Proactive Service Coordination Framework Empowered by Predictive Analytics:
The Case of ED–Inpatient Unit Interface

Operations in modern service systems entail complex interactions between customers, service providers, and resources. In particular, we identify patient treatment, handling, and flow across the departments of hospitals as a rich representative problem setting that encompasses intricate interdependencies among activities and requires responsive services corresponding to uncertain patient needs. Although health information technology (HIT) is being broadly adopted in hospitals along with lean and six-sigma programs to improve the quality and safety of care, current HIT systems mostly support clinical/operational processes in a reactive manner. In this paper, we discuss an early task initiation strategy, the proactive use of HIT, empowered by predictive analytics to enhance near real-time operational intelligence. Especially, we show that, when used properly, the future information (disposition decision prediction and LOS estimation) of ED patients can enable proactive inpatient bed reservations for ED patients to significantly expedite the interdepartmental operations between the ED and inpatient units, reducing the boarding delay.

We formulate the ED–inpatient unit network with mathematical abstractions upon which we can investigate the following critical aspects for implementing proactive coordination. First, the increasing trend of predictive power of patient information being accumulated throughout the course of ED processes is studied. Second, the decreasing trend of timeliness of prediction is discussed. Lastly, the operational impact of proactive bed reservations that is derived from the two aforementioned trends is discussed. To demonstrate the effect of prediction timing in a practical setting, we analyze electronic health record (EHR) data gathered over multiple years (May 1, 2014 – December 15, 2016) in a leading healthcare facility in Midwest, constituting 230,845 ED visits and 1,942 admissions. By analyzing the clinical information collected, we show that there is the
optimal timing to send a bed request to an inpatient unit for a patient under a given operational setting.

As a baseline model, we analyze a fork-join queueing network that represents the proposed proactive inpatient bed reservations for ED patients and reveal that the bed assignment delay for ED patients is a function of bed preparation service time and early bed request signal lead-time (Figure 1).

![Figure 1. Impact of proactive inpatient bed reservations for ED patients](image)

The operational impact of prediction depends both on prediction quality and remaining ED length-of-stay of the patient. At the initial stages of care in the ED, the reliability of prediction would be low due to the insufficient amount of patient information accumulated. As the patient goes through ED care processes, better prediction (with higher performance measures) will become feasible. However, as prediction timing becomes late (with the increasing amount of patient information), the operational impact of proactive coordination would be compromised. There is a clear tradeoff relationship between the timeliness of predictions and the reliability of the future information of patients as shown in Figure 2. Through data analysis, we show that there is
a time (T1 in Figure 2) that the reliability of prediction rapidly increases for a patient. This is usually the time when a set of vital measures, lab tests or medication orders are made (such as triage and the first encounter with a care provider). Also, from Figure 1, we observe that there is a time (T2 in Figure 2) that the timeliness of prediction rapidly decreases. Therefore, if the ED sends an advance bed request between T1 and T2 (when T1 is earlier than T2), proactive bed allocation for ED patients can be effective. Whereas, when T1 is later than T2, the operational benefit diminishes quickly without concrete prediction. In this case, a decision on sending an early bed request should be based not only on the benefit of an individual patient but also on the current inpatient bed demand–supply situation. We demonstrate relationship between two factors (i.e., the reliability and the utility) based on the distributions of T1 and T2 from the gathered data.

Figure 2. Tradeoff between diagnostic certainty and reliability of prediction

With ever increasing attentions to predictive analytics, the implementation of early task initiation in healthcare systems based on predictions should become a promising area of scientific research and exploration for both industry and academia. The insights gained from our study should give practical guidance to hospital managers in implementing proactive coordination enabled by modern healthcare IT systems.