Contract Optimization at Texas Children’s Hospital

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In 1998, faced with mounting financial pressure, Texas Children’s Hospital found its mission in jeopardy. Payors sought to reduce expenditures, while physicians wanted to provide the highest quality patient care, research, and teaching. Working with PROS Revenue Management, the hospital spearheaded an initiative to bring greater analytic capabilities to administrative operations, initially focusing on optimizing the performance of contracts with insurers because of the potential revenue leverage. It did so by (1) quantifying expected future demand through forecasting, (2) establishing risk as an important means of measuring contract performance, and (3) embedding the underlying Bayesian forecasting and nonlinear optimization models in a software system that supports the daily activities of contract negotiators. Direct benefits include revenue improvements of up to $17 million annually on contracts renegotiated with use of the PROS technology. The project’s initial success has spawned efforts to improve the hospital’s planning and operational activities. With a system designed for transfer to other hospital settings and possible enhancement of the diagnosis-related group (DRG) classification system through the use of patient pathways, the health-care optimization technology has the potential for broad impact in the industry.

Key words: health care: hospitals; forecasting: applications.
PROS recognized that the situation Texas Children’s faces differs from the situation faced by more traditional practitioners of revenue management, such as airlines, hotels, and rental car operators. Among the most important differences is that the hospital’s mission is to save lives and support teaching excellence, not to maximize profit. Hospitals speak of services, charges, and reimbursements, not products and prices. Further, the revenue stream is driven almost entirely by large contracts rather than individual payments. In this new world of revenue management, Texas Children’s and PROS began a collaboration in 1999 to formulate revenue optimization solutions for health care.

How Hospitals Generate Revenue

Hospitals provide a variety of services, including access to operating room facilities, medical equipment, tests, beds, and nursing care. Hospitals and physician groups, who operate autonomously from a payment perspective, are known collectively as health-care providers. In the United States, health-care providers are paid for patient services almost entirely by private commercial insurers and their governmental equivalents, Medicare and Medicaid. Patients meet the requirements of a governmental program, directly or indirectly purchase coverage from an insurer, or remain uninsured. When patients buy insurance coverage, they usually do so through a sponsor, for example, an employer or a professional organization. Sponsors can purchase access to health-care resources outlined in an evidence of coverage or benefit plan from an insurer or negotiate flat-rate contracts with insurers who administer all operational aspects of the payer’s health-care coverage plan. Insurers in turn negotiate contracted terms of payment with health-care providers for the patient groups they represent (Figure 1).

When an individual covered by an insurance policy obtains services from a health-care provider, the insurer pays the health-care provider according to the terms of the contract. When no contract exists, insurers pay the health-care provider’s standard billed charges. Because covered individuals typically pay more out-of-pocket expenses when their insurer does not have a contract with a given health-care provider, they naturally tend to stay within the network of providers under contract with their insurer. Patients who do not carry coverage deal with health-care providers directly.

Hospitals typically obtain most of their service-related revenue from private commercial insurers, Medicare, Medicaid, and other public programs. According to the Federal Centers for Medicare and Medicaid Services, 81 percent of health-care expenditures can be attributed to one of these sources, with slightly less than half of this percentage coming from private commercial insurers (The nation’s health dollar 2001; for additional statistics see National health expenditures and selected economic indicators, levels and average annual percent change: Selected calendar years 1980–2012, 2003, National health care expenditures projections, 2002–2012, 2003). Charitable donations from institutions or individual benefactors may constitute a substantial source of non-service-related revenue. This is especially true of well-respected, nonprofit, teaching institutions, such as Texas Children’s. Medicare and Medicaid are federal and state programs that respectively pay for the care of the elderly and disabled, and low-income groups. While health-care providers have some input into the rates Medicare and Medicaid set, there are no negotiations similar to those with private insurers.

From the standpoint of hospitals, the contract terms they establish with insurers provide the point of greatest revenue leverage. A hospital or hospital system manages a portfolio of contracts with payors that may consist of 50 to 200 active contracts with widely varying revenues. With so much at stake, contract negotiations are critical business transactions for hospitals. Insurers need well-respected institutions, such as Texas Children’s, to attract a strong patient base, while Texas Children’s and other hospitals require contracts to ensure a steady flow of patients.

Contracts between insurers and hospitals do not establish minimum volume or payment guarantees, only the rates of reimbursement when patients seek services. Insurers may therefore steer patients with
particular ailments to the least-expensive health-care provider, and health-care providers may seek to increase demand through direct or indirect marketing initiatives.

Contracts, Reimbursement, and Risk

Insurers accept risk by taking a set premium of dollars in exchange for making available a specified scope of services under a benefit plan. Private insurance companies set the premium amounts using a variety of techniques, often including an underwriting review to estimate the probability of an individual’s use of services or a review of a similar person or population’s historical usage of services. Medicare and Medicaid operate somewhat differently as they are funded through a budgeted amount of federal and state dollars with possible cost sharing by covered individuals. Both private and government insurers lose money when expended claim dollars exceed premium or budget formulations.

From a historical perspective, risk was considered the domain of insurers. If the insurer collected enough money to cover expenses, it realized a profit; if not, it realized a loss. On the other hand, hospitals determined “fair and reasonable charges” for their services, with an expectation that their costs would be covered. As a result, hospitals are well versed in cost accounting and cost-based reimbursement methods. They maintain lists for services at a very granular level, from overnight monitoring of a patient’s vital signs to administering aspirin. For many years, insurers based the primary method of reimbursement to health-care providers on these charge lists. Hospitals would record the various services they performed while caring for a patient and insurers would base the payments on standard charges for the services performed.

Charge-based reimbursement methods still remain the basis of some contracts between hospitals and insurers. However, instead of paying standard rates, insurers negotiate a percentage reduction known as a discount on charges. Discount-off-charges reimbursement is generally considered low risk, though in fact it has proven to carry a number of risks. The primary risk stems from the calculation of cost in general and the allocation of fixed cost in particular. A hospital can have a high volume of patients with every rendered service covering its cost, yet still find that it loses money under a contract if demand deviates significantly from the estimates used to allocate fixed cost.

A number of other reimbursement structures are traditionally viewed by the health-care industry as carrying risk. Throughout the 1990s insurers looked for ways to tighten control of contract reimbursement rates. The methods that evolved offer insurers a more reliable means of estimating future claim-dollar expenditures while shifting risk to health-care providers in the process. We will describe some of these creative reimbursement methods.

Per-Diem Reimbursement

Under per-diem pricing methods, hospitals receive a unit reimbursement rate for an agreed set of resources. For example, an acute-care room might be reimbursed at $1,800 per day while an intensive-care room might be reimbursed at $2,200 per day. The per diem is typically an all-inclusive rate designed to pay for all services provided during each day of hospitalization.

Diagnosis-Related Group (DRG) Reimbursement

The foundation for the DRG reimbursement structure was established through the groundbreaking work of Robert Fetter at Yale University in the 1980s (Fetter 1991, Ellis et al. 1996). Fetter introduced a formal methodology for grouping ailments into diagnosis-related groups, or DRGs, for use in clinical studies of resource consumption and other related clinical studies. Medicare (now CMS) adopted this system as a basis for payments to health-care providers, replacing a cost-based reimbursement methodology (Table 1).

Reimbursement is based on the diagnosis of a patient mapped to a DRG rather than the use of resources, although DRGs were defined to make resource usage fairly homogeneous. The impact of DRGs cannot be understated, and they are used today as the basis for inpatient Medicare payments. In 1990, Fetter received the Franz Edelman Award for his work (Fetter 1991).

Capitated Reimbursement

With capitated reimbursement structures, payors give hospitals a fixed periodic fee for the people they insure or for a specified population. They give hospitals the total periodic fee independent of patient volumes or charges billed.

<table>
<thead>
<tr>
<th>DRG</th>
<th>Ailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Nervous system infection except viral meningitis</td>
</tr>
<tr>
<td>21</td>
<td>Viral meningitis</td>
</tr>
<tr>
<td>22</td>
<td>Hypertensive encephalopathy</td>
</tr>
<tr>
<td>23</td>
<td>Nontraumatic stupor and coma</td>
</tr>
<tr>
<td>24</td>
<td>Seizure and headache age &gt;17 w cc</td>
</tr>
<tr>
<td>25</td>
<td>Seizure and headache age &gt;17 w/o cc</td>
</tr>
<tr>
<td>26</td>
<td>Seizure and headache age 0–17</td>
</tr>
<tr>
<td>27</td>
<td>Traumatic stupor and coma, coma &gt; one hour</td>
</tr>
</tbody>
</table>

Table 1: We show example diagnosis-related groups (DRGs). DRGs are used to classify patients based on their ailments and may be used to establish the payment a hospital should receive from a payor under certain types of contracts. For example, a hospital might receive a payment of $2,500 for each encounter of DRG 21 (viral meningitis).
Each of these four basic methods of reimbursement—discount off charges, per diem, DRG, and capitated—may be amended with special provisions, including stop-losses and carve-outs. An example of a stop-loss on a discount-off-charges contract might require an insurer to pay a higher rate once the discounted charges have exceeded a prespecified billed-charge threshold. In effect, stop-losses represent a tiered pricing methodology. Carve-outs are reimbursement methods associated with any procedures either party wishes to give special treatment. Contracts with a carve-out allow for a different pricing structure for a prespecified group of hospital resources.

Complex, risky reimbursement models and continuing cuts by government and commercial payors caused financial crises for many facilities. Hospitals were taking risk and often providing care for patients at a financial loss. Texas Children’s was not immune to these struggles. In 1997, the Texas Medicaid program was moving to a managed-care model similar to that of Medicare that would place a greater burden of risk on the hospital. The unpredictability of this change was especially disconcerting as Medicaid clients are largely children, and children covered by Medicaid accounted for a significant number of admissions at Texas Children’s. In addition, the hospital struggled with the terms of per-diem, DRG, and capitation contracts with a variety of private insurers.

Improving Contract Performance: Forecasting

Improving contract performance begins with understanding future demand. If the hospital knew demand with certainty, it could easily calculate the revenue performance of any contract. If both the hospital and the payor knew demand with certainty, negotiation skills would play a far more fundamental role than management science. In reality, demand is not known with certainty, and forecasting plays a critical role in determining contract performance. Forecasters try to pick up on future trends and to quantify the inherent variability in future demand. An improperly structured contract that performed well last year may have a high probability of producing a substantial loss this year.

Forecasting is challenging in a health-care context. Foremost is the question of what to forecast. Because contract revenue fundamentally depends on patient encounters—interactions with a patient that use hospital resources and lead to a billable list of charges for those resources—we needed forecast entities consisting of generic encounters with fairly consistent resource usage. After we defined forecast entities, we made forecasts of fixed cost, variable cost, demand, and charges by day of week for each entity. In addition, because forecast entities never use resources consistently, we made simple forecasts of critical resources, such as operating room time or room nights. Incidental resources, such as the number of aspirin consumed, were not forecast.

A hierarchy of entities proved useful in conceptualizing and ultimately defining the proper level of detail for forecasting demand under a contract. Lower levels of the hierarchy correspond to increasingly detailed levels of patient encounters. At the highest level are all patient encounters, followed by patient encounters at the service line at the next level. A service line is a high-level aggregation of similar services health-care providers use to track revenue performance. While we never considered either of these two levels as candidates for forecasting, they are business-related entities used for reporting that impose restrictions on how demand can be partitioned into forecast entities.

Beneath service lines are DRGs, that were an obvious candidate as forecast entities. However, a detailed analysis showed that the cost, charges, and resource usage of patient encounters within a DRG had undesirably high variation. This is not entirely surprising in that DRGs were defined at an industry-wide level for national health-care management. An individual health-care provider can use more refined entities to greater effect.

After much data analysis, we decided to use flexible forecast entities that we called patient pathways, which constitute the next level in the hierarchy. Patient pathways are similar to DRGs, but they are defined using encounters and services unique to the hospital rather than broad industry classifications. We formed them by taking historical patient encounters, which formed a vector of usage for critical resources, and mathematically clustering these encounter vectors using the Mahalanobis metric (Mardia et al. 1979). We thus provided input at the level of detail needed for optimization and obtained forecasts markedly better than those based on DRGs.

By partitioning patient encounters into groups of similar resource usage, patient pathways provide important information not captured in DRGs that can be used effectively in optimization models to improve contracts (Table 2). Patient pathways also clarify the relationship between encounters, resources, and margins in a way that DRGs cannot (Table 3). With patient pathway analysis, we found that Texas Children’s often lost money on its many routine patient encounters. As a result, contracts depended upon a small number of highly variable, high-margin patient encounters to generate a positive net margin.

Our analysis led us to forecast demand, costs, charges, and resource consumption for each patient pathway, maintaining means, variances, and relevant
coviability in critical resource usage is evident among the 49 encounters of DRG 21.

Table 2: Ten critical resources and four patient pathways (arbitrarily labeled 26, 29, 33, and 34) make up DRG 21 (viral meningitis). Critical resources are chargeable items deemed sufficiently significant to track from a cost perspective. By defining critical resources, one can ignore a large number of relatively insignificant chargeable items, such as aspirin. Patient pathways are established by clustering individual patient encounters within a DRG into groups of similar critical resource usage. High variability in critical resource usage is evident among the 49 encounters of DRG 21.

Improving Contract Performance: Optimization

To appreciate how optimization supports contract negotiations, one needs to understand some of the basics of contract negotiation. Many of the contracts between hospitals and payors are evergreen, meaning that they remain in effect until one party informs the other that the contract needs to be renegotiated. When a hospital initiates a negotiation, it typically does so because of changes in cost structure or because of the recent performance of a contract. It must form bargaining strategies and financial targets before negotiation. The complex collection of services offered and the myriad of ways to package and price them provide many opportunities for structuring highly productive contracts.

Historically, analysts have used cost-accounting systems to identify unprofitable agreements and renegotiate their rates in an effort to achieve target margins. From a mathematical perspective, the process used by analysts is akin to a local search heuristic. It is labor intensive and consists of reading through reports on costs and charges and trying various what-if scenarios. This method also tends to bring to the surface issues that negotiators on both sides of the table are well aware of, thus quickly focusing negotiations on price. Because optimization models can find globally optimal solutions that meet prescribed objectives over many different contract types, they often provide recommendations that are not immediately obvious, giving the party using the optimization model opportunities to negotiate terms to which the other party may not be sensitive.

Contract performance can be measured in many ways. The most obvious measure is expected revenue, but revenue risk stemming from demand variability is also an important concern. The objective of the optimization model is risk minimization, which is represented as a measure of variance in net margin for a contract. The model minimizes risk subject to achieving an expected target margin, which we provide as input. The decision variables are the prices for patient pathways. Because hospitals and payors do not currently write contracts with prices on patient pathways, we use additional constraints to ensure that as a whole the patient pathway prices adhere to one or a combination of the standard packaging methods.

Implementation and Use

The Hospital Optimization System (HOS) is used by the managed-care staff of Texas Children’s to monitor

<table>
<thead>
<tr>
<th>Critical Resource</th>
<th>26</th>
<th>29</th>
<th>33</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Day in pediatric intensive care unit</td>
<td>0.05</td>
<td>1</td>
<td>0.10</td>
<td>1.84</td>
</tr>
<tr>
<td>2. Day in neonatal intensive care unit</td>
<td></td>
<td></td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>3. Day in intensive care unit</td>
<td></td>
<td></td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>4. Day in progressive care unit</td>
<td></td>
<td></td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>5. Day in premature nursery unit</td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>6. Day in acute care unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Operating room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Emergency room</td>
<td>0.87</td>
<td>0.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9. Observation</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Day in pediatric acute care unit</td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Actual encounters</td>
<td>44</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3: An analysis of patient pathways for DRG 21 (viral meningitis) shows that patient pathway 26 has the most encounters and the lowest average cost, but lost money on average. The remaining five encounters generated a positive margin but were unable to offset the loss associated with the many encounters in patient pathway 26.
contract performance and to support contract negotiations. The HOS uses input from other hospital systems related to each contract, including detailed information on past patient encounters, such as charge data and resource usage. It also uses master charge list and hospital capacity information. The primary HOS output is optimized contract terms for entering into contract negotiations. However, HOS also produces demand forecasts, what-if functionality, and other decision-support capabilities that make it a general decision-support tool.

Texas Children’s and PROS personnel worked closely together to design and create HOS. PROS personnel conducted interviews with managed-care contractors, business-services staff, decision-support analysts, and facility executives to understand hospital operations and goals. Scientific staff reviewed hospital charge list structures and typical patient work flows, helping us to make the first breakthrough in identifying patient pathways. Specified users access the system through protected Internet platforms with system administrators at both the hospital and PROS monitoring their access and utilization. Texas Children’s currently has five active users and has little difficulty with system access and reliability. PROS professional services staff works with Texas Children’s users when they have trouble with the system or need help working through the complications of contract design and optimization.

The system has evolved from rudimentary screens and time-intensive contract entries with no allowances for standard industry practices to a user-friendly forecasting and optimization tool closely aligned with hospital-industry practices as a whole. Texas Children’s and PROS staff collaborate closely to discuss periodic system updates and modifications.

The hospital draws up contracts for no more than 12-month time periods to ensure forecast reliability. Hospital contracting staff monitors the contract directory closely and updates the system with new contract entries. Users can set alerts for all contracts or for a subset of contracts. Alerts notify them when volumes or margins under a contract fall above or below forecasts. Performance monitor and report functions allow users to monitor contract performance with a defined set of metrics, including visits, cost, and revenue by contract. Staff members can initiate renegotiation efforts with payors when the tools identify variations and trends.

While we originally developed the PROS system for use exclusively as a contract-design tool, we realized that we could use its forecasting and optimization power for other purposes. The what-if module allows users to examine resources that exceed user-defined capacities for one contract or a pool of contracts. They can review loss of possible revenue streams due to restrictions in availability of services. We anticipate these tools can be used for strategic planning, from facilities planning and development to staffing and budgeting. Texas Children’s is using the system to design contracts and is contemplating additional system uses.

Benefits

The contract-design capabilities of the HOS have given an intelligent contracting staff with over 50 years of contracting experience the tools to be smarter. Front-line negotiators for the hospital have experience working for insurers and providers in contracting, and they know the idiosyncrasies of the health-care industry. Forecasting and optimization have helped them create a portfolio of over 100 active contracts that is tremendously better than the contract portfolio at Texas Children’s in the late 1990s.

The staff members can review contracts at varying levels of detail. They can group patient pathways into service lines or other groups of their choice for purposes of writing a contract. Texas Children’s uses a standard set of grouping packages. The system groups forecasted data into these classifications for any contract, and negotiators ensure margin balance and positive margins for all groupings.

The hospital previously relied on historical data from its cost-accounting system in reviewing all contract proposals and pricing analyses, running reviews of historical contract performance. The PROS technology takes the data one step further, showing utilization patterns of a contract for the past and also for the future.

Users can run multiple test cases and what-if scenarios. With the available data, managed-care staff can continue running test scenarios until they achieve balanced and optimized pricing of services. Users can review a payor’s contract proposal and develop counterproposals more rapidly than before.

Access to forecasted data has given Texas Children’s an invaluable advantage. Texas Children’s has reviewed its contracts with all major payors and has been able to strategically correct risky contracts. A review of one payor’s book of business showed a total of 900 patient encounters for fiscal year 2001. The aggregate net margin was positive but was tied to a positive margin on fewer than two percent of the payor’s referrals. Historical review of the contract showed that only 88 of the 900 encounters were profitable. Removing those cases would result in a negative margin with no change in contract terms.

A particular payor’s business at Texas Children’s had a positive net margin; however, its annual margin had been eroding from year to year. Some groupings showed excellent margins, while others were
Conclusions
The HOS technology and close interaction with the PROS team members have given Texas Children’s a competitive edge in the health-care marketplace. Hospital contractors equipped with detailed data can design contracts to meet the forecasted utilization patterns for any payor’s contract or contracts. This ability has become increasingly important as government payments continue a downward trend. The 2003 Texas state legislative session is projecting a nearly $12 billion budget shortfall that will almost certainly result in decreased revenues for hospitals, physicians, and other health-care providers. State Medicaid plans nationwide are also facing financial challenges and deficits that will certainly affect hospitals.

The multiyear collaboration between Texas Children’s and PROS has many important results. Building on the groundbreaking work of Fetter on DRGs (Fetter 1991), we defined patient pathways as an alternative and more suitable entity for forecasting and tracking the demand for hospital services. Our efforts allowed us to identify risk as a crucial and often overlooked factor in structuring effective contracts, and we developed optimization algorithms to minimize risk while meeting target revenue objectives. The forecasting and optimization models are embedded in an enhanceable system that helps staff members to negotiate contracts.

The potential impact of optimization on the health-care industry is substantial. Hospitals manage an array of contracts and many of the thousands of hospitals worldwide could benefit from optimization methodologies. In addition, the high level of predictability found through use of patient pathway clustering could further enhance the impact of the DRG classification system used widely by hospitals and insurers.

Through its success, the HOS has laid the groundwork for more extensive use of operations research techniques in hospital administration in such areas as facilities planning and development, staffing, and budgeting. In addition, many of the techniques we developed for contract management are applicable to industries outside of the health-care industry. Both Texas Children’s and PROS are excited about the opportunities that lie ahead.

Appendix
The optimization model is designed to set prices for hospital services to achieve a target margin established by the contract negotiator at minimum risk. Margin for a patient pathway \( j \) is closely related to pathway profitability, which is defined as

\[
(p_j - c_j)d_j,
\]

where

\[
p_j = \text{price (revenue) generated from pathway } j,
\]

\[
c_j = \text{cost for pathway } j, \text{ and}
\]

\[
d_j = \text{demand (number of cases) for pathway } j.
\]

Demand \( d_j \) is a random variable, and because resource usage within a pathway is a random variable, both \( p_j \) and \( c_j \) are also random variables. The cost \( c_j \) is dependent only upon the specific resource usage, but the price \( p_j \) is dependent upon the resource usage and the terms of payment established under the contract. Many of the constraints in the optimization model link \( p_j \) to the choice of contract terms.

Objective Function
There are numerous ways of defining risk, and the financial literature on the subject is vast. For expository purposes, we present risk as the variance in net profitability of a contract, though many different risk measures could be used. The objective function is then

\[
\min \left( \text{var} \left( \sum_{j \in J} (p_j - c_j)d_j \right) \right),
\]

where

\[
J = \text{set of pathways, an input.}
\]

Note that the specific form of the objective function differs radically depending on the method of contract pricing. The distributions for the random variables \( d_j \) and \( c_j \) are inputs to the optimization model, while the decision variables are implicitly captured in the \( p_j \), which are functions of decision variables that appear in the package constraints defining the contract prices.

Net Margin Constraint
The net margin constraint ensures that the expected contract margin achieves a desired level:

\[
\frac{\sum_{j \in J} (E[p_j] - E[c_j])E[d_j]}{\sum_{j \in J} E[c_j]E[d_j]} = \bar{r},
\]

where

\[
\bar{r} = \text{return on contract, an input.}
\]
Resource Pathway Constraints
The resource pathway constraints place lower and upper bounds on the expected price that may be charged for a pathway:

\[ E[c_i] \leq E[p_j] \leq E[B_j], \quad \text{where} \]

\( B_j = \text{billed charge for pathway } j, \) an input random variable with distributional information calculated from standard list rates independent of the contract.

Package Constraints
Contract prices are typically established at a much more aggregate level than patient pathways. For example, an especially simple contract might have all inpatient encounters billed at a 40% discount off of standard list rates (a simple discount-off-charges contract). Constraints are therefore required that relate both the type of contract billing method that may be used, and the level of aggregation at which it may be applied. Together, contract billing method and level of aggregation constitute a package, which is a fundamental business entity under the control of the contract negotiator. The classes of package constraints coincide with the primary methods of contract pricing presently in use.

Discount Off Charges (DOC)

\[ p_j = f_{DOC}^k B_j \quad \forall j \in J(k), \quad \text{where} \]

\( J(k) = \text{set of pathways in package } k, \) an input, and \( f_{DOC}^k \in [0, 1] = \text{discount associated with DOC package } k, \) a decision variable.

Per Diem

\[ p_j = \sum_{i \in I_j} A_{ik} p_{ik}^{pd} \quad \forall j \in J(k), \quad \text{where} \]

\( I_j = \text{critical resources used by per diem package } k, \) an input,
\( A_{ik} = \text{usage of critical resource } i \text{ for per diem package } k, \) an input random variable, and
\( p_{ik}^{pd} = \text{unit price of critical resource } i \text{ for per diem package } k, \) a decision variable.

DRG/Case Rate

\[ p_j = p_{k^*}^i \quad \forall j \in J(k), \quad \text{where} \]

\( p_{k^*}^i = \text{price of DRG/case rate package } k, \) a decision variable.

In practice, the model is somewhat more complex than presented here, accounting for special terms known as stop-losses and carve-outs. However, this formulation is true to the spirit of the overall model.

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