Capacity Planning and Performance Contracting for Medical Imaging Facility Operators

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Extended Abstract

Managing capital-intensive service centers, such as radiation oncology centers, computerized diagnostic imaging facilities, or short-run contract manufacturing systems, is a challenging task. In such centers, a fixed technological capacity is installed for handling variable demand, with stochastic task times. The owners of these centers are responsible for all the upfront capacity investments, which involve a significant layout for equipment, software and installation. For instance, the typical costs for modern radiation oncology, or MRI and CT units range from two to four million dollars and the costs for the newly introduced proton therapy centers are usually north of one hundred million dollars. While high utilization is a critical profitability driver, these service centers are also facing uncertain market demand, and they have to maintain an acceptable service level and relatively short waiting times in order to compete in the market successfully. The managers of these facilities are often contracted to run them as profit centers. As such, they are usually responsible for managing daily activities and for generating demand through additional marketing or service quality efforts. For example, we have seen that at most of the free-standing radiology facilities that are run by the national networks in the US (such as Insight Imaging and Radnet Inc.), the local managers are responsible for staffing, scheduling, marketing and other demand generating activities in their territory.

To make the correct capacity investments at each market, it is necessary for the investors to solicit true market information from the local managers who own the specific knowledge about the region. As the agents responsible for running the service centers, they often possess private information about local market conditions, referral patterns, demographic preferences, and their own demand-generating efforts. They may not willingly or truthfully share that information with the investment firms which plan to build and own these centers. In this paper, we propose a solution to this problem that has been motivated by
our practical experience and by the latest research on mechanism design. We do so by embedding queuing service models in the principal-agent framework as a way for effectively analyzing and solving the ensuing managerial tradeoffs above.

We model a computerized diagnostic imaging center as a queueing system with stochastic arrivals of service requests and random service rates. In our model, the agent (or the manager running the center) possesses private information about the exact local market conditions, whereas the principal (or the owners of the firm) knows only the distribution of the local market demand. In addition, the manager can influence the service demand rate through exerting additional marketing and service efforts. This managerial effort level is his private information, which gives rise to information asymmetry between the investing firms and the service centers’ management. Facing uncertain market demand, the principal is responsible for the center’s capacity investment and for ensuring that the center meets industry-wide service standards. The principle must develop the right incentive contracts in order to solicit the correct market information from the local site managers, and to induce the desired levels of managerial efforts that properly balance capacity planning, profitability and service quality.

We propose and analyze three incentive contracts to address the above information asymmetry issues. We show that the uniform-contract, which offers the same payment terms regardless of market conditions, is able to induce the desired demand-generating effort from the manager but fails to solicit the manager’s market knowledge, and leads to a suboptimal capacity installation. Addressing this issue, we present two new information-soliciting contracting approaches which are simple to implement in practice. The first approach is to offer a menu of variable-rate linear contracts in which the per-case payments are modified for different market conditions. Under this contracting mode the manager is induced to report the realized local market demand and the investing firm is responsible for capacity selection and for meeting the service standard. Under the second approach the investor charges the manager a differential franchise fee for using the installed capacity and pays the manager a uniform per-case fee regardless of the market conditions. Thereby, here the manager is explicitly responsible for capacity selection and for meeting the service standard. We prove that the firm can solicit true market information by properly
setting the capacity charges and we explain why this approach (of charge-back contracting) not only can solicit true market information from the manager, but also induce the first-best (full-information) effort level.

We are able to derive the closed-form solutions for all three contracts in the information asymmetry case and compare them with the first-best outcome (full-information case). Using the proposed variable-rate or charge-back contracts, the investing owner can significantly improve on the standard uniform contract since they effectively solicit truthful market information and induce the desired managerial effort from the manager. As a result, the owner can install higher service capacity, have a higher demand rate and realize higher profits.

While both the variable-rate and charge-back contracts can help the owner successfully solicit the manager’s local market information, the owner’s eventual optimal contract choice depends on the probability distribution of local market demand. Specifically, the charge-back contract, which produces the first-best effort levels, only dominates the variable-rate contract when the probability of having a low local base demand is high. We show that because of information asymmetry, the manager is able to reserve an information rent under both contracts. Thus, the firm’s profit level is lower than that in the full-information case, even with the charge-back contract which produces the first-best results across the board.

Our work extends existing literature on contract design and service resource management in multiple ways. Prior studies addressing contract design and service resource management often focus on only a subset of the related factors, and thus do not provide a complete solution for firms dealing with fixed capacity planning decisions combined with adverse selection and moral hazard issues in an uncertain service environment. Our study applies to many capital intensive and congestion prone service systems such as healthcare facilities, modern IT service and manufacturing centers, and provides guidelines for investment firms dealing with uncertain service environments and local operations managers who typically possess specific knowledge and have an information advantage.