of their time as opposed to patient time, most likely due to their lack of criteria for accurately evaluating time cost for the patient to clinical management. This method effectively eliminates the cost of patient time and the bias inherent in cost ratios from the model in favor of well defined constraints. The underlying constraint is to ensure the optimal time interval has a less than 50% chance of patient waiting, $\Pr(T_i \le X^*) \ge 0.5$. Aside from the constraint of the probability of a patient wait in the absence of a prior wait, there are other clinical conditions, generally administrative constraints established by management, that can affect scheduling time intervals that need to be considered, such as clinic or session finish time, time of last appointment, number of patients to be seen in a given session, average patient wait time, and average physician idle time. Once the optimal time intervals are determined, a physician schedule can be constructed.

An example from an Orthopedic Surgery Clinic, there are three major visit types used: Follow-up patient (FU), New Patient (NP), and Patient requiring X-ray before seeing physician (XR). The current schedule is shown in Figure 2. The physician treatment time data summary is shown in Table 1.

Table 1. Physician Treatment Time Summary

Patient Type	Average	Standard Deviation
NP	10.6	4.5
FU	7.3	4.0
XR	5.5	3.4

Unit: minutes

Three clinic constraints are addressed:

- Session should be finished by 11:30 am.
- Last patient should be scheduled by 11:00 am.
- There should be 25 patients scheduled in a session.

From the simulation optimization model, the R^* that satisfies clinic constraints is 18, which also stratifies the underlying constraint of $\Pr(T_i \le X^*) = 0.57 \ge 0.5$.

Therefore, the optimal time intervals (X^*) for FU, NP, and XR are 7.4, 10.6, and 5.3, respectively. Then the physician schedule is constructed as shown in Figure 2.

Patient Arrival Schedule Development

Once a physician schedule is established, then the corresponding patient arrival schedule must be determined. The main concept behind the arrival schedule is to provide sufficient time between the patient arrival at the clinic and the actual examination time for the patient to complete activities and required pre-visit activities such as signing in, filling out paperwork, having vitals taken, having an x-ray taken, providing a specimen, and moving between lab or x-ray room and exam room. The time assigned to pre-visit activities will differ from clinic to clinic and between specialties. However, if the time needed for these activities is not well defined, wait time will be compounded for either physician or patients. Ideally, the physicians should be able to maintain their schedules without contributing significantly to patient wait time. Ancillary services such as x-ray, lab test, diagnosis vascular studies, and electrocardiogram (EKG) are important to assist the physician in making an accurate assessment and are most likely required prior to a physician visit in many outpatient clinics. The focus here is for clinics that prefer both ancillary and physician services to be done in one visit.

Patient wait time increases by both underestimating and overestimating the length of time required for ancillary services. When ancillary service time is overestimated, increased wait times result from early completion before the physician is ready for the patient. When ancillary service time is underestimated patients experience delays in being seen by the physician. The time assigned to pre-visit activities will differ from physician to physician. Hence, the best scheduled ancillary service time interval to be considered in scheduling should be determined according to individual physician's schedule and needs. The goal is to minimize the patient wait time by determining the best scheduled ancillary service time interval in scheduling systems.

Continuing with the example from the Orthopedic Surgery Clinic, the main ancillary service is x-ray. From the data, x-ray time can be estimated by a Gamma distribution with mean of 6.3 minutes and standard deviation of 3.7 minutes. The clinic is currently asking patients who are required to have an x-ray before seeing the physician to come in 10 minutes earlier. Two observed problems are: 1. This 10-minute time is not accounted in the scheduling system so that patients tend to disregard it and arrive at the scheduled time. 2. There is no basis for this 10-minute decision. From the simulation optimization model that minimizes the average patient wait time, the best scheduled time interval of the ancillary service is found to be 5 minutes. Therefore, on top of 10 minutes for all pre-visit activities such as signing in, a 5-minute early arrival is added to XR patients. Hence, if a patient is scheduled to see the physician at 9:00 am and is required to have x-ray taken, then this patient should arrive at 8:45 am to accommodate 10-minute pre-activity and 5-minute x-ray; see Figure 2 for patient arrival schedule. Furthermore, 23% of NP and 21% of FU from data required x-ray. After interviewing with medical assistants and nurses, some rules were found:

- Patients who have had joint replacement will need to have x-rays at post operation, 3 month check, and 1year check scheduled under FU patient slots. After a year, if a patient calls in and complains of "pain", they would be scheduled as FU and have an x-ray.
- Patients who have had bone displacement or fracture that was manipulated or operated on in the hospital will need an x-ray and are scheduled as FU.
- All new patients will need x-rays if they have not had one done elsewhere. A special case is new patients with an indication of arthritis in their knee; if their x-ray only has two views, then they will need to have an x-ray for two additional views.
- Patients who are over 60 years old will need x-rays.

If those criteria are transferred to the schedulers, then the x-ray time can be taken into account when scheduling an appointment so that the first consultation time and the patient wait time can be reduced to improve patient access to care and service quality.

Original		Proposed		
Patient Type	Patient Arrival	Patient Type	Physician Schedule	Patient Arrival
FU	8:00	FU	8:00	7:50
XR	8:00	XR	8:07	7:50
NP	8:05	NP	8:13	8:00
FU	8:15	FU	8:23	8:15
XR	8:15	XR	8:31	8:15
NP	8:20	NP	8:36	8:25
XR	8:25	FU	8:47	8:35
FU	8:30	XR	8:54	8:40
FU	8:30	FU	8:59	8:50
NP	8:45	NP	9:07	8:55
FU	8:55	FU	9:17	9:05
FU	9:00	XR	9:25	9:10
FX	9:00	FU	9:30	9:20
FU	9:15	NP	9:37	9:25
XR	9:15	FU	9:48	9:40
NP	9:20	XR	9:55	9:40
FX	9:30	FU	10:01	9:50
XR	9:30	FU	10:08	10:00
FU	9:45	NP	10:16	10:05
NP	9:45	XR	10:26	10:10
FX	10:00	FU	10:31	10:20
XR	10:00	FU	10:39	10:30
NP	10:15	NP	10:46	10:35
FU	10:20	FU	10:57	10:45
FU	10:30	FU	11:04	10:55

Figure 2. The proposed physician and patient schedules

Implementation Results

The approach thus far has been implemented in three clinics. They are Orthopedic Surgery, Plastic Surgery, and Vascular Surgery clinics. The results indicate the significant reduction on patient wait time as much as 56%; see Table 2. As for physician idle time, it was found that there is not a significant difference.

Table 2. Implementation Results for Three Clinics

In minutes	Orthopedic	Plastic	Vascular
Before	27.8	15.0	27.8
After	13.1	7.5	12.4
Reduction	53%	50%	56%

Overbooking Policy

One of the major issues that has been wildly studied by researchers is no-shows. Clinic no-shows are when a patient does not arrive to a previously scheduled clinic appointment. This is problematic for multiple reasons. For example, patients in need of an urgent clinic appointment cannot be seen when the schedule is full even if a last minute opening occurs due to a no-show. It also deprives the clinic of needed revenue since an empty visit slot results in non-billable "down time". One way to help avoid this problem is to overbook appointments, which is where more than one patient is scheduled at the same time. This can also create significant problems because if all patients do arrive for their appointments the wait times can be very long, which may lead to clinic overtime, and will result in significant patient dissatisfaction. Many reasons for no-shows have been studied and reported such as patient mobility and physician specialty. One scheduling approach developed to reduce no-shows is known as Open Access used by Murray and Tantau (1999). Open Access approach uses the philosophy of “doing today’s work today”. This approach seems to improve patient access and no-show rate, but practically burdens patients in attempting to get appointments, which may drive away patients and leads to profit losses. Due to the nature of this approach, overtime is allowed to occur when the demands are high. This, in turn, increases the cost for clinics and burdens clinics’ management. This approach did not focus on reducing patient wait time, but exclusively attempted to fill up the clinic day so that the resources could be fully utilized.

This paper proposes an approach using the traditional appointment order scheduling to cautiously overbook patients into appointment slots by understanding scheduled patients’ no-show behaviors so that the total costs (patient wait time, physician idle time and overtime) can be minimized. There are two major components here. First, a statistical prediction model will determine the probability of no-shows given patient characteristics and considered with other environmental factors such as the predictive model built by Glowacha et al (2009). Then, a simulation optimization model will find the optimal threshold of no-show rate obtained from the prediction model to minimize the total costs. Let $p_{i,j}$ be the predicted probability of no-show for patient *j* at appointment slot *i* and *p* be the threshold of no-show rate for each slot. At any time slot, overbooking can be performed as long as the joint probability at a slot is still greater than the threshold, $\prod_j p_{i,j} \geq p$. Let *W* be the total patient wait time, *P* be the total physician idle time, and *O* be the overtime for a clinic day. Given c_w is the cost of patient wait time, c_p is the cost of physician idle time, c_o is the cost of overtime, and c_T is the total cost of patient wait time, physician idle time and overtime. Therefore, $c_T = c_w W + c_p P + c_o O$. The objective is to find the optimal value for the threshold of no-show rate $\left(p^*\right)$ that minimizes c_T. Therefore, if the simulation optimization model determines p^* is equal to 0.32. This means that clinics will overbook a patient where the predicted probability of no-show scheduled in a time slot is greater or equal to 0.32.

This paper presents a theoretical concept for a dynamic approach which accommodates overbooking into a patient scheduling system based on the prediction of an individual patient’s no-show probability. This approach is unlike the traditional built-in overbooking approach that does not account for an individual patient’s conditions and tends to favor a physicians’ time. Although the foundation of this proposed approach is based on the prediction of patient’s no-show probability, which is more likely case-by-case different, the approach itself is generalized enough for any patient schedule to be implemented. Each clinic determines the least amount of patients to schedule without overbooking and then uses the proposed overbooking approach to find where and how many to overbook based on the objectives of minimizing the total cost including the costs of patient wait time, physician idle time and overtime.

Implementation Steps and Outcomes

To implement the proposed approach, steps from data collection, model development including determining the optimal treatment time and ancillary service time intervals and the overbooking optimal threshold level, to implementation with anticipated activities and expected outcomes is explained; see Table 3.

Table 3. Project Activities and Anticipated Outcomes

Project Activities	Project Development	Project Outcomes
Data for physician and medical staff treatment time	Understand patient visit time and its variability	Improve physician and staff understanding of time required for different patient types
Data for patient and physician wait time		
Clinic process flow	Build simulation model corresponding to the process flow of the clinics	
Clinic constraints	Determine the optimal treatment time intervals for each visit type	Develop improved scheduling policies for providers
	Build physician schedule	
Data for treatment time of ancillary services	Build patient arrival schedule	Develop improved scheduling practices for patient arrival
Data for no-show patient characteristics and preferences	Build statistical model to estimate no-show rate	Improve patient access to care providers and reduce negative impact of no-shows
	Incorporate overbooking policy in scheduling system	
Data for patient and physician wait time after implementation	Approach implementation	Enhance patient satisfaction and quality of care

Summary of Research Design

This approach uses an interesting concept of 'wait ratio' instead of traditional cost ratios of patient wait time and the physician idle time. As many researchers have used traditional cost ratios, the issue of the long patient waits in a physician's office still exists. In addition, this research demonstrates an approach for patient scheduling developed to reduce patient wait time, enhance patient flow, and improve patient access to care, without significantly increasing physician idle time. The approach allows clinic management to quickly determine the best scheduled time interval for different visit types and then integrate clinical constraints to construct two scheduling templates: physician and patient arrival. Separating the two schedules will make it possible to create a template for patient arrival that accommodates any patient processing tasks or ancillary services that need to be conducted in conjunction with a given physician service. This will reduce the unnecessary first consultation and improve the timely delivery and patient access. In addition, the common issue of no-shows is considered into the scheduling system and the approach provides a dynamic way of overbooking patients that minimizes total costs. The conceptual and theoretical framework of this paper allows the changes of input parameters such as provider treatment time, ancillary service time(s), number of patients seen and no-show rates among physicians in a variety of clinic settings. This approach allows clinic management to input its own parameters such as physician treatment time, scheduling sequence of visit types, types and times of ancillary services, and no-show rates to accommodate the difference of each clinic or physician's practice.

Conclusion

Wait ratio is a novel concept of the relationship between patient wait time and physician idle time. This concept provides an advantage over the traditional cost ratio to prevent it from being the 'physician centric' solution to ensure patients being treated equally regardless their visit types and conditions, as well as full utilization of clinic resource capacity. The main reason that cost ratios favor physician wait time is due to the definition of cost values assigned to both patient wait time and physician idle time. Realistically, the cost of physician idle time is much higher than that of patient wait time. Hence, the high cost ratio between physician and patient wait time becomes the most dominant factor when deciding patient scheduling time intervals. Therefore, it is much more objective to consider wait time itself instead of placing a cost value to wait time while designing schedule time intervals. By adopting the concept of 'wait ratio' this allows a clinic to actually take into account clinic constraints for determining an appointment schedule to generate a better patient flow.

Secondly, the concept of two scheduling systems, physician and patient arrival schedules, has not been wildly considered when scheduling. According to the findings from interviewing clinic management regarding what the patient scheduled time means, the general answer has been the scheduled time is the time for a patient to see the physician. This indicates that the pre-activities such as x-ray are completely ignored, which tends to compound the impact of waiting from the beginning of a clinic session. Incorporating two schedules makes it possible to account for any ancillary services before seeing the physician to customize patients' needs and conditions. In addition, most clinics assume the same amount of time to complete the required ancillary services, for example, 10 minutes for any patients who needs x-rays. This assumption does not account for the variation of ancillary service time at all, which generates waiting for both patients and physicians. Therefore, considering individual needs for ancillary services is important for a better scheduling system.

Third, even though overbooking approaches have been widely used in most scheduling systems, most of the overbooking slots are designed into the scheduling systems before actually scheduling patients. This traditional approach does not consider the individual no-show behavior, without understanding patients' characteristics and preferences. This means the majority of the time when two patients actually show up at the same time, one of them is bound to wait for service. This paper provides an overbooking concept that accounts for the individual patient's probability of no-show based on patient characteristics (age, gender, location, mobility) and preferences including environmental factors (weather and traffic conditions).

In conclusion, one of the major concerns from literature is the gap between theoretical concepts and feasibility in reality. This paper provides a solution for execution of the proposed approach, conceptually and theoretically, from an initial data collection and model development to implementation of the approach. This approach will not only close the gap between theory and practices but also provide evidence of applicability for any physicians in any specialty. In short, the successful demonstration of this proposed approach will shift the perception of long waits in a physician’s office, transform outpatient environment to be much more pleasant, and ultimately improve the outpatient experience.

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Biographical Sketch

Dr. Huang joined the Department of Industrial Engineering at New Mexico State University as an Assistant Professor in 2009. He earned his Ph.D., M.S.E. and B.S.E degrees from Industrial & Operations Engineering Department at the University of Michigan, Ann Arbor, in 2008, 2007 and 2000, respectively. Dr. Huang’s research interests focus on process improvement using simulation optimization modeling methods in health care delivery systems including outpatient scheduling system, pharmacy layout design, radiology operation improvement, emergency delivery system, and operation room scheduling system. He is also interested in cancer prevention decision aid development. Dr. Huang has three years of experience as a project facilitator for scheduling in outpatient clinic settings supplemented by three years of experience as business analyst in an industrial supplier and two years of experience as an industrial engineer in manufacturing systems.