An Empirical Investigation on Overflow Decisions in Inpatient Flow and their Impact on Patient Outcomes

Inpatient flow management is often presented with high utilization in bed capacity and high variability in demand. When the preferred inpatient units are overloaded, patients may experience extensive delays in the admission process. To avoid excessively long waiting time, the hospital may choose to place patients in a non-primary unit. These patients are referred to as off-service patients. Delay and overflow can lead to worse medical outcomes and generate extra workload to physicians and nurses. It is important to optimize inpatient flow to insure the right level of care is delivered in a timely manner.

In this paper, we study the overflow decision in inpatient flow management and its impact on both individual-level patient outcomes and system-level congestion. Using patient level data from a large teaching hospital in Singapore, we first empirically investigate the causal effect of overflow on inpatient length-of-stay (LOS) and readmission rates. Then, we develop a structural model to estimate what factors drive the overflow decision in practice. Finally, motivated by the empirical findings, we use simulations to identify optimal overflow decisions that balance the cost and benefit of overflow.

Causal effect of overflow on patient outcome. We conduct reduced form analysis to measure the causal effect of overflow on patients’ LOS and readmission rates. Specifically, we first measure the outcome by differentiating patients who are assigned to a primary unit and a non-primary unit. We then further differentiate the off-service patients by whether the non-primary unit is medically close
to the primary unit.

The effect of overflow on patient outcome is difficult to identify empirically because there are many confounding factors. First of all, unobserved patient characteristics are correlated with both the overflow decision and the patient outcomes. For example, patients with less severe conditions are more likely to be overflowed to another unit, but they are also more likely to have shorter LOS. Second, the usual candidate for instrumental variables (IV) may not apply in our setting. For instance, system status such as primary ward occupancy level has been a common choice of IV’s in the literature (Kim et al 2015). In our setting, however, primary ward occupancy level can be correlated with both the overflow decision and the outcome of the patient. Particularly, the higher the primary ward occupancy level, the more likely the patient is to be overflowed to another unit. In the meantime, when the primary ward occupancy level is higher, the LOS of the patient might also be shorter (KC and Terwiesch 2012). We deal with the difficulty by constructing a new set of IVs that identifies the causal effect of the overflow decision.

**Determinants in overflow decisions.** To understand how the overflow decisions are made in practice, we build a structural model to estimate the effect of different factors. We consider a two-stage decision model. In the first stage, the decision maker chooses whether to overflow a patient. If the patient is chosen to be overflowed, in the second stage, the decision maker decides on to which non-primary unit. Particular factors we incorporate in the decision models are occupancy levels of the primary units and the non-primary units, medical closeness between the non-primary units and the primary units, physical distances between the non-primary and the primary units, patients’ delay in the admission and other
patients’ characteristics. We also take the time of the day effect into account, as this will affect the anticipation of how many beds will become available later.

**Optimal overflow policy.** Based on the estimated overflow decision model (from the second part), we conduct counterfactual analyses to quantify the importance (weights) of various factors. Our goal is to strike a balance among (i) patient outcome (measure by the empirical findings in the first part), (ii) cost of overflow assignment such as extra workload posted on physicians and nurses, and (iii) system-level performance such as average delay and overflow proportions. Motivated by (Shi et al 2016), we build a detailed simulation model to capture inpatient flow dynamics and use the simulation model to identify the optimal weights to put on different factors when making overflow decisions.

**References:**

