Spring 2013

HOSX: Hospital operations excellence model

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ABSTRACT

HOSX: HOSPITAL OPERATIONS EXCELLENCE MODEL

by
Shivon S. Boodhoo

Hospital performance can be evaluated in four categories: (i) quality of care, (ii) process of care (iii) financial and (iv) operations productivity. Of these, 'quality of care' is the most widely reported and studied measure of performance, and focuses primarily on the clinical outcomes of the patient. In contrast, operations productivity and efficiency is the least studied measure, and currently there is limited ability to evaluate how efficiently the hospital has used its resources to deliver healthcare services. Cost containment in the healthcare industry is a challenging problem, and there is a lack of models and methods to benchmark hospital operating costs. Every hospital claims they are unique, and hence comparative assessments across hospitals cannot be made effectively. This research presents a performance framework for hospital operations to be called HOSx: Hospital Operations Excellence Model, used to measure and evaluate the operations productivity of hospitals. A key part of this research is healthcare activity data extracted from Medicare Provider Analysis and Review (MedPAR) database and the Healthcare Provider Cost Reporting Information System (HCRIS), both of which are maintained by the Center for Medicare Services (CMS).

A key obstacle to hospital productivity measurement is defining a standard unit of output. Traditionally used units of output are inpatient day, adjusted patient day (APD) and adjusted discharge, which are reasonable estimators of patient volume, but are fundamentally limited in that they assume that all patients are equivalent. This research develops a standardized productivity output measure for a Hospital Unit of Care (HUC), which is defined as the resources required to provide one general medical/surgical inpatient day. The HUC model views patient care as a series of healthcare related activities that are designed to provide the needed quality of care for the specific disease. A healthcare activity is defined as a patient centric activity prescribed by physicians and requiring the direct use of hospital resources. These resources include (i) clinical staff (ii) non-clinical staff (iii) equipment (iv) supplies and (v) facilities plus other indirect resources. The approach followed here is to derive a roll-up equivalency parameter for each of the additional care/services activities that the hospital provides. Six HUC components are proposed: (i) case-mix adjusted inpatient days (ii) discharge disposition (iii) intensive care (iv) nursery (v) outpatient care and (vi) ancillary services. The HUC is compatible with the Medicare Cost Report data format. Model application is demonstrated on a set of 17 honor roll hospitals using data from MedPar 2011. An expanded application on 203 hospitals across multiple U.S. states shows that the HUC is significantly better correlated than the more traditional APD to hospital operating costs. The HUC measure will facilitate the development of an array of models and methods to benchmark hospital operating costs, productivity and efficiency.

This research develops two hospital operations metrics. The first is the Hospital Resource Efficiency (HRE), which is defined as operating cost per Hospital Unit of Care, and the second is the Hospital Productivity Index, which benchmarks performance across the reference set of hospitals. Productivity analysis of all 203 hospitals in our database was conducted using these two measures. Specific factors studied include (i) functional areas (ii) patient volume (iii) geographical location. The results provide for the first time a ranking of most productive hospitals in each state – New Jersey, Pennsylvania, Nebraska, South Dakota and Washington as well as an interstate ranking. This research also provides detailed analysis of all outlier hospitals and causes of productivity variance in hospitals. The final output, the Hospital Total Performance Matrix combines clinical performance with productivity to identify the leading U.S. hospitals.

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by
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A Dissertation
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Industrial Engineering

Department of Mechanical and Industrial Engineering

May 2013

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This dissertation is dedicated to Dr. Martin Katzen.

Sir Marty, my friend, “Thank You.”

ACKNOWLEDGMENT

I would like to express my deepest gratitude to Professor Das, my dissertation advisor for his unwavering guidance and whose vision, depth and breath of knowledge and insight in all things engineering, business and art constantly amazed me.

I would also like to thank my dissertation committee members: Dr. Bladikas, Dr. Caudill, Dr. Gopalakrishnan and Dr. McDermott for their support not just in this dissertation but throughout my university career.

I owe a debt of gratitude to the Greater Philadelphia Louis Stokes Alliance for Minority Participation (LSAMP) and the National Science Foundation's Bridges to the Doctorate Program for funding my Master's degree. My deepest thanks to the McNair Postbaccalaureate Achievement Program for funding and for giving me my first exposure to engineering research as an undergraduate student.

My thanks to Dr. Leonid Tsybeskov, Chair of the Department of Electrical and Computer Engineering (ECE) as well as the faculty and my fellow staff members of the ECE department for supporting me in my studies and for allowing me the flexibility to pursue my research.

I am thankful for the invaluable assistance of my fellow research team members who contributed their time, knowledge and expertise to this dissertation - to Nicole (Lian) Meng for her work on the first feasibility study, to Adweeth Shakti for the many hours spent on coding and data mining, to Olga Kalaba for her knowledge of statistics, to Muthu Senthil Selvam for help in hospital field studies and Anna Zhang for building simulations and providing the outpatient services perspective. To Dr. Tejas Gandhi and Mr. Tom Gregorio, my thanks for granting access to Virtua and Meadowlands Hospitals, respectively.

I would like to thank the Albert Dorman Honors College (ADHC) and the Educational Opportunity Program (EOP) at NJIT for becoming my second families and funding my undergraduate studies. I am forever indebted to Dr. Joel Bloom and Ms. Lois Chipepo and the staff of ADHC and EOP for their support, praise and belief in my abilities.

I will be eternally grateful to Ms. Janet Buck for trusting a 21 year-old who had no work experience to build a metrics program for the Global Quality Processes group at Catalent Pharma (formerly Cardinal Health PTS). In so doing, she taught me what it means to be a mentor, to support and trust people to innovate and to be a 'power tourist.' The practical knowledge I gained from my years with her laid the foundation for this dissertation and the soft skills she taught by example, allowed me to become a successful advisor.

I would like to thank my family and friends for standing firmly by my side despite the many years of studying that consumed my time and energy. Firstly, my gratitude to my parents, Samuel and Cassandra for their lifelong efforts and sacrifices made in support of my education. To my sister, Shannon-Amanda, your intense love for life and the passion and inventiveness with which you approach every situation is inspiring - thank you for your support.

To the Thatcher, Hinton, LeBon, Goullet, Katzen, Lerner, Zisman, Denis and Danso families, Dr. Maryann McCoul and Lucie Tchouassi, Mr. Lawrence Tony (dad) Howell, Auntie Pam, Brandon and Gail, Uncle Sohan and Aunt Marilyn, Mark and Lawrence, Samaroo Sookoo, John and Rita Boodoo, Jen, Armando, Deoraj and Arnaud for your love, friendship, constant and unwavering support over the years - thank you.

This dissertation is gratefully dedicated to the memory of my mentor, friend and dissertation committee member, Dr. Martin Katzen, who taught me to enjoy a sunny day, to drink coffee and to be passionate about teaching and helping students achieve their potential.

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CHAPTER 1

INTRODUCTION

Corporations rely on measurement systems to provide the vital information needed to run day-to-day operations and to create strategic plans for the future. Likewise, hospitals in the United States, regardless of size or location, all have some form of performance measurement system and typically evaluate themselves on two dimensions - clinical quality and financial stability (Figure 1.4). This reporting burden derives from two main sources - (i) regulatory and accreditation bodies, which require clinical quality measures and patient satisfaction data and (ii) hospital administrators and investors who require financial numbers for accounting and measurement of solvency. In contrast, there are only a limited number of readily available evaluation metrics that focus on hospital operations productivity and efficiency. Performance metrics are watchwords for companies striving to find and maintain competitive advantages in their field.

Traditionally, performance has been monitored using spreadsheets. Although these are ubiquitous in industry and remain popular at all levels of management, there has been a shift by executives towards use of a dashboard or scorecard whereby key data is summarized and presented visually as a 'snapshot.' As outlined in Section 1.2 and detailed in Chapter 3, this dissertation develops an operations performance framework called **HOSx: Hospital Operations Excellence Model**, which measures and evaluates the operations productivity of hospitals. In this model, operations activity is clearly differentiated from the clinical and financial performance of a hospital. The current versus ideal state of performance measurement is summarized in Figure 1.1. The goal of this thesis is to fill in the 'operational efficiency' axis of the metrics grid and thereby provide for the first time a total performance measurement of United States hospitals.

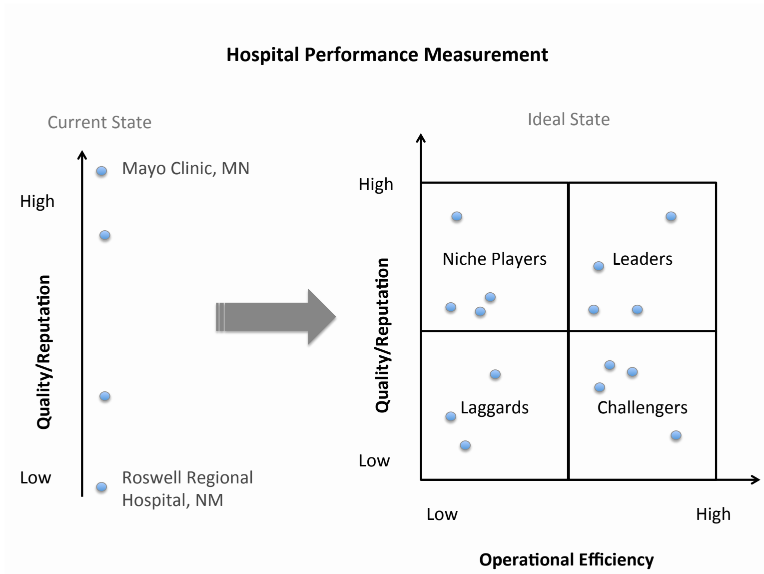


Figure 1.1 Hospital performance measurement.
Source: [U.S.News, 2011; The Leapfrog Group, 2012].

1.1 HOSx: Hospital Operations Excellence Model

The five focus areas in the HOSx model are: (i) Resource Utilization (ii) Patient Safety (iii) Patient Flow (iv) Customer Satisfaction and (v) Information Flow Figure 1.2. The model integrates existing data reporting requirements. For example, the federally mandated clinical quality measures of hospital-acquired infections (HAIs) under Patient Safety with new measures such as the speed of surgery room cleaning turnover which falls under Resource Utilization. As with all management dashboards, the HOSx system is scalable and can be modified to suit users' needs at all levels of the organization.

To investigate hospital resource utilization under the HOSx model, this research creates a unified measure of hospital output, the **Hospital Unit of Care, (HUC)** (Figure 1.3). In traditional industries, measuring efficiency and productivity is a simple undertaking. Operations productivity is measured as 'resources used per unit of output.' In a manufacturing setting, any system which is 'McDonaldized' (at McDonald's restaurants the world over the time to produce one McDonald's hamburger is essentially the same everywhere), has processes which can be compared.

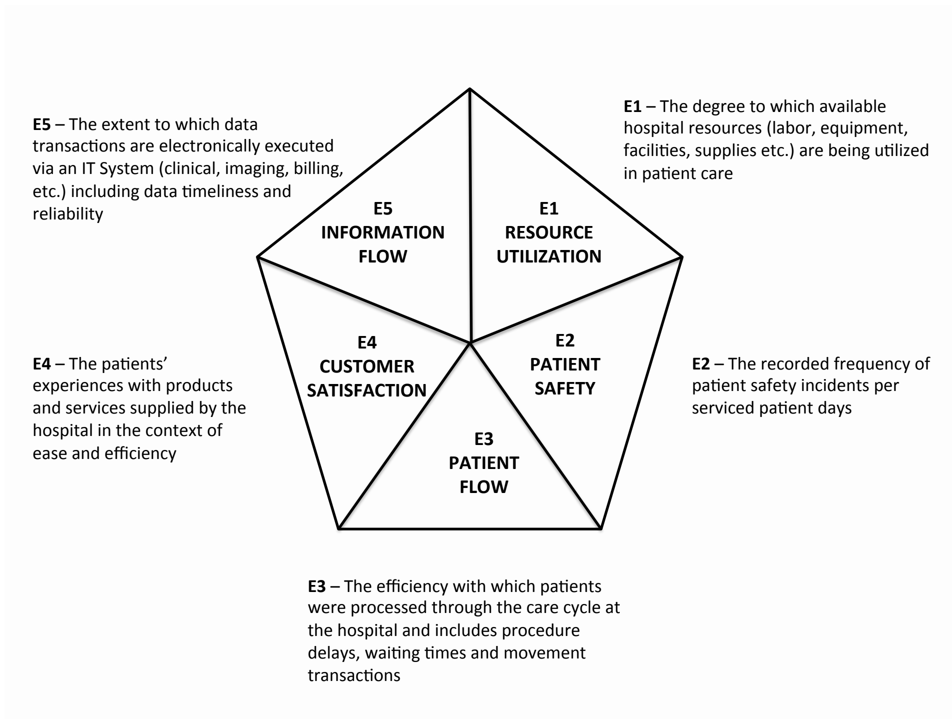


Figure 1.2 The HOSx model.

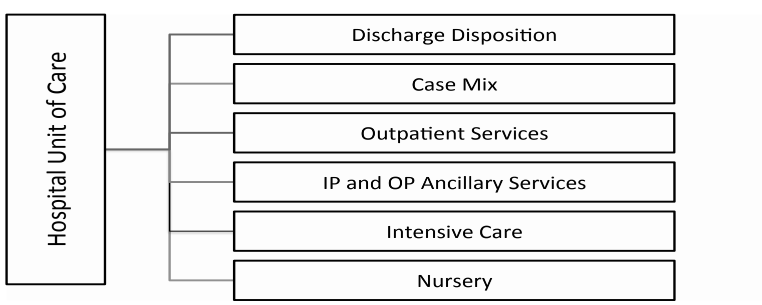


Figure 1.3 The Hospital Unit of Care top level view.

In the case in automobile plants, a typical productivity metric might be the time to produce one vehicle. As cars are manufactured in discrete units and models of particular market segments are comparable, productivity measured as the time to manufacture one car may be used to compare manufacturing plants.

Example:

Plant 1, Time to manufacture Vehicle Type 1 = 29.9 hours

Plant 2, Time to manufacture Vehicle Type 1 = 15 hours

This measurement indicates that Plant 2 is more productive than Plant 1 because it requires less resources (time) to manufacture the same product. This method can also be applied to service industries such as help-desk call centers whereby productivity would be measured as time to issue resolution or the call center volume per hour.

In cases where the denominator is very large, an inverse measurement is used and focus switches to efficiency. As highlighted in Figure 1.4, when applied to hospitals, the most commonly used metric for operating efficiency is the *cost per adjusted patient day*. This metric is fundamentally limited in that it assumes that all patients are equivalent. To address this issue, as outlined in Section 1.2, and detailed in Chapter 4, the Hospital Unit of Care (HUC) calculation can be used to standardize and compare output productivity across hospitals.

The HUC measure starts with the base inpatient day unit of output and then adds all other hospital activities using an indexed scale. This integrates case mix variation, discharge disposition, nursery services, intensive (critical) care activity, ancillary service activity (inpatient and outpatient) as well as outpatient volumes and intensity of outpatient care. The HUC allows for an ‘apples to apples’ comparison of short-term acute care hospitals by normalizing the elements of variation, thereby removing the major obstacle to hospital comparison - the claim of unicity. As illustrated in Chapter 5, the HUC is used to create a **Hospital Resource Efficiency metric (HRE)** to measure efficiency. The HRE is further refined into an **Hospital Productivity Index (HPI)** whereby a single number can be used to describe any hospital's comparative productivity.

1.2 Dissertation Overview

Chapter 1 presents an introduction to the topic of hospital operations performance and a summary of the research project. Chapter 2 presents a review of literature and an overview of hospital measurement in the context of healthcare systems. Chapters 3, 4, 5, and 6 fulfill the Research Objectives outlined in Section 1.2 and Chapter 7 presents the Significant Findings and Future Work of this research. This dissertation addresses the following research objectives by chapter:

Research Objective 1. Chapter 3 develops a framework to measure and evaluate the operations productivity of hospitals where operations activity are clearly differentiated from the clinical and financial performance of a hospital.

Research Objective 2. Chapter 4 creates a unified measure of hospital output that can be used to standardize and compare output productivity across hospitals. The output measure starts with the base patient day output and then adds all other hospital activities using an indexed scale. The indexed scale integrates case mix variation, discharge disposition, nursery services, intensive (critical) care activity, ancillary service activity (inpatient and outpatient) as well as outpatient volumes and intensity of outpatient care.

Research Objective 3. Chapter 5 presents a new metric for measuring hospital operations productivity and efficiency of hospitals across the United States. This is based on Medicare data and using as a proxy for a national dataset, hospitals in South Dakota (6 hospitals), Nebraska (11 hospitals), Washington (26 hospitals), New Jersey (57 hospitals), Pennsylvania (87 hospitals). All hospitals in the study are short-term acute care hospitals with at least 70 beds (non-government, non-military, non-speciality, non-psychiatric). The national set of hospitals (187 hospitals) is benchmarked against hospitals ranked with the highest clinical quality nationally (17 hospitals across 15 states) as represented by the U.S. News & World Report best hospitals Honor Roll list.

Research Objective 4. Chapter 5 utilizes data mining and statistical analysis tools to study resource utilization trends and patterns in national hospitals. The study focuses on the relationship between efficiency and size (beds), patient volume, location (urban or suburban) and teaching status (teaching or non-teaching). Chapter 6 studies the correlation between individual outpatient service elements and inpatient service categories.

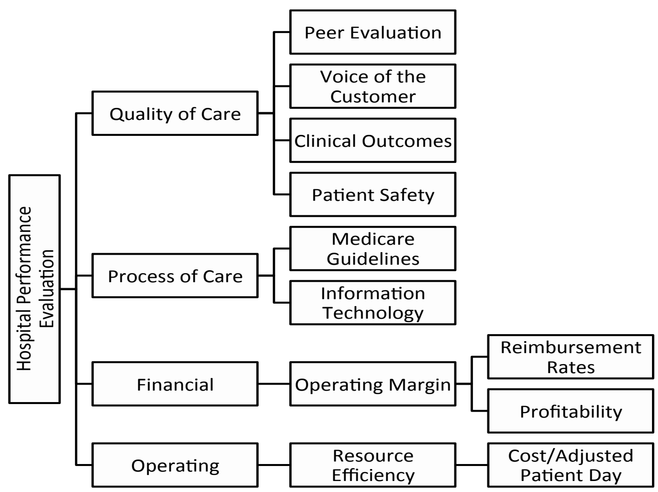


Figure 1.4 Overview of hospital performance measurement.

1.3 Significant Findings

The relevance of this research can found in many newspaper headlines. The *L.A. Times* recently ran an article which showed that 50 percent of US hospitals are operating in the red. This is a staggering number when considering the life-sustaining role played by these organizations [Girion, 2009]. Opinions differ on the cost drivers, but all researchers agree that the current situation is unsustainable and it is in the interest of every American to find an effective means of hospital cost measurement and control.

In light of these facts, the work of the hospital performance measurement forefather Avedis Donabedian comes to the fore. His work showed that with the proper measurement systems and management support, hospitals could deliver the same or better quality of patient care at drastically reduced costs [Donabedian, 1980]. In the spirit of Donabedian's work, this study allows hospitals to compare and benchmark themselves at the operations level. This research accomplishes the following significant research objectives:

1. Creates Hospital Operations Excellence Model (HOSx) - a flexible, scalable model to measure and evaluate operations productivity.
2. Defines a new measure of hospital volume, the Hospital Unit of Care (HUC).
3. Creates a new measure of hospital efficiency, the Hospital Resource Efficiency (HRE).
4. Proves statistically that for a cross-section of national hospitals, the HUC is a better predictor of cost than the traditional inpatient days and adjusted patient days (APD) measures.
5. Shows that the HRE measure can be used to study and benchmark hospital operations performance.
6. Creates a benchmarking scale, the Hospital Productivity Index (HPI) for ranking hospitals operationally.
7. Creates a Total Performance Matrix to be used in benchmarking clinical quality versus operational efficiency for U.S. hospitals.
8. Proves statistically that for New Jersey hospitals, there is no correlation between efficiency and size, location or teaching status.
9. Proves statistically that for South Dakota hospitals, there is a significant relationship between inpatient case mix index and average length of stay for specific inpatient services. Also proves statistically that for a cross-section of national hospitals, there is a correlation between some outpatient services.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of the current literature on hospital performance and an overview of hospital measurement in the context of healthcare systems.

2.1 Hospital Cost

2.1.1 The Hotel Analogy

Is hospital care too expensive? A night at the exclusive Four Seasons George V Hotel in Paris, France costs about $1,000 USD. For this price, every imaginable luxury is provided, just steps away from the Champs-Elysées - Paris' shopping district. Guests of the George V enjoy access to the hotel's private terraces, rooms with 18th century tapestries, marble floors, in-room saunas, and food prepared by some of the world's premiere chefs. For the same price as the George V hotel, a patient can spend a night at a hospital in South Dakota, the state with the second lowest average hospital cost in the United States. Given the choice, few people would pay $2,696 USD to spend a night at a hospital in Washington, the state with the second highest average hospital cost in the country (Figure 2.1 and Table 2.2) [American Hospital Directory, 2011]. Staying at a Washington hospital costs more than spending a night in a private over-water bungalow surrounded by the sapphire sea, emerald forests, and ivory beaches at the elite Le Méridien Hotel in Bora Bora, French Polynesia. Interestingly, both the George V and Le Méridien offer private valet, concierge and a doctor on call services which are included in the nighty price.

The hotel versus hospital cost comparison is not exact since most people do not pay out of pocket per night at a hospital and the prices quoted are only estimates of the average hospital cost by state not a stay for a specific condition. There are similarities between hospitals and hotels: beds need to be filled, amenities offered, staff have to be paid and services must be delivered in a safe, clean environment [Ancona-Berk and Chalmers, 1986]. This analogy can be taken further. Hotels have long been held legally responsible for the safety of their guests just as a hospital can be held liable for the actions of a nurse which results in harm to a patient [Hardy, 1986].

Optimizing bed management or finding the solution to a classic ‘hotel problem’ is critical to the efficient functioning of any hospital [Balaji and Brownlee, 2009]. Hospitals and hotels both experience seasonality of demand and cost variation due to location, which hinder their ability to fill beds. One study found that in 1987, the cost of an empty hospital bed was approximately “$36,000 per year with unused beds accounting for 18% of total costs” [Gaynor, 1991]. Over two decades have passed since that initial study and inpatient bed utilization has steadily declined over that time [American Hospital Association, 2011]. Research has also shown a strong seasonality of demand in hospitals, which for several specialties is negatively correlated with hotel demand. One study found a “significant winter peak for general medicine and orthopedics in ‘elective’ specialties, bed occupancy fluctuates widely, with reduced occupancy at weekends and Christmas” when considering a hospital with almost 200,000 bed days across a year” [Fullerton and Crawford, 1999].

2.1.2 National Hospital Cost Distribution

There is a wide range between the second lowest cost state South Dakota, and the second highest, Washington. The national average is roughly twice the inpatient per day expense in South Dakota Table 2.2. The chart in Figure 2.1 shows a geographic clustering trend throughout the country. States in the lowest quadrant for expense are clustered together in areas, which are typically considered to be ‘rural’: the Dakotas, Kansas, Nebraska, West Virginia, Alabama and Mississippi. The states in the second lowest quadrant are also primarily ‘rural’ but have some metropolitan areas such as Philadelphia and Pittsburgh in Pennsylvania, New York City, New York, Raleigh and Research Triangle Park, in North Carolina. The states in the third quadrant tend to be a mixture of urban and rural areas and the highest tier cost states are clustered on the West Coast and the North-East Coast (with the exception of Colorado). This distribution of costs led to the selection of the following groups for this study, together comprising a national snapshot of hospital cost: (1) National Benchmark Set: U.S. News & World Report Top 17 Honor Roll hospitals [U.S.News, 2011], (2) North East: New Jersey - Upper quartile cost and Pennsylvania - Median cost, (3) Midwest: Nebraska - Lower quartile cost and (4) the West Coast: Washington - Highest cost.

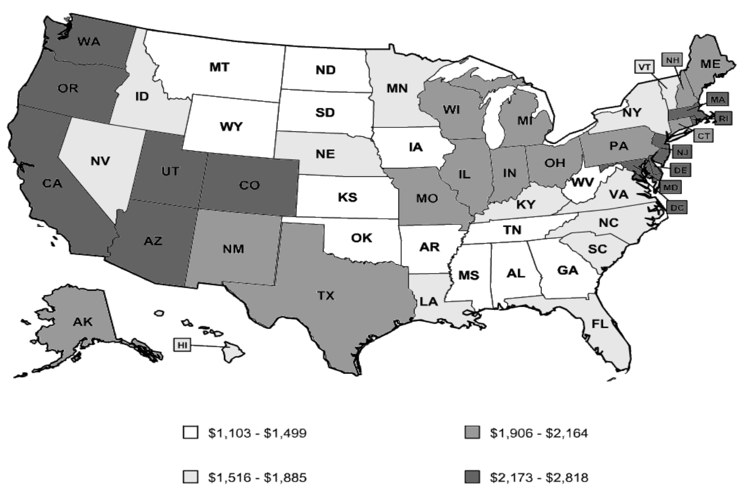


Figure 2.1 Map of the United States: average inpatient expense per day.
Source: [Kaiser Family Foundation, 2009].

The Rural Hospital Flexibility Program was created by the Medicare Balanced Budget Act of 1997, intended to strengthen rural health care by encouraging states to take a holistic approach to health care delivery. The Flex Program requires the creation of a state rural health plan and provides grants to each state to be used in implementing a Critical Access Hospital program, to encourage the development of rural health networks, to assist with quality improvement efforts, and improve rural emergency medical services. It promotes a process for improving rural health care, using the Critical Access Hospital (CAH) program as one method of promoting strength and longevity through CAH conversion for appropriate facilities [Rural Assistance Center, 2011]. Rural access hospitals lower the average

State	Cost per Adjusted Patient Day (APD)	State	Cost per Adjusted Patient Day (APD)
Wyoming	$1,103	**Pennsylvania**	**$1,906**
South Dakota	**$1,113**	*United States*	*$1,910*
Mississippi	$1,154	Texas	$1,943
Montana	$1,190	Wisconsin	$1,953
Iowa	$1,288	Michigan	$1,959
Kansas	$1,304	Indiana	$1,964
West Virginia	$1,323	Missouri	$1,981
Georgia	$1,338	Illinois	$1,983
North Dakota	$1,342	Alaska	$2,020
Alabama	$1,372	New Mexico	$2,058
Tennessee	$1,462	Maine	$2,077
Arkansas	$1,477	Ohio	$2,138
Oklahoma	$1,499	Connecticut	$2,154
Nebraska	**$1,516**	New Hampshire	$2,164
Kentucky	$1,546	Arizona	$2,173
Louisiana	$1,561	**New Jersey**	**$2,179**
North Carolina	$1,633	Colorado	$2,190
Vermont	$1,656	Delaware	$2,227
Minnesota	$1,731	Utah	$2,233
Virginia	$1,736	Rhode Island	$2,325
Idaho	$1,748	Maryland	$2,338
Hawaii	$1,755	Massachusetts	$2,419
South Carolina	$1,788	District of Columbia	$2,434
Florida	$1,837	California	$2,566
New York	$1,883	**Washington**	**$2,810**
Nevada	$1,885	Oregon	$2,818

Figure 2.2 Average inpatient expense per day.
Source: [Kaiser Family Foundation, 2009].

costs for the state since they receive federal subsidies and cost-based reimbursements from Medicare unlike typical acute care hospital which receive fixed rates.

Not all CAHs may take advantage of the more flexible Medicare Conditions of Participation (CoP) and the related cost savings. In states that license CAHs under the same licensure rules as other hospitals, CAHs must comply with those licensure rules. If those rules are stricter than the CoP, the CAH is unable to benefit from the Medicare flexibility. In addition, five states, Connecticut, Delaware, Maryland, New Jersey and Rhode Island, do not participate in the Flex Program and therefore hospitals in those states are not eligible for CAH status.

New Jersey, Massachusetts, California and Washington are the highest cost states, clustered on the coasts and are categorized as having major metropolitan populations with fewer areas which could be designated as ‘rural.’ Notably, New Jersey is considered exempt from the rural designation and therefore is one of only a handful of states that do not have any rural or critical access hospitals. As illustrated in Figure 2.3, the CAHs are clustered in many cases in the states with the lowest costs. Arguably, these states also have lower populations so this begs the question: *What are the cost drivers of hospital expenditure?*

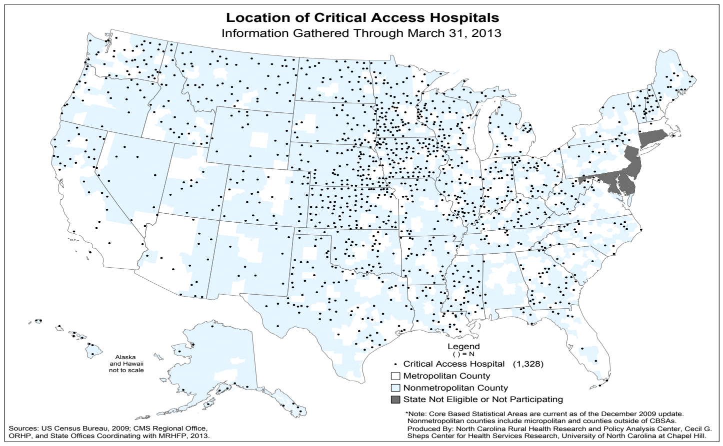


Figure 2.3 Map of the United States: location of Critical Access Hospitals.
Source: [US Census Bureau, 2009].

2.1.3 Cost Drivers

Staff. For both hospitals and hotels, staffing represents the largest cost segment – on the order of 60 % [Presbury et al., 2005; Centers for Medicare and Medicaid Services, 2009]. Hospitals though, incur costs that most hotels do not have to bear. Operating in a highly regulated industry, hospitals spend a lot on administrative overhead [Woolhandler, 1997]. For example, one study of a representative set of 36 large U.S. urban hospitals found that all hospitals participated in multiple quality-reporting programs at both the national and local levels with a significant negative impact to cost and staff perception of work load [Pham et al., 2006]. Still, there appears to be some benefit to multiple reporting. A study in the New England Journal of Medicine found that when considering a set of 613 hospitals (207 hospitals who were incentivized as part of pay for performance versus 406 with public reporting only), hospitals engaged in both public reporting and pay for performance achieved modestly greater improvements in quality than did hospitals engaged only in public reporting [Lindenauer, 2007]. As illustrated in Figure 2.4, salary and benefits for its specially trained, highly educated staff also drains hospital resources.

Though physicians are typically not staff members and teaching hospitals receive credit for interns and residents' salaries, the cost of support staff remains very high. In

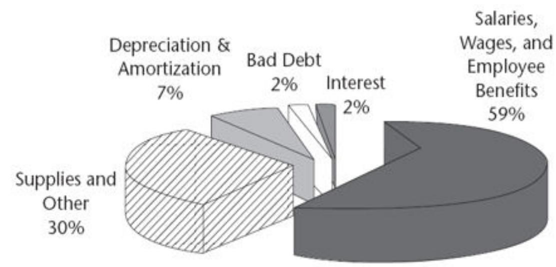


Figure 2.4 Hospital cost distribution by type of expense.
Source: [Roberts et al., 1999].

particular, the decades-long nursing shortage has steadily driven up costs as hospitals have to increase nursing wages in order to remain competitive against private home-health firms [Aiken et al., 1981]. Additionally, expenses for new medical equipment, information technology, prescription drugs and uncompensated care cause hospitals' costs escalate rapidly [Schapira et al., 1993; Mann et al., 1997; Roberts et al., 1999; Lichtenberg, 2001].

New technology. The same advances in medical technology and methods that allow patients to have better outcomes, fewer complications and longer lives also drive up costs very sharply. Regarding new technology, one university study found that the "operating costs of laparoscopic and robot-assisted prostatectomy are 200 to 300 percent higher, respectively, than a traditional open radical prostatectomy" [American Cancer Society, 2010]. Hospitals also seek competitive advantage over other hospitals by purchasing and marketing the services of the newest medical technologies and equipment. A quote from Forbes magazine has now become a popular catchphrase "Pittsburgh has more MRI machines [per person] than Canada" [Whelhan, 2008]. Indeed, the city of Pittsburgh in that phrase could be easily replaced with the "Mayo Clinic's Gonda Building" in Rochester, Minnesota which also has more MRI machines than the country of Canada. This is not a phenomenon isolated to the United States. As can be seen in Figure 2.5, countries the world over are pursuing advances in medical technology – with varying results.

Patients who live longer also consume more health services as they age since older people tend to have more health problems than younger people (Hartman 2008). In 2007,

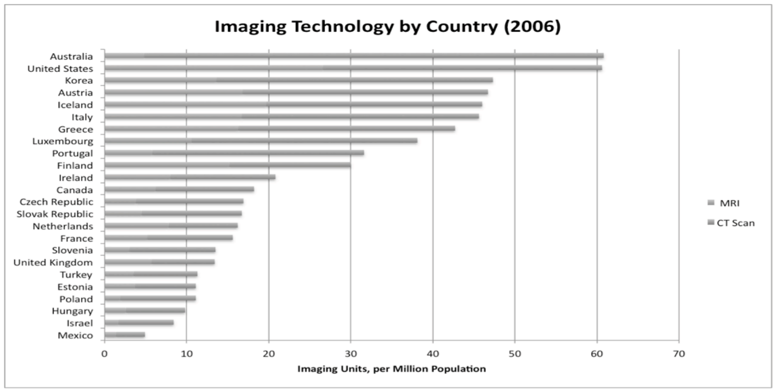


Figure 2.5 Imaging technology by country.
Source: [National Center for Health Statistics, 2011].

the mean annual expense for healthcare and prescribed medications to those age 65 and older ($9,696) was over six times as much the cost to care for the lowest cost segment, patients 6-17 years old ($1,496) [National Center for Health Statistics, 2011]. Granted, new therapies can help hasten patients' return to work and thereby reduce economic losses due to illness. Cancer alone costs the U.S. economy over $263 billion in morbidity, mortality and productivity loss [American Cancer Society, 2010]. Therefore advances that increase survivability and return patients to work quickly will put money back into the economy.

Uncompensated care. Hospitals play an essential role in society as providers of health care services to the most acutely ill. Annually, about 37 million people are admitted as inpatients and over 120 million visits are made to emergency rooms; countless others are seen as outpatients [Centers for Medicare and Medicaid Services, 2009]. One of the drivers of utilization is the 1986 EMTALA law whereby any hospital receiving Medicare payments (most U.S. hospitals) must provide care to anyone needing emergency healthcare treatment; regardless of citizenship, legal status or ability to pay [EMTALA, 1986]. The latter statement is important because not all patients seeking treatment have the 'ability to pay', and treatment is not cheap. Healthcare spending in recent years has topped $2.5 trillion (17.6% of GDP) with the lion's share of expenditure going to hospital care at around

$700 billion [Centers for Medicare and Medicaid Services, 2009]. This does not mean that all hospitals are profitable.

A recent Thomson Reuters survey discovered that fully half of U.S. hospitals were operating in the red and facing unprecedented levels of staffing and service cuts [Girion, 2009]. Public hospitals have been particularly hard hit in this recession and many have sought privatization as a means to combat losses. The reduction in the number of public hospitals and recent changes in Medicare reimbursement laws have caused concern to healthcare researchers. Some studies have suggested that public hospitals which privatize and change to for-profit status subsequently reduce their levels of uncompensated care [Desai et al., 2000]. This may lead to cost shifting and patients being moved to other hospitals for care but there is still more work to be done before definitive conclusions can be drawn.

2.1.4 Inter- and Intra-Hospital Cost Variance

For the purposes of most academic cost comparisons, hospitals are assumed clinically equivalent, i.e., all hospitals are assumed to provide effective medical care. Yet, studies have found that individual hospitals' costs vary widely, even when operating under near-exact conditions [Macario et al., 2001]. This was illustrated in Dr. Atul Gawande's now-famous *New Yorker Magazine* article, "The Cost Conundrum". In his article, Dr. Gawande examined two Tex-Mex border towns: McAllen, Texas and El Paso, Texas. McAllen has the distinction of being one of the most expensive health care markets in the world. Both towns have comparable access to technology and an almost identical patient demographic but El Paso's costs are almost half those of McAllen [Gawande, 2009]. Notably, *expensive care does not guarantee quality of care*. Dr. Gawande noted that on Medicare's 25 quality metrics, McAllen's five largest hospitals performed worse, on average, than neighboring El Paso's hospitals. In those two towns, he found the most significant drivers of healthcare cost were the utilization of specialized services such as

CT/MRI scans, lab tests and a siloed, physician-centric approach. Conversely, medical communities such as the Mayo Health System, which organized itself around teams focused on reduction of waste and improving patient-centeredness consistently proved to be the high-quality, low-cost providers [Macario et al., 2001; Gawande, 2009].

These findings are not new. Several studies have shown that more expensive care is not necessarily better care and in many cases, the converse is true [Feldstein, 1971; Lanes et al., 1997]. In response, *many hospitals argue that their patient-mix is unique, so different from others that they cannot be compared with other hospitals* [Averill et al., 1992; Hvengaard and Gyrd-Hansen, 2009]. Studies have found significant differences in the distribution of severity levels of patients treated in different hospitals and the impact on total hospital payments was approximately +/- 6 % [Averill et al., 1992]. This issue has been addressed at the federal level with the implementation of the MS-DRG systems which account for severity of a condition [Bryant, 2008]. Opinions differ on the sources of cost drivers but all agree on one thing – the current situation is unsustainable and it is in the interest of every American to find an effective means of hospital cost measurement and control. As Dr. Atul Gawande commented 2011 commencement speech at Harvard Medical School:

> We all are in medicine. Reports show that every dollar added to school budgets over the past decade for smaller class sizes and better teacher pay was diverted to covering rising health-care costs [Gawande, 2011].

2.2 Hospital Performance Measurement

2.2.1 Challenges to Measurement

In 2003, the World Health Organization's European office published a synthesis report on the best strategies for ensuring quality in hospitals. The report stated:

> There is little research assessing the effectiveness of one or more hospital or national quality strategies that can be used to answer these questions: Which

> strategies are most appropriate and cost effective for a particular hospital in a specific situation? Which approach should a government or founder promote? [Therefore] there is a strong case for more independent and scientific research [Ovretveit, 2003].

A study reviewing issues in health care measurement identified six challenges in healthcare measurement: (1) Balancing perspectives, (2) Defining accountability, (3) Establishing criteria, (4) Identifying reporting requirements, (5) Minimizing conflict of financial and quality goals, and (6) Developing information systems [McGlynn, 1997].

(1) Balancing perspectives: physicians, purchasers, and patients. When considering the challenges of evaluating hospital performance, many echo the words of Jerod Loeb from the Joint Commission: “measurement provokes considerable angst, frustration, and worry among those being measured and often also among those doing the measuring. As he further comments, it is very important to understand this aversion to measurement and the “disparate nature and varying perspectives of key stakeholders [Loeb, 2004].

Physicians. A hospital’s primary caregivers, physicians have long sought to deliver health care in the way that is best for patients. Defining ‘best care’ has proved problematic in practice. For instance, the current national movement towards ‘evidence-based medicine’ or ‘treatment by consensus’ has received mixed reviews. The major crux of the discord is the old challenge of balancing the age-old art vs. science ratio in medicine. Many physicians have become resistant to what they deem as a removal of the ‘art’ of medicine – physician independence in decision-making being replaced by the ‘science’ of medicine. The ‘science’ in this case referring to courses of treatment which meet some level of national criteria based on rules of scientific evidence [McGlynn, 1997]. Those involved in process-improvement initiatives have also become disenchanted because of measure-ambiguity and in many cases, a failure to properly balance patient outcomes-based and process-based metrics. The challenge of physician perspective is therefore the need for a basic level of physician-judgment and flexibility beyond the levels set by third-party payers and regulators.

Nurses. In the majority of hospitals, physicians are not salaried employees but have admitting privileges at several hospitals. The constant caregivers in these settings are typically the nursing staff. Nurses are typically the ones that are pulled into process improvement initiatives. The benefit of this is that nurses are usually the closest to the processes and most times have figured out ‘workarounds’ for issues that arise in the care setting. The problem with performance measurement beyond the angst of being measured is that the work involved with tracking measures. This will also typically fall to the nurses who may be resistant to additional paperwork, which takes them away from patient care.

Hospital administrators. The other major stakeholders in a hospital setting are the administrators. Considering financial performance measurement, most find that quality metrics gathering and reporting is cost prohibitive. Also, few studies have been able to provide strong evidence of financial return on investment for these initiatives. This is compounded by the fact that most hospitals are still largely paper-based. Therefore, there exists strong resistance to adding any measures to the current reporting burden. With this perspective, there is a move to create metrics from already existing data and those that are easily sourced – ‘cheap metrics’. The major pitfall of the ‘cheap metrics’ is that many of these measures such as volume of procedures and total expenditures are not very useful because they do not give enough detail to provide a clear picture of operations. Also, there may be a large gap between currently existing data and key metrics that cannot be discerned without a study of hospital processes.

Purchasers. On the other side of the scale, regulatory bodies and patients have not bought-in to the hospital’s reasons for performance measurement resistance. In the current recession, payers are drawing analogies from commercial industry and applying these to hospitals. The public policy perspective has therefore shown an increasing desire for transparency in all sectors. Regulators, politicians and insurers all display a ‘need to know' regarding the way that hospitals are spending invested capital. The payers have to balance payment for volume (over- and underutilization) with outcomes and evidence-based medicine. That is, insurers seeking value for their reimbursement dollar have to ensure that their policies are such that they are not building a system where patients either receive unnecessary procedures nor will those needing procedures be denied. In a value-based system where outcomes are rewarded, payers must also account for severity so that very sick patients are not turned away in the interest of good outcome ratios. Likewise, any process measures that are defined must be strongly based on implementation of the state of the art of medicine to ensure that patients receive the benefit of advances in science whenever possible.

Patients. Consumers demand standardized measures by which to compare hospitals before accepting treatment. Patients and families are not only interested in outcomes (readmission rates, mortality, recurrence), they are placing heavy emphasis on 'patient experience,' waiting times and infection rates. Some of the decisions made by physicians and payers to reduce cost such as limits on access to care and choice of providers or shortened hospital stays may be viewed negatively by patients [McGlynn, 1997]. In the new Internet age, many patients are also spending time on self-diagnosis and deciding beforehand the course of treatment that they believe they need to get well. This behavior places these patients at odds with their payers and physicians and leaves the door open for patient dissatisfaction with care. The perspectives of payers and patients though, cannot be underestimated. As Jerod Loeb stated,

> In many respects, demands by purchasers and regulators for demonstrable evidence of quality, and demands for accountability, have become a major driver (if not the major driver) responsible for the burgeoning work in performance measurement over the past decade or so [Loeb, 2004].

(2) Defining accountability. The concept of accountability has been long established in the financial and legal realms. A person or entity is considered to be 'accountable' for an item if they possess it or wield control over it. Likewise, a person is considered to be ‘accountable’ for their actions once they possess a level of mental maturity. What about health care? In health matters, the issue of responsibility is less clearly defined. For instance, a hospital is considered to be legally accountable for the actions of their employees and for events that occur on hospital grounds but they are exempt from responsibility towards the actions of doctors who are not salaried employees [Hardy, 1986]. Yet, the major accreditation bodies, Joint Commission and the National Committee for Quality Assurance NCQA have used standardized systems for holding professionals and facilities responsible for the care they provide [McGlynn, 1997].

Report cards have been developed for hospitals, physicians and healthcare plans. These scorecards measure everything from clinical outcomes to volume of procedures performed and survival rates (30 day mortality and readmission rates) [Muri, 1998]. In the current health care system, most payers reimburse hospitals and physicians separately and reimbursement is usually tied to the ‘intensity of care.’ This means that caregivers are rewarded for doing more procedures, scans and surgeries. Eventually the costs add up and overutilization has been pointed to as one of the major cost drivers in today’s health care system. As Dr. Gawande’s *Cost Conundrum* article pointed out, though, more expensive care is not necessarily better care and in many cases, it has been shown that the health care quality leaders such as the Mayo Clinic are consistently lower–cost providers [Gawande, 2009].

In recent years, as costs have skyrocketed and political policies have changed, an essential shift has been occurring. One of the major buzzwords in health care today is ACO, Accountable Care Organization, defined as a provider-led organization whose mission is to manage the full continuum of care and be accountable for the overall costs and quality of care for a defined population [Rittenhouse et al., 2009]. There are many possible configurations for an ACO. Providers, physician groups, hospitals and even insurance companies can each create their own flavor of ACO as long as a few criteria are met. The

ACO: (i) agrees to manage all the health care needs for at least 5,000 Medicare beneficiaries (ii) contracts for at least 3 years (iii) hospitals, doctors and insurers must share a single payment and (iv) healthcare information for patients has to be shared to avoid duplication of effort.

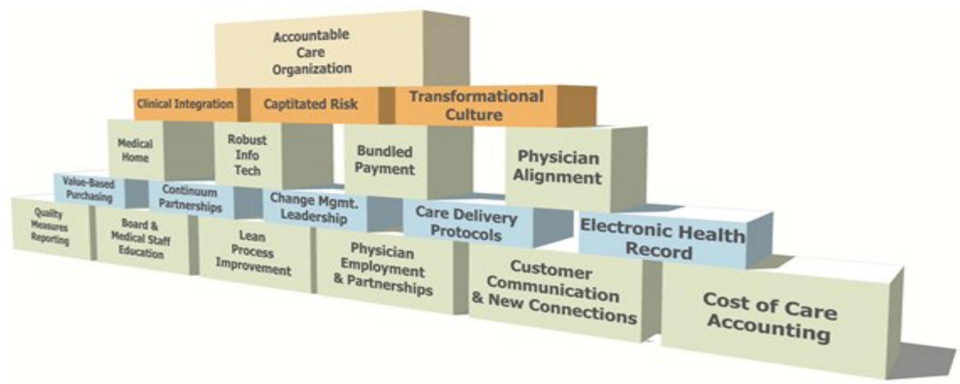


Figure 2.6 Accountable Care Organization structure.
Source: [Sauve, 2011].

Once established, ACOs would look similar to large health care providers such as California-based Kaiser Permanente, the United States' largest managed care organization. Founded on the heels of the "Great Depression and World War II, when most people could not afford to go to the doctor," Kaiser provides one stop health care for members [Kaiser Family Foundation, 2011]. Kaiser health insurance plans are pre-paid to spread costs and Kaiser physicians are in every specialty and they practice in Kaiser hospitals. As both hospitals and physicians receive funding from Kaiser health plans directly, there is a focus on wellness and prevention as opposed to utilization. Caring for the needs of 8.8 million members, Kaiser Permanente employs 164,098 people. These employees belong to three segments - the not-for-profit insurer/payer, Kaiser Foundation Health Plans in 8 regions, the 36 Kaiser Foundation Hospitals, and the 454 not-for-profit hospital providers at Permenante Medical Offices and 15,853 physicians in for-profit physician partnerships [Kaiser Family Foundation, 2011].

A product of the 2010 Patient Protection and Affordable Care Act, the practical implementation of ACOs is still in its infancy and there are serious concerns about the concept. For instance, where does the ACO's responsibility for a patient end and where does the patient's own responsibility begin? That is to say, the ACO can only provide 'reasonable care' for its members - it cannot force a person to exercise, eat health or refrain from overeating, drinking excessively or smoking. Under such circumstances, it becomes a highly subjective measure for reimbursement based on attainment of healthcare goals. There are also concerns over anti-trust laws being violated and the very real possibility that an ACO might become so large that it can negotiate rates at a scale that drives up costs for the overall health care system.

(3) Establishing criteria. In his address to the 2011 graduating class at Harvard Medical School, Dr. Atul Gawande stated an 'inconvenient truth' that few Americans wish to admit:

> Medical performance tends to follow a bell curve, with a wide gap between the best and the worst results for a given condition, depending on where people go for care. The costs follow a bell curve, as well, varying for similar patients by thirty to fifty per cent. But the interesting thing is: the curves do not match. The costs follow a bell curve, as well, varying for similar patients by thirty to fifty per cent. But the interesting thing is: the curves do not match. The places that get the best results are not the most expensive places. Indeed, many are among the least expensive [Gawande, 2011].

Clearly defined rules allow for standardization of measurement. This is in to answer Dr. Gawande's questions *What hospital gives the best care? What is the best value, i.e. the best results at the lowest price?* In health care, explicit clinical criteria is called for in defining technical quality, provider's skill and the cost-efficient delivery of the preceding [McGlynn, 1997]. Technical quality can be thought of as the application of 'evidence based medicine', EBM or 'evidence based practice' EBP. These are rooted in five linked ideas: [1] clinical decisions should be based on the best available scientific evidence; [2] clinical problem-rather than habits or protocols-should determine the type of evidence to be sought; [3] identifying the best evidence means using epidemiological and biostatistical ways of thinking; [4] conclusions derived from identifying and critically appraising evidence are useful only if put into action in managing patients or making health care decisions [5] performance should be constantly evaluated [Davidoff et al., 1995].

The lofty goals of EBM are tempered by an awareness by the medical community that it is impossible for any one clinician to read every article written in his discipline, to understand its implications, and then to routinely then apply them to his clinical practice of medicine with continuous improvement. At the same time, patient, providers and payers alike agree that patients deserve to have the benefit of the state of the art and latest findings from clinical research. There are several scientific journals which search, validate and synthesize research findings published in medical journals with an emphasis on providing physicians with treatment guidelines. One such publication, *Evidence-Based Medicine*, uses an expert panel to "appraise the validity of the most clinically relevant articles and summarize them including commentary on their clinical applicability" [The BMJ Group, 2011].

Beyond journals, the U.S. Department of Health and Human Services' Agency for Healthcare Research and Quality (AHRQ), has created and funded USPSTF, the U.S. Preventive Services Task Force. This group is an independent panel of non-Federal experts which "conducts scientific evidence reviews of a broad range of clinical preventive health care services (such as screening, counseling, and preventive medications) and develops recommendations for primary care clinicians and health systems.' USPSTF grades scientific evidence on a scale that ranges from Grade A or B: Recommended Service and Grade C: Do not routinely offer this service to Grade D: Discourage the use of this service. A grade of I: Insufficient evidence indicates that the current body of evidence is insufficient to make a general statement regarding the benefits/risk trade off of this treatment. The implications of USPSTF findings are far-reaching. For example, with a Grade D, the

USPSTF "recommends against routinely screening women older than age 65 for cervical cancer if they have had adequate recent screening with normal Pap smears and are not otherwise at high risk for cervical cancer" [U.S. Preventive Services Task Force, 2011]. In practice, this means that payers who use the USPSTF recommendations as guidelines for reimbursement will not pay for this routine screening unless there is a clinical need.

Not everyone, however, is convinced by the methods and applications of Evidence Based Medicine (EBM). There have been legal challenges and legislation put forth to congress by various stakeholders wishing to maintain autonomy in clinical practice. This stance calls into direct question the skill of the physician. The various means of measuring 'skill': board certifications, peer reviewed publications, outcomes and adherence to process guidelines have come under fire at various times for being inadequate measures. Finally, none of the preceding accountability measures take into account the cost-effectiveness of care. Though an indelicate subject when discussing a person's loved ones, cost containment must be considered if society is to continue providing care.

(4) Identifying reporting requirements. The science of measurement advanced from the early days of primitive societies needing rudimentary measurements for distance to water for drinking and quantity of roots and berries for treatment of ailments to the current age of space travel and nano-scale clinical therapies. This need for clearly defined indicators has not escaped hospitals; in many ways this has been amplified in the hospital setting. The National Council on Quality Assurance (NCQA) has used three criteria when evaluating quality measures. These are "relevance, scientific soundness, and feasibility" [McGlynn, 1997].

Relevance. For a measure to be relevant, it has to be considered important by major hospital stakeholders. If stakeholders do not see a measure's importance, they will not put forth the effort needed to collect and report the metrics. *Relevance* also carries the thought of prioritization of resource allocation [McGlynn, 1997]. Any dynamical system which experiences dwindling resources in the face of constant or increasing demand must prioritize its resources or face a meltdown. For hospitals, the surface may seem calm but it is in a similar situation: pressed by economic hardships, hospitals must ration its resources. Many hospitals use per diem nurses to fill in gaps on the schedule provide flexibility for days with unexpected volume. In order to best use this resource, it would be good for the hospital to track and trend several related measures. A nominal case would be patient volume by day, but it would be better to look at patient volume by time of day each day; nursing ratio; patient cycle times and intensity of care. It would also be best to measure care delivered across the hospital, not just for a particular segment such as the Emergency Department (ED) or Surgical Services (Operating Room, OR).

Scientific soundness: reliability, validity, adjustability. Reliability or repeatability is one of the foundation cornerstones of scientific inquiry. In designing a measure, it is very important to ensure that the actions which are measured will consistently produce the same result [McGlynn, 1997]. This speaks to the natural variation explored in the Quality Measures section of this paper. If a measure is too sensitive or is not pronounced enough to account for natural variability of the system it will not succeed. A measure's Validity is an indication of its direct bearing on the quality of care delivered and the measure's adjustability is related to take into consideration the impact of external factors. Understanding also the data sources, the hospital's administration should be able to do root cause analysis to find and areas of 'special cause variation.'

Feasibility. It should always be foremost in the minds of the measurement system designers that enthusiasm for measurement must be tempered by a concern for feasibility of implementation. There is usually large leeway given to systems engineers during design phases but it is implementation plans which typically place financial goals at odds with quality goals.

(5) Minimizing conflict between financial and quality goals. The Triple Constraints Model of project management theory, shown in Figure 2.7 states that only two of the three constraints: time, cost and scope can be maximized at any one time for a particular measure.

In hospital applications, this implies that optimizing patient throughput (minimum time to cycle the maximum number of patients) through the entire hospital (large scope) will come at a large cost both monetarily and in human resources. The placement of 'quality' inside this triangle is deliberate. This indicates that changes to any of the three major constraints will have an impact on hospital quality.

Figure 2.7 The Triple Constraints Model.
Source: [Stiffler, 2009].

As management theory has evolved, project management methodology likewise, has changed and the certifying body for Project Management now supports a six constraint model. This refinement reflects a keen understanding by project managers that all of the six project components: scope, schedule, cost, resources, quality and risk must be considered when planning and executing any project [PMI, 2008]. Hospital systems managers must successfully manage all six areas if their project is to be successful.

(6) Developing information systems (HealthIT). The United States has one of the most connected populations on the planet. Of Americans over the age of 18, "93% watched television and 77% accessed the internet" [United States Census Bureau, 2011]. This would lead most to believe that essential service providers such as hospitals were as technologically advanced as developments in medical science would imply. According to one of the largest surveys of electronic medical technology ever conducted:

> Only 1.5% of U.S. hospitals have a comprehensive electronic-records system (comprehensive EHR), and an additional 7.6% have a basic system (basic EHR). Computerized provider-order entry for medications (CPOE) has been implemented in only 17% of hospitals. [Jha et al., 2009]

This astonishing result leaves major implications for clinical practice. This means that regardless of the measures developed or the consensus reached, the largest challenge to measurement is unequivocally the lack of information systems in healthcare.

Acknowledging this barrier, the federal government allocated an unprecedented $787 billion stimulus package for obtaining meaningful use in Health Information Technology (HealthIT/HIT)as part of the American Recovery and Reinvestment Act of 2009 (ARRA) [Blumenthal, 2010]. The *meaningful use* criteria embedded in the ARRA legislation is intended to provide impetus for health care practitioners to move forward quickly with developing electronic systems for storing and sharing patient information. Another key component of HealthIT is the use of decision support systems such as CPOE which reduces medication errors as physicians enter medication orders and prescriptions directly into the dispensing system. The nurses, hospital pharmacy or even the patient's own local pharmacy can directly retrieve the prescription reducing the risks related to handwriting errors and patient identification/medication errors.

The collection of a wide range of metrics is also possible with electronic health records. A shared database of many patients' information allows researchers and systems engineers to drill-down through data, review deviations and understand outcomes and patterns resulting from hospital processes. This facilitates refinement of measures and continuous quality improvement with metrics which are constantly evolving to define the true state of the hospital. Built to run as Graphical User Interfaces (GUI), scorecards and dashboards have become the medium of choice for reporting information to be used in executive decision making. Notably at other levels of the organization spreadsheets remain a stronghold due to low cost and ease of use.

A simple real-time hospital 'dashboard' can be developed for monitoring patient progress through surgical services as in Figure 2.8. In a system with multiple-data entry points and a display at every step on *day of surgery*. Nurses, physicians and family members can visually track patient progress and monitor occupancy with minimal intervention. This reduces the high volume of phone calls received by nurses in each segment of the flow - calls which take away from patient care. Also, a patient hospital 'scorecard' can be created at the end of any reporting period to show the stresses and strains on hospital resources as patient volume and acuity are trended.

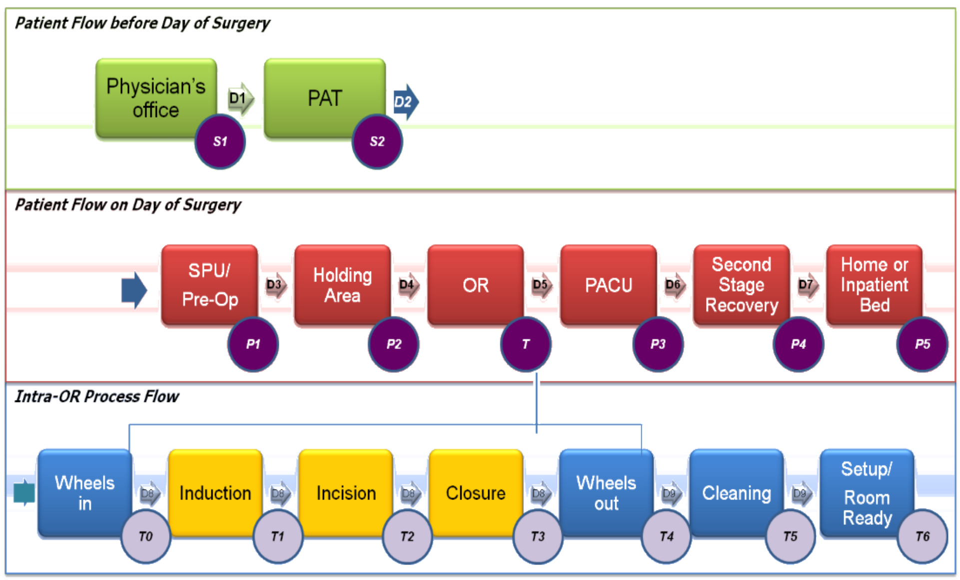


Figure 2.8 Generalized patient view - flow through surgical services.

Most hospitals are currently only reporting T0 and T4 timestamps of Figure 2.8 - the intra-operative time and using data collected for this segment to plan future surgeries. The problem with this approach is that it does not take into account downstream issues such as slow recovery times and medicine reactions which can dramatically impact patient flow. Hospitals only looking at intra-operative times also miss the opportunity to see operation delays at every step of the process. For instance, any patient that shows up on day of surgery without having previously obtained Pre-Admission Testing (PAT) clearance slows down and adds churn to the surgical services process as many PATs end up being done on day of surgery. Also, with a global view of patient flow, hospitals would be able to see schedule deviations i.e., the difference between scheduled starts and actual starts to understand operating theatre turn around times.

2.2.2 Hospital Metrics

In the hospital industry today, when *performance measurement* is mentioned, most people think of *quality of care* and *process of care* measures. As discussed in Section 2.3, quality of clinical care is the most widely reported and studied measure of performance, with primary focus on the clinical outcomes of the patient. The process of care measures highlighted in Section 2.3.5 are used to evaluate the degree to which hospitals provide the patients with appropriate equipment, timely treatment, adequate services, and evidence-based medicine within their facility. These measures are largely required by regulatory and accreditation bodies.

A hospital's *financial* performance is typically measured by liquidity, profitability, cost-to-charge ratios, average cost per adjusted patient day, staffing costs and investment in new technology. The measures are monitored closely by hospital administrators and investors need to a hospital's viability and benchmark prices against competitors. As detailed in Section 2.1, these are key determinants of continued success as hospitals which are not able to manage adequately their finances are often forced to close their doors.

The fourth category of performance is in *operations*, through which, hospitals measure utilization and resource efficiency. Hospital performance can therefore be considered as segmented into four major categories: quality of clinical care, process of are, financial stability, and operations productivity (Figure 2.9).

Hospitals today use a myriad of measurement schemes, usually a combination of metrics from the four major categories. In commenting on strategies for ensuring quality in hospitals, the World Health Organization's Europe office stated that "no evidence exists to

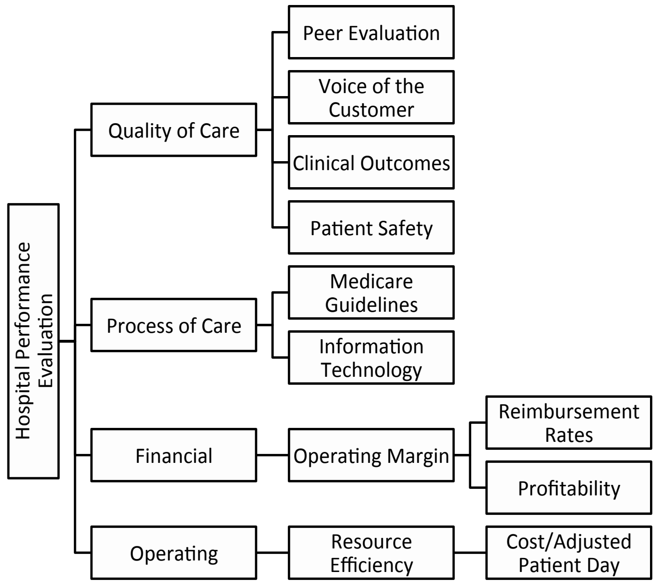


Figure 2.9 Overview of hospital performance measurement.

suggest that there is one 'best' strategy." Instead, the WHO's synthesis report recommended that any chosen strategy should balance quantity, cost and quality of service in a transparent systems which rewards safety and quality while maintaining financial goals [Ovretveit, 2003].

Li and Benton said that performance criteria should be evaluated according to a four-segment matrix: internal vs external and cost or financial performance vs quality performance.

1. Internal cost measures. As with industrial applications, hospitals measure internal costs in terms of *production efficiency* (length of stay and case mix, cost per day, cost per case) and *utilization* (average output rate/effective capacity = nurse to patient ratio, bed utilization, task assignment, shift schedules).

2. Internal quality measures. *Process of care* (appropriate equipment, timely treatment, adequate services, evidence-based medicine) and *outcomes* (30 day mortality, 30 day readmission).

3. External financial status measures. *Financial performance* (liquidity, profit, issued bond values) and *market share* (value of issued bonds, physician affiliations, HMO memberships, case-mix changes over time).

4. External quality measures. *Patient perceived quality* and *patient satisfaction* (H-CAHPS Hospital Survey).

2.2.3 The Influence of Medicare on Hospital Measurement

The Federal Government is the largest purchaser and provider of health care services in the United States and its service, Medicare, is one of the largest health insurers in the world. Spending roughly $260 billion annually to provide healthcare to 42 million elderly (age 65+) and permanently disabled people (under age 65), Medicare consumes about "one eighth of the federal budget and 2% of the nation's GDP" [Finkelstein, 2005].

1965 - Medicare created. Medicare split reimbursement for medical charges into two groups - Part A (Hospital Insurance) and Part B (Outpatient Physician Services). Hospitals are reimbursed for reported costs ($1 spent is $1 earned). *This created incentives for inefficient care.*

1983 - Prospective Payment Systems, PPS created. Prospective payment changed to retrospective reimbursement using IPPS for inpatient reimbursement to hospitals per discharge or per case on the basis of Diagnosis-Related Group, DRG weight and market conditions. These are fixed rates based on *Case Mix Index* (Figure 2.10). OPPS is used for outpatient reimbursement per individual service or procedure based on Ambulatory Payment Classifications, APC as in Figure 2.11. These are flexible rates based on a fee-for-service model. *This removed the direct link between hospital spending and Medicare revenue - costs per inpatient day dropped significantly within the next decade.*

1990s - early 2000s. This was a period of declining reimbursement and saw the growth of ambulatory Services with clinical quality measures implemented. The 1980s were a cost-containment era. In an attempt to force hospitals to cut costs, after 1983, Medicare paid hospitals for inpatient services at fixed rates, but continued to reimburse outpatient services based on reported cost. Hospitals responded by increasing outpatient services to Medicare patients compared to non-Medicare patients.

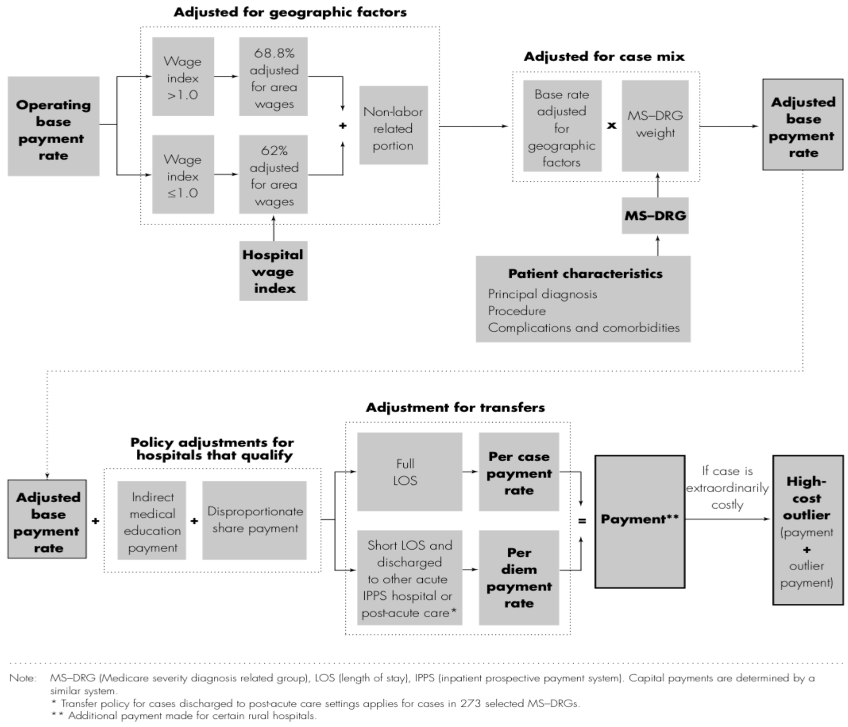


Figure 2.10 Detail of Inpatient Prospective Payment System.
Source: [MedPac, 2011].

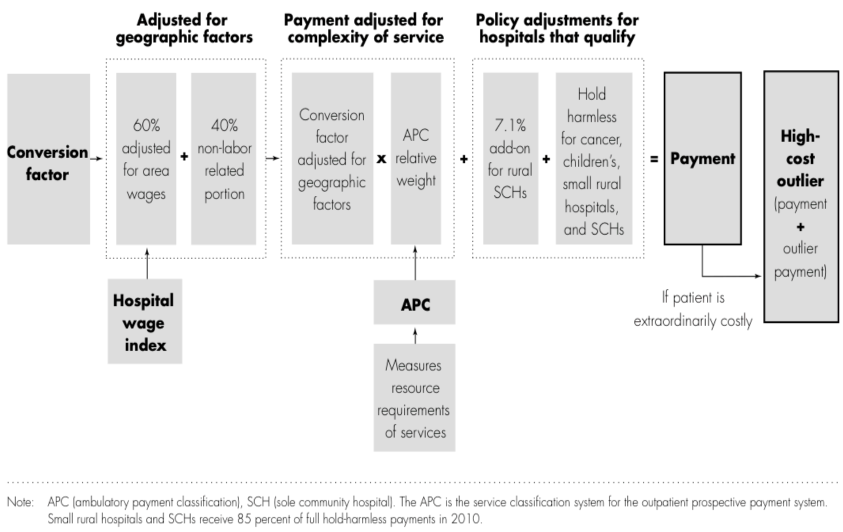


Figure 2.11 Detail of Outpatient Prospective Payment System.
Source: [MedPac, 2011].

Although "inpatient full costs (i.e., direct cost plus allocated costs) decreased relative to outpatient full costs after 1983, when cost allocations were excluded, inpatient direct costs increased relative to outpatient direct costs, thus providing no evidence of cost-containment" [Eldenburg and Kallapur, 2000].

The Balanced Budget Act (BBA) of 1997 allowed for a volume adjustment to PPS to help small hospitals. These were struggling with fixed costs which could not be distributed at a reasonable rate due to the low volume of patients seen in annually. Many of these small hospitals became "Critical Access Hospitals" and they receive cost-based reimbursement instead of PPS rates as mentioned in Figure 2.3. This era also showed sharp growth in physician-owned Ambulatory Service Centers. These outpatient services-only clinics became notorious for holding on to 'good patients' - those with private insurance and dumping 'bad patients' those with little or no insurance or those on Medicare and Medicaid. With little overhead costs (an outpatient surgery center can refuse care - hospital emergency departments must stabilize all patients). These surgery centers became both large and profitable.

This was also the time of implementation of 'quality of care measures.' Hospitals faced pressure to perform well on outcomes (mortality and readmission rates) and process of care (aspirin administration, smoking cessation etc.) measures. Failure to perform meant penalties - hospitals had to endure reduced reimbursements and negative publicity amidst global economic downturn and increasing costs for salaries and new technology.

Medicare Today and the Near Future. The American Recovery and Reinvestment Act of 2009, ARRA called for wide-ranging changes in several sectors of the U.S. economy and Healthcare was a major focus area. ARRA made provisions for billions of dollars worth of incentives earmarked for healthcare. One of the key changes of ARRA was the *implementation of HealthIT*. As discussed in Section 2.2.1, the lack of information technology is a major limiting factor in health care. To combat this issue, the ARRA legislation provides incentives for hospitals and primary care physicians to implement and becoming 'meaningful users of HealthIT.' There is also provision for the *"voice of the customer" or H-CAHPS surveys* to be factored into hospital reimbursements.

The United States places primary emphasis on clinical quality measurement. Jerod Loeb noted that in only a few specific clinical focus areas (acute myocardial infarction, heart failure and pneumonia) is there substantial evidence to support the use of clusters of standardized process measures as key indicators. Beyond this, he noted, there is much debate as to what to measure: a single measure is too limited in scope while a large measurement set is both cost-prohibitive and confusing to stakeholders [Loeb, 2004].

Loeb's findings are echoed by Rubin et al whose paper found that process of care measures are desirable to all stakeholders. Payors, clinicians and patients alike prefer process measures because they are more clearly able to demonstrate physician competency than outcome measures. Still, process measures are difficult to implement because the state of the art is constantly advancing and in order to be useful, they must be linked to important outcomes and their validation requires a large and constant time investment by clinical experts [Rubin et al., 2001].

Several organizations have implemented Clinical Quality Improvement (CQI) or Total Quality Management (TQM) as a means to make incremental changes. Commenting on the impact of these programs, Short states that CQI/TQM programs "can help with the current financial crisis, lead to improved quality of care, and better relationships with both internal and external customers" [Short, 1995]. Another researcher, Shortell outlined characteristics for making CQI effective. Hospitals should carefully focus initiatives on areas of real importance to the organization and address these with clearly formulated intervention. Organizations should implement CQI only when the organization is ready for change and has prepared itself by appointing capable leadership, created trusting physician relationships and developed adequate information systems [Shortell et al., 1998].

2.3 Quality of Care Measures

2.3.1 Definition and History of Healthcare Quality

In the United States, healthcare quality practitioners acknowledge five significant periods in healthcare quality improvement [Colton, 2000; McIntyre et al., 2001]:

- 1850 – 1915: The Industrial Revolution and scientific management.
- 1915 – 1935: The advent of bureaucracies and organizations.
- 1935 – 1960: Introduction of human resources, statistical process control, and the expansion of health care.
- 1960 – 1980: Maintenance of the status quo.
- 1980 – 2011: Introduction of the quality health care organization.

'Quality of care' has been defined as the ability to access effective care on an efficient and equitable basis for the optimization of health/well-being for the whole population [Campbell et al., 2000]. 'Access to care' is typically focused on geographical location and physical access to facilities. It is also concerned with the affordability, equity and availability of that care. These are issues that are typically covered under the auspices of researchers in the public policy field.

Efficiency (cost/benefit ratio or process or outcome benefit) and *effectiveness* (delivery of knowledge-based care) are both quality characteristics that fall under the realm of systems research. As the grandfather of modern healthcare quality, Avedis Donabedian noted, there is a need to balance effectiveness and efficiency to gain the highest net benefit to individuals and society [Donabedian, 1980]. He also postulated that health care quality can be measured by observing its structure (characteristics of the health care setting), its processes (what is done in the health care setting) and its outcomes (ultimate status of the patient after a given set of health care interventions) [Donabedian, 2003]. In modern health care, 'quality of care' has become synonymous with clinical performance and standard measures have been developed for this segment as illustrated in Figure 2.12.

Figure 2.12 Quality of care triad.
Source: [Campbell et al., 2000].

2.3.2 Crossing the Quality Chasm

A decade ago, the Institute of Medicine (IOM) released their report on the U.S. healthcare delivery system. In this seminal report, the IOM wrote that "healthcare harms patients too frequently and routinely fails to deliver its potential benefits. Between the health care that we now have and the health care that we could have lies not just a gap, but a chasm" [Institute of Medicine, 2000]. This 'chasm' or profound difference has typically been attributed to rapid advances in medical science and technology, growing complexity in health care. These two factors have increased at such a rate that it has been difficult for the majority of health care providers, especially hospitals to keep pace. Hospitals also traditionally have been organized as complex bureaucracies and these are slow to react to a changing environment [Woolhandler, 1997].

If Helen of Troy was the face that launched a thousand ships, the IOM's *Crossing the Quality Chasm* report was the book that launched a million initiatives [Institute of Medicine, 2000]. Hospitals across the country brought in quality and systems' specialists to provide insights on system redesign. Philosophies such as the Toyota Lean Manufacturing and Motorola/GE's Six Sigma were often tailored to fit the healthcare system [Womack, 1990; Pande, 2000]. Consultants and hospital managers alike also used traditional methods such as Total Quality Management TQM or Continuous Quality Improvement CQI, and

Statistical Process Control SPC, to implement the IOM's redesign imperatives [Short, 1995; Shortell et al., 1998; Benneyan et al., 2003].

2.3.3 Statistical Process Control and Continuous Quality Improvement

As no two patients are the identical, no two patient encounters are exactly identical – this is the essence of natural variation in a system. To account for this, Statistical Process Control SPC, and its main tool, control charting, has been extensively used to study how hospital processes change over time. At a departmental level, practitioners of Lean and Six Sigma methodologies have implemented control charts to identify sources of natural variation and 'special cause variation.' Once identified, these statistically significant signals can be acted upon. Management attention can be focused on investments that deliver value. Control charts can also help teams to decide whether to search for special causes if the process is out of control or to work on more fundamental process improvements and redesign if the process is in control [Benneyan et al., 2003]. Control charts are also simple visual tools, which can be used by employees who are not systems experts – allowing for buy-in across the organization and aiding in key decision making as in Figure 2.13.

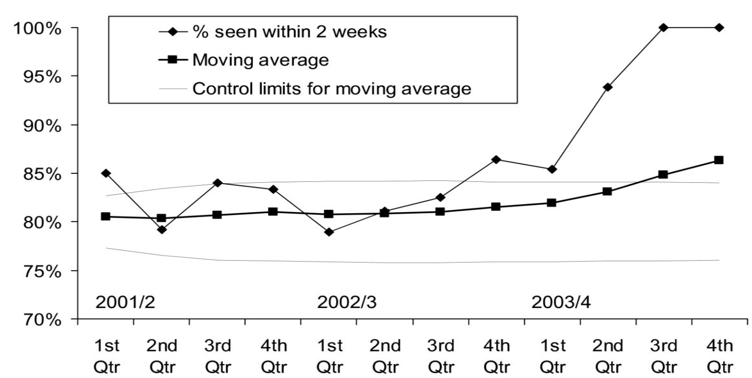


Figure 2.13 Sample use of control charts: urgent referrals for lung cancer.
Source: [McCarthy et al., 2008].

The American Society for Quality (ASQ), defines Total Quality Management (TQM) or Continuous Quality Improvement (CQI) as a management approach to long-term success through customer satisfaction'. The central tenet of TQM is that it is not a program or system but a philosophy, and as such, it flies in the face of the traditional hospital structure. As noted by Short and Rahim, the most difficult barrier to implementing TQM in hospitals is their complex, bureaucratic and highly departmentalized structure. Also most physicians are not salaried hospital employees but rather, they have admitting privileges at several hospitals. This model sets up a competitive environment whereby hospitals are traditionally 'physician centric' [American Society for Quality, 2011]. In this situation, physicians tend to be less likely to be engaged in hospital programs. If TQM or any other performance management initiative is to succeed in making sweeping changes towards patient-centered, effective care, hospital and medical staff must all be involved. Encouragingly, several studies have shown that "early involvement of physicians in a non-threatening environment can lead to long-term success in TQM implementation [Lopresti and Whetstone, 1993].

2.3.4 Outcome Measures and Voice of the Customer

On the national level, an important consequence of the focus on quality was the creation of the Agency for Healthcare Research and Quality (AHRQ) and the National Quality Forum (NQF) by the U.S. government to promote the development and reporting of quality measures [Miller, 1999; Agency for Healthcare Research and Quality, 2003]. The first report from this collaboration, the National Healthcare Quality Report included results on a broad set of 57 performance measures. This provided data on the trend in the quality of services for several clinical conditions. The report was reasonably well received but there were deficiencies. Pre-existing data sources were very limited and resulted in several metrics being skewed. Additionally, there was a general lack of feedback from the Centers for Medicare and Medicaid Services (CMS) and AHRQ. This hampered hospitals' ability to implement continuous quality improvement, Continuous Quality Improvement (CQI) [Williams et al., 2005].

As the federal programs were floundering, the Joint Commission (formerly known as Joint Commission on Accreditation of Healthcare Organizations, JCAHO) had been successfully measuring hospitals at the national level for years. The first to implement a national quality performance measurement program, Joint Commission first in 1997 and then in 2002, implemented evidence-based standardized measures of performance in over 3000 accredited hospitals as part of its ORYX initiative [Muri, 1998]. This was significant since JCAHO accreditation accounts for more than 90% of the acute care medical-surgical hospitals in the United States. Hospitals were required to submit data on standardized performance measures on their choice of at least two of the four initially available sets of measures: acute myocardial infarction, heart failure, pneumonia and pregnancy. Note that pregnancy is typically excluded from studies (as are hospitals considered to be psychiatric or specialty-only) as well as hospitals with an average daily census less than 10 patients [Williams et al., 2005].

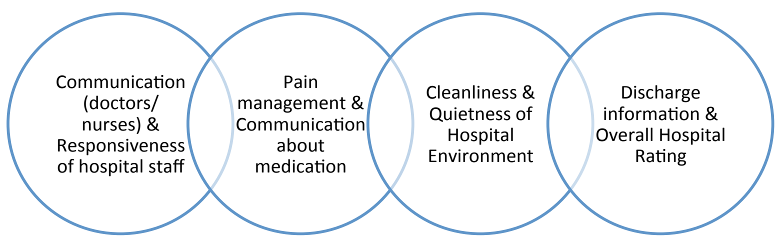


Figure 2.14 Elements of Hospital Satisfaction Survey (H-CAHPS).
Source: [Williams et al., 2005].

In 2007, CMS and the Hospital Quality Alliance (HQA) began reporting 30-day mortality measures for acute myocardial infarction (AMI), heart failure (HF) and pneumonia (PN). The initial process of care measures and outcome measures list has since been expanded to include measures for patient safety and hospital acquired infections. Recognizing that patients are the ultimate health care consumers and therefore should have a right to provide feedback on their treatment, AHRQ has implemented the Consumer Assessment of Healthcare Providers and Systems, CAHPS. The 27-question survey referred to as H-CAHPS (for the hospital version) is used to assess the patient-centeredness of care, compare and report on performance with the intended consequence of continuous improvement in quality of care (Figure 2.14). In an early study, Shortell noted progress at hospitals but commented that these represent "pockets of improvement" and at that time there was "no evidence has yet emerged of an organization-wide impact on quality" [Shortell et al., 1998].

2.3.5 Process of Care Measures

The core process of care measures for acute myocardial infarction, pneumonia and heart failure have been supported by a large body of work that indicate these have a strong correlation with outcomes (Figure 2.15). The *New England Journal of Medicine* published two of the largest studies on health care quality as part of special articles in 2003 and 2005. These studies were very significant as they gave a comprehensive view of the level of quality of care given to the average person in the U.S. as they were not confined to a specific population (Medicare/Medicaid, geographic area or insurer).

AMI	HF	PN
• Aspirin within 24hrs • Aspirin at discharge • ACE inhibitor • Smoking cessation counseling • Beta-blocker at discharge • Mean time from arrival to thrombolysis • Mean time from arrival to PCI	• Discharge instructions – medication, diet, weight, worsening symptoms, follow-up and activity • Assessment of left ventricular function • ACE inhibitor at discharge • Smoking cessation counseling	• Oxygenation assessment • Pneumococcal screening/vaccination • Blood cultures collected before initiation of antibiotic therapy • Smoking cessation counseling • Mean time from arrival to initial antibiotic administration

Figure 2.15 Joint Commission process of care measures.
Source: [Williams et al., 2005].

The first article reviewed 439 indicators for 30 conditions and preventative care that ranged from alcohol dependence to hypertension and headaches to breast cancer for 6,712 participants. The study, which included phone calls, chart abstractions and a multidisciplinary expert panel of judges produced alarmingly varied results.

> At a 95% confidence level, in the 25 conditions for which at least 100 persons were eligible for analysis, persons with senile cataracts received 78.7% of the recommended care; persons with alcohol dependence received 10.5% of the recommended care and on average Americans receive about half of the recommended medical care processes [McGlynn et al., 2003].

The second report examined the 3000 hospitals in the aforementioned JCAHO study. To encourage and aid in continuous quality improvement, the hospitals in the study received quarterly feedback in the form of written reports throughout the two-year study period. Assessing the standardized indicators of quality of care in Figure 2.15, the study found a "significant improvement [where ($p < 0.01$)] in the performance of U.S. hospitals on 15 of 18 measures and the magnitude of improvement ranged from 3% to 33%" [Williams et al., 2005].

2.3.6 Hospital Type: Urban or Rural, Teaching Status, For- or Non-profit

Hospital administrators have expressed concern that the quality measures do not take into consideration the differences between rural and urban hospitals, teaching status and between for-profit and community hospitals. Many believe the hospital structure have a large bearing on performance and there has been some evidence to support this. One large study of Medicare patients found:

> "On average, the performance of not-for-profit hospitals in treating elderly patients with heart disease appears to be slightly better than that of for-profit hospitals. Even after accounting for systematic differences in hospital size, teaching status, urbanization, and patient demographic characteristics. This average difference in mortality performance appears to be increasing over time" [McClellan and Staiger, 2000].

Considering a broad subset of hospitals, studies have found that "hospitals with higher teaching intensity appear to have lower risk-adjusted mortality after major surgery than less teaching intensive hospitals" [Silber and Rosenbaum, 2009]. Another study stated that although quality varies from state to state, but teaching, larger, and more urban hospitals have better quality in general than nonteaching, small, and rural hospitals [Keeler et al., 1992]. Though lagging behind their urban counterparts, studies have shed light on the progress brought by the healthcare quality metrics in rural hospitals. For example, the University of Minnesota's update on rural Critical Access Hospitals, CAHs in 2010 showed a trend of increasing quality on all three process of care measure segments over the time period 2005 to 2008. A review of the patient satisfaction data showed a favorable comparison with national averages [Casey et al., 2010].

2.3.7 Readmission rates, Mortality and Hospital Quality

Though the core measure set has been validated to a large extent, there has been controversy regarding the validity of readmission and mortality measures as indicators of quality performance. The first challenge to the inclusion of mortality measures is the small sample size.

One study examined whether the seven operations for which mortality has been advocated as a quality indicator by AHRQ are performed frequently enough to reliably identify hospitals with increased mortality rates and found that for only one operation did the majority of hospitals exceed the minimum caseload [Dimick et al., 2004].

Another study used Monte Carlo simulation models to determine if mortality rates could distinguish 172 average-quality hospitals (5% preventable deaths) from 19 poor-quality hospitals (25% preventable deaths). They found that for individual DRG groups, mortality rates were a poor measure of quality, even using the optimistic assumption of perfect case mix adjustment [Hofer and Hayward, 1996]. At the macro level, some policy makers have expressed an interest in using the overall hospital mortality, the hospital standardized mortality ratio (HSMR) to measure performance. One study found that hospital standardized mortality ratios correlate weakly with other measures of quality of care and have additional limitations when derived solely from administrative data. It also stated that the low cost of measurement is offset by expenses to institutions that choose to investigate their performance, since, in contrast to other performance measures, hospital mortality ratios provide no indication of the underlying quality problems [Shojania and Forster, 2008].

Studies have also found that like mortality rates, readmission rates are not a stable indicator of quality. One stated that "12% to 75% of all readmissions can be prevented by patient education, pre-discharge assessment, and domiciliary aftercare yet without a standardized method to adjust for confounders, global readmission rates are not a useful indicator of quality of care" [Benbassat and Taragin, 2000]. One meta-analysis review of literature found that the "risk of early readmission is increased by 55% when care is of relatively low quality, that is, substandard or normative instead of normative or exceptional" [Ashton, 1997]. Others have found that when evaluation their predictive value, "readmissions did not predict and was not a valid indicator of the quality of care for patients with heart failure admitted to three Swiss university hospitals" [Luthi et al., 2004]. Interestingly, in a study of Veterans Affairs hospitals, primary care intervention "increased, rather than decreased the rate of rehospitalization, although patients in the intervention group were more satisfied with their care" [Weinberger et al., 1996].

2.3.8 Hospital Compare and U.S. News & World Report

Researchers are not the only ones interested in hospital quality information. Private citizens are becoming increasingly concerned about the care that they receive and many desire to become partners in their own treatment. To facilitate this shift, CMS launched the Hospital Compare tool, which provides the public with information on hospital performance for quality of care measures. In addition to looking at the metrics for a particular hospital, a consumer can select up to three different hospitals in the online Hospital Compare database.

This system allows for a side-by-side comparison of surgical care, heart attack or chest pain, pneumonia, heart failure, hospital mortality and readmission rates, children's asthma, use of medical imaging and patient satisfaction. With heightened interest in care process data, it begs the question – *is there a strong association between hospital process performance and favorable outcomes?* If the answer is 'yes', then the Hospital Compare report and others like it are providing a public service, allowing an accurate impression of hospitals. On the other hand, if the current data set is in any way misleading, it can be dangerous to the system.

Most public citizens are not well versed in health care comparison and typically people turn to the media for their information and guidance in decision-making. The ever-popular U.S. News & World Report's ranking issues have guided Americans on picking the best colleges to cars and now hospitals. For 2011-12, 4,825 hospitals were assigned Index of Hospital Quality IHQ, scores in 16 adult specialties: Cancer, Neurology & Neurosurgery, Cardiology & Heart Surgery, Ophthalmology, Diabetes & Endocrinology, Orthopedics, Ear, Nose, & Throat, Pulmonology, Gastroenterology, Psychiatry, Geriatrics, Rehabilitation, Gynecology, Rheumatology, Nephrology, and Urology [U.S.News, 2011]. The *U.S. News & World Report* IHQ applies Donabedian's model for measurement of quality in health care – structure (volume, technology, staffing); processes (peer reputation) and outcome (30 day readmission and mortality).

Rank	Hospital	Points	Specialties
1	Johns Hopkins Hospital, Baltimore	30	15
2	Mayo Clinic, Rochester, Minn.	28	15
3	Mass General Hospital, Boston	27	15
4	Cleveland Clinic	26	13
5	Ronald Reagan UCLA Medical	24	14

Figure 2.16 U.S. News & World Report Honor Roll Top 5 U.S. hospitals.
Source: [U.S.News, 2011].

Based on IHQ ranking, the top 50 hospitals (140 ranked in at least 1 specialty) in each of the 16 specialties are published in special U.S. News & World Report Best Hospitals issue with particular attention given to the 17 Honor Roll hospitals. These hospitals are considered to be the 'best of the best.' Honor Roll hospitals rank at or near the top in six or more specialties. Typically, they handle very large volumes and have better outcomes than many of their counterparts and are well-regarded by their peers. The latter measure is very important as it not only weighs heavily for ranking of 12 specialties, in four specialties: ophthalmology, psychiatry, rehabiliation and rheumatology, peer reputation is the only ranking factor (Figure 2.16).

The Top 10 Honor Roll hospitals rarely fall out of the top tier ranking and routinely trade places each year in the ranking system as they are separated by mere fractions of points and are for all intents and purposes, interchangeable. The intent of the *U.S. News & World Report* list is not to judge a hospital's ability to deliver routine care but to highlight the hospitals who have the technology, staff and specialized expertise to handle the most complicated cases. These are the cases that most hospitals cannot perform such as "heart valve replacement on a 90 year old patient" - a challenging procedure which represents high risk due to age and physical condition. The Honor Roll hospitals also handle a staggering volume of patients. For instance, the Mayo Clinic sees upwards of 500,000 patients annually and is nationally ranked in 16 adult and 10 pediatric specialties - a feat that places the Mayo Clinic squarely as one of the world's most elite institutions [U.S.News, 2011].

2.3.9 Financial Measures

The average American hospital barely breaks even but some are enormous profit centers. Forbes' first-ever survey of America's most profitable hospitals reveals that some American hospitals make 25 cents or more for every $1 in patient revenue they take in (Figure 2.17). After this article was written, several hospitals contacted *Forbes Magazine* to complain that the report was not representative of their true financial position due to the special way that hospitals compute their financials. As illustrated in Figure 2.18 and detailed in Section 4.1, gross revenues or margins are a misleading indicator of hospital financial performance because 'contractual allowances,' the difference between catalog price and contracted insurance reimbursement for a specific service must be subtracted from gross revenues to obtain true operating revenue.

Rank	Hospital	Beds	Patient Revenue (Millions)	Operating Margin
1	Flowers Hospital, Dothan, AL	235	$389	53%
2	Del Sol Medical Center, El Paso, TX	304	$243	45%
3	Rochester Methodist Hospital, MN	336	$446	37%
4	St. Luke's Hospital, Cedar Rapids, IA	296	$263	36%
5	Seton Medical Center, Austin, TX	405	$432	34%

Figure 2.17 Forbes Top 5 most profitable hospitals, 2010.
Source: [Whelhan, 2010].

Hospital ABC (235 Beds)
Consolidated Statement of Revenue and Expense (for a 12-month fiscal year)

	Annual P&L in $ ($000s Omitted)
Operating Revenue	
Inpatient Service Revenue	265,421
Outpatient Service Revenue	168,220
Gross Revenue	433,641
Less: Contractuals	(279,495)
Other Deductions	(8,637)
Net Patient Service Revenue	145,509
Other Operating Revenue	13,750
Total Operating Revenue	**159,259**
Operating Expenses	
Salaries-Wages	61,315
Employee Benefits	18,315
Purchased Services	21,564
Supplies	26,270
Physician Fees	1,843
Rent, Utilities, etc.	16,853
Depreciation and Amortization	7,906
Total Operating Expenses	**154,066**
(Before Interest Expense)	
Operating Margin Before Interest	**5,193**
	3.3%

Figure 2.18 Financials of a hypothetical 235-bed hospital.

2.4 Operational Efficiency and Productivity

The relationship between output and input, productivity, has long been considered as one of the most important variables governing economic production [Singh, 2000]. As productivity is often confused with the related terms of profitability, performance, efficiency, effectiveness, it is critical to have a clear definition for all six terms (Figure 2.19).

Productivity can help practitioners to decide what measures to use and the way that these metrics can be utilized in productivity improvement [Tangen, 2002]. Productivity is one of the most basic ratios in industrial engineering, classically defined as the ratio of resources consumed per unit of output. Similar to productivity, "profitability" is also defined as Output/Input but it takes into consideration price factors. That is, profitability can be impacted by factors which are unrelated to productivity - a change in prices can affect a change in profitability with no change in productivity. "Performance" encompasses both productivity and profitability. The focus of most management improvement schemes, performance gives strong consideration to the full range of business deliverables by including non-cost factors such as quality, speed, delivery and flexibility.

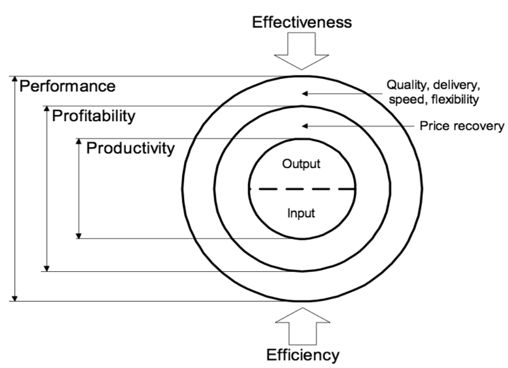


Figure 2.19 The Triple P Model.
Source: [Tangen, 2002].

Efficiency and effectiveness are external factors which exert pressure on the system and one study goes so far as to define quality of care as a delicate balance between efficiency and effectiveness [Campbell et al., 2000]. Efficiency is closely related to input productivity in that its aim is the minimum resource required to run the desired processes (resources expected to be consumed/resources actually consumed). It can also be described as a cost-benefit ratio [Campbell et al., 2000]. Effectiveness is similar to efficiency but it impacts output productivity and is typically measured as value creation (actual output/expected output) [Tangen, 2002]. In other words, effectiveness might be described as maximizing desired outcomes for individual users [Campbell et al., 2000].

In hospital research, studies typically define standard ‘inputs’ as resources such as expenses, physicians and medical care beds. These studies also classify ‘outputs’ as one of two categories: ‘intermediate’ when counting patient days and discharges and ‘long-term’ when specifying proxies of health outcomes as outputs: life expectancy of women at age 40 and the reciprocal of the infant mortality rate [Fare et al., 1997]. The former measure of days and discharges is used for productivity studies and the latter measure - health prediction, is prevalent in public policy studies. In the hospital setting, the traditional efficiency metric is hospital resource efficiency as defined by resources expended (cost) per unit of volume (inpatient days or adjusted patient days).

All six elements in the Triple P Model (Figure 2.19) referenced above, can use ‘volume’ as a measure of output and hospitals traditionally measure this as the number of patients receiving care. The definition of this volume, however, has evolved over time and in so doing, it has changed the way that hospital efficiency is measured and costs are reimbursed by Medicare, as illustrated in Figure 2.20.

A century ago, a hospital’s role was almost exclusively inpatient - physicians would admit patients who were ill to the hospital where they stayed for some period of time. By this definition, the nominal case existed and the “number of inpatient days” was the measure of hospital volume and all ratios would be measured against this value. Inpatient days was calculated as simply the grand sum of the product between the number of patients entering the hospital and the number of days each stayed at the hospital.

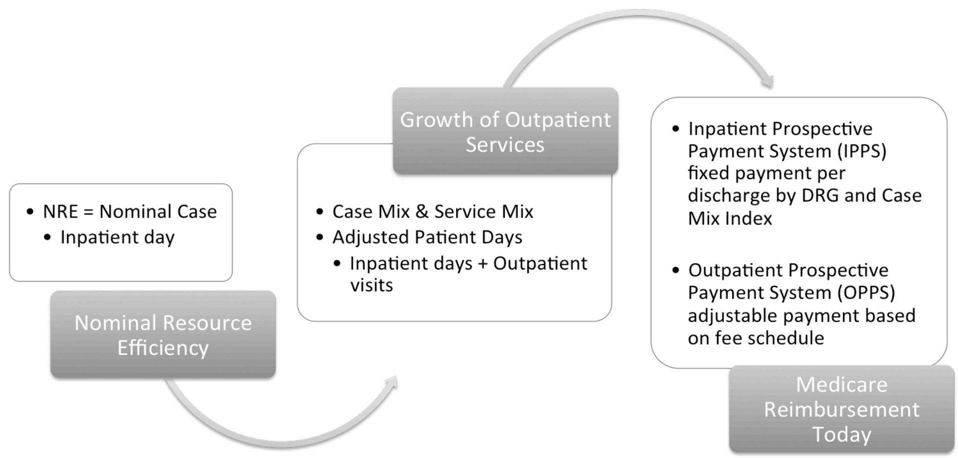


Figure 2.20 Evolution of hospital efficiency measurement.
Source: [Scanlon, 2006].

Nominal Resource Efficiency, NRE, estimates the operating cost per unit of hospital load as follows:

$$\text{NRE} = \frac{\text{Total operating expense}}{\text{Total patient days}} = \frac{\text{Total operating expense}}{\text{Number of inpatients x inpatient days of care}} \qquad (2.1)$$

For a system with primary emphasis on inpatient hospital visits and relatively few outpatient visits to hospital emergency rooms and outpatient departments, NRE is an adequate measure of efficiency. An issue only arises if there is a disproportionate number of outpatients. As NRE does not take into consideration the volume of outpatient services, in this situation, a "patient day is merely a measure of the volume of patient services, while the cost of outpatient services is included in the input [operating expense]" [MacLean and Mix, 1983].

In recent decades, there has been a major shift in healthcare delivery. As inpatient hospital costs have increased, hospitals have changed the way that they treat patients. One study found that "from 1992 through 1996 declining length-of-stay explained 97 percent of the decrease in real costs per discharge. Much of the drop was probably caused by care shifted from inpatient to post-acute settings" [Ashby et al., 2000]. There has also been rapid growth in the number of patients seeking care as outpatients both through hospital outpatient departments and emergency rooms (and at ambulatory surgery centers)

[Davis and Russell, 1972]. In fact, the volume of patients seen as outpatients report was almost seven times the number of inpatients in a recent survey study [American Hospital Association, 2011].

There is a large impact to a hospital's efficiency ratios based on the definition of volume used for calculation, so MacLean and Mix recommended that adjusted patient days should be used as a way to more accurately reflect a hospital's productivity [MacLean and Mix, 1983]. Indeed, "for at least the past 50 years, the predominant measures of hospital volume have been either adjusted patient days or adjusted discharges" [Cleverley, 2011]. These metrics take into account outpatient volume have a standard definition of:

$$\text{Adjusted discharges} = \text{Discharges} + \text{Discharges} \times \frac{\text{Outpatient charges}}{\text{Inpatient charges}}$$

$$\text{Adjusted patient days} = \text{Inpatient days} \times \frac{\text{Total patient revenue}}{\text{Inpatient revenue}}$$

Once calculated, the adjusted patient days metric is used as a baseline to compare hospitals performance. Rates are typically calculated for occupancy, nurse to patient ratios, operating costs per patient, and financial measures. For instance, the metric 'operating expense per patient day' in Table 2.2 uses 'Patient day = Adjusted patient days' as a denominator.

2.4.1 Service Mix and Case Mix Approaches

Researchers are divided on the utility of *adjusted discharges* and *adjusted patient days* as measures of output. Some are happy that the metrics take into consideration the volume of hospital outpatients but most feel that sheer volume measures do not consider the level of services delivered or the complexity of the patients' cases.

Researchers such as William Tatchell have advocated strongly for a change in hospital operations measurement which goes beyond an accounting for volume. In his review of approaches, Tatchell advised that there should be a shift away from the traditional count of inpatient days to a measure that would take into account the range of patient conditions treated *case-mix approach* and the types of procedures and services delivered to patients during their stay *service mix approach* [Tachell, 1983].

The *service mix approach* can be considered as one of two methods: measuring hospitals according to (1) facilities and services offered and (2) services performed.

1. Facilities and services offered. Groups of hospitals with identical facilities or service capabilities. *Issues*: (i) there are doubts regarding the assumption that hospitals with similar facilities produce produce patient days that are homogenous in service content (ii) few studies account for the differences in size, complexity or rate of utilization of facilities
2. Services performed. Weighted output measure standardized for differences in the number of specific services performed for the patient. *Issues*: (i) the weighted procedures are controversial (ii) some doubt the assumption that hospitals which provide the same number of services produce similar outputs (iii) no account is taken of case mix differences between hospitals.

The *case mix approach* can be considered as one of ten methods or a combination approach.

1. Specialty mix. Inpatients are grouped according to the specialty in which they were treated. *Issues*: specialty categories are extremely broad and are unlikely to be homogenous measures of output.
2. Broad ICD groupings. Inpatients are grouped according to the broad ICD codes (18 chapters). *Issues*: there are problems with the large number of variables and homogeneity of the broad classifications.
3. Factor analyzed ICD groupings. Groups of diagnoses based on ICD codes are factor analyzed to reduce the dimensionality of the case mix measures. *Issues*: there is doubt if whether the factors obtained have any plausible interpretation as meaningful variables in their own right.
4. Diagnostic related groupings (DRG). The DRGs are groups of ICD categories with similar average lengths of stay and clinical attributes. *Issues*: individual DRGs do not necessarily contain similar patients regarding resource consumption and other patient and hospital characteristics.
5. Complexity through information theory. This captures the impact of differing case complexity through an information measure for distribution of diagnoses. *Issue*: complexity may be confused with rarity, no allowance is made for variation in case severity within diagnostic groups. There is a loss of reliability with large numbers of diagnoses.

6. Staging for severity within diagnoses. Three stages of severity are defined for 41 diagnostic codes. *Issues*: technique requires considerable input from consultant physicians and detailed computerized hospital patient files.

7. Surgical complexity. This uses an index measure of surgical difficulty based on a national index of relative charges for surgical procedures. *Issues*: charges may not be an accurate indicator of relative complexity.

8. Severity indices. A number of detailed indexes have been developed. *Issues*: most studies are too specific to be of much use in deriving overall measures of disease severity for large groups of patients or hospitals.

9. Common diagnoses. This is a summary measure of the more 'common' diagnoses treated. *Issues*: no account is taken of the variations in case severity within diagnostic groups.

10. Age and sex. Inpatients are grouped by age and sex and expressed as proportions of total patient numbers. Occasionally groups are factor-analyzed to reduce dimensionality. *Issues*: age-sex groupings are generally too broad: they need to be related to the patient's diagnosis.

11. Combination of measures. Several researchers have developed a variety of case-mix measures for use in hospital cost studies both to test their comparative performance and to represent the various aspects of hospital case mix. *Issues*: the problems specific to particular measures are referred to individually above.

Tatchell takes a global view and considers the approaches to be 'supply side' service mix and 'demand side' case mix. He suggests that the United States could benefit from both approaches. The growth of medical technology and hospital competition in clinical expertise lends itself to the service mix approach and the modern Medicare-led movement towards quality measurement in terms of clinical performance requires a case mix approach [Tachell, 1983].

One large scale study validated the *case mix approach* by implementing it in nine acute-care hospitals. This research examined the relationship between hospital costs and casemix. All episodes were assigned to a diagnosis-related group (DRG) and an appropriate cost-weight. Costs per finished consultant episode, before and after adjustment for case mix differences, were analyzed at the hospital and specialty level. The study analysis found that case mix differences were significant, and accounted for approximately 77% of the difference in costs between providers. This implies that case mix differences need to be taken into account when comparing providers for the purposes of contracting, as unadjusted unit costs may be misleading [Soderlund et al., 1995].

A second study, performed the same year, investigated the role hospital types play in providing outpatient services and this impact on the creation of a Prospective Payment System (PPS). Using the *service mix approach*, this study found “Hospital Outpatient Departments (HOPDs) in major teaching hospitals and hospitals serving a disproportionate share of the poor play an important role in providing routine visits.” HOPDs in both major and minor teaching hospitals are important providers of high-technology services [Miller et al., 1995]. Many of these hospitals serve as high level care centers and provide the only access to laboratory services and specialized scans for patients who may be treated elsewhere, at physicians’ offices and ambulatory care centers. In such cases, the study showed, it is vital that the service mix be considered so that the hospitals are reimbursed according to workload.

2.4.2 Equivalent Patient Units

New research, by Cleverley and Cleverley postulates that adjusted discharges and adjusted patient days are no longer reliable for benchmarking and volume analysis. They combine case mix approach, service mix approach and modify these into a new metric. Citing increasing trends of volume shifting from inpatient to post-acute [outpatient] settings, and cost allocations shifting to outpatient services, Cleverley and Cleverly make the case that Ratios of Cost to Charge (RCCs) are improperly skewed [Ashby et al., 2000; Cleverley, 2011]. To illustrate, after the 1980’s era of cost containment due to Medicare reimbursement changes, most hospital reduced expenses by shifting costs from inpatient cost centers to outpatient cost centers.

$$\text{Adjusted discharges} = \text{Discharges} + \text{Discharges} \times \frac{\text{Outpatient charges}}{\text{Inpatient charges}} \tag{2.2}$$

Therefore, as hospitals implement pricing strategies to increase outpatient charges, the overall effect is an increase in adjusted discharges, though the changes had nothing to do with volume, prices artificially inflate the discharges. There is also a trickle down effect that impacts RCCs defined as:

$$\text{Ratio of Cost to Charge} = \frac{\text{Cost (or Revenue)}}{\text{Charges}} \tag{2.3}$$

"RCCs differ between inpatient and outpatient and both rates change at different rates for every hospital and this implies that benchmarking among hospitals unreliable" [Cleverley, 2011]. To resolve these differences, Cleverley and Cleverly suggest a new metric, Equivalent Patient Units as defined:

$$\text{Equivalent patient units} = \text{Equivalent discharges} + (\text{Payment ratio} \times \text{Equivalent visits}) \tag{2.4}$$

$$\text{Equivalent discharges} = \text{Number of discharges} \times \text{Average case mix index (CMI)} \tag{2.5}$$

$$\text{Equivalent visits} = \text{Number of outpatient visits} \times \text{Relative Weights (RW)}) \tag{2.6}$$

$$\text{Payment ratio} = \frac{\text{Medicare reimbursement for outpatient visit with RW = 1.0}}{\text{Medicare reimbursement for inpatient discharge with CMI = 1.0}} \tag{2.7}$$

The use of two different cost metrics, cost per adjusted discharge (CMI adjusted) and cost per equivalent patient unit results in sizably different benchmark information about costs at any hospital [Cleverley, 2011].

2.4.3 Simulation and Mathematical Models

The growth of computing power discussed at length in Section 2.2.2 has also spawned a niche industry of simulation and mathematical modeling for the health care industry. Hospitals are especially well-poised to provide a rich environment for model building which stretches from lean methodology applications to people's homes. For instance, a game called *Emergency Hospital* on PC, Wii, XBox, and PS3 allows a player to control the protagonist ‘Sarah’, a recent graduate nurse. Sarah’s first job is to manage the waiting room of a small town hospital. The faster and better she directs the patients to the correct doctor the more experience she gets and the happier the patients become. Sarah keeps moving up to bigger and busier hospitals as the player progresses in the game [Merscom, 2011].

Another game, *Hospital Tycoon*, is a simulation video game. It lets the player manage a hospital from a ‘god view’. The hospital is staffed by medical personnel and encounter sick patients. The player’s objectives are to manage the staff, care for patients and provide adequate services and facilities. Over time, the player has to cope with the stresses of a growing business - purchasing new equipment, training employees and expanding facilities [DRStudios, 2007].

On the industrial side, companies such as CreataSoft has patented large-scale professional hospital simulation models which show the hospital in a 3D environment. Users are able to interact with the model from a resource or patient point of view and complete a variety of actions such as: scheduling of the operating room (OR) and identifying the most efficient facilities layout by studying the effect of layout, staff, and case load on the efficiency of each OR [Createasoft, 2011].

Mathematical modeling also plays a large roll in hospital scheduling or prediction. For instance, there is an entire specialization which has grown around the modeling and optimization of critical hospital systems. Many companies have followed the path of DGHPSim and produced segmented models which can be run separately for tracking (i) Emergency Department (ED), (ii) inpatient services and (iii) outpatient services or together as a comprehensive hospital-wide tool. Figure 2.22 shows an overview of the hospital with all the models working together with the *waiting list model* in Figure 2.23, linking both outpatient services and inpatient services [Gunal and Pidd, 2011].

2.4.4 Operationalization of Patient Flow

In today's hospitals, delays, and cancellations have become so common that patients and providers many times assume that waiting is simply part of the care process. On the contrary, recent work assessing the reasons and root causes for delays suggests this is not the case. The Institute for Healthcare Improvement (IHI) has released a series on optimizing patient flow. The patient flow program offers new perspectives on the impediments to timely and efficient flow of patients through acute care settings. This program offers a model for evaluating patient flow, testing changes for improvement, and measuring results [IHI, 2003]. Likewise, The Robert Wood Johnson Hospital Foundation (RWJ), one of the United States' most prestigious teaching hospitals launched its *Urgent Matters* initiative. The project included an extensive 10-hospital collaboration with goals such as smoothing patient flow and reduction of Emergency Department (ED) crowding. Measuring key performance indicators (KPIs) as detailed in Figure 2.21, the collaborative created an input versus throughput or output model. These items allowed for a comprehensive cross-functional study with the one-year report providing vital input and insights to hospital patient flow.

Hospitals in the study saw major improvements. For example, Grady Health System in Atlanta Georgia was facing a 'crisis situation' before participation in the *Urgent Matters* initiative: the average patient throughput in ED sometimes exceeded 10 hours and this led to ED overcrowding and an ambulance diversion for 2,000 hours or 20% of the time in 2003 [Wilson et al., 2005]. The hospital saw dramatic improvements after implementing the *Urgent Matters* recommendations of (1) centralized order entry, (2) implementation of a dedicated discharge nurse position (3) creation of a 'care initiation unit' for patients previously directed to the ED from clinics, (4) implementation of a centralized admissions and transfer center.

The Grady Health System was able to (1) reduce time from arrival to bed placement for Fast Track Patients from 219 minutes to 94 minutes (57% decrease), (2) time from

Factor	Indicator		Reporting Interval
ED Throughput	1. Total ED throughput time — time from patient's arrival in the ED → time of patient disposition*		Weekly
	2. *By treatment path:* Admitted/Fast Track /Other ED Discharged	a. Time from arrival to bed placement — patient arrival in the ED → time the patient is first placed in a bed for exam and treatment	
		b. Time from bed placement to examination — time patient is first placed in a bed → time the patient is first seen by a physician	
		c. Time from disposition decision to departure — time physician issues a discharge or admit order → time patient has left the ED	
Inpatient Flow	3. Time from inpatient bed assignment to bed placement — inpatient bed available and assigned → patient arrives in unit and placed in bed		Weekly
	4. Time of day of discharge — average time of day that inpatients are discharged**		
	5. Bed turnaround time — time that a bed becomes empty → time that the bed is reported as cleaned and available for use by a new patient		
Clinical Processes (Choose one)	6. Time to heart treatment — patient arrival at the ED → time thrombolytic medication is administered or a vessel is opened		Monthly
	7. Time to pain management (fractures/dislocations) — time of arrival → 1st administration of pain management, e.g., medication or ice packs		
Other ED	8. Hours on diversion — if hospitals are allowed to go on diversion, total number of hours on diversion		Monthly
	9. Percent incomplete treatment — percent of patients that leave prior to completion of treatment (left without being seen, against medical advice, or for any other reason before medical treatment is completed)		
	10. Patient Satisfaction — use existing measures of patient satisfaction		

* Disposition is when the physician's orders have been written to admit or discharge the patient and the patient has left the ED.

** Time of discharge is when the physician's discharge orders have been written and the patient has left the hospital.

Figure 2.21 Urgent Matters Initiative key performance indicators.
Source: [Wilson et al., 2005].

disposition decision to actual disposition (other ED patients) was a 17% decrease and (3) average total ED throughput saw a reduction from 6.8 hours to 5.3 hours (22% decrease) [Wilson et al., 2005].

The DGHPSim simulated waiting list model incorporates some of the IHI and RWJ ideals. Patients are classified as 'urgent' or 'routine' and the model uses a waiting list for each (user-defined) medical specialty. Each simulated week, the model allocates admission slots, based on the number of patients that could be admitted for elective care based on normal processing rates. Patients are allocated to slots based on their priority, which increases if they have waited longer than a defined time. Not all of the patients in a slot may actually be admitted, however, as the required bed may not be available due to other factors such as emergency patients or longer than expected lengths of stay [Gunal and Pidd, 2011].

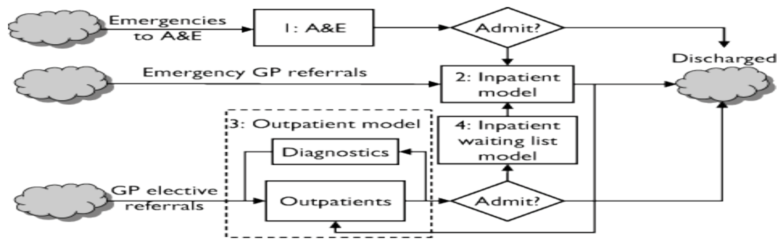


Figure 2.22 Hospital-wide simulation model overview.
Source: [Gunal and Pidd, 2011].

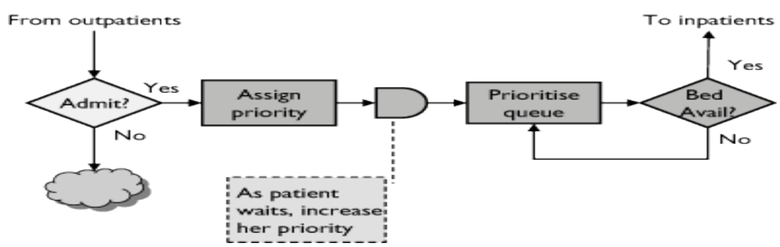


Figure 2.23 Hospital waiting list priority model.
Source: [Gunal and Pidd, 2011].

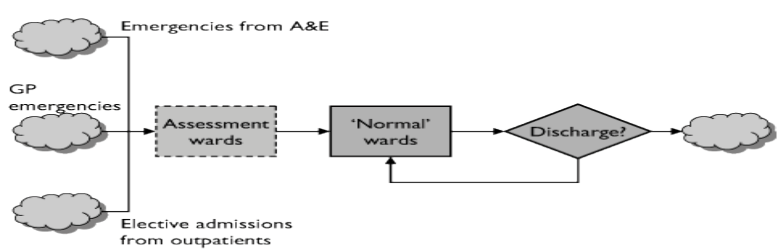


Figure 2.24 Hospital inpatient simulation model.
Source: [Gunal and Pidd, 2011].

2.4.5 The Emergency Department (ER or ED)

In most simulation packages, actual admission rates vary, as in real life. This is especially true for the Emergency Department or Accident and Emergency (ED or A&E). The ED accepts patients who arrive themselves (walk-ins) or are brought in by ambulance. Most ED patients are not subsequently admitted as inpatients but are fully treated in ED and discharged to home. In many hospitals, those that require inpatient care are admitted to assessment units for observation (cubicles or resuscitation rooms). Later, they they may be discharged from the assessment unit or moved onto inpatients wards [Gunal and Pidd, 2011].

Advanced mathematical modeling and technological advances have both helped save countless lives. For example, many automakers have incorporated into vehicles automatic crash sensors which recognize the signs of an accident and call emergency personnel. Some high-end manufacturers such as BMW are going even further. The on-board BMW Assist telematics can automatically dial 911 and report to the 911 call center the likely severity of occupant injuries, even transmit the injury information to a nearby hospital trauma center. BMW's enhanced automatic collision notification (EACN) uses a sophisticated set of algorithms to instantly read the car's crash sensor data and make an informed estimate of how to respond to the accident – police car or ambulance or helicopter, and what injuries to look for when the victims get to the hospital or trauma center [Howard, 2011].

2.4.6 Inpatient Services

The hospital's inpatient wards are illustrated in Figure 2.24 and cover both elective and emergency patients. Elective patients are usually admitted from a waiting list after one or more outpatient consultations. They may spend less than 24 hours in the hospital as day cases or may remain for several days. Emergency patients either come direct from their Primary Care Physicians (GPs) or via the ED/A&E unit.

The length of stay of individual simulated patients varies by model, following which patients are discharged. An inpatient may require within-hospital transfers to other wards or units. For example the typical journey of emergency patients starts on an Emergency Admission Unit from which they are moved to a surgical or medical ward [Gunal and Pidd, 2011]. There are many algorithms which have been developed for estimating the input key parameters in an inpatient simulation: patients' transfer probabilities between wards/units, patients' length of stay parameters on wards/units, and arrival rates at wards/units. Most inpatient models then output ward occupancies or bed utilization, waiting times before admission and estimated total length of stay [Gunal and Pidd, 2011].

In a hospital inpatient system, there is variability of patients' length of stay at the hospital and this studied through queuing theory. In particular, the hospital experiences prolonged stays in intensive care after cardiac surgery. Studies have been launched to investigate potential interactions between such variability, booked admissions, and capacity requirements. One project found that "the vast majority of patients (89.5%) had a length of stay in intensive care less than 48 hours, but there was considerable overall variability and the distribution of stays has a lengthy tail." The same study also indicated that the "variability has a considerable impact on intensive care capacity requirements, indicating that a high degree of reserve capacity is required to avoid high rates of operation cancellation because of unavailability of suitable postoperative care" [Gallivan et al., 2001].

Figure 2.25 Manikin in the Mayo Clinic Simulation Center.
Source: [The Mayo Clinic, 2011].

As capacity is frequently tightly constrained, many hospitals have turned to real-time patient monitoring systems and high-tech training tools to keep patient length of stay/treatment windows short while maintaining a high quality of clinical care. For instance, in 2007 the American College of Surgeons (ACS) accredited the Mayo Clinic Simulation Center as one of 11 outstanding simulation centers in the United States. In the 10,000 square feet state-of-the-art complex four of its larger rooms can be configured to be exact replicas of surgical suites that Mayo Clinic surgeons operate in, or emergency rooms, or rooms within intensive care units, or a cardiac catheterization laboratory. Like independent stages in a theater, all rooms are multipurpose. Additional smaller rooms (up to 10) provide realism for training within spaces configurable as inpatient hospital rooms, an outpatient clinic, or other areas. The equipment and its placement in the rooms are identical to those used in real patient care at Mayo Clinic.

The 'manikins' respond just like humans - they can answer questions about smoking and pain, they bleed and can be programmed to respond in complex manners [The Mayo Clinic, 2011]. Just as aviation pilots master complexity through cockpit simulators, at Mayo Clinic's Simulation Center, health care professionals across disciplines improve performance and reduce errors through comprehensive medical care simulation training (Figure 2.25). The utility of practice has been proved so many times over that even hospitals without the resources of large organizations like the Mayo Clinic are purchasing simulation dummies. These 'manikins' go beyond the old CPR dummies of yesteryear. Almost all of these dummies are anatomically correct with programmable sensors and they can both be fed information and respond with life-like accuracy.

Hospitals are also increasingly using hand-held devices such as the iPhone, iPad and Android phones to access real-time patient data for monitoring and interaction without needing to be in the patient's room (Figure 2.26). This allows doctors to provide consultation that is timely and accurate from remote locations and this speeds the delivery of care. The high resolution images on these devices are also beneficial to care givers explaining a course of treatment to the patient. Patients can 'see' videos and virtual surgeries on their devices as provided by their doctors before surgery. This adds to patients' understanding of their course of treatment and providing in many cases patient buy-in and peace of mind prior to surgery.

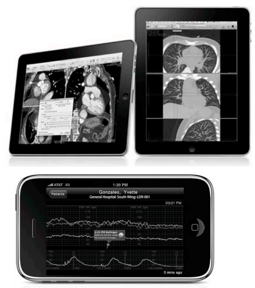


Figure 2.26 Electronic devices are used to remotely monitor and assess patient prognosis. Source: [Gallaga, 2010].

2.4.7 Outpatient Services

The outpatient services segment of most simulation packages is illustrated in Figure 2.27. Patients who require elective care are usually admitted from a waiting list onto which they are placed after one or more outpatient consultations. The outpatient model simulates GP referrals and then tracks each simulated patient through outpatients to discharge or admission as an inpatient. Core of the DGHPSim outpatient model (like many other simulation models) is patient flow between 7 events [Gunal and Pidd, 2011].

1. GP: First referral event, generally by a GP.
   Delay between GP referral and first outpatient appointment with a specialist (GP-OP1).

2. OP1: First outpatient appointment event.
   Delay between specialist first appointment and later appointments (OP1-OP2).

3. OP2: Pre-operation follow-up outpatient appointment event.
   Delay between decision to admit and admission (OP2-IP).

4. IPDC: Inpatient as day-case admission event.

5. IPOR: Inpatient as ordinary admission event.
6. POP: Post-operation follow-up outpatient appointment event.
7. END: Discharged from consultant's care (in OP stage).

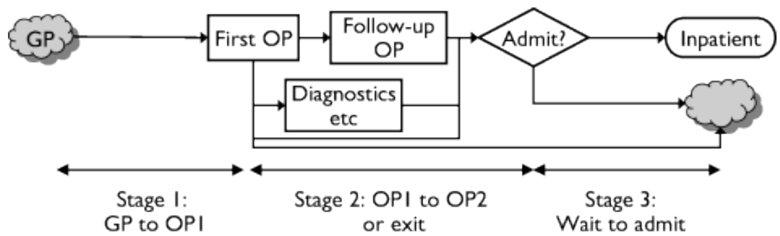


Figure 2.27 Hospital outpatient model.
Source: [Gunal and Pidd, 2011].

This segment of hospital operations is rapidly gaining increased importance each day as patients are moving from the traditional inpatient hospitalization to the outpatient or ambulatory services department. Many of these patients have also opted to receive elective surgical procedures at non-hospital physician owned clinics known for fast, uncomplicated service. These patients are almost exclusively privately insured or full-payment patients with few complications. This is a major loss for hospitals as the higher reimbursements received from such patients is typically used to off-set costs from under- and un-insured patients who receive uncompensated hospital care. Hospitals therefore have a huge incentive to improve their surgical services business in order to remain competitive with the outpatient clinics who have grown through lower overhead costs and higher profit margins.

2.4.8 Dashboards and Scorecards

One of the newest means of monitoring performance has been the use of a corporate dashboard or scorecard. Running on spreadsheets or automated databases in the background, key company data is summarized into metrics and presented visually to executives. One of the most popular 'dashboarding' methodologies is the *Balanced Scorecard*. First introduced in the 1990's by Robert Kaplan and David Norton, the 'balanced scorecard' approach looks at summarized information from four quadrants – financial, customer, internal business processes and learning and growth (Figure 2.28).

In the twenty-odd years since the Balanced Scorecard articles, the use of metrics has blossomed and business intelligence products abound in industry. Typing balanced scorecard into an internet search engine can return about 2 million results in under one tenth of one second on a cable modem. Browsing the resulting pages, it becomes quickly apparent that dashboards and scorecards are frequently used interchangeably.

Wayne Eckerson, of The Data Warehousing Institute is one of the foremost authorities on business intelligence and he provides disambiguation of the terms by saying a dashboard is a performance monitoring system, whereas a scorecard is a performance management system. In other words, a management dashboard like that of a car, uses real-time feeds to warn and alert users when performance deviates from the norm and a scorecard gives summary snapshots of performance and charts progress against pre-set targets. It can be said that the dashboard is a visual container for the scorecard [Eckerson, 2011].

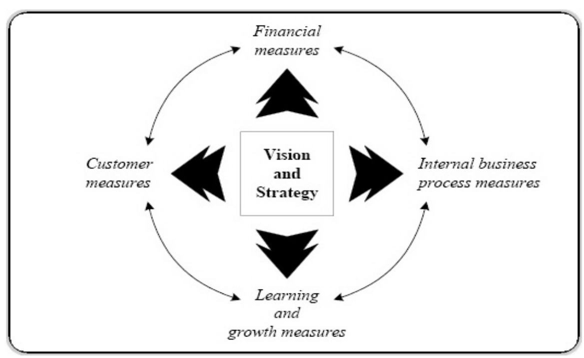


Figure 2.28 Illustration of the Balanced Scorecard methodology.
Source: [Business Excellence, 2011].

Spreadsheets remain the primary method used by businesses to monitor and track performance, however Dashboards and Scorecards have been replacing spreadsheets at the executive levels of industry with a trend towards forecasting and analytics, all of the major business intelligence 'megavendors' have made major acquisitions in the past four years. In 2007 and 2008, many of the leading independent BI players were acquired by big data warehouse and analytics vendors. Oracle bought Hyperion, SAP bought Business Objects and IBM bought Cognos. Though the top five business intelligence vendors control 75% of the market, several small pure play companies still survive and have been thriving lately as customers seek quick analytics and are willing to rely on alternative in-memory architectures over the traditional database stacked structure roach being pioneered by a cluster of vendors including iDashboards, Seatab and LucidEra [Gartner Research, 2010].

Recently, *Gardner Research* reported that the major pure play vendors are Information Builders, Tibco Software [Spotfire] and Microstrategy. Open source business information leaders Jaspersoft and Pentaho have partnerships with a wide range of independent software vendors and are delivering business intelligence at a much lower price point (80% according to Gartner Research) than the big megavendors. Other companies provide software-as-a-service (SaaS) which is one new approach being pioneered by a cluster of vendors including iDashboards, Seatab and LucidEra [Gartner Research, 2010].

All of the major business intelligence players provide specialized products for health applications with a full suite of IT products from data warehouses and reporting applications to statistics and forecasting packages for dashboards and scorecards. From initial research it appears that some business intelligence companies do not provide canned reports and KPI lists but leave this to the individual organizations and the and KPI lists but leave this to the individual organizations and their business analysts to develop while other vendors appear to provide some metrics as out of the box functionality (part of the appeal of pure play applications). The latter behavior seems evident with the smaller pure play companies who need to distinguish themselves from their bigger, more established, name-brand megavendor competitors. For all dashboards and scorecards, information is parsed into relevant pieces and then presented graphically to executives (Kaplan:2011). It should be noted that despite the popularity of dash boarding and scorecards at the executive the use of spreadsheets is still prevalent in business today, especially in mid-management and on the shop floor.

CHAPTER 3

HOSX: HOSPITAL OPERATIONS EXCELLENCE MODEL

3.1 Hospital Operations Excellence Model (HOSx) Theoretical Framework

3.1.1 Introduction

Hospitals across the United States are concerned with delivering high quality clinical care to the population within their market segment in a fiscally-responsible manner. Some hospitals go into business seeking to reap profits while others are not for profit community organizations created to serve the needs of the local population. Regardless of their type, hospitals must be able to cover their salary, overhead, facility and uncompensated care costs or they will be forced to close as many have during the past decade of economic downturn.

Managing the ages old cost to benefit ratio has therefore become critical for hospitals to master if they wish to remain solvent. The top three categories of hospital metrics: quality of care, process of care and financial as introduced in Chapter 1 and illustrated in Figure 1.4, receive primary attention from hospital management. The fourth and smallest segment of metrics, the operations category, currently provides only limited ability to evaluate hospital performance at a tactical level, leaving hospitals vulnerable to lingering operational issues. To fulfill Research Objective 1, this dissertation develops an operations performance framework called **HOSx: Hospital Operations Excellence Model** to measure and evaluate the operations productivity of hospitals as shown in Figure 3.2.

3.1.2 Guiding Principles

The HOSx Measurement Goal is to create an operations focused scorecard that will facilitate both performance improvement and cost reduction initiatives at all levels of management. The HOSx methodology will create metrics which are: (1) defined by data elements from an enterprise planning system, (2) sourced from publicly available data with common definitions for hospital comparison and benchmarking, (3) relate directly to operational productivity and efficiency, and (4) provide a detailed perspective on hospital operations.

Hospitals currently collect a large number of data elements through both legacy (paper-based) methods and electronic systems. The data is then transformed through either automatic data feeds or manual processes to populate dashboards and scorecards. The HOSx Model will utilize many of these existing measures. This is in order to balance the need for representative metrics (some of which will need to be created) with the desire to improve compliance and smooth implementation.

One of the chief complaints of hospitals regarding measurement systems is that most do not account for patient complexity and there is largely a lack of metric standardization for cross-hospital comparison. This leads to many hospitals balking at cross-comparison as most claim that they are unique and cannot be equated with others. In many ways though, these two objectives are at odds with each other. It is difficult to have a standardized measurement system which at the same time, sufficiently scaling cost of care by resources consumed, services delivered and complexity of patient cases. The HOSx model will therefore use data elements which have been defined by the federal government in existing reporting structures such as the Medicare Cost report and other MedPar systems in order to derive metrics from a common dataset. *The HOSx model assumes that hospitals are clinically equivalent - a patient will receive 'good care' at any accredited hospital.*

All measures created through the HOSx model have a direct link to operational productivity (the relationship between output and input) and efficiency (the achievement of the minimum resource output needed to run the desired process). The HOSx model creates a unified measure of hospital output which will allow for a common measure of productivity (Chapter 4). The system is designed to present and display operations data so as to facilitate both performance improvement and cost reduction initiatives. As a contrast, one of the US News & World report metrics is nurse staffing, which is the ratio of nurses per patient, with higher the better. But from a lean systems view clearly we would attempt to lower nurse staffing levels, while at the same time maintaining target quality of care levels. The expectations is that the HOSx model will be used by hospital executives to continually track performance at the aggregate level, and then drill down to specific operations as when necessary.

Utilizing industrial engineering tools and insights gained from the large dataset under consideration, the HOSx methodology provides insights into hospital operations on a scale and detail that has not previously been published. The flexible, scaleable HOSx methodology will also allow for an operationalized view of each hospital at four levels (Figure 3.1).

This 4-level hospital operations management scoreboard is not unique. Similar multi-level models have been successfully implemented in other industries to achieve significant productivity gains.

Level 1: E - Executive. The highest level of the HOSx model is divided into five primary categories which together represent the full range of hospital operations - Figure 3.2. *Example: Surgical Services Resource Utilization*.

Level 2: T - Tactical. In this segment view, focus is on specific operational systems and it allow management to action performance at this level *Example: Facilities Utilization*.

Level 3: C - Component. This level tracks performance of key components within each subsystem. *Example: OR Theatre No.1 Utilization*.

Level 4: D - Data measures. The basic building blocks of the measurement system, these data elements are linked to the enterprise planning system. *Example: Available Hours and Usage Hours.*

3.1.3 Structure

Beyond the two typical dimensions of hospital measurement, financial and clinical metrics, the HOSx model has five elements or concentration areas (Figure 3.2). This model augments existing schema to provide the missing link: operational measurement.

Element E1, ‘Resource Utilization.’ The focus of this dissertation, resource utilization measures the degree to which available hospital resources such as labor, equipment, facilities,

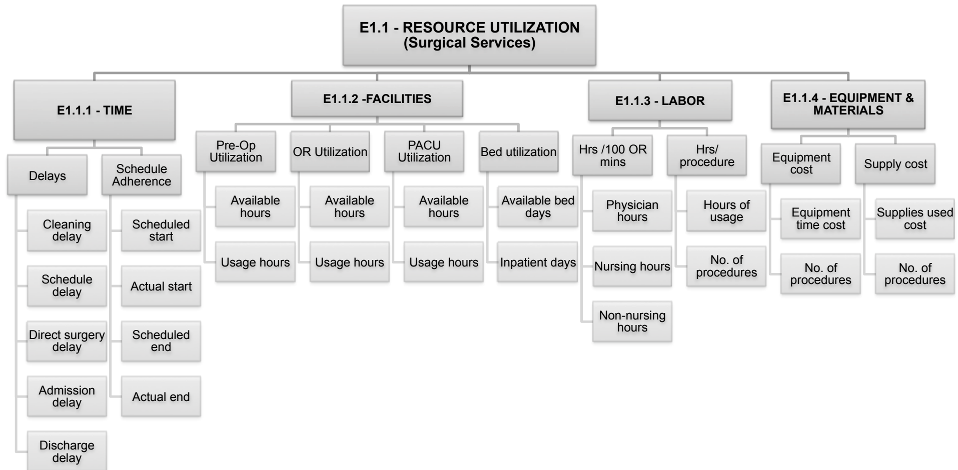


Figure 3.1 Sample performance measurement drill down to specific operational elements.

and supplies, are being utilized for patient care in a cost-effective manner. Hospitals currently report metrics such as ‘cost per adjusted patient day or cost per adjusted discharge, nurse-to-patient ratio and capitalization. The HOSx Model introduces new measures to this set and creates a scaleable framework through which new metrics may be created and implemented in both department-specific and hospital-wide schemes.

Element E2, ‘Patient Safety.’ This critical component of hospital measurement is often reported through the national Hospital Compare: Quality of Care measure set which considers hospital acquired infections, patient falls, medication errors and staff injury, a typical ratio for patient safety is the recorded frequency of patient safety incidents per serviced patient day.

Element E3, ‘Patient Flow.’ This element is focused on the efficiency with which patients are processed through the care cycle at the hospital. Patient flow is currently one the most operationalized focus areas of the hospital. Most work in this segment has been focused on Emergency Department (ED)throughput and reduction of cycle times. A hospital-wide model will look at all aspects of patient flow including number of moves and movement transactions, waiting times, procedural delays and duplication of effort.

Element E4, ‘Customer Satisfaction.’ Measuring patients’ experiences with products and services supplied by the hospital in the context of ease and efficiency, the ‘Voice of the Customer’ has been a key tenet of modern management systems but has today taken on new significance as hospitals compete for market share. They also have a vested interest in the high reimbursements received from insured patients with repeat elective procedures for themselves and from those to whom they recommend the hospital. Recent changes in Medicare reimbursement procedures are also creating emphasis on patient satisfaction. In the near future, patients’ responses to the Medicare hospital satisfaction survey (H-CAHPS) will determine a portion of a hospital’s Medicare reimbursement for most procedures and inpatient stays.

Element E5, ‘Information Flow.’ Hospitals, like most healthcare facilities in the United States, have operated in a largely paper-based environment since their inception. Patient charts, prescriptions, laboratory reports, physician and nursing notes are all collected and reported on paper. The recent American Reinvestment and Recovery Act, ARRA legislation’s requirements for hospitals to become ‘meaningful users of HealthIT’ and associated reimbursements for implementation of electronic medical records and health information exchanges has spurred growth in this segment.

The hospitals which currently use electronic systems for managing procedures face a problematic situation with each hospital system running its own specialized system with little integration and roll-up for data. At the current time, the ARRA legislation demands that hospitals who are not meaningful users of medical technology by 2015 will endure reduced Medicare reimbursements. A comprehensive system would therefore focus on the hospital’s data burden: The extent to which data transactions are electronically executed via an IT System (clinical, imaging, billing, etc.), including data timeliness, reliability and automatic links between systems.

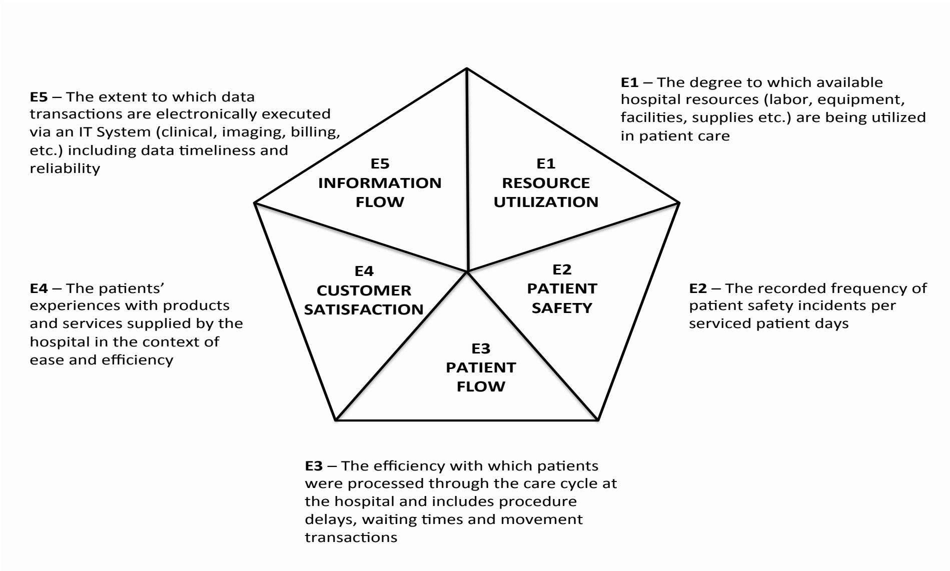


Figure 3.2 Executive level view of HOSx: Hospital Operations Excellence Model.

3.1.4 Feasibility Study - Virtua Hospital at Marlton, NJ

In order to validate the utility of the HOSx Model and to investigate the feasibility of the resource utilization element, an in-situ study was performed as a collaboration with Virtua Marlton hospital. Virtua Marlton is a 188 bed short-term acute care hospital that offers a full range of inpatient and outpatient services, specializing in advanced surgical procedures, which range from the common to the most complex, as well as cardiovascular diagnoses and treatments [Virtua, 2011]. Data was collected for the following operating room (OR) measures: OR scheduled time versus actual usage time, OR usage by procedure, classification of procedures by category (19 categories) and subcategory (565 subcategories). These data elements were then rolled up into metrics and the metrics were used to run studies to create performance benchmarks.

Results. The first step of the project is to create a detailed process map of the major time-steps and segments involved in conveying a patient through the surgical services department. This flow chart allowed for segmentation of resources and a clear view of surgical operations, as illustrated in Figure 3.3. Note: S*, T*, P* = Activity Duration and D* = Operational Delays.

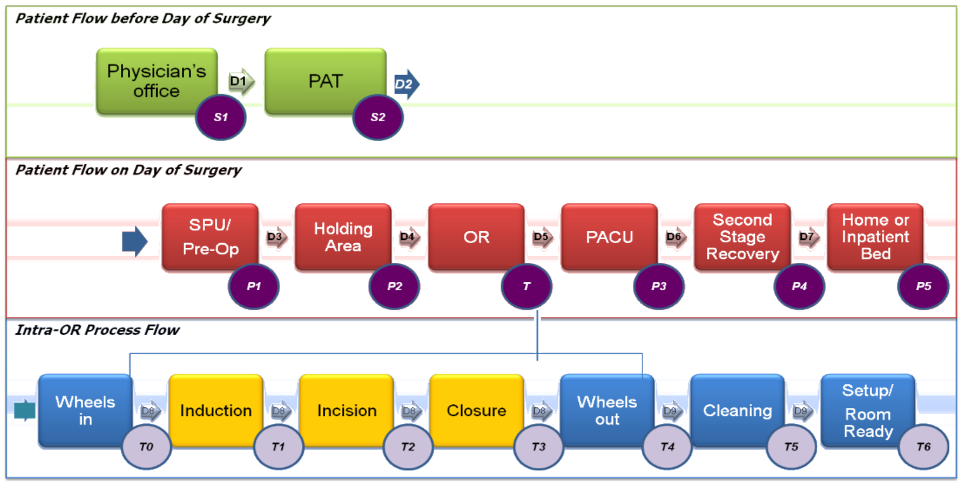


Figure 3.3 Patient flow through the Virtual Marlton operating room (OR).

Formulae:

Surgery Actual Value Adding Time = Wheels Out - Wheels In = T4 - T0.

OR Setup Time (*Minimize*) = Room Ready - Wheels Out = T6 - T4.

Late Start Time (*Minimize*) = TS - T0 = D3 + D4.

OPERATIONAL DELAYS (Minimize):

D1 = Schedule delay for (pre-approval testing) PAT completion.

D2 = Schedule delay for surgery appointment.

D3 = Chart updates delay determines when patient moved to Holding area.

D4 = Schedule delay determines when patient wheeled in to OR at T0.

D5 = (Post-anesthesia care unit) PACU recovery delay. Time between Wheels out at T1 and PACU hook-up.

D6 = Secondary recovery delay. Time between ready for PACU exit and second stage entry.

D7 = Discharge delay. Time between ready for second stage exit and discharge/bed.

D8 = Resource delays in the OR.

D9 = Schedule and resources delays in OR cleanup.

Most hospitals (including Virtua Marlton) are recording only T0 and T4. The HOSx systems requires that in the future hospitals track all activity durations and start times, this will enable them to monitor operational performance in detail. At Virtua: The data covered 21 months of operations, and more than 15,000 procedures conducted at 9 surgical facilities. Procedures were classified into 19 categories, which were further classified into 565 sub-categories. Each sub-category is defined by a standard surgery time T*. The shorter procedures shows a relatively large Operational Variation which may be due to patient complications and the amplified effect of delays in the OR. For the short procedures there is a large standard deviation in actual times. At the time of writing, standard ratios by procedure were not readily available, but such data could be used to benchmark the efficiency of these operation and identify the delays.

CHAPTER 4

THE HOSPITAL UNIT OF CARE (HUC)

This chapter presents the Hospital Unit of Care (HUC), a unified measure of hospital output that can be used to standardize and compare output productivity across hospitals in fulfillment of Research Objective 2. Hospitals are the primary provider of medical services and are in a sense the factories of the healthcare industry. About a third of all US healthcare costs are hospital related [American Hospital Association, 2011]. Hospitals typically evaluate performance in two dimensions: clinical outcomes (quality of care and process of care) and financial stability (reimbursement rates and profitability). The well known U.S. News and World Report rankings are a surrogate measure for clinical outcomes. Financial stability is closely related to health policy, healthcare reform and relationships that hospital establish with insurance companies. There are only a limited number of readily available evaluation metrics or even studies that focus on hospital operations productivity and efficiency. A classical measure of productivity is resources used to provide or create a unit of output, which in most cases is standardized (e.g. mid-sized automobile). A key obstacle to hospital productivity measurement is defining a standard unit of output, since every patient is different in terms of diagnosis, response to medical care and their acuity level.

Traditionally used units of hospital output have been patient days, adjusted patient days and adjusted discharge, all of which are reasonable estimators of hospital output activity. When combined with total cost or total patient revenue they can be used to derive the nominal resource efficiency (e.g.: Total cost per adjusted patient day or Total revenue per adjusted discharge). These metrics are, however, fundamentally flawed in that they assume that patient profiles are generally equivalent across hospitals. Clearly this is not the case and as a result comparative assessments across hospitals cannot be made effectively.

It is difficult to identify an operationally productive hospital, even though one can today identify the best hospitals in terms of clinical outcomes.

As an example, consider two hospitals with the same volume of adjusted patient days, and the same level of clinical outcomes, but one has an operating budget that is 20% more than the other. One cannot conclude that the hospital with the larger budget has a lower operational productivity. This inability to compare hospital operational productivity limits many healthcare cost reduction efforts. Since researchers can only search for system wide cost reductions, as opposed to focusing improvement on the less productive parts of the system. What is needed are measures that help identify hospital operational excellence, allowing these practices to be replicated across the weaker units of the healthcare system.

The HUC is here presented as a standardized measure for a hospital unit of care, created as a function of the direct patient care activities. The HUC can then be used to generate the total productive healthcare output units of any hospital. The HUC measure facilitates the development of an array of models and methods to benchmark hospital operating costs, productivity and efficiency. One study notes that in an environment of rising health care costs hospitals, in particular, are increasingly being held accountable for their efficiency and financial performance. A key assumption made by this research is that all hospitals provide good/acceptable levels of patient care, that is as required by the patient's condition and specified by general medical process of care. The research here therefore does not address variances in 'quality of care' [Tiemann and Schreyogg, 2012].

In an equation of 'Hospital productivity = Operating costs per patient day,' it is essential that the patients in 'patient day' be normalized to a standard output unit. This output unit would account for patient profile differences and activity-related delivery of care differences. An HUC is defined as the resources required to provide one general medical/surgical inpatient day. The approach is to derive an equivalency parameter for each of the additional care/services that the hospital provides, allowing for the roll-up of all hospital activities into a unified output measure. The HUC is compatible with the Medicare

Cost Report data format. Model application is here demonstrated on a set of 17 honor roll hospitals. An expanded application on 203 hospitals shows that the HUC is significantly better correlated than the more traditional adjusted patient day (APD) to hospital operating costs.

4.1 Traditional Measures of Hospital Output

The simplest measure of hospital volume/output is total annual inpatients days. There has been a progressive shift away from this approach, and MacLean and Mix recommended that adjusted patient days (APD) provided a more accurate measure of hospital output since hospitals deliver services to both inpatients and outpatients [MacLean and Mix, 1983]. An inpatient day represents patients who were in residence during the hospital's midnight census. The cost for an inpatient day includes a bed with non-charge medicine such as aspirin and the nurse checking in on the patient at intervals. All other services such as tests (both diagnostic and therapeutic) and custodial items are considered as 'ancillary services.' An outpatient visit is one where the patient arrives to the hospital, receives treatment and then returns home. Same-day surgeries and emergency room visits as well as labor and delivery are all considered as outpatient visits. The cost for an outpatient visit varies by condition and is accounted for as 'outpatient services' and the hospital receives a fee for each service delivered and 'ancillary services' fees.

For a long time, the APD metric highlighted in Chapter 2, has been the primary measure of hospital care volume. Many in healthcare use hospital volume (APD) as a proxy for predicting hospital costs i.e., higher APD indicates higher cost and a hospital with low APD is expected to have low costs. The APD accounts for both inpatient days and outpatient visits (expressed as equivalent inpatient days) through the equation:

$$\text{Adjusted Patient Days} = \text{Inpatient days} \times \frac{\text{Total patient revenue}}{\text{Inpatient revenue}} \tag{4.1}$$

Hospital revenue A hospital's *total patient revenue* or *gross revenue* is not the amount that the hospital received for services rendered. Revenue in a hospital setting, unlike any other industry, does not follow a standard financial definition as the 'funds received for services rendered.' Instead it it indicates the amount that the hospital charged for its services which in turn are a markup of costs. Hospitals also have relationships with payers for 'contractual allowances.' These indicate a percentage of charges that is discounted to third-party payers. Private insurance companies negotiate this percentage for each of its providers - hospitals, physicians, labs and the federal government sets (not negotiates) payment rates for Medicare and Medicaid providers. The subject of much discussion in the media and in economic circles, 'contractuals' mean that hospitals collect 60% or less of their billed charges (*patient revenue*) based on the payer rate [Analysis, 2004]. As a result of this cycle, patient revenue and its derivative metrics are unlikely to accurately predict operating cost (see Figure 4.1).

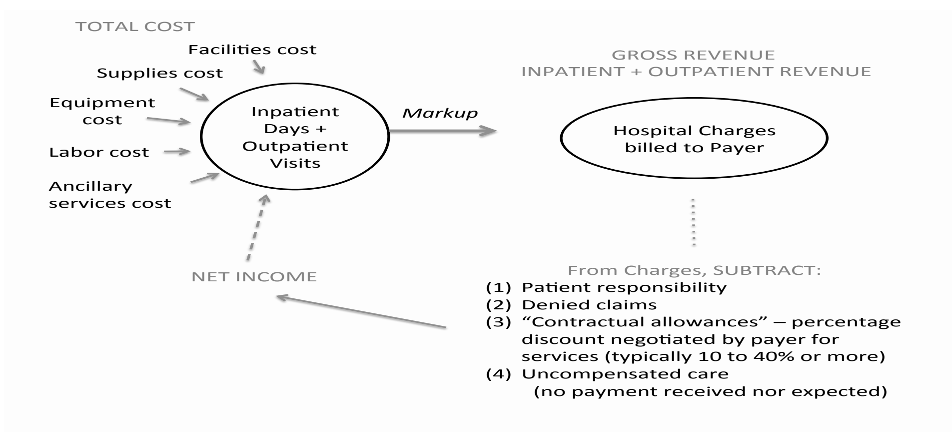


Figure 4.1 Hospital revenue cycle.

Current research postulates that APD is no longer a reliable approach for benchmarking hospital output. As detailed in Section 2.4.1, Tatchell (1983) presented a survey of the literature on the definition and measurement of hospital output concentrating on those studies that have used either 'service-mix' or 'case-mix' as their basic output measure. He noted that hospital output measurement has rarely been tackled directly. Typically such work has been secondary to the principle research objectives which have related to the study of hospital cost structure and economies of scale. Soderlund found that case mix differences accounted for 77% of the cost variance between healthcare providers emphasizing the need for case-mix [Soderlund et al., 1995].

While Miller found that for many patient groups hospitals serve as primary care centers and provide the only access to lab and radiological services, and argues that service mix must be considered in calculating workload [Miller et al., 1995]. More recently, Cleverly and Cleverly suggest a new metric, Equivalent Patient Units (EPU) outlined in Section 2.4.2 [Cleverley, 2011]. Several researchers have studied the cost inefficiency of hospitals using Data Envelopment Analysis (DEA) [Rosko and Mutter, 2008]. These studies usually measure inefficiency as a function of cost per APD. For example, Zhivan and Diana propose a cost efficiency measure for hospitals as a function of the price of labor, number of discharges, number of outpatient visits, price of capital that is normalized by the price of labor [Zhivan and Diana, 2012]. The HUC model developed could be integrated with these approaches.

4.2 Hospital Data

Reliable datasets for hospital activity are difficult if not impossible to gather at the individual level. Clearly a study such as this must access a broad based data set if it is to be effective. Hospitals collect and store a myriad of data elements at the local level. Every patient encounter generates a mountain of paperwork: timestamps, patient chart, medication record, scans, labs, nursing notes, surgeon notes and prescription information just to name the major elements. Considering that even a relatively small hospital could have two or three thousand annual discharges, the potential national dataset is enormous. Though large, this data set is typically unusable for cross-hospital comparisons as few hospitals use a common definition for data elements not required by regulatory and accreditation bodies.

Even at the local level, many hospitals keep all patient records on paper charts in files not easily accessible to analysts. In fact, the norm has become for hospitals to hire an entire department devoted to 'chart abstractions' - clinical support staff whose job is to comb through patient records to provide data for regulatory audits and billing. Under these circumstances, many large hospitals do not routinely perform operational analysis or even root cause analysis for adverse events unless there are legal ramifications for not investigating these.

A good source of hospital-specific data would be payors such as insurance companies. These entities require detailed reports on patient care - diagnoses, comorbidities, services rendered and procedures delivered. This is a wealth of information which could be used to understand the full range of patient treatment. Unfortunately, in most cases, there is no true link between hospital charges and payor reimbursements. The reimbursement rates are also typically a well-guarded secret as these 'contractual discounts' are all based on negotiated rates per hospital. *The only truly national, publicly accessible hospital information is the Medicare database*.

4.2.1 The Medicare Database

As detailed in Section 2.2.2, the federal government is the largest purchaser and provider of health care services in the United States and Medicare is one of the largest health insurers in the world. Spending roughly $260 billion annually to provide healthcare to 42 million elderly (age 65+) and permanently disabled people (under age 65), Medicare consumes about "one eighth of the federal budget and 2% of the nation's GDP" [Finkelstein, 2005]. As disseminated through the Medicare and Medicaid Research Data Assistance Center ResDAC, the national Medicare Provider Analysis and Review MedPAR file, contains records of Medicare-covered inpatient discharges in the United States. Each patient record contains up to nine diagnosis codes, up to six procedure codes, claim costs and charges, the DRG, the length of stay, and many other admission-specific parameters. Each claim also contains the hospital's provider number, making it possible to correlate diagnoses with providers.

MedPAR tracks discharges rather than patients, and this makes a distinct record available for each patient encounter. This permits analysis based on hospital encounters rather than on patients. Medicare-certified institutional providers are also required to submit an annual cost report to a Fiscal Intermediary, FI. The cost report contains provider information such as facility characteristics, utilization data, cost and charges by cost center (in total and for Medicare), Medicare settlement data, and financial statement data. CMS maintains the cost report data in the Healthcare Provider Cost Reporting Information System HCRIS [ResDAC, 2011]. The cost reports are filed by year and each consists of four flat files which together form the database of all non-federal, short-term U.S. acute care hospitals and are available as free downloads to researchers as:

hosp_YEAR_ALPHA.csv

hosp_YEAR_NMRC.csv

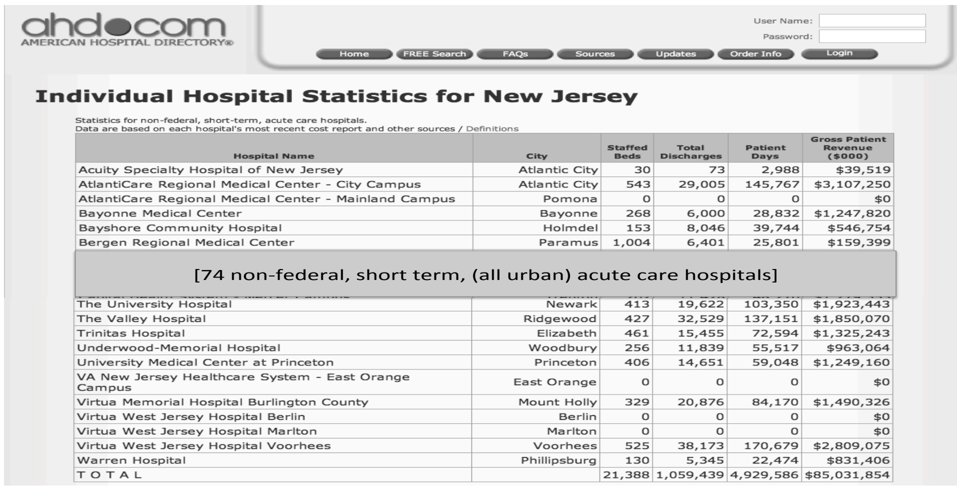
hosp_YEAR_ROLLUP.csv

hosp_YEAR_RPT.csv

Cost report data cannot be loaded into Microsoft Excel or Microsoft Access as the files are too large for these applications. Instead, most users load the data into Oracle, SAS, SPSS Statistical Package, Microsoft SQL Server, or DB2. Making the cost report functional requires a strong background in data analysis/database and programming and this deters many analysts from working with the Medicare database. This fact has spawned the growth of a small niche market - technology companies such as American Hospital Directory (through AHD.com) collect data from Medicare claims data, hospital cost reports and commercial licensors and turns these into user-friendly reports as in Figure 4.2 and Figure 4.3.

4.2.2 The American Hospital Directory Database

The American Hospital Directory database is intuitive and formatted with measures which have been vetted and approved. As the data elements are from the common-definition federal reports, there is no ambiguity as to the meaning of terms. For these reasons, this dissertation uses the AHD.com database as the source for all metrics.

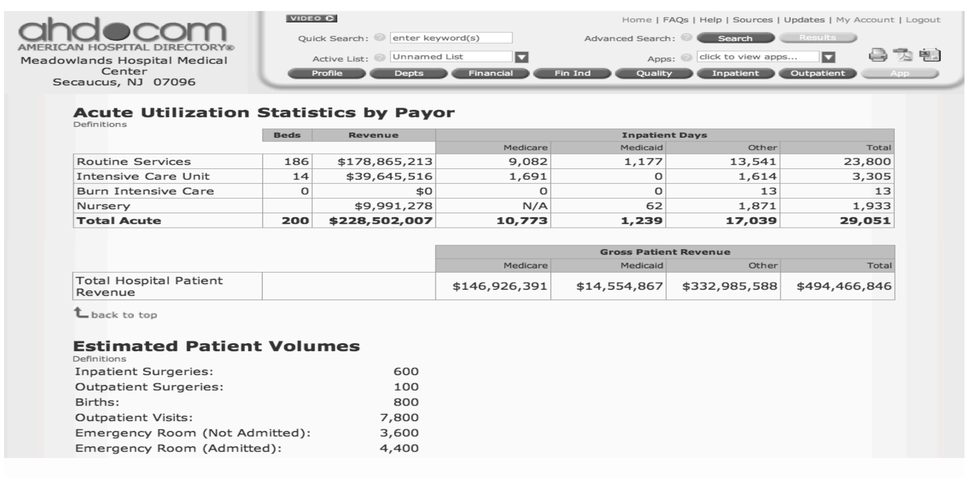


Individual Hospital Statistics for New Jersey

Statistics for non-federal, short-term, acute care hospitals.
Data are based on each hospital's most recent cost report and other sources / Definitions

Hospital Name	City	Staffed Beds	Total Discharges	Patient Days	Gross Patient Revenue ($000)
Acuity Specialty Hospital of New Jersey	Atlantic City	30	73	2,988	$39,519
AtlantiCare Regional Medical Center - City Campus	Atlantic City	543	29,005	145,767	$3,107,250
AtlantiCare Regional Medical Center - Mainland Campus	Pomona	0	0	0	$0
Bayonne Medical Center	Bayonne	268	6,000	28,832	$1,247,820
Bayshore Community Hospital	Holmdel	153	8,046	39,744	$546,754
Bergen Regional Medical Center	Paramus	1,004	6,401	25,801	$159,399
[74 non-federal, short term, (all urban) acute care hospitals]					
The University Hospital	Newark	413	19,622	103,350	$1,923,443
The Valley Hospital	Ridgewood	427	32,529	137,151	$1,850,070
Trinitas Hospital	Elizabeth	461	15,455	72,594	$1,325,243
Underwood-Memorial Hospital	Woodbury	256	11,839	55,517	$963,064
University Medical Center at Princeton	Princeton	406	14,651	59,048	$1,249,160
VA New Jersey Healthcare System - East Orange Campus	East Orange	0	0	0	$0
Virtua Memorial Hospital Burlington County	Mount Holly	329	20,876	84,170	$1,490,326
Virtua West Jersey Hospital Berlin	Berlin	0	0	0	$0
Virtua West Jersey Hospital Marlton	Marlton	0	0	0	$0
Virtua West Jersey Hospital Voorhees	Voorhees	525	38,173	170,679	$2,809,075
Warren Hospital	Phillipsburg	130	5,345	22,474	$831,406
T O T A L		21,388	1,059,439	4,929,586	$85,031,854

Figure 4.2 Overview of New Jersey hospitals' dataset.
Source: [American Hospital Directory, 2011].



Acute Utilization Statistics by Payor

Definitions

	Beds	Revenue	Inpatient Days			
			Medicare	Medicaid	Other	Total
Routine Services	186	$178,865,213	9,082	1,177	13,541	23,800
Intensive Care Unit	14	$39,645,516	1,691	0	1,614	3,305
Burn Intensive Care	0	$0	0	0	13	13
Nursery		$9,991,278	N/A	62	1,871	1,933
Total Acute	**200**	**$228,502,007**	**10,773**	**1,239**	**17,039**	**29,051**

		Gross Patient Revenue			
		Medicare	Medicaid	Other	Total
Total Hospital Patient Revenue		$146,926,391	$14,554,867	$332,985,588	$494,466,846

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Estimated Patient Volumes

Definitions

Inpatient Surgeries:	600
Outpatient Surgeries:	100
Births:	800
Outpatient Visits:	7,800
Emergency Room (Not Admitted):	3,600
Emergency Room (Admitted):	4,400

Figure 4.3 Sample hospital-specific data (Meadowlands Hospital, NJ).
Source: [American Hospital Directory, 2011].

Each hospital's measures are segmented into seven tabs each with their own measures as follows [American Hospital Directory, 2011].

1. **Profile**: Characteristics, Components, NPIs, Purchasing Organizations, Utilization and Volume by Payor, Clinical services, Teaching Status, Accreditations.
2. **Departments**: Cost Center Statistics, General Service Costs, Staffing.
3. **Financial**: Balance Sheet, Income Statement, Uncompensated Care.
4. **Financial Indicators**: EBITDAR, Operating Margin, Excess margin, Total Operating Revenue, Personnel Expenses, Return on Equity, Return on Assets, Current and Quick Ratio, Days cash on Hand, Accounts Receivable, Inventory and Asset Turnover, Debt to Net Assets and Average Age of Plant.
5. **Quality Report**: Process of Care Measures, Survey of Patient Experiences, No. of patients for imaging by type, Hospital Acquired Conditions (Air embolism, blood incompatibility, catheter-associated UTI, falls and trauma, manifestations of poor glycemic control, foreign object retained after surgery, pressure ulcers at stage III and IV, vascular catheter-associated infection).
6. **Inpatient Utilization**: Patient Origin, Trend Report (Case Mix Index, MS-DRGs, Discharge destination), Top 20 Base MS-DRGs, Statistics by Medical Service.
7. **Outpatient Utilization**: Top 20 Medical Diagnoses, Top 20 Ambulatory Payment Classifications (APC), Service Statistics. Example: Pharmacy or Laboratory with details for patient claims, units of service, average costs, charges, payments and Service Mix Index.

4.3 Hospital Unit of Care Definition

The productive output of a hospital is directly related to the medical care it provides to its patients. Medical care in hospitals can be modeled as a series of healthcare related activities that are designed to provide the needed quality of care for the specific disease. A healthcare activity is defined herein as a patient centric activity prescribed by physicians and requires the direct use of hospital resources. These resources include (i) clinical staff (ii) non-clinical staff (iii) equipment (iv) supplies and (v) facilities and (vi) indirect resources.

Hospitals are typically compensated for a specific activity or a care process which includes a defined set of activities. Healthcare activities are therefore the basic element of the measurable output that a hospital provides to its patients. Consider two admitted patients with the same diagnosis and different acuity levels but the same length of stay. The care may involve different activities and hence they will consume different levels of hospital resources. Presumably the patient with higher acuity will require higher units of care output for the hospital. An effective output measure must therefore track this difference.

4.3.1 Direct care Activities and Assumptions

In order to formulate a productivity measure, it is necessary to make a standardization assumption. That is the resources required to complete a specific healthcare activity are generally independent of the patient acuity and/or diagnosis. For instance the resources used to conduct a chest X-Ray will be the same for any patient type, and arguably should be the same at any U.S. hospital. Then similar to other industries, difference in resource use can be attributed to differences in worker skill and/or difference in process design.

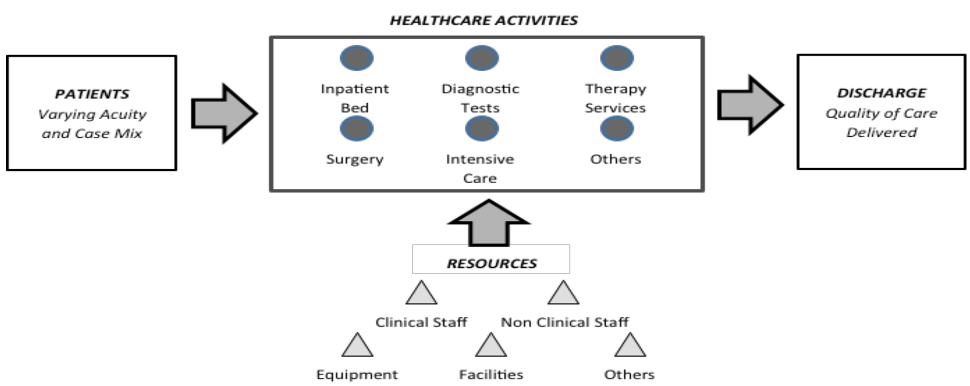


Figure 4.4 Hospital productivity view of inputs & outputs.

The approach proposed tracks all healthcare activities in the hospital, and equates that to the productive output. Then an indexed or weighted summation of the activities would be functionally equivalent to the total medical care output of a hospital. Figure 4.4 translates the classical productivity input-output model to a hospital. Key attributes of this model are:

Patients. The primary flow entity in a hospital and the focus of all resources. Patients are non homogenous and there is a great variance in resource utilization. This variance will depend on acuity and case-mix.

Activities. The hospital provides a large range of healthcare activities all of which are intended to provide a health related service to the patient. Specific activities that patient will access are expected to meet the required process of care to achieve accepted quality of care standards for their diagnosis.

Resources. Each healthcare activity will require or consume one or more resources at varying levels. Resources include staff, equipment, supplies, utilities, and numerous other items. Together these represent both the direct and indirect costs of operating the hospital.

Discharge. Patients exiting from the hospital after having received the accepted quality of care.

In this model there are two key assumptions: (i) a hospital does provide the needed process of care to meet the accepted quality of care standards, and (ii) resources used to perform a healthcare activity are in general standardized across hospitals. Any difference in the resources utilization by activity can be attributed to either differences in acuity and/or difference in hospital efficiency. Acuity differences should normalize over the annual patient population for a hospital. Ultimately, this study identifies productivity differences.

4.3.2 Research Study Procedure

From a productivity analysis perspective, a baseline hospital unit of care (HUC) is defined as the resources required for delivery of one general medical-acute care inpatient day which includes the needed healthcare staff, ancillary and support services and facilities to deliver the required (acceptable quality) continuum of care. Frequently this is referred to as a general medical/surgical inpatient day, or the provision of a bed with routine care. The baseline HUC measure does not include outpatient care and services, specialty or intensive care, surgeries, prescribed services, prescribed diagnostics, enhanced facilities, patient complexity etc. The HUC expands to account for all additional care/service activities that the hospital provides. The proposition here is to do this by deriving an equivalency value for all activities. For example, it may be estimated that 1 Intensive Care Patient Day = 2.3 Hospital Units of Care. The approach provides a function to roll-up all the reported hospital direct patient care activities into a unified output measure.

The implementation strategy is to develop a measure which can readily be applied to an available dataset. While hospitals collect and store a myriad of data elements at the local level, this data is typically unusable for cross-hospital comparisons as few hospitals use a common definition set. Further, HIPPA regulations make it restrictive for analytical groups to get data directly from hospitals. Clearly, developing a measure which is dependent on unavailable or typically unrecorded data is unlikely to be implemented and therefore will be of little practical value to the health analysis community.

The only truly national, publicly accessible hospital operations information is the Medicare database. The data exists in large raw data files and can be accessed through AHD.com; there users can selectively extract specific data reports. The model presented here used data fields that are reported in the Medicare and a program has been developed which extracts the data needed for our analysis. Access is through AHD.com [American Hospital Directory, 2011].

Development of the HUC measure involved several activities including: review of patient activity process flows for different hospitals, both from onsite studies and those reported in the literature, review of Medicare billing and payment procedures and the link to direct patient activity and review of the Medicare-sourced AHD.com dataset to identify data elements that relate to identified activities.

The HUC measure is comprised of six components (Figure 4.5), each of which represents a different set of activities for the hospital. Specific measures for each component is introduced next. All parameters used in these measures correspond to specific data fields in the Medicare database. Note that each component is calculated for a specific hospital.

Some parameters refer to an aggregate statistic from a reference dataset, these are identified as such.

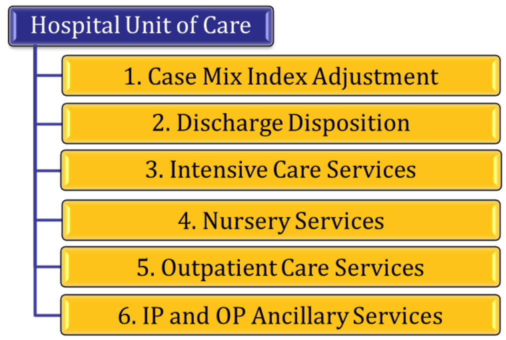


Figure 4.5 HUC output activity components.

4.3.3 Case Mix Index Adjustment

A mix of cases in a hospital reflects the diversity and clinical complexity of the population of inpatients served by the hospital. The base line HUC measure is simply the number of inpatient days. This category factors the difference in resource usage as a function of the patient case mix to derive the adjusted number of inpatient days. Medicare tracks patient volumes in 16 medical service categories, examples are Cardiology, Gynecology and Neurology (Appendix A). Each category is based on groupings of patient MS-DRGs and is assigned a case mix index (CMI) for the hospital.

$$Case\ Mix\ Adjusted\ Inpatient\ Days = \Omega_1 = \Psi_{in} \sum_i N_i L_i C_i \tag{4.2}$$

The CMI indicates the mix of patient severity levels. Higher severity levels will consume relatively more hospital resources. Additionally, the CMI adjusts for geographic factors, salary differences, teaching status and disproportionate share of uncompensated care. Since data is reported only for Medicare patient volumes the coefficient Ψ_{in} scales the data for the total hospital patient volume. The assumption here is that the case mix

Table 4.1 Case Mix Adjusted Inpatient Days

Ω_1	Inpatient Case Mix Index load
i	Medical service categories
N_i	Number of Medicare patients (annual) in this category
L_i	Average length of stay (LOS) in this category
C_i	Medicare Case Mix Index for this category
V_{in}	Total inpatient volume at hospital
Ψ_{in}	Inpatient volume coefficient = $V_{IN}/\sum_i N_i$

profile of Medicare and non-Medicare patients is the same. Observe that depending on the patient severity mix at a hospital Ω_1 could be greater or less than the baseline $(N_i\, L_i)$.

4.3.4 Discharge Disposition

Every patient discharge requires additional resources, on top of that required for a regular impatient day. This component factors in the difference in resource usage as a function of patient discharge disposition. All patients discharged alive (to a home, skilled nursing facility, transfer to acute care facility, or other) require the same amount of resources. Expired patients require additional resources.

$$\Omega_2 = \sum_r \frac{P_r\, \delta_r}{\gamma_u} \tag{4.3}$$

On average, a hospital's incremental cost for a patient on day of discharge is \$420, while that for expired patients to be \$623 on the day of morbidity [National Center for Policy Analysis, 2000]. Benchmarked against the average inpatient day cost of \$1,246, the derived values are $D_1/\gamma_u = 0.3$ and $D_2/\gamma_u = 0.8$. A key data point in this component and

Table 4.2 Discharge Disposition Adjusted Inpatient Days

Ω_2	Discharge disposition load
r	Discharge disposition (1 = Expired, 2 = Alive)
δ_r	National average incremental cost per day by disposition
P_r	Annual discharges in this category for hospital
γ_u	Average cost (reference set, U) per general medical/surgical inpatient day

several other components is γ_u the average cost per medical/surgical day. The analytical objectives for a specific study will determine the reference set from γ which is derived. For example, a study focusing on New Jersey hospitals may set 'U = New Jersey hospitals.'

4.3.5 Intensive Care Adjusted Inpatient Days

Intensive care is an integral part of a hospital's operations, consuming a significant portion of all beds and of the hospital operating budget [Michalopoulos et al., 2012]. Intensive Care Units (ICUs) provide specialized care to critically ill patients and are typically characterized by additional resource requirements, due to services being rendered at a heightened level of care. Rene et al (1999) observe that maintenance of the ICU location and its personnel is the most costly component of ICU service. This component factors in the additional resources required to provide ICU services. Several types of ICU services are possible, and Medicare requires hospitals to track and report patient volumes in ten ICU categories, including General ICU, Coronary ICU and Neonatal ICU (Appendix A).

$$\Omega_3 = \sum_j \frac{M_j \alpha_j}{\gamma_u} \tag{4.4}$$

Table 4.3 Intensive Care Services Load Equation Elements

Ω_3	Intensive or critical care load
j	Intensive care categories (j = 1 to 10)
M_j	Annual number of patient days in this category for hospital
α_j	Average cost per day for ICU category j
γ_u	Average cost (reference set, U) per general medical/surgical inpatient day

Hospitals report their average cost per day in each ICU category, α_j is therefore directly derived from this data. It is estimated that intensive care represents 13.4% of hospital costs in the U.S., and there are currently about 80,000 ICU beds in the U.S. alone (Halpern and Pastores, 2005). Carr et al (2010) reports that there is significant variation in critical care beds per capita in the U.S. and between hospitals. This emphasizes the need to model ICU resource usage in modeling hospital output activity. The factor Ω_3 adjusts hospital output for ICU care and hence is an important factor in productivity analysis.

4.3.6 Nursery Services Adjusted Inpatient Days

This component factors the additional load placed on hospital resources by caring for newborns in the nursery. Newborns are not considered in the traditional ‘inpatient days’ count but nonetheless consume resources. Typically the newborn is taken to the nursery, which does not count ‘beds’ hence does not appear in many output measures, but certainly incurs its own costs. Any special care for the newborn such as neonatal ICU is treated separately as part of the ICU adjustment factor. Only when a newborn enters a special care unit does it become an identified patient, and the associated resources are directly tracked. The March of Dimes estimates that about 14.4% of U.S. newborns will enter a special care unit.

$$\Omega_4 = B(G_u)\frac{\beta_u}{\gamma_u} \tag{4.5}$$

Table 4.4 Nursery Services Load Equation Elements

Ω_4	Nursery services load
B	Annual number of newborns delivered at the hospital
G_u	Average nursery length of stay (reference set U)
β_u	Average cost (reference set, U) per nursery day
γ_u	Average cost (reference set, U) per general medical/surgical inpatient day

Childbirth represents a very special segment of hospital output. For hospitals with large maternity units and consequently a large number of births, makes this a significant load. The time an expectant mother spends in the labor and delivery room is excluded from the 'inpatient days' count. In the Medicare cost report, labor and delivery costs are rolled into ancillary costs and postpartum care is considered to be rolled into the cost of a general inpatient day.

4.3.7 Outpatient Services

In recent years there has also been rapid growth in the number of patients seeking care as outpatients both through hospital outpatient departments and emergency rooms. The 2011 CDC trend report indicates that the volume of outpatients is approaching almost seven times the number of inpatients. In many cases outpatients now account for larger portions of a hospital's resource utilization. This component accounts for the resource usage by the hospital's outpatient population. Medicare tracks a mix of 39 different healthcare services provided to outpatients (Appendix A). These services reflect the diversity and clinical complexity of the population of outpatients served by the hospital. Example services include pharmacy orders, IV therapy, surgical supplies, CT scans and pathological lab orders.

$$\Omega_5 = \Psi_{out} \frac{\theta_u}{\gamma_u} \sum_k S_k P_k \tag{4.6}$$

Table 4.5 Outpatient Services Load Equation Elements

Ω_5	Outpatient services load
k	Outpatient service categories (k=1 to 39)
S_k	Service Mix Index for category k
P_k	Annual number of units of service for category k
T_k	Annual number of Medicare outpatients in category k
V_{out}	Total outpatient volume at hospital
Ψ_{out}	Outpatient volume coefficient V_{OUT} / $\sum_k T_k$
θ_u	Average cost (reference set, U) per outpatient service
γ_u	Average cost (reference set, U) per general medical/surgical inpatient day

For each outpatient service category Medicare derives an average intensity estimation for the care received by outpatients, this is called the service mix index. The service mix profile is only available for the hospital's Medicare volume. It is assumed here that the outpatient service mix profile of Medicare and non-Medicare patients is the same. Similar to the inpatient volume, he coefficient Ψ_{out} scales the data for the total hospital outpatient volume.

4.3.8 Inpatient and Outpatient Ancillary Services

Hospitals provide a range of additional or ancillary services that are delivered to both inpatients and outpatients. Ancillary services are considered to be ‘supplemental’ services provided to patients and typically fall into one of three categories. Diagnostic ancillary services are provided in support of physician services and includes audiology, radiology, pulmonary testing services and clinical lab services. Therapeutic ancillary services focus on treatment of illness or disease and includes medications, dialysis and rehabilitation. The third category, custodial ancillary services have a primary focus on hospice, home health and nursing home care. These services should not be confused with routine services that patients receive.

For example inpatients receive basic nursing care and non-charge medicine such as aspirin as part of ‘routine services’ provided to all patients. For outpatients any services administered beyond those covered in the Ambulatory Payment Classification (APC) for a particular diagnosis are considered ancillary. Medicare tracks 20 different ancillary services provided to patients. An x-ray of an injured leg for an inpatient would be considered a diagnostic ancillary service. Physical therapy in the hospital on that leg would be an example of therapeutic ancillary service.

One limitation in the analysis of ancillary services is that the Medicare dataset does not provide units of service for ancillary services; only total cost, inpatient charges, and outpatient charges by ancillary service type. In order to account for the associated resource usage, the total ancillary services cost is converted to inpatient costs and outpatient costs.

$$\Omega_6 = \sum_p \left(\frac{\lambda_u}{\lambda_p}\right)\left(\frac{\tau_p}{\gamma}\right) \tag{4.7}$$

In this equation, the function τ_p/γ converts the total ancillary service costs into inpatient days at the normalized rate. Since instead of using units of service the above function utilizes cost data, it is necessary to factor in the cost efficiency difference between hospitals.

Table 4.6 Ancillary Services Load Equation Elements

Ω_6	Inpatient and outpatient ancillary services load
p	Ancillary service categories
τ_p	Hospital ancillary service cost (inpatient + outpatient)
F_p	Hospital ancillary service charges (inpatient + outpatient)
λ_p	Hospital ancillary services cost to charge ratio

Hospitals with charge ratios λ_p lower than the normalized ratio λ_u are more efficient. The function λ_u/λ_p adjusts the equivalent inpatient days by accounting for the efficiency difference.

As noted all of the above six HUC output activity components can be derived from data reported by hospitals to Medicare for a given year. The total HUC delivered by a specific hospital is thus given by:

$$\text{Total Delivered HUC per year} = \Omega_1 + \Omega_2 + \Omega_3 + \Omega_4 + \Omega_5 + \Omega_6 \qquad (4.8)$$

The measurement unit of the HUC is inpatient-days equivalency, the same unit as APD. The HUC value will change from year to year for a specific hospital. In the next section this model is applied to a sample of US hospitals.

4.4 Hospital Selection and Study Parameters

To demonstrate model feasibility, the HUC model is compared to the traditional Adjusted Patient Days method in a dataset of 203 hospitals. These hospitals are split between the 17 benchmark hospitals which comprise the 2011 edition of the *U.S. News & World Report's Best Hospitals Honor Roll* and 186 hospitals from five states [U.S.News, 2011]. The states included in this study - South Dakota, Nebraska, Pennsylvania, New Jersey and Washington represent a range of hospital expense per patient day from South Dakota (lowest $1,113) to the highest Washington State ($2,810) [Kaiser Family Foundation, 2011]. Interestingly, population is a significant factor as their per capita spending on healthcare is relatively similar, on the order of $7,000 as shown in Figure 4.6. In fact, South Dakota spent $274 more than Washington on a per capita basis. The rationale for selecting each hospital is detailed in the subsections to Section 4.4.

4.4.1 Delimitations

Bed Count. Hospitals are typically segregated by 'bed-size,' a term which refers to the number of beds the hospital is licensed to use. The three size categories are: less than 70 beds (small); 70-199 beds (medium); and 200 or more beds (large). These size categories are commonly used by national organizations to classify hospitals for comparison. This study limited its scope to hospitals classified as medium or large with a lower limit of 70 beds. This delimitation strengthened the assumption of *quality of care is constant* for the chosen hospital set and this is because medium and large hospitals are expected to deliver a minimum level of good care products and services.

Short-term acute care hospitals. The hospitals in the study were confined to short-term acute care hospitals which were non-federal government, non-specialty, non long term care, non-psychiatric and not hospital units of institutions (such as prison hospitals, college infirmaries). This restriction allowed for a similar hospital profile across all participant hospitals where the assumption of 'good quality care' could be held in common without the confounding effect of specialization or psychiatric care. This delimitation is consistent with most other hospital comparison studies. In particular, 'quality of care' studies such as U.S. News & World Report which restricts hospital comparison studies to remove confounding factors derived from hospital specialization/psychiatric specialties.

Time. This study was performed under strict time constraints with the schedule spread across a two year time period. The most labor intensive segment of the study was data gathering and formatting. The study collected 300 data elements for each of the 203 hospitals in the study. This required individually sourcing and coding into tables 60,900 unique records before any analysis could begin. Even with the assistance of modern technology, after the process was defined and the necessary elements were identified in a data map, each hospital still required at least half an hour to collect and format for a total time expenditure of roughly 300 man hours for just data collection.

Metric development and framework design were also very time intensive steps leading to the decision to limit the study to five states (South Dakota, Nebraska, Pennsylvania, New Jersey and Washington) plus a 'Benchmark' set as discussed in Section 2.1.2 and detailed in this section, which together act as a proxy for the National Model. An overview of the hospitals in these states is provided by Figure 4.6.

4.4.2 Hospitals Overview

South Dakota Hospitals. The state of South Dakota was chosen for this study as it had the lowest hospital cost per inpatient day in United States in 2010 as shown in Table 2.2 and consistently ranks in the bottom tier for hospital cost as detailed in Appendix B. Geographically, South Dakota and neighboring Nebraska represent the Mid-West United States.

Nebraska Hospitals. The state of Nebraska was chosen for this study as it is proximal to South Dakota, the lowest cost state and itself ranks consistently in the bottom tier for hospital cost as detailed in Appendix B. Geographically, Nebraska and neighboring South Dakota represent the Mid-West United States.

Pennsylvania Hospitals. The state of Pennsylvania was chosen for this study as it consistently ranks in the median cost per inpatient day in the United States Table as shown in 2.2 and detailed in Appendix B. Geographically, Pennsylvania and neighboring New Jersey represent the Eastern United States.

New Jersey Hospitals. The state of New Jersey was chosen for this study as it is the research team's home state and the proximity allowed access to several hospitals for feasibility studies and consultation with hospital administrators in a range of hospitals. New Jersey is also one of the most densely hospital-populated states in the country and because of this, it is one of only a handful of states with no 'Critical Access Hospitals.' New Jersey has one of the highest cost of living ratios in the United States. As shown in Table 2.2 and detailed in Appendix B, New Jersey hospitals are consistently in the highest cost segment of U.S. hospitals. Geographically, New Jersey and neighboring Pennsylvania represent the Eastern United States.

Washington Hospitals. The state of Washington was chosen for this study as it had the highest cost per inpatient day in United States in 2010 as shown in Table 2.2 and consistently ranks in the top tier for hospital cost. Geographically, Washington represents the Western United States.

Honor Roll Hospitals. The seventeen hospitals of the U.S. News & World Report's Best Hospitals 2011 report comprise the Benchmark Set listed in Figure 4.7. These hospitals represent eleven states and span the nation, and include California, Massachusetts, Maryland, Michigan, Minnesotta, Missouri, North Carolina, New York, Ohio, Pennsylvania, Tennessee and Washington State which are distributed across the nation [U.S.News, 2011]. The U.S. News list was chosen as it is the seminal 'go-to guide' for consumers researching hospitals for complex procedures. The U.S. News ranking is also a simple and quick method of determining a hospital's ability to deliver excellent 'Quality of Care' - an element which is being assumed as a constant in our study.

	South Dakota	Nebraska	Pennsylvania	New Jersey	Washington
Total Health Spending ($ millions)	5,721	12,649	97,414	65,924	45,246
Average Spending Growth 91-09 (%)	6.9	6.9	5.7	6	7.3
Health Spending per Capita ($)	7,056	7,048	7,730	7,583	6,782
Retail Rx Drugs Filled (millions)	10	25	176	108	77
Retail Rx Drugs Filled Per Capita	12.7	13.6	13.8	12.3	11.4
Retail Rx Drugs Filled ($ millions)	551	1,392	10,362	7,919	3,665
Cost per Inpatient Day ($/day)	1,113	1,516	1,906	2,179	2,810
Median Household Income ($)	47,353	53,927	50,087	65,072	59,370
St Dev of Household Income ($)	1,626	1,572	1,241	2,150	1,743
Population Density (per sq mile)	10	24	284	1195	101
Total Hospitals (70+ beds)	6	11	89	57	26

Figure 4.6 Overview of South Dakota, Nebraska, New Jersey and Washington hospitals. Source: [Kaiser Family Foundation, 2011].

4.5 HUC Feasibility Study

To demonstrate its feasibility, the HUC model was applied to the *U.S. News & World Report* 17 Honor Roll hospitals [U.S.News, 2011]. Data for these hospitals was extracted from the 2011 MedPAR database. The results are shown in Figure 4.7, along with the HUC/APD ratio. The HUC units are much larger than the APD, but there is a significant range in the ratio from a low of 2.09 to a high of 56.61. Excluding three hospitals (#s 3, 4, and 13), the range is much tighter. APD appears to be only a partially reliable indicator of resource intensive activities at the hospital. Hospitals #6 and #15 have similar HUC units, but in terms of APD #15 is about 90% bigger. Any analysis based on purely APD could thus lead to erroneous conclusions.

The three hospitals with high HUC/APD ratios (Stanford University Hospital, Ronald Reagan UCLA Hospital, University of Michigan Hospital) and the lowest HUC/APD ratio (Johns Hopkins Hospital) raise an interesting question, *are they simply exceptions or representative of a special class of hospitals?* The table in Figure 4.8 shows the HUC component break-up for the hospitals. Two of the components Ω_2 and Ω_4 have an insignificant contribution to the HUC. The Johns Hopkins Hospital has a different profile from other honor roll hospitals. While the Outpatient Services Ω_5 contributes almost one third of their HUC volume (31% set average), Johns Hopkins does not report any outpatient volume.

Identifier	Hospital	APD	HUC	HUC/APD Ratio
1	Univ of Washington Medical Center	161,725	574,232	3.55
2	Univ of Pittsburgh Medical Center - Magee	212,107	516,358	2.43
3	Stanford Hospital	220,153	11,516,180	52.31
4	Ronald Reagan UCLA Medical Center	220,749	3,132,051	14.19
5	St Mary's Hospital (Mayo Clinic)	243,955	964,778	3.95
6	Univ of California SF Medical Center Parnassus	287,252	1,728,527	6.02
7	Hospital of the Univ of Pennsylvania	381,710	2,467,459	6.46
8	Mount Sinai Medical Center	415,646	1,578,068	3.80
9	Johns Hopkins Hospital	421,333	882,280	2.09
10	Brigham and Women's Hospital	422,800	1,673,611	3.96
11	Vanderbilt Univ Medical Center	435,089	1,761,810	4.05
12	Barnes-Jewish Hospital	465,497	1,600,644	3.44
13	Univ of Michigan Hospitals and Health Centers	489,117	12,691,053	25.95
14	Duke University Hospital	502,819	2,048,541	4.07
15	Massachusetts General Hospital	558,434	1,740,484	3.12
16	New York-Presbyterian Hospital	797,712	2,822,023	3.54
17	Cleveland Clinic	947,496	3,218,909	3.40

Figure 4.7 Adjusted patient days versus Hospital Units of Care for U.S. News and World Report Honor Roll hospitals.

The inpatient services business at Johns Hopkins is disproportionately high (71% of HUC compared to set average 37%). It is for this reason that this hospital is lower than the average HUC/APD ratio.

		Case Mix	Discharge	ICU	Nursery	Outpatient	Ancillary
Identifier	Hospital	Ω 1	Ω 2	Ω 3	Ω 4	Ω 5	Ω 6
1	Univ of Washington Medical Center	49%	1%	9%	0%	14%	27%
2	Univ of Pittsburgh Medical Center - Magee	35%	2%	10%	3%	14%	36%
3	Stanford Hospital	3%	0%	0%	0%	90%	7%
4	Ronald Reagan UCLA Medical Center	15%	0%	4%	0%	71%	11%
5	St Mary's Hospital (Mayo Clinic)	59%	1%	8%	0%	8%	24%
6	Univ of California SF Medical Center Parnassus	25%	1%	5%	0%	41%	29%
7	Hospital of the Univ of Pennsylvania	36%	1%	3%	0%	7%	52%
8	Mount Sinai Medical Center	49%	1%	3%	1%	27%	18%
9	Johns Hopkins Hospital	71%	2%	11%	0%	0%	16%
10	Brigham and Women's Hospital	42%	1%	5%	1%	13%	37%
11	Vanderbilt Univ Medical Center	34%	1%	9%	0%	26%	29%
12	Barnes-Jewish Hospital	43%	1%	4%	0%	23%	28%
13	Univ of Michigan Hospitals and Health Centers	5%	0%	1%	0%	90%	4%
14	Duke University Hospital	33%	1%	6%	0%	38%	22%
15	Massachusetts General Hospital	36%	1%	4%	0%	14%	45%
16	New York-Presbyterian Hospital	52%	1%	5%	0%	17%	25%
17	Cleveland Clinic	39%	1%	4%	0%	26%	31%
	Set Average	**37%**	**1%**	**5%**	**0%**	**31%**	**26%**

Figure 4.8 Distribution of Hospital Units of Care activity across components.

As shown in Figure 4.8, the three hospitals that are above the set average HUC to APD ratio (Stanford, Ronald Reagan UCLA and University of Michigan Hospital) all have disproportionately large outpatient HUC volume (above 70%) whereas the set average for outpatient HUC is 31% inclusive of these three hospitals. A detailed analysis of their outpatient volume showed that the manner in which a single outpatient service - 'drugs requiring specific identification' is reported, accounted for over 90% of the outpatient HUC volume in these hospitals. As detailed in the table in Figure 4.9, Ronald Regan UCLA saw over 1 million units of service for this type of service and the other two hospitals each saw over 2 million units of service for these drugs. This large volume combined with a non-zero service mix index accounted for the disproportionately large outpatient volume. It should be noted that most other hospitals in the study reported a service mix index of zero for this outpatient service.

Figure 4.8 indicates the HUC profile varies significantly across the sample set. A review of the data shows that hospitals could be characterized by their HUC profile. That is, hospitals that have a HUC component percent significantly above the set average belong to the same group:

Hospital Group Ω_1 – #1, #5, #8, #9, #12, #16.

Hospital Group Ω_3 – #1, #2, #9.

Hospital Group Ω_5 – #3, #4, #6, #13, #14.

Hospital Group Ω_6 – #7, #10, #15.

Average – #11, #17.

		HUC Units by component| % of HUC						
Hospital Name	State	Case Mix	Discharge	ICU	Nursery	Outpatient	Ancillary	Total HUC
The Johns Hopkins Hospital	MD	629,749 | 71%	17,340 | 2%	95,110 | 11%	1,917 | 0%	0 | 0%	138,162 | 16%	882,280
Ronald Reagan UCLA Medical Center	CA	454,517 | 15%	8,443 | 0%	114,604 | 4%	2,343 | 0%	2,210,254 | 71%	341,891 | 11%	3,132,051
Stanford University Hospital	CA	320,776 | 3%	8,905 | 0%	43,264 | 0%	0 | 0%	10,392,888 | 90%	750,347 | 7%	11,516,180
University of Michigan Hospital	MI	674282 | 5%	15,781 | 0%	118,794 | 1%	2,449 | 0%	11,422,065 | 90%	457,681 | 4%	12,691,053

Figure 4.9 Outpatient services detail.

The average hospitals have a profile close to the set average. When evaluating best practices or efficiency solutions, initially one would focus on hospitals in the same Ω group.

4.6 Relating HUC Activity to Hospital Operating Cost

The productive output of hospitals should be closely correlated to their operating costs. The proposition here is that the HUC is better correlated than the more traditional APD to operating costs. This would then validate the proposition that HUC is a more reliable indicator of hospital output relative to APD. To validate the proposition a regression analysis was done for operating costs as a function of (i) HUC and (ii) APD. Both a linear and power model were studied. The dataset was expanded to include 203 U.S. hospitals. Includes all 70+ bed (90% of dataset 150+ bed) hospital in five states (New Jersey, Pennsylvania, Nebraska, South Dakota and Washington). The set excludes Veterans Administration and psychiatric hospitals. These 203 hospitals provide a good representation of the spectrum of hospital profiles in the US. The regression analysis results are shown in Figures 4.10 and 4.11.

Iteration	*Sample Size (Hospitals)*	*HUC-Linear R^2*	*HUC-Power R^2*
1	203	0.398	0.766
2	197	0.678	0.805
3	192	0.702	0.802
4	181	0.803	0.817

Figure 4.10 Regression study results for operating cost vs. annual Hospital Units of Care.

Iteration	*Sample Size (Hospitals)*	*APD-Linear R^2*	*APD-Power R^2*
1	203	0.160	0.076
2	169	0.191	0.141
3	143	0.467	0.154
4	107	0.651	0.352

Figure 4.11 Regression study results for operating cost vs. annual adjusted patient days.

In Figure 4.10, outlier hospitals are progressively removed in four iterations for the Cost-HUC model. A 10% reduction in the sample size provides very significant R^2 values for both the linear and power curve functions. In contrast Figure 4.11 shows that initial R^2 values are very low for the Cost-APD model, and only after removing about 50% of the hospitals was R^2 significant for the APD-Linear function. The APD-Power function performed poorly.

For a second direct comparison, the Cost-APD model was then applied to the set of 197 hospitals in iteration-1 in table 3. This gave a $R^2 = 0.151$ for the APD-Linear function

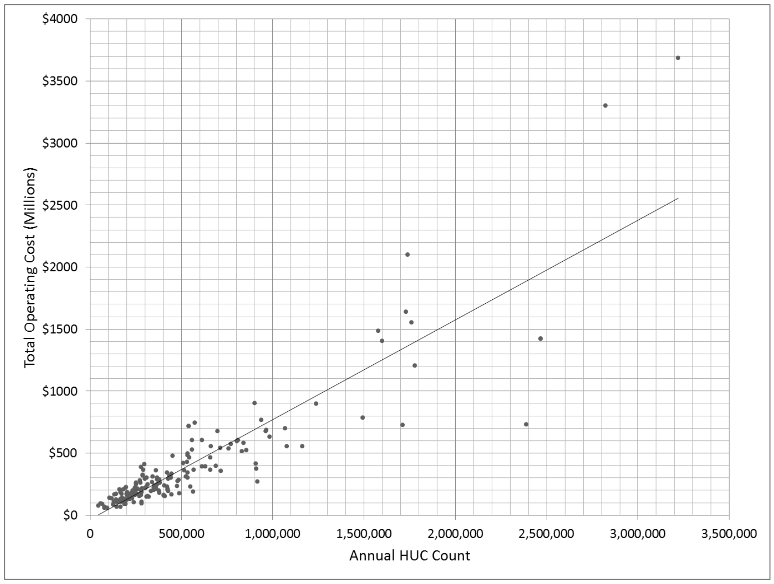


Figure 4.12 Linear regression plot of operating cost vs. annual HUC (181 hospitals).

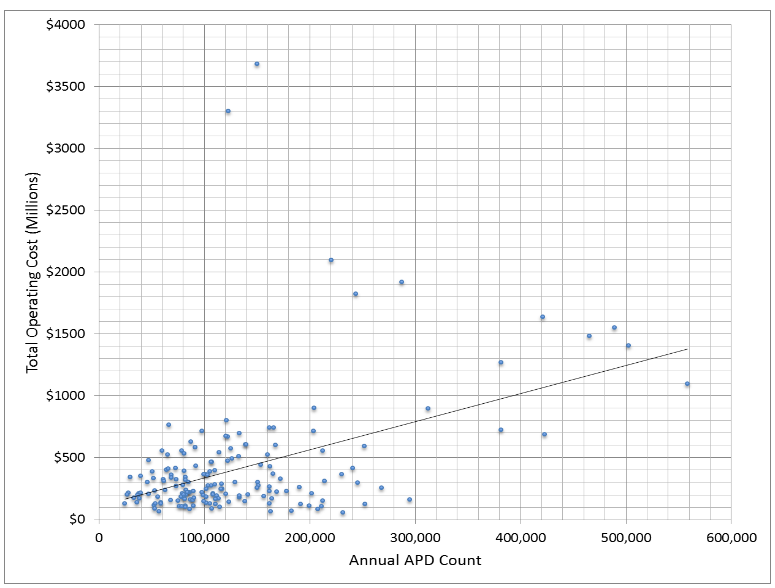


Figure 4.13 Linear regression plot of operating cost vs. annual APD (169 hospitals).

and $R^2 = 0.067$ for the APD-Power function. It can therefore be concluded that HUC is a more reliable indicator of total hospital operating cost. Possibly as much as 80% of the cost variance between hospitals can be attributed to HUC activity. The remaining variance may be attributed to efficiency and other reasons. Figures 4.12 and 4.13 plot the HUC-Linear and APD-Linear models.

Summary The HUC extends the classical APD measure to provide a more detailed and reliable measure of the healthcare activity in a hospital. It is shown that HUC provides an effective and readily implementable method for quantifying the productive output of hospitals. In its current format it can be applied to the MedPAR database to give a reading on any US hospital. The HUC categorizes hospital healthcare activities into six components: (i) case-mix adjusted inpatient days (ii) discharge disposition (iii) intensive care (iv) nursery (v) outpatient care and (vi) ancillary services. The model is almost exclusively based on patient encounters or transactions, and uses a cost ratio to derive the equivalency. For the most part revenue is not used, hence the model is not susceptible to differences due to payor contracts a hospital may have. The model was validated by showing a strong linear correlation ($R^2 = 0.803$) to the total hospital operating cost, relative to the APD correlation. Using the HUC as a basis it is now possible to evaluate productivity of hospitals laterally, since most patient profile differences are resolved in this new measure.

CHAPTER 5

OPERATIONS ANALYSIS OF U.S. HOSPITALS

This chapter presents the Hospital Resource Efficiency (HRE) metric as a new measure of hospital operations productivity designed to satisfy Research Objective No. 3 and to provide a national snapshot of hospital operations performance. The HRE metric uses the traditional efficiency dividend of 'operating expense' and as a divisor takes the Hospital Unit of Care volume measure introduced in Chapter 4. The resulting quotient, the HRE, is presented as a more robust measure of hospital efficiency than the traditional Basic Resource Efficiency (BRE = Cost per inpatient day) and Nominal Resource Efficiency (NRE = Cost per adjusted patient day). The HRE metric is subsequently used to identify the Top 10 Most Efficient hospitals and Bottom 10 Least Efficient hospitals in a national study. Further, the HRE metric is combined with the U.S. News & World Report Best hospitals report to create for the first time a Total Performance Matrix of the relationship between hospital quality and productivity to identify the Best and Worst hospitals in a national study.

5.1 Hospital Efficiency Metrics

The Law of Supply and Demand does not hold in Healthcare. Hospital capacity is a finite resource, however, in an insured population, the demand for healthcare is infinite [Roemer, 1961]. This competition for scarce resources strains the system, drives up cost and leads to rationing. As a Reuters study reported, "fully half of all U.S. hospitals operate in the red" [Girion, 2009]. It is therefore critical to examine operational efficiency for hospitals.

Historically, persons who fell ill were treated in their home by a family physician. At the inception of the 'hospital concept,' *inpatient care* is the only type of care that existed - those too ill to be treated at home are taken to the hospital for the duration of their convalescence and then returned home when their condition improved. At that time, hospital volume is calculated solely as inpatient days and a Basic Resource Efficiency (BRE) metric is used for efficiency measurement as shown in Equation 5.1.

$$\text{Basic Resource Efficiency (BRE)} = \frac{\text{Total Operating Cost}}{\text{Inpatient Days}} \tag{5.1}$$

As the continuum of care extended, hospitals became *short-term acute care* inpatient treatment centers. Patients too ill to return home after treatment are transferred to skilled nursing facilities and from there to *long term care* centers or nursing homes for convalescence. With improvement in technology, and advances in treatment options, there is the advent of hospital *outpatient services*. Patients today who need minor surgery enter the hospital for a few hours where they are treated and returned home. Emergency Room visits, Same-Day-Surgery as well as Labor & Delivery remain in this category - there is no overnight stay or this visit is converted to an *inpatient stay*. This mix of inpatient and outpatient volume has led to the creation of the adjusted patient day (APD) measure discussed in Chapter 3. The associated Nominal Resource Efficiency (NRE) metric as shown in Equation 5.2, has been the standard hospital efficiency metric for decades.

$$\text{Nominal Resource Efficiency (NRE)} = \frac{\text{Total Operating Cost}}{\text{Adjusted Patient Days}} \tag{5.2}$$

$$\text{Adjusted Patient Days} = \text{Inpatient days} \times \frac{\text{Total patient revenue}}{\text{Inpatient revenue}} \tag{5.3}$$

The *Hospital Unit of Care* measure, as detailed in Chapter 4, takes the inpatient day as a base unit of hospital volume and then gives credit to hospitals for their patients' criticality and the intensity of care and services delivered. Following the traditional model of efficiency measurement, this dissertation proposes a new metric, the Hospital Resource Efficiency (HRE) as shown in Equation 5.4.

$$\text{Hospital Resource Efficiency (HRE)} = \frac{\text{Total Operating Cost}}{\text{Hospital Units of Care}} \tag{5.4}$$

$$\text{Hospital Unit of Care Equivalent Days} = \sum \Omega_1\ \Omega_2\ \Omega_3\ \Omega_4\ \Omega_5\ \Omega_6 \tag{5.5}$$

5.1.1 Efficiency Study of Honor Roll Hospitals

Dataset. Hospitals are selected from the 2011 edition of the *U.S. News & World Report's best hospitals Honor Roll* report and are the same hospitals which are in the Chapter 4 study of hospital volume [U.S.News, 2011]. These hospitals are shown in Figure 5.1. **Delimitations**. The *Honor Roll hospitals* dataset contains three hospitals which are also

Hospital	State	U.S. News Rank
Massachusetts General	MA	1
Johns Hopkins Hospital	MD	2
Mayo Clinic	MN	3
Cleveland Clinic	OH	4
Ronald Reagan UCLA	CA	5
Barnes-Jewish	MO	6
NY Presbyterian Columbia and Cornell	NY	7
Duke University	NC	8
Brigham and Women's	MA	9
UPMC University of Pittsburgh Medical Center	PA	10
Hospital of the Univ of Pennsylvania*~	PA	10
NYU Langorne Medical Center**	NY	11
Northwestern Memorial Hospital, Chicago**	IL	12
UC San Francisco	CA	13
University of Washington*~	WA	13
Vanderbilt*~	TN	14
Mount Sinai	NY	14
Indiana University Health**	IN	16
University of Michigan Hospitals and Health Centers	MI	17

*~ = not ranked in 2012-2013 Honor Roll, 2011-2012 ranking displayed
** = not ranked in 2011 - 2012

Figure 5.1 List of Honor Roll hospitals.
Source: [U.S.News, 2011; U.S.News, 2012].

part of the state datasets - the University of Pennsylvania Hospital and the University of Pittsburgh Hospital in Pennsylvania and University of Washington Medical Center in Washington state. To avoid convolution of the study results, these three hospitals are removed from the Honor Roll dataset and treated only as part of their own state's data.

Research Study Procedure

1. Convert inpatient days to Adjusted Patient Days (Equation 5.3).
2. Convert inpatient days to hospital units of care (Equation 5.5).

3. Calculate Basic Resource Efficiency (BRE) (Equation 5.1).
4. Calculate Nominal Resource Efficiency (NRE) (Equation 5.2).
5. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
6. Generate table of results (Appendix B).
7. Generate graph of initial productivity (Figure 5.2).
8. Analyze graph and remove outliers from dataset (with justification).
9. Generate graph of normalized productivity (Figure 5.5).
10. Generate graph of scaled productivity (Figure 5.6).
11. Perform statistical comparison of the BRE, NRE, HRE metrics (Figure 5.7).

Data analysis of Honor Roll hospitals. In examining the study results in Appendix B, the median values for the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 1,751,147.
- Adjusted Patient Days (APD) = 428,945.
- Ratio of HUC to APD = 3.96.

Discussion of results. Most of the hospitals' data fit within a close range but four hospitals are found to be *outliers* from the Honor Roll dataset: The Johns Hopkins Hospital, Ronald Reagan UCLA Medical Center, Stanford University Hospital and University of Michigan Hospital. As discussed in Section 4.5, these hospitals reported their 2010/2011 data in a manner that is inconsistent with the other hospitals in the Honor Roll group therefore they are removed from the dataset for the efficiency ranking. As shown in Figure 5.4, the three hospitals with disproportionately high Outpatient Services which are driven by higher than average Service Mix Indices all revised down their Service Mix Indices for 'Drugs Requiring Specific Identification' for the year which followed the major calculation set and in turn, changed their HUC totals. If the study is performed on 2011-2012 data, these hospitals would be included in the dataset as they would no longer be outliers.

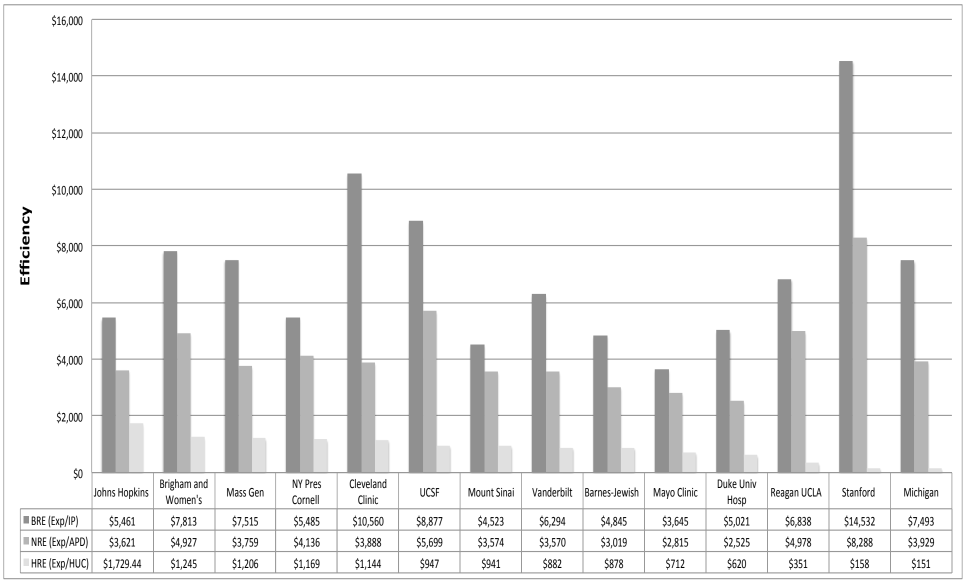


Figure 5.2 Initial efficiency comparison for Honor Roll hospitals.

		HUC Units by component| % of HUC						
Hospital Name	State	Case Mix	Discharge	ICU	Nursery	Outpatient	Ancillary	Total HUC
The Johns Hopkins Hospital	MD	629,749 | 71%	17,340 | 2%	95,110 | 11%	1,917 | 0%	0 | 0%	138,162 | 16%	882,280
Ronald Reagan UCLA Medical Center	CA	454,517 | 15%	8,443 | 0%	114,604 | 4%	2,343 | 0%	2,210,254 | 71%	341,891 | 11%	3,132,051
Stanford University Hospital	CA	320,776 | 3%	8,905 | 0%	43,264 | 0%	0 | 0%	10,392,888 | 90%	750,347 | 7%	11,516,180
University of Michigan Hospital	MI	674282 | 5%	15,781 | 0%	118,794 | 1%	2,449 | 0%	11,422,065 | 90%	457,681 | 4%	12,691,053

Figure 5.3 Detail of Honor Roll outlier hospitals' data.

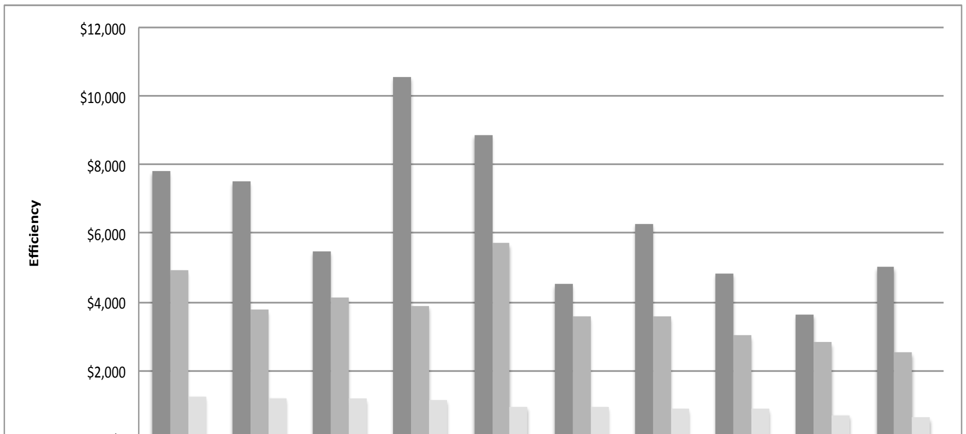
2010/2011 Figures					
k = 26 (Drugs Requiring Specific Identification)	Number of Patient Claims	Units of Service P_{26}	Service Mix Index S_{26}	P_{26}*S_{26}	% of Ω 5
Stanford Hospital	47,243	2,618,191	24.27	63,543,496	96%
Ronald Reagan UCLA Medical Center	63,224	1,242,340	8.15	10,125,071	91%
Univ of Michigan Hospitals and Health Centers	122,657	2,583,448	25.77	66,575,455	97%

2011/2012 Figures					
k = 26 (Drugs Requiring Specific Identification)	Number of Patient Claims	Units of Service P_{26}	Service Mix Index S_{26}	P_{26}*S_{26}	1 YR % CHANGE
Stanford Hospital	34,709	1,998,454	2.31	4,616,429	-93%
Ronald Reagan UCLA Medical Center	39,510	1,250,077	3.95	4,937,804	-51%
Univ of Michigan Hospitals and Health Centers	70,413	2,401,854	24.48	58,797,386	-12%

Figure 5.4 Change in outpatient services for Honor Roll outlier hospitals.

After the outlier hospitals (Johns Hopkins Hospital, Ronald Reagan UCLA Medical Center, Stanford University Hospital, University of Michigan Hospital) are removed from the Honor Roll dataset, a chart of Normalized Productivity is generated as shown in Figure 5.5. A comparison of the three efficiency measures indicates that the Basic Resource Efficiency (BRE) measure is misleading. It does not account for the large volume of outpatient services rendered by the hospitals and shows a large fluctuation across hospitals in the dataset because of this limitation.

The Nominal Resource Efficiency (NRE) measure fares better than the BRE as it accounts for the volume of outpatient services served by the hospital through the Adjusted Patient Day (APD) volume metric discussed in Chapter 4. The Hospital Resource Efficiency (HRE) measure, based on the Hospital Unit of Care (HUC) introduced in Chapter 4 shows the least variation of the three measures and takes into account not just volume of inpatient and outpatient services but also the intensity of care.



	Brigham and Women's	Mass Gen	NY Pres Cornell	Cleveland Clinic	UCSF	Mount Sinai	Vanderbilt	Barnes-Jewish	Mayo Clinic	Duke Univ Hosp
BRE (Exp/IP)	$7,813	$7,515	$5,485	$10,560	$8,877	$4,523	$6,294	$4,845	$3,645	$5,021
NRE (Exp/APD)	$4,927	$3,759	$4,136	$3,888	$5,699	$3,574	$3,570	$3,019	$2,815	$2,525
HRE (Exp/HUC)	$1,245	$1,206	$1,169	$1,144	$947	$941	$882	$878	$712	$620

Figure 5.5 Normalized efficiency comparison for Honor Roll hospitals.

The **BRE** metric shows the Cleveland Clinic has the most expensive care at $10,560 per inpatient day - a cost which is almost three times that of the low-cost provider the

Mayo Clinic at $3,645. This is an unreliable metric, however, since the Cleveland Clinic, like most other short-term acute care hospitals, has a mixed volume of patients not just inpatients which contributes to the overall hospital expense. This mismatch between the dividend source and the divisor causes the data to be skews for BRE.

The **NRE** metric accounts for the hospitals' volume of outpatients and reduces the range between the hospitals significantly. This measure gives the cost per adjusted patient day for the Cleveland Clinic to $3,888 and the Mayo Clinic to $2,815. Under this scheme, the University of California at San Francisco hospital is the highest cost provider at $5,699 per adjusted patient day and the lowest is Duke University hospital at $2,525.

The **HRE** metric accounts for both volume and intensity of care significantly reduces the cost of all hospitals per unit of output. Under the HRE measurement, the Cleveland Clinic's cost per equivalent patient unit is $1,144 and the lowest cost provider is again Duke University at $620 per unit of care. From the State of Massachusetts, the highest cost provider under the HRE is Brigham and Women's Hospital at $1,245 and the second highest cost provider, is Massachusetts General Hospital at $1,206 per unit of care.

To bring these measures into a tighter range and to compare each hospital operationally to its peers, a *scaled resource efficiency* measure can be derived. This scaled resource efficiency metric can be calculated as the quotient of (Resource Efficiency for Hospital A) divided by the (Average Resource Efficiency for all hospitals). This method is applied to the three types of efficiency to obtain a scaled BRE, scaled NRE and scaled HRE, with the result displayed in Figure 5.6.

The scaled Hospital Resource Efficiency (HRE) metric shows 6 out of 10 Honor Roll hospitals are within the mean range of efficiency (scaled HRE 0.9 to 1.2): New York Presbyterian Weil Cornell Hospital, The Cleveland Clinic, University of California at San Francisco Hospital, Mount Sinai Hospital, Vanderbilt University Hospital and Barnes Jewish Hospital. Two hospitals are less efficient than the average Honor Roll hospital: Brigham and Women's Hospital (scaled HRE = 1.21) and Massachusetts General Hospital

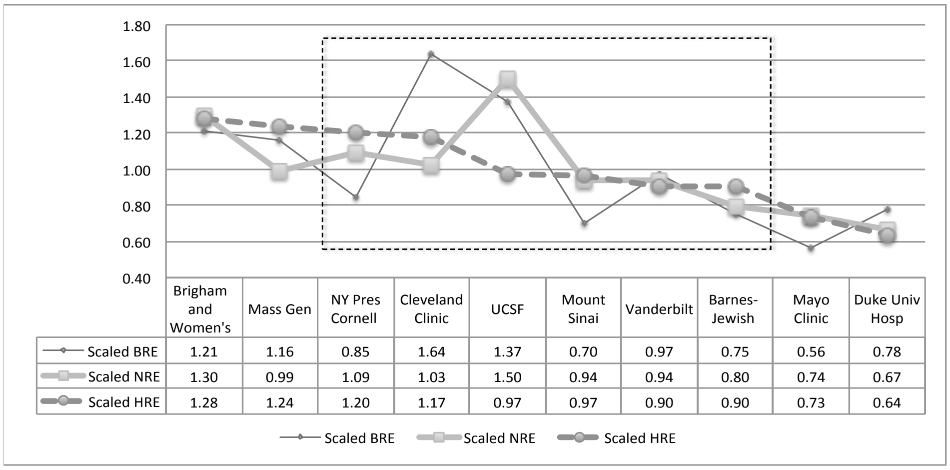


Figure 5.6 Scaled efficiency measures for Honor Roll hospitals.

(scaled HRE = 1.16). *The two most efficient hospitals are The Mayo Clinic (scaled HRE = 0.73) and Duke University Hospital (scaled HRE = 0.64).*

A basic statistical comparison of the three efficiency measures is presented in Figure 5.7. This table shows that for the Honor Roll hospitals, the scaled HRE has the smallest range, lowest variance and lowest standard deviation - indicating that this efficiency is more reliable than the BRE and NRE.

Excellence Hospitals	BRE (Exp/IP)	NRE (Exp/APD)	HRE (Exp/HUC)	Scaled BRE	Scaled NRE	Scaled HRE
Average	$6,457.81	$3,791.20	$974.39	1.00	1.00	1.00
Range	$6,915.01	$3,174.56	$624.87	1.07	0.84	0.64
Variance	3,919,758	786,966	47,262	0.094	0.055	0.050
Standard Deviation	2,184	961	213	0.338	0.253	0.218

Figure 5.7 Comparison of efficiency measures for Honor Roll hospitals.

5.1.2 National Efficiency Study

Dataset. The number of hospitals included in this study by state are: Nebraska - 11, New Jersey - 57, Pennsylvania - 89, South Dakota - 6, and Washington - 26.

Research Study Procedure

		HUC Units by component| % of HUC						
Hospital Name	State	Case Mix	Discharge	ICU	Nursery	Outpatient	Ancillary	Total HUC
BryanLGH Medical Center East	NE	180,460 | 8%	8,322|0%	21,530 | 1%	3,494 | 0%	1,840,413 | 83%	174,184 | 8%	2,228,406
The Nebraska Medical Center	NE	319,075 | 13%	11,268 | 0%	41,805 | 2%	2,912 | 0%	1,697,982 | 71%	316,019 | 13%	2,389,063
Southern Ocean	NJ	45,685 | 9%	2,920 | 1%	6,771 | 1%	571 | 0%	427,660 | 82%	36,829 | 7%	520,440
Robert Wood Johnson Hamilton	NJ	0 |0%	7,201 | 1%	11,189 | 1%	3,238 | 0%	873,880 | 84%	150,293 | 14%	1,045,802
Penn Presbyterian MC	PA	191,138 | 11%	8,092 | 0%	22,027 | 1%	0 | 0%	73,734 | 4%	,475,810 | 83%	1,770,804
Univ of Pittsburgh MC - Hamot	PA	218,817 | 12%	9,460 | 1%	28,952 | 2%	1,170 | 0%	1361955 | 76%	181,830 | 10%	1,802,185
Virginia Mason MC	WA	167,180 | 11%	5,761 | 0%	12,043 | 80%	0 | 0%	1,230,968 | 80%	120,653 | 8%	1,536,604

2010/2011 Figures							
k = 26: Drugs Requiring Specific Identification	State	Number of Patient Claims	Units of Service, P_{26}	Service Mix Index, S_{26}	$S_{26}*Q_{26}$	Total unweighted outpatient volume $\Sigma S_k * Q_k$	% Contribution to Outpatient HUC total
BryanLGH Medical Center East	NE	16,774	875569	28.9	25,303,944	31,615,803	80%
The Nebraska Medical Center	NE	18,331	775,370	28.9	22,408,193	25,249,224	89%
Southern Ocean	NJ	6,721	406,384	6.56	2,665,879	2,858,733	93%
Robert Wood Johnson Hamilton	NJ	7,489	90,935	41.9	3,810,177	5,021,651	76%
Univ of Pittsburgh MC - Hamot	PA	19,801	725,400	8.15	5,912,010	6,408,774	92%
Virginia Mason MC	WA	52,110	1,048,104	7.17	7,514,906	8,270,210	91%
k = 1: Pharmacy							
Robert Wood Johnson Hamilton	NJ	7,489	90,935	41.9	3,810,177	5,021,651	76%

Figure 5.8 Detail of outlier hospitals' data.

1. Convert inpatient days to adjusted patient days (Equation 5.3).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate Basic Resource Efficiency (BRE) (Equation 5.1).
4. Calculate Nominal Resource Efficiency (NRE) (Equation 5.2).
5. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
6. Generate table of results (Appendix B).
7. Analyze outliers (Figures 5.8).
8. Remove outliers from dataset (with justification).
9. Generate graph of normalized efficiency for Nebraska, New Jersey, Pennsylvania, South Dakota and Washington State (Figure 5.9).
10. Generate graph of scaled efficiency (Figure 5.10).
11. Perform statistical comparison of the BRE, NRE, HRE metrics (Figure 5.11).

Nebraska data analysis In examining the study results in Appendix B, the median values of the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 233,033.
- Adjusted Patient Days (APD) = 72,518.
- Ratio of HUC to APD = 3.21.

Most of the hospitals' data fit within a close range but two hospitals are found to be *outliers* from the Nebraska dataset:

1 Bryan LGH Medical Center East:
HUC = 2,228,406; APD = 132,816; HUC/APD = 16.78.

2 The Nebraska Medical Center:
HUC = 2,389,064; APD = 231,395; HUC/APD = 10.32.

Detailed analysis and discussion of outliers: Nebraska

1. Bryan LGH Medical Center East. This hospital's adjusted patient days' volume is within range for the set of Nebraska hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (83%) of the HUC volume is generated by the 'outpatient services load'. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Drugs Requiring Specific Identification* accounted for 80% of the outpatient load. The reason for this deviation is the Service Mix Index of 28.29 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for the Bryan LGH Medical Center, the decision is made to remove this hospital from future calculations of the Nebraska data set.

2. The Nebraska Medical Center. This hospital's adjusted patient days' volume is within range for the set of Nebraska hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (71%) of the HUC volume is generated by the ‘outpatient services load’. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Drugs Requiring Specific Identification* accounted for 89% of the outpatient load. The reason for this deviation is the Service Mix Index of 28.29 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for The Nebraska Medical Center the decision is made to remove this hospital from future calculations of the Nebraska data set.

New Jersey data analysis In examining the study results in Appendix B, the median values of the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 323,522.
- Adjusted patient days (APD) = 93,882.
- Ratio of HUC to APD = 3.45.

Most of the hospitals’ data fit within a close range but two hospitals are found to be *outliers* from the New Jersey dataset:

1 Southern Ocean Medical Center:
HUC = 520,440; APD = 50,932; HUC/APD = 10.22.

2 Robert Wood Johnson University Hospital at Hamilton:
HUC = 1,045,802; APD = 105,163; HUC/APD = 9.94.

Detailed analysis and discussion of outliers: New Jersey

1. Southern Ocean Medical Center. This hospital’s adjusted patient days’ volume is within range for the set of New Jersey hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (82%) of the HUC volume is generated by the ‘outpatient services load’. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Drugs Requiring Specific Identification* accounted for 93% of the outpatient load. The reason for this deviation is the Service Mix Index of 6.56 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for the Southern Ocean Medical Center, the decision is made to remove this hospital from future calculations of the New Jersey data set.

2. Robert Wood Johnson University Hospital at Hamilton. For this hospital, the adjusted patient days' volume is within range for the set of New Jersey hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (84%) of the HUC volume is generated by the 'outpatient services load'. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Pharmacy* accounted for 76% of the outpatient load. The reason for this deviation is the Service Mix Index of 41.9 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. Also, this hospital did not report any Inpatient Case Mix and volume information while all other hospitals reported outpatient volume. As this difference in data reporting effectively skews the data for Robert Wood Johnson University Hospital at Hamilton the decision is made to remove this hospital from future calculations of the New Jersey data set.

Pennsylvania data analysis In examining the study results in Appendix B, the median values for the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 496,447.
- Adjusted patient days (APD) = 140,149.
- Ratio of HUC to APD = 3.54.

Most of the hospitals' data fit within a close range but two hospitals are found to be *outliers* from the Pennsylvania dataset:

1 Pennsylvania Presbyterian Medical Center:
HUC = 1,770,804; APD = 106,283; HUC/APD = 16.66.

2 University of Pennsylvania Medical Center at Hamot:
HUC = 1,802,185; APD = 123,016; HUC/APD = 14.65.

Detailed analysis and discussion of outliers: Pennsylvania

1. Pennsylvania Presbyterian Medical Center. This hospital's adjusted patient days' volume is within range for the set of Pennsylvania hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (83%) of the HUC volume is generated by the Ancillary Services Load. In further investigation, it is found that of the 20 component services in ancillary services, a single element, *Other* accounted for 84% of the total ancillary load. Most other hospitals in the dataset keep this number at 10% of their total ancillary which means that this element does not play a major role in the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for the Pennsylvania Presbyterian Medical Center, the decision is made to remove this hospital from future calculations of the Pennsylvania data set.

2. University of Pittsburgh Medical Center at Hamot. This hospital's adjusted patient days' volume is within range for the set of Pennsylvania hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (76%) of the HUC volume is generated by the 'outpatient services load'. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Drugs Requiring Specific Identification* accounted for 92% of the outpatient load. The reason for this deviation is the Service Mix Index of 8.15 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for the University of Pittsburgh Medical Center at Hamot, the decision is made to remove this hospital from future calculations of the Pennsylvania data set.

Washington data analysis In examining the study results in Appendix B, the median values for the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 900,997.
- Adjusted patient days (APD) = 285,770.
- Ratio of HUC to APD = 3.15.

Most of the hospitals' data fit within a close range but one hospital is found to be *outliers* from the Washington dataset:

1 Virginia Mason Medical Center:
HUC = 1,536,604; APD = 203,930; HUC/APD = 7.53.

Detailed analysis and discussion of outliers: Washington

1. Virginia Mason Medical Center. This hospital's adjusted patient days' volume is within range for the set of Washington hospitals, therefore a detailed analysis is concentrated on the composition of its Hospital Units of Care as shown in Figure 5.8. The largest contributor (80%) of the HUC volume is generated by the 'outpatient services load'. In further investigation, it is found that of the 40 component services in outpatient services, a single element, *Drugs Requiring Specific Identification* accounted for 91% of the outpatient load. The reason for this deviation is the Service Mix Index of 7.17 - most other hospitals in the dataset keep this number at 0 which as a multiplier, means that this element does not factor into the HUC equivalent patient load for these hospitals. As this difference in data reporting effectively skews the data for the Virginia Mason Medical Center, the decision is made to remove this hospital from future calculations of the Washington data set.

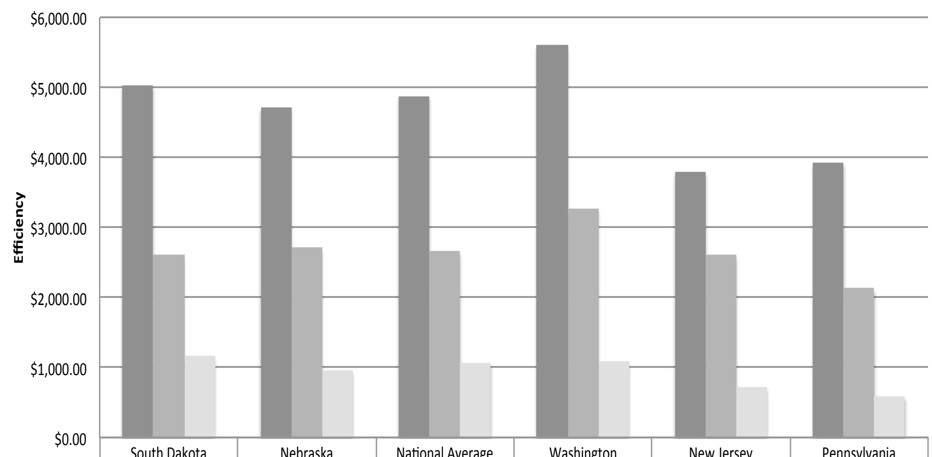
South Dakota data analysis In examining the study results in Appendix B, the median values for the volume parameters are:

- Hospital Units of Care (HUC) Equivalent Patient Days = 244,258.
- Adjusted patient days (APD) = 94,751.
- Ratio of HUC to APD = 2.45.

All of the hospitals' data fit within a close range so there are no *outliers* from the South Dakota dataset.

Discussion of results As shown in Figure 5.8, three of the four states with hospitals which are outliers due to disproportionately high Outpatient Services which are driven by higher than average Service Mix Indices all revised down their Service Mix Indices for 'Drugs Requiring Specific Identification' for the year which followed the major calculation set and in turn, changed their HUC totals. New Jersey and Pennsylvania hospitals changed their Service Mix Index to 'SMI = 0' and Washington State revised the SMI down by half of its original value. If the study is performed on 2011-2012 data, these hospitals in New Jersey, Pennsylvania and Washington State would be included in the dataset as they would no longer be outliers. The hospitals in Nebraska also revised their Service Mix Index number but revised up instead of down as the other three states therefore the Nebraska hospitals would still be excluded if the study is performed on 2011-2012 data.

After the outlier hospitals, are removed from the dataset, (Bryan LGH Medical Center East and The Nebraska Medical Center from Nebraska, Southern Ocean Medical Center and Robert Wood Johnson University Hospital at Hamilton from New Jersey, Pennsylvania Presbyterian Medical Center and University of Pennsylvania Medical Center at Hamot in Pennsylvania and Virgina Mason Medical Center in Washington), a chart of Normalized Productivity is generated as shown in Figure 5.9. A comparison of the three efficiency measures indicates that the BRE measure is misleading. It does not account for the large volume of outpatient services rendered by the hospitals and shows a large fluctuation across hospitals in the dataset because of this limitation. The Nominal Resource Efficiency (NRE) measure fares better than the BRE as it accounts for the volume of outpatient services served by the hospital through the Adjusted Patient Day (APD) volume metric discussed in Chapter 4. The Hospital Resource Efficiency (HRE) measure, based on the Hospital Unit of Care (HUC) introduced in Chapter 4 shows the least variation of the three measures and takes into account not just volume of inpatient and outpatient services but also the intensity of care.

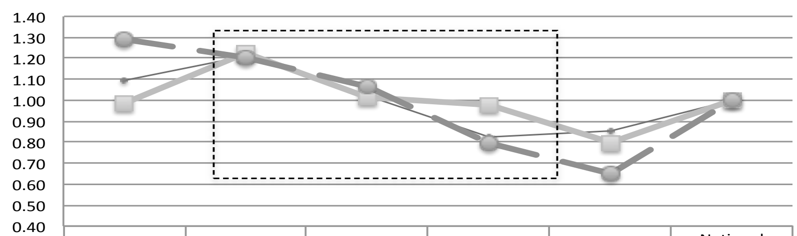


	South Dakota	Nebraska	National Average	Washington	New Jersey	Pennsylvania
BRE	$5,031.50	$4,714.39	$4,872.94	$5,597.55	$3,787.83	$3,927.54
NRE	$2,615.74	$2,702.88	$2,659.31	$3,261.06	$2,601.20	$2,125.29
HRE	$1,169.16	$961.95	$1,065.56	$1,089.29	$720.09	$587.34

Figure 5.9 Normalized efficiency comparison for national hospitals.

To bring these measures into a tighter range and to compare each hospital operationally to its peers, a *scaled resource efficiency* measure can be derived. This metric can be calculated as the quotient of (Resource Efficiency for Hospital A) divided by the (Average Resource Efficiency for all hospitals). This method is applied to the three types of efficiency to obtain a scaled Basic Resource Efficiency (BRE), scaled Normalized Resource Efficiency (NRE) and scaled Hospital Resource Efficiency (HRE) with the result displayed in Figure 5.10.

The scaled Hospital Resource Efficiency (HRE) metric shows 3 out of 5 states' hospitals are within the mean range of efficiency (scaled HRE 0.8 to 1.2): Washington, Nebraska and New Jersey. Nebraska is exactly at the national average for efficiency with an HRE = 1.06. One state is less efficient than the average national hospital: South Dakota (scaled HRE = 1.29). *The most efficient state is Pennsylvania (scaled HRE = 0.65).*



	South Dakota	Washington	Nebraska	New Jersey	Pennsylvania	National Average
Scaled BRE	1.09	1.21	1.02	0.82	0.85	1.00
Scaled NRE	0.98	1.23	1.02	0.98	0.80	1.00
Scaled HRE	1.29	1.20	1.06	0.80	0.65	1.00

Figure 5.10 Scaled efficiency measures for national hospitals.

This study also gives the average national hospital cost by volume measure. The results indicate that across the United States, if a hospital's cost is only considered in terms of inpatient days, for every night that a patient stayed in a U.S. hospital the average cost would be $4,611 (BRE). If the NRE is considered, i.e., the hospital's volume of inpatients and outpatients regardless of services the cost would be $2,661. The HRE metric, however, indicates that the actual hospital cost is $905 per unit of care delivered regardless of location, intensity of care or hospital type as long as it is a short-term acute care hospital over 70 beds.

Statistical comparison of efficiency measures A basic statistical comparison of the three efficiency measures is presented in Figure 5.11. This table shows that for the five states' hospitals, the HRE has the smallest range, lowest variance and lowest standard deviation - indicating that it is a very good efficiency measure.

	BRE	NRE	HRE	Scaled BRE	Scaled NRE	Scaled HRE
National Average	$4,611.76	$2,661.23	$905.57	1.00	1.00	1.00
Range	$1,809.72	$1,135.77	$581.82	0.39	0.43	0.64
Variance	576,376	163,609	60,521	0.03	0.02	0.07
Standard Deviation	759	404	246	0.16	0.15	0.27

Figure 5.11 Comparison of efficiency measures for national hospitals.

5.1.3 Hospital Resource Efficiency National Ranking

This study is performed to fulfill Research Objective No. 3 - an operations efficiency analysis of hospitals across the United States. This is as represented by a national subset (Nebraska, New Jersey, Pennsylvania, South Dakota, Washington State) and a benchmark set of Honor Roll hospitals (U.S. News & World Report Best hospitals Honor Roll).

Dataset The 190 hospitals included in this study are the same as Chapter 4 national study with the exception of outliers removed in Sections 5.1.1 and 5.1.2. Hospital count: Honor Roll - 10, Nebraska - 9, New Jersey - 55, Pennsylvania - 85, South Dakota - 6, and Washington - 25.

Research Study Procedure

1. Convert inpatient days to Hospital Units of Care (Equation 5.5).
2. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
3. Assign a unique identifier to enable ease of reporting.

   The hospital identifier is alphanumeric and comprised of two parts *Alpha* - the first two letters of the dataset name (EX = Honor Roll) or the state abbreviation (NE = Nebraska, NJ = New Jersey, Pennsylvania = PA, South Dakota = SD, Washington = WA). *Numeric* - a number is assigned to each hospital indicating their 'HRE Rank' - the hospital with the best (lowest) HRE in its state for instance, Morristown Medical Center in New Jersey is assigned the number 1 for a hospital identifier of NJ 1. Note that hospitals which are removed from the efficiency analysis are assigned an identifier which indicates their state and a randomly generated letter from the end of the alphabet such as WA X = Virginia Mason Medical Center.
4. Generate tables for 'Top 10', 'Median' and 'Bottom 10' efficiency hospitals (Figure 5.13).

5. Generate graph of HRE distribution (Figure 5.12).

Results The findings of the national study are as follows:

- *Most efficient hospital:* St. Mary Medical Center in Langhorne, Pennsylvania.
- *Median efficiency hospital:* Hospital of The University of Pennsylvania located in Philadelphia, Pennsylvania.
- *Median efficiency hospital:* Saint Marys Hospital (Mayo Clinic) located in Rochester, Minnesota.
- *Least efficient hospital:* Avera Queen of Peace Hospital in Mitchell, South Dakota.

Discussion of results The State of Pennsylvania, as shown in Section 5.1.2, is the most efficient state in the national study as measured by HRE. As highlighted in Figure 5.12, this state has the Top 9 Most Efficient hospitals in the national study. New Jersey, the second most efficient state in Section 5.1.2, has the 10th most efficient hospital in the national study - Morristown Medical Center (most efficient hospital in New Jersey).

The median efficiency level hospitals in the national study are from New Jersey and Pennsylvania (with the exception of the Mayo Clinic). It is likely that the sheer number of hospitals from these two states exerted a large influence on their placement in the median range and yet since none of their hospitals are located in the least efficient range, they are comparatively efficient states.

With the exception of Fremont Area Medical Center in Fremont, Nebraska, the Least Efficient hospitals are from Washington State and South Dakota. The three least efficient hospitals in South Dakota and the six least efficient hospitals in Washington State comprise the other 9 of 10 least efficient hospitals in the national study.

These findings imply a connection between efficiency and cost or volume. The two least efficient states are also the lowest cost (South Dakota) and highest cost (Washington) per average inpatient day in the nation, thereby indicating that there are mitigating factors which impact efficiency.

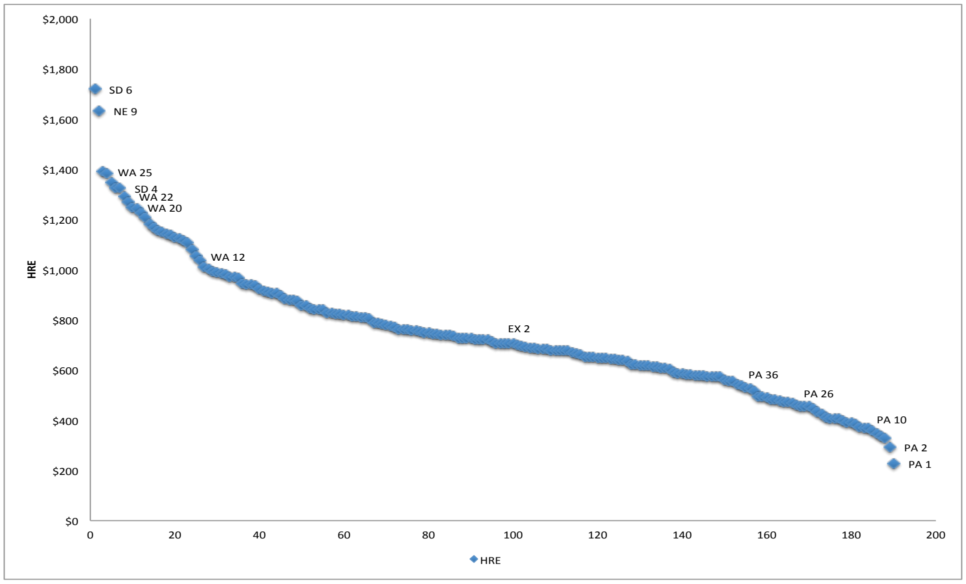


Figure 5.12 Distribution of Hospital Resource Efficiency for national hospitals.

Top 10 Most Efficient Hospitals In National Study			
Hospital Name	Hospital Code	HUC	HRE
St Mary	PA 1	1,453,972	$228
St Vincent Health Center	PA 2	915,336	$294
Butler Mem Hospital	PA 3	566,057	$330
Schuylkill - South Jackson Street	PA 4	282,267	$337
Penn State Milton S. Hershey	PA 5	2,156,995	$345
The Williamsport Hospital &	PA 6	488,578	$359
Holy Redeemer Hospital and	PA 7	447,334	$368
Moses Taylor Hospital	PA 8	410,002	$370
Sacred Heart Hospital	PA 9	283,503	$374
Morristown	NJ 1	1,842,378	$384
Median Efficiency Hospitals In National Study			
Hospital Name	Hospital Code	HUC	HRE
St Francis	NJ 23	185,609	$699
Indiana Regional	PA 65	184,561	$703
Albert Einstein	PA 66	961,835	$704
Kimball	NJ 24	205,568	$704
Jersey Shore Univ	NJ 25	758,893	$705
Pennsylvania Hospital	PA 67	657,477	$706
Mayo Clinic	EX 2	964,778	$712
St Clair Hospital	PA 68	280,534	$721
Univ at Princeton	NJ 26	434,182	$721
Hunterdon	NJ 27	302,779	$721
Montgomery Hospital	PA 69	154,608	$722
Bottom 10 Least Efficient Hospitals In National Study			
Hospital Name	Hospital Code	HUC	HRE
St Joseph Hospital	WA 20	292,502	$1,249
Highline	WA 21	162,343	$1,268
Univ of Washington	WA 22	574,232	$1,293
Avera St Luke's Hospital	SD 4	105,872	$1,324
Harborview	WA 23	540,150	$1,325
Avera Sacred Heart Hospital	SD 5	67,092	$1,350
Valley	WA 24	296,919	$1,382
Evergreen Hospital	WA 25	279,356	$1,391
Fremont Area	NE 9	57,805	$1,634
Avera Queen of Peace Hospital	SD 6	44,612	$1,719

Figure 5.13 Hospital Resource Efficiency for national hospitals.

5.2 Inter- and Intrastate Variance in HRE

If all hospitals in the United States are standardized, their efficiency would be equivalently distributed across the same mean. Under such circumstances, the Normal distributions of Hospital Resource Efficiency (HRE) for the six hospital datasets (Nebraska, New Jersey, Pennsylvania, South Dakota, Washington State and Honor Roll) to be superimposed on each other. The table presented in Figure 5.14 shows that there exists both interstate and intrastate variance in United States hospitals' efficiency. In the set of states studied, Pennsylvania and New Jersey are models of hospital efficiency while South Dakota has the lowest state efficiency. It is also possible to show the '10 Most Efficient hospitals' and '10 Least Efficient hospitals' by state.

Pennsylvania has the lowest average cost and lowest standard deviation in Hospital Resource Efficiency (Mean HRE = $ 587 and Standard Deviation = $157 per Hospital Unit of Care). The histogram in Figure 5.15 shows that most hospitals in the state are clustered between $ 400 and $ 800 HRE, the best spread in the national dataset. The full list of Pennsylvania hospitals and their associated HUC volume and HRE efficiency can be found in Appendix B. The Most Efficient and Least Efficient hospitals in Pennsylvania are listed in Figure 5.16.

New Jersey has second lowest average cost in Hospital Resource Efficiency (Mean HRE = $ 758 and Standard Deviation = $193 per Hospital Unit of Care). The histogram in Figure 5.17 shows that most hospitals in the state are clustered between $ 600 and $ 800 HRE, the second best spread in the national dataset. The Most Efficient and Least Efficient hospitals in New Jersey are listed in Figure 5.18.

Nebraska has the median average cost in Hospital Resource Efficiency (Mean HRE = $ 962 and Standard Deviation = $ 336 per Hospital Unit of Care). The histogram in Figure 5.19 shows that most hospitals in the state are clustered between $ 600 and $ 1,200 HRE, the median of the national dataset. There are only nine hospitals in the Nebraska dataset so all are listed in Figure 5.20.

Washington has the second highest average cost in Hospital Resource Efficiency (Mean HRE = $ 1,089 and Standard Deviation = $ 165 per Hospital Unit of Care). The histogram in Figure 5.21 shows that most hospitals in the state are clustered between $ 900 and $ 1,300 HRE, the second worst spread in the national dataset. There are only twenty-five hospitals in the Washington State dataset and the Most Efficient and Least Efficient hospitals are listed in Figure 5.22.

South Dakota has the highest average cost and highest standard deviation in Hospital Resource Efficiency (Mean HRE = $1,169 and Standard Deviation = $ 353 per Hospital Unit of Care). The histogram in Figure 5.23 shows that most hospitals in the state are not clustered but staggered between $800 and $1,400 HRE, the worst spread in the national dataset. South Dakota, notably has the smallest number of hospitals in the state dataset (six hospitals) and it is possible that the low number of samples is skewing the data unfairly, all are listed in Figure 5.24.

State	Min	Q1	Q2 (Median)	Q3	Max	Average	St Dev
Pennsylvania	228	464	585	699	913	587	157
New Jersey	384	652	743	818	1634	758	193
Nebraska	539	703	907	1191	1634	962	336
Washington	762	973	1079	1215	1391	1089	165
South Dakota	815	877	1117	1442	1719	1169	354
Average	546	734	886	1073	1458		
St Dev	248	199	225	306	328		

Figure 5.14 Hospital Resource Efficiency quartiles for national hospitals.

5.3 National Resource Efficiency by Cost Category

It is possible to drill down into a hospital's total cost by expense type as in Figure 5.25. This level of detail is useful in analyzing a hospital's overall fiscal viability but gives little insight into its operational efficiency/efficiency. To examine this detail, the HRE metric can be broken down into components by Hospital Unit of Care element.

Research Study Procedure

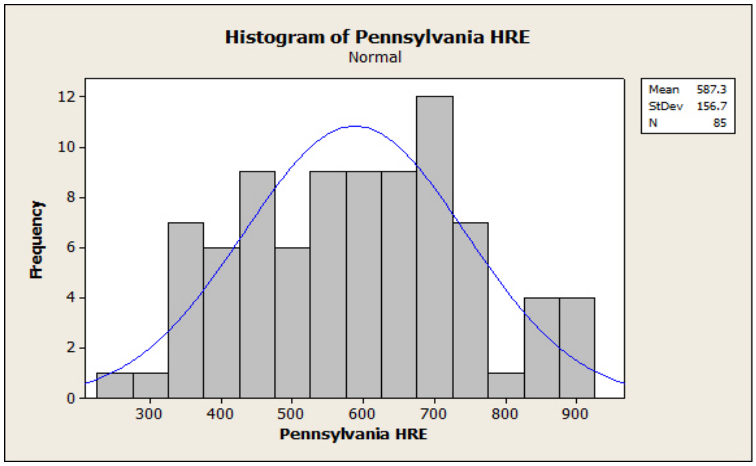


Figure 5.15 Hospital Resource Efficiency histogram for Pennsylvania hospitals.

Top 10 Most Efficient Hospitals In Pennsylvania			
State	Hospital Code	HUC	HRE
St Mary Medical Center	PA 1	1,453,972	$228
St Vincent Health Center	PA 2	915,336	$294
Butler Mem	PA 3	566,057	$330
Schuylkill - South Jackson Street	PA 4	282,267	$337
Penn State Milton S. Hershey Medical Cent	PA 5	2,156,995	$345
The Williamsport & Medical Center	PA 6	488,578	$359
Holy Redeemer and Medical Center	PA 7	447,334	$368
Moses Taylor	PA 8	410,002	$370
Sacred Heart	PA 9	283,503	$374
U Pittsburgh Medical Center Presbyterian	PA 10	4,746,944	$388

Bottom 10 Least Efficient Hospitals In Pennsylvania			
State	Hospital Code	HUC	HRE
Lancaster General	PA 77	937,001	$819
Thomas Jefferson University	PA 78	1,341,183	$827
Harrisburg	PA 79	660,976	$839
The Good Samaritan	PA 80	199,459	$845
Elk Regional Health Center	PA 81	78,034	$856
Uniontown	PA 82	141,484	$877
The Washington	PA 83	246,387	$885
St Joseph Medical Center	PA 84	203,009	$906
The Reading and Medical Center	PA 85	733,661	$913

Figure 5.16 Most efficient and least efficient hospitals in Pennsylvania.

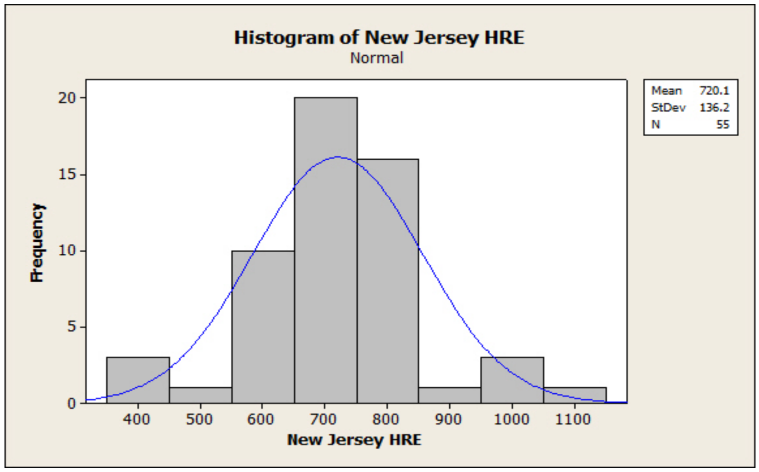


Figure 5.17 Hospital Resource Efficiency histogram for New Jersey hospitals.

Top 10 Most Efficient Hospitals In New Jersey			
State	Hospital Code	HUC	HRE
Morristown	NJ 1	1,842,378	$384
Robert Wood Johnson (RWJ)	NJ 2	1,776,920	$405
Meadowlands Hospital	NJ 3	168,145	$408
Cooper Univ Hospital	NJ 4	1,077,912	$515
Mountainside Hospital	NJ 5	334,160	$577
South Jersey Healthcare Regional	NJ 6	486,726	$578
Raritan Bay	NJ 7	406,610	$583
Palisades	NJ 8	217,526	$604
St Barnabas	NJ 9	855,559	$613
Newark Beth Israel	NJ 10	831,956	$616
Bottom 10 Least Efficient Hospitals In New Jersey			
State	Hospital Code	HUC	HRE
St Clare's Hospital - Denville	NJ 46	367,693	$821
Riverview	NJ 47	259,069	$821
Ocean	NJ 48	255,712	$828
Shore Mem Hospital	NJ 49	234,402	$839
Lourdes of Burlington Cty	NJ 50	129,360	$843
Kennedy Mem Hospitals	NJ 51	542,168	$857
Trinitas Hospital	NJ 52	311,233	$973
Jersey City	NJ 53	300,676	$974
UMDNJ	NJ 54	612,664	$988
Bergen Regional	NJ 55	182,472	$1,129

Figure 5.18 Most efficient and least efficient hospitals in New Jersey.

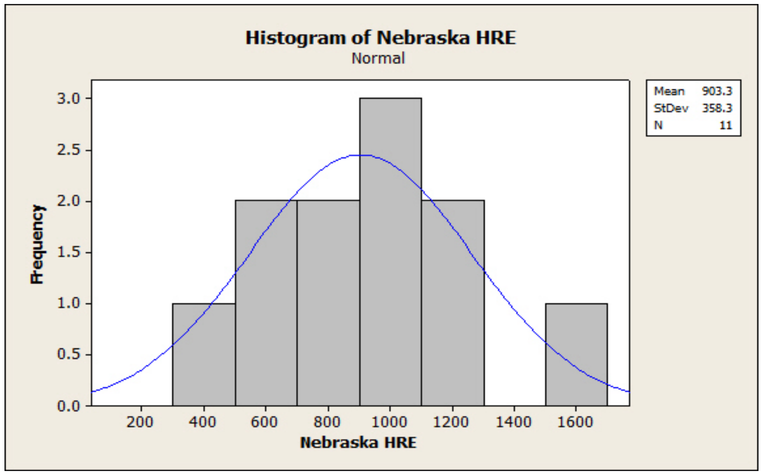


Figure 5.19 Hospital Resource Efficiency histogram for Nebraska hospitals.

Hospital	Hospital Code	State	HUC	HRE
Methodist Hosp	NE 1	NE	744,358	$539
Creighton Univ MC - St Joseph Hosp	NE 2	NE	283,884	$652
St Elizabeth Regional MC	NE 3	NE	284,749	$755
Immanuel MC	NE 4	NE	233,033	$804
Bergan Mercy MC	NE 5	NE	355,909	$907
Good Samaritan Hosp	NE 6	NE	173,644	$985
St Francis MC	NE 7	NE	117,817	$1,155
Regional West MC	NE 8	NE	135,269	$1,227
Fremont Area MC	NE 9	NE	57,805	$1,634

Figure 5.20 Most efficient through least efficient hospitals in Nebraska.

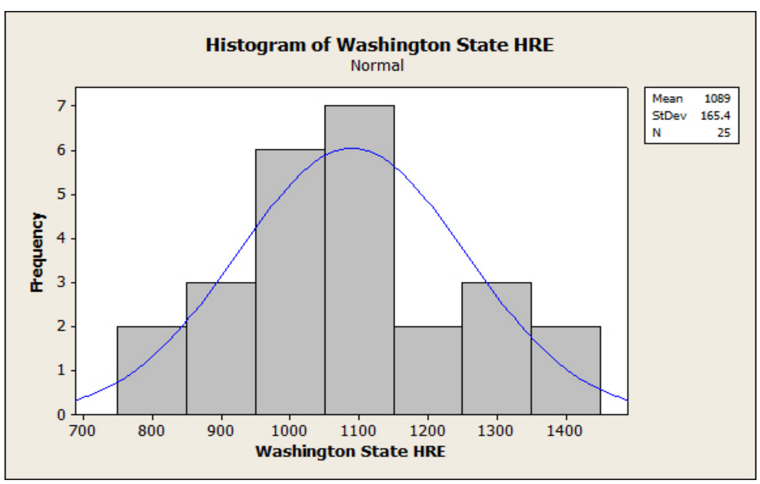


Figure 5.21 Hospital Resource Efficiency histogram for Washington hospitals.

Top 10 Most Efficient Hospitals In Washington State			
State	Hospital Code	HUC	HRE
Auburn Regional	WA 1	167,851	$762
Providence St Peter Hospital	WA 2	416,557	$814
Providence Regional	WA 3	535,421	$925
Kadlec Regional	WA 4	276,767	$936
St Joseph	WA 5	559,920	$941
Sacred Heart	WA 6	698,943	$965
Deaconess	WA 7	250,749	$981
Overlake Hospital	WA 8	362,537	$996
Swedish / First Hill	WA 9	900,997	$1,001
Yakima Valley Mem Hospital	WA 10	274,769	$1,013

Bottom 10 Least Efficient Hospitals In Washington State			
State	Hospital Code	HUC	HRE
Harrison - Bremerton	WA 16	289,272	$1,125
Northwest Hospital &	WA 17	193,069	$1,138
St John	WA 18	196,181	$1,149
Legacy Salmon Creek Hospital	WA 19	142,501	$1,182
St Joseph Hospital	WA 20	292,502	$1,249
Highline	WA 21	162,343	$1,268
Univ of Washington	WA 22	574,232	$1,293
Harborview	WA 23	540,150	$1,325
Valley	WA 24	296,919	$1,382
Evergreen Hospital	WA 25	279,356	$1,391

Figure 5.22 Most efficient and least efficient hospitals in Washington.

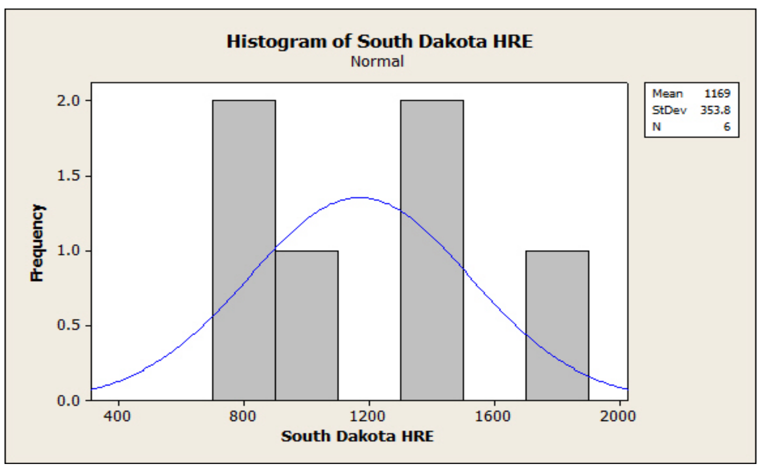


Figure 5.23 Hospital Resource Efficiency histogram for South Dakota hospitals.

State	Hospital Code		HUC	HRE
Avera McKennan Health Center	SD 1	SD	421,424	$815
Sanford USD MC Sioux Falls	SD 2	SD	535,180	$897
Rapid City Regional Hosp	SD 3	SD	342,512	$910
Avera St Luke's Hosp	SD 4	SD	105,872	$1,324
Avera Sacred Heart Hosp	SD 5	SD	67,092	$1,350
Avera Queen of Peace Hosp	SD 6	SD	44,612	$1,719

Figure 5.24 Most efficient through least efficient hospitals in South Dakota.

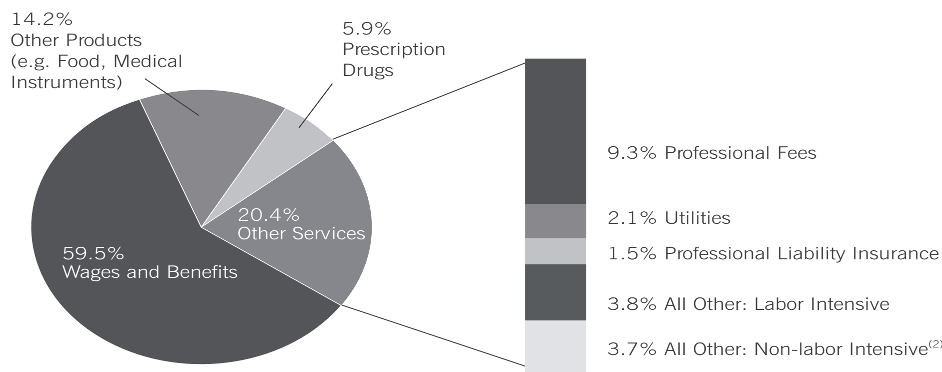


Figure 5.25 Overview of hospital cost.
Source: [American Hospital Association, 2011].

1. Decompose total cost into its component elements: inpatient expenses (room & board and non-charge medicine); outpatient expenses (emergency room and ambulatory surgical services; ancillary services; nursery care services expenses; intensive/critical care expenses; discharge disposition expenses; other administrative expenses.

2. Calculate Hospital Unit of Care Component Efficiency for each element of total cost except 'other' category.

3. Generate graph of interstate variance in Hospital Unit of Care Component Efficiency (Figure 5.26).

4. Generate graph of intrastate variance in Hospital Unit of Care Component Efficiency for South Dakota (Figure 5.27).

5. Generate graph of intrastate variance in Hospital Unit of Care Component Efficiency for Washington (Figure 5.28).

For all elements Total Cost, data is sourced from the AHD Database for each hospital in the national study [American Hospital Directory, 2011].

Inpatient services expense: Tab: 'Depts', Section: Cost Center Statistics, Subsection: Inpatient Routine Service Cost Centers, Row: General Med/Surg, Column: Total Costs.

Outpatient services expense: Tab: 'Depts', Section: Cost Center Statistics, Subsection: Outpatient Service Cost Centers, Row: Total (Clinic + Emergency + Observation Beds + Other), Column: Total Costs.

Ancillary services expense: Tab: 'Depts', Section: Cost Center Statistics, Subsection: Ancillary Service Cost Centers, Row: Total (Operating Room + Recovery Room + Delivery

Room/Labor Room + Anesthesiology + Radiology Diagnostic + Radiology Therapeutic, Radioisotope + Laboratory + PBP Clinical Lab Services + Whole Blood/Packed RBC + Blood Stor + Process + Trans + IV Therapy + Respiratory Therapy + Physical Therapy + Occupational Therapy + Speech Pathology + ECG + Electroencephalography + Renal Dialysis + ASC (non-distinct part) + Other), Column: Total Costs.

Nursery Care Services Expense: Tab: 'Depts', Section: Cost Center Statistics, Subsection: Inpatient Routine Service Cost Centers, Row: Nursery, Column: Total Costs.

Intensive Care services expense: Tab: 'Depts', Section: Cost Center Statistics, Subsection: Inpatient Routine Service Cost Centers, Row: Intensive Care Unit, Column: Total Costs.

Discharge disposition expense: Tab: 'Profile', Section: ID Characteristics, Row: Total Discharges. Discharge Disposition Expense = $1,246*(Total Discharges).

Rationale: Average first day admission cost = $1,246; the average cost per discharge regardless of length of stay, over the long run average is assumed to be $1,246 averaged out across all discharges [National Center for Policy Analysis, 2000].

Research Study Equations

$$\text{Inpatient services efficiency} = \frac{\text{Inpatient services expense}}{\text{Inpatient Hospital Units of Care}} \tag{5.6}$$

$$\text{Outpatient services efficiency} = \frac{\text{Outpatient services expense}}{\text{Outpatient Hospital Units of Care}} \tag{5.7}$$

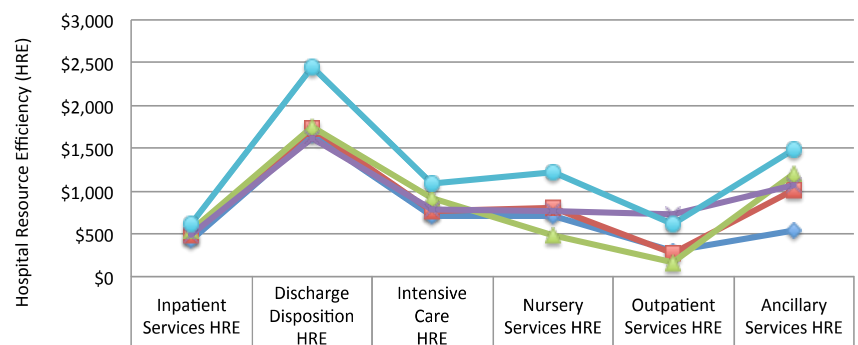
$$\text{Ancillary services efficiency} = \frac{\text{Ancillary expense}}{\text{Ancillary Hospital Units of Care}} \tag{5.8}$$

$$\text{Nursery services efficiency} = \frac{\text{Nursery expense}}{\text{Nursery services Hospital Units of Care}} \tag{5.9}$$

$$\text{Intensive care efficiency} = \frac{\text{Intensive care expense}}{\text{Intensive care Hospital Units of Care}} \tag{5.10}$$

$$\text{Discharge disposition efficiency} = \frac{\text{Discharge expense}}{\text{Discharge Hospital Units of Care}} \tag{5.11}$$

Discussion of results The study results graph as shown in Figure 5.26 comparing all five states indicates that the HRE Component Efficiency follows a similar trend regardless of state. Notably, Washington State stands out in the analysis as it consistently shows the highest HRE across all the cost components.



	Inpatient Services HRE	Discharge Disposition HRE	Intensive Care HRE	Nursery Services HRE	Outpatient Services HRE	Ancillary Services HRE
Pennsylvania	$429	$1,649	$710	$710	$300	$537
New Jersey	$476	$1,723	$765	$796	$270	$1,011
Nebraska	$546	$1,754	$914	$486	$168	$1,209
South Dakota	$490	$1,626	$785	$769	$734	$1,076
Washington State	$607	$2,443	$1,088	$1,222	$620	$1,483

Figure 5.26 National efficiency study by cost category.

Inpatient services

This cost component efficiency is very close for three states - only separated by $61 between the highest ($490, South Dakota) and lowest efficiency cost ($429, Pennsylvania). New Jersey has the median efficiency cost at $476 per inpatient unit of care. The top two inpatient cost component states - Washington State ($607) and Nebraska ($546) are likewise only separated by $61.

Discharge disposition

This cost component efficiency is the most expensive for all states but in a close range for all states (HRE $1,626 to $1,754) with the exception of Washington State, the highest cost state (HRE $ 2,443). It is possible that the cost for this HUC element is incorrectly estimated and that is leading to the results. In the current situation, however, there is no readily available data on the direct cost of discharge and as such, the current estimate is the best can be done in the circumstances.

Intensive care services

This cost component efficiency is in a close range for all states (HRE $ 710 to $ 914) with the exception of Washington State, the highest cost state (HRE $ 1,088). The Intensive Care Services HRE cost is on average 1.67 times that of the Inpatient Services HRE. This implies the hospital services for intensive care are approximately 67% more on this ward than in a general medical/surgical bed as expected due to the higher level of criticality for patients requiring intensive care.

Nursery services

This cost component efficiency is clustered in the middle of the range (HRE $ 710 in Pennsylvania, $ 769 in South Dakota, $ 796 in New Jersey) and diverges widely between the lowest (HRE $ 486 in Nebraska) and the highest cost (HRE $ 1,222) in Washington state. Nursery Services HRE is the same as the General Med/Surg inpatient HRE for Pennsylvania and double for Washington State.

Outpatient services

This cost component HRE is the least expensive category for Nebraska - $ 168, over three times less than the Nebraska Inpatient Services HRE. Outpatient Services HRE is also least for Pennsylvania ($ 300) and New Jersey ($270). This is noteworthy as more hospital volume shifts to outpatient services from the traditional inpatient services role, it is possible that there will be an overall minor shift downward in total cost. **Ancillary services**

This cost component efficiency is clustered in the middle of the range (HRE $ 1,011 in New Jersey, $ 1,209 in Nebraska, $ 1,076 in South Dakota) and diverges widely between the lowest (HRE $ 537 in Pennsylvania) and the highest cost (HRE $ 1,483) in Washington state. Ancillary Services HRE is difficult to quantify as there is no readily available volume detail i.e., both inpatient and outpatient ancillary services are reported solely in terms of cost versus charges and not units of service. It is possible that this lack of visibility into the volume measure is skewing the data upward, however, given the current circumstances, it is the best estimate that can be derived for this segment.

Hospital detail for South Dakota

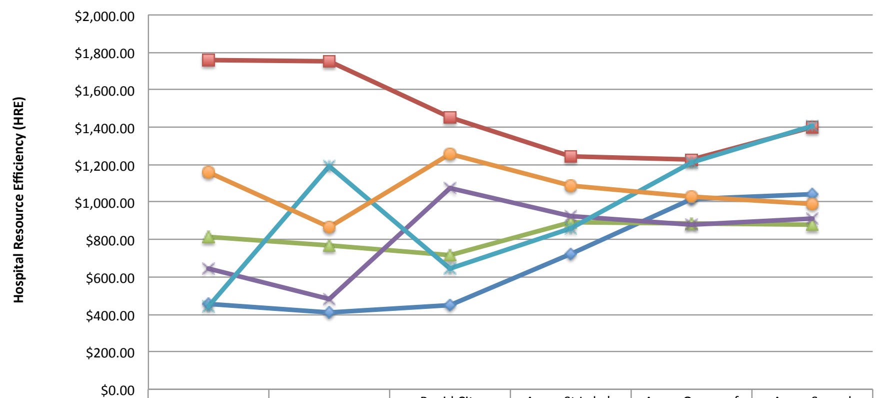
The six hospitals in South Dakota have wide variance in the HRE component costs as illustrated in Figure 5.27. Segment costs converge for two hospitals - Avera Queen of Peace Hospital and Avera Sacred Heart in the middle of the range. Discharge Disposition cost is the least efficient (most costly) segment for all South Dakota hospitals.

Hospital detail for Washington

The twenty-five hospitals in Washington display variance in the HRE component costs as illustrated in Figure 5.28. Discharge Disposition is by far the largest cost category for all of the state's hospitals. Nursery Services' HRE shows the greatest fluctuation as five hospitals have no nursery services volume. Inpatient Services HRE is relatively consistent for all of Washington's hospitals and is the most efficient for most hospitals.

5.4 Determining Predictors of Efficiency

Hospitals in the United States are not standardized. As shown in Section 5.2, the hospital efficiency graphs for the five states in this study show both inter- and intra-state variance. Colloquially, those involved in healthcare research think of volume as directly related to efficiency in that hospitals can benefit from economies of scale - the larger the hospital, the more efficient it should be. In fulfillment of Research Objective 4, the relationship between volume and efficiency is examined in Section 5.4.1 through two correlation experiments of



	Sanford USD	Avera McKennan	Rapid City Regional	Avera St Luke's Hosp	Avera Queen of Peace	Avera Sacred Heart
Inpatient Services HRE	$458.53	$408.56	$452.71	$725.53	$1,017.35	$1,042.96
Discharge Disposition HRE	$1,760.99	$1,750.38	$1,453.82	$1,244.26	$1,227.53	$1,402.13
Intensive Care HRE	$816.22	$767.26	$715.21	$894.63	$886.88	$880.28
Nursery Services HRE	$647.03	$480.53	$1,074.87	$925.23	$876.76	$912.59
Outpatient Services HRE	$440.41	$1,190.00	$645.08	$857.94	$1,214.54	$1,405.98
Ancillary Services HRE	$1,160.92	$864.20	$1,256.30	$1,088.42	$1,028.13	$992.57

Figure 5.27 South Dakota efficiency study by cost category.

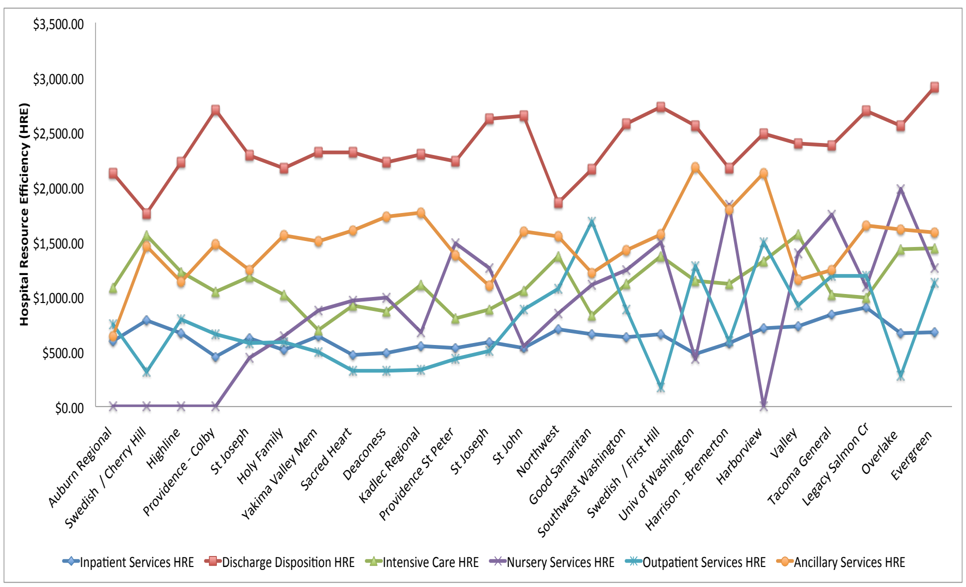


Figure 5.28 Washington efficiency study by cost category.

the 190 national hospitals in the study. At the state level, it is often assumed that efficiency is directly linked to location, size or teaching status. This relationship is examined in Section 5.4.2 through three hypothesis tests of the 57 hospitals in New Jersey. Research Objective 4 is completed by the two studies presented in Chapter 6 - one study is an analysis of inpatient case mix versus length of stay and the second is a correlation study of outpatient services' volume.

5.4.1 The Relationship between Volume and Efficiency

In order to examine the relationship between volume and efficiency, a regression test is performed for Hospital Units of Care (HUC) Volume versus Hospital Resource Efficiency (HRE) and adjusted patient days (APD) Volume versus Nominal Resource Efficiency (NRE).

Dataset The 190 hospitals included in this study are the same as Chapter 4 National Study with the exception of outliers removed in Sections 5.1.1 and 5.1.2. Hospital count: Honor Roll - 10, Nebraska - 9, New Jersey - 55, Pennsylvania - 85, South Dakota - 6, and Washington - 25.

Research Study Procedure

1. Convert inpatient days to Hospital Units of Care (Equation 5.5).
2. Convert inpatient days converted to adjusted patient days (Equation 5.3).
3. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
4. Calculate Nominal Resource Efficiency (NRE) (Equation 5.2).
5. Generate graph of HRE versus HUC distribution and regression equation calculated (Figure 5.29).
6. Generate graph of NRE versus APD distribution and calculate regression equation (Figure 5.30).

Results of HUC to HRE regression study $y = 3038\,x^{0.113}$ and $R^2 = 0.069$.

Results of APD to NRE regression study $y = 2108\ e^{1E-06x}$ and $R^2 = 0.144$.

Discussion of results The results of the two regression studies show that volume is not directly correlated to efficiency. For the Nominal case, only 14% of the variation in efficiency can be explained by the 'best fit' equation relating Adjusted Patient Days and Nominal Resource Efficiency. For the Hospital Units of Care case, only 7% of the variation is explained by the 'best fit' equation relating Hospital Units of Care to Hospital Resource Efficiency. These results indicate that for the states in this national study, the relationship between volume and efficiency is insignificant.

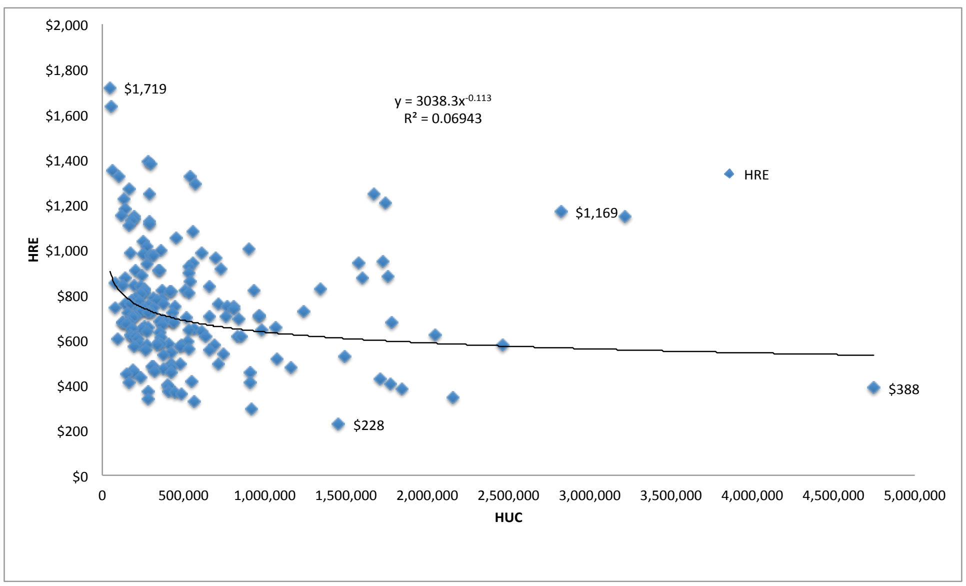


Figure 5.29 Relationship between HUC volume and HRE efficiency.

5.4.2 Analysis of Efficiency Variance in New Jersey Hospitals

What is the cause of the intrastate variation in efficiency? Specifically, can this be attributed to the Top 3 Reasons hospital administrators citep as root causes for efficiency differences in hospitals:

1. Geographic factors (urban versus suburban).

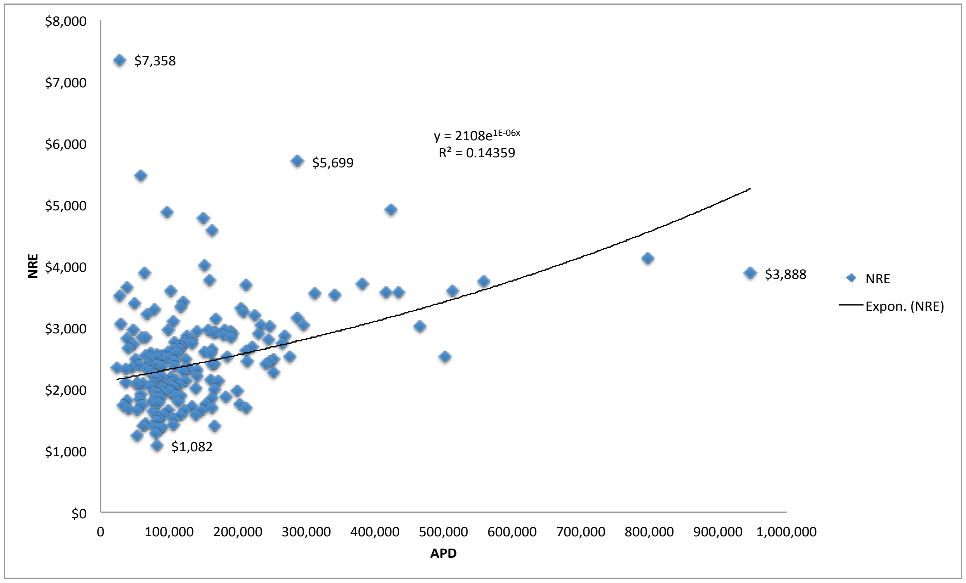


Figure 5.30 Relationship between APD volume and NRE efficiency.

2. Size (large versus small).
3. Teaching status (teaching versus non-teaching).

To answer this question in fulfillment of Research Objective 4, three hypothesis tests are set up to do a test of means of the Indexed Resource Efficiency for the two groups in each set for the State of New Jersey.

Hypothesis Test 1: Does hospital efficiency vary by size? As set up in Table 5.1, the 57 hospitals in New Jersey are split between those with less than 250 beds (small hospitals) and those above 250 beds (large hospitals). A student t-test of means of the Indexed Resource Efficiencies for these hospitals is performed and the results are as displayed in Table 5.2. The two-tailed p-value for this test is 0.6594 at a 95% Confidence Level, indicating that the result is not statistically significant and therefore, *for New Jersey short-term acute care hospitals, efficiency does not vary by size*.

Hypothesis Test 2: Does hospital efficiency vary by location? As set up in Table 5.3, the 57 hospitals in New Jersey are split between those in a 'Core Urban' area versus those in a 'Suburban' area. New Jersey does not have any hospitals classified as 'rural' so median income is used as a proxy for delineating urban from suburban. Using data from the United States Census Bureau, hospitals located in towns where the median household income is less than $65,000 are classified as urban and those above are classified as suburban. The cut off point of $65,000 is chosen as it gave an almost exact split between the two groups of hospitals and this number is in the middle of the range definition for the 'middle class.' A student t-test of means of the Indexed Resource Efficiencies for these hospitals is performed and the results are as displayed in Table 5.4. The two-tailed p-value for this test is 0.5481 at a 95% Confidence Level, indicating that the result is not statistically significant and therefore, *for New Jersey short-term acute care hospitals, efficiency does not vary by urban or suburban location*.

Hypothesis Test 3: Does hospital efficiency vary by teaching status? As set up in Table 5.5, the 57 hospitals in New Jersey are split between those designated by the Association of Teaching hospitals as having a 'teaching' status and those that did not. A student t-test of means of the Indexed Resource Efficiencies for these hospitals is performed and the results are as displayed in Table 5.6. The two-tailed p-value for this test is 0.1666 at a 95% Confidence Level, indicating that the result is not statistically significant and therefore, *for New Jersey short-term acute care hospitals, efficiency does not vary by teaching status*.

The conclusion of this statistical study is therefore, since the three major root causes of variance are not drivers of the variance in hospital efficiency, the only logical conclusion is that the *variation in efficiency is likely caused by management style*.

Table 5.1 Hypothesis Test 1 Data: Efficiency varies by Size

	Group 1: Less than 250 beds (small hospital)	**Group 2: Greater than 250 beds (large hospital)**
Mean	690.74	710.40
SD	204.94	130.37
N	23	34

Table 5.2 Hypothesis Test 1 Results: Efficiency varies by Size

T-test Results	t = 0.4432, df = 55
Standard Error of difference	44.361
Difference of Means (Group 1 - Group 2)	-19.6602
95% confidence interval	From -108.5616 to 69.2410
Two-tailed P value	0.6594
Result	Not statistically significant.

Table 5.3 Hypothesis Test 2 Data: Efficiency varies by Geographic Location

	Group 1: Urban (Median Income Less than $65,000)	Group 2: Suburban (Median Income Greater than $65,000)
Mean	689.10	715.37
SD	156.43	171.09
N	28	29

Table 5.4 Hypothesis Test 2 Results: Efficiency varies by Geographic Location

T-test Results	t = 0.6044, df = 55
Standard Error of difference	43.467
Difference of Means (Group 1 - Group 2)	-26.2708
95% confidence interval	From -113.3813 to 60.8396
Two-tailed P value	0.5481
Result	Not statistically significant.

Table 5.5 Hypothesis Test 3 Data: Efficiency varies by Teaching Status

	Group 1: Teaching hospitals	Group 2: Non-teaching hospitals
Mean	641.05	717.15
SD	172.26	159.30
N	11	46

Table 5.6 Hypothesis Test 3 Results: Efficiency varies by Teaching Status

T-test Results	t = 1.4018, df = 55
Standard Error of difference	54.285
Difference of Means (Group 1 - Group 2)	-76.0982
95% confidence interval	From -184.8878 to 32.6913
Two-tailed P value	0.1666
Result	Not statistically significant.

5.5 Total Performance Matrix

In the early 1970's, the Boston Consulting Group (BCG) developed a model for managing a portfolio of different strategic business units (SBUs) or major product lines. The BCG Growth-Share Matrix is a four-cell (2 by 2) matrix used to perform business portfolio analysis as a step in the strategic planning process [Boston Consulting Group, 1968]. The traditional BCG model maps companies as a scatterplot on two axes - Market Growth versus Relative Market Share and creates a four-quadrant rank to distinguish four groups - Stars, Cash Cows, Dogs and Question Marks. This approach can be modified and applied to hospitals. To complete Research Objective 3, the HRE derived in Section 5.1 is used to create a ranked order of efficiency (Hospital Productivity Index) and is plotted against the U.S. News & World Report Best hospitals state ranking (a proxy for quality). The resulting matrix of US News & World Report Relative Rank versus Hospital Productivity Index, called the Total Performance Matrix gives for the first time a BCG-style quadrant ranking of the best hospitals in a national study and identifies hospitals in four groups - Leaders, Quality Stars, Laggards and Efficiency Stars.

5.5.1 Hospital Productivity Index (HPI)

This section proposes the Hospital Productivity Index (HPI) as an enhancement to the Hospital Resource Efficiency (HRE) measure. The HRE is a dollar amount which is useful for measuring efficiency i.e., hospitals with lower HRE figures as in Section 5.1.3 are better than those with higher dollar amounts per equivalent patient unit of output (Hospital Unit of Care, HUC). The HPI measure uses the HRE as a basis then creates an indexed ranking based on the formula and methodology illustrated in Figure 5.31. This single number can be used to describe a hospital's productivity in reference to others in the national subset. For instance, University of Michigan's HPI = 1.7 indicating that it is 70% more efficient than the average national hospital and John's Hopkins Hospital's HPI = 0.3 indicating that it is 70 % less productive than the average national set hospital.

Research Study Procedure

1. Calculate total cost for all hospitals in national set = $88 billion.
2. Calculate total HUC volume for all hospitals in national set = $151 million.
3. Set average productivity level, HPI = 1.0.
   Whereby HRE = $88 billion/$151 million = $583 = A when HPI = 1.0.
4. Calculate Hospital Resource Efficiency for each hospital (Section 5.1).
5. Calculate total cost for hospitals whose HRE is in the Top 20% of all hospitals in national set = $16 billion.
6. Calculate total HUC volume for hospitals whose HRE is in the Top 20% of all hospitals in national set = $63 million.
7. Set higher than average productivity level, HPI = 1.5.
   Whereby HRE = $16 billion/$63 million = $266 = B where HPI = 1.5.
8. Calculate total cost for hospitals whose HRE is in the Bottom 20% of all hospitals in national set = $27 billion.
9. Calculate total HUC volume for hospitals whose HRE is in the Bottom 20% of all hospitals in national set = $24 million.
10. Set lower than average Productivity Level, HPI = 0.5.
    Whereby HRE = $27 billion/$24 million = $1,141 = C when HPI = 0.5.
11. Calculate HPI for each hospital in the national set.
    Whereby HPI upper = (1+(x-A)*(0.5/(B-A))) at x = HRE less than $583.
    Whereby HPI lower =(0.5+(x-C)*(0.5/(A-C))) at x = HRE greater than $583.

Discussion The HPI number can be calculated for any hospital and if adopted by industry can become a simple and accurate method of reporting on a hospital's operations productivity performance in comparison with others without showing the actual HRE numbers and comparing those directly.

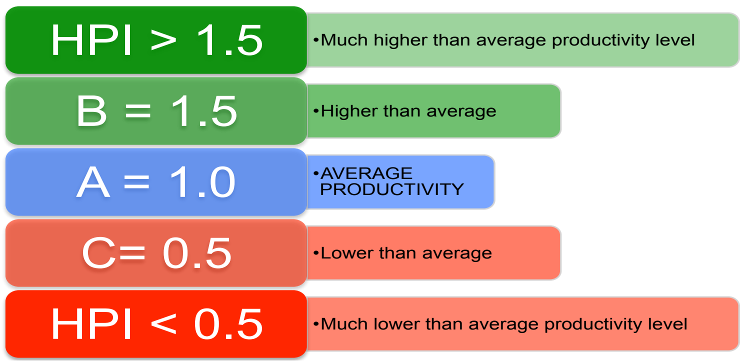


Figure 5.31 Overview of the Hospital Performance Index.

5.5.2 Total Productivity Matrix

The U.S. News & World Report publishes an annual 'best hospitals' report which ranks clinical quality of care for all short-term acute care hospitals in the United States. When combined with the Hospital Resource Efficiency measure (converted to an indexed measure) as Hospital Indexed Productivity, HPI, the Total Productivity Matrix is produced and this completes the goal of Research Objective 3.

5.5.3 Ranking of Honor Roll Hospitals

Hospitals identified by the U.S. News & World Report's 'Honor Roll' of best hospitals - the top seventeen hospitals in the nation to consistently deliver high quality, effective patient care for a range of complex cases in a broad spectrum of specialties. These hospitals are considered to be the 'best of the best.'

Dataset The 17 Honor Roll hospitals are Duke University Hospital, the The Johns Hopkins Hospital, Ronald Reagan UCLA Medical Center, Stanford University Hospital, University of Michigan Hospital, The University of Pennsylvania Hospital, University of Pittsburgh Hospital, University of Washington Medical Center, The Mayo Clinic, Barnes Jewish Hospital, Vanderbilt Hospital, Mount Sinai Hospital, University of San Francisco Hospital, Cleveland Clinic, New York Presbyterian Hospital, Massachusetts General Hospital, and Brigham and Women's Hospital.

Research Study Procedure

1. Select hospitals (Dataset).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
4. Calculate Hospital Productivity Index (Section 5.5.1).
5. Convert U.S. News Rank to Rank Score.
   Rank Score =1-((y - 1)/z) and y = U.S. News Rank; z = lowest rank in list.
6. Generate table generated of HPI versus Rank Score (Figure 5.32).
7. Generate graph of Quality (Rank Score whereby 1 = highest) vs. Efficiency (HPI whereby 1.7 = highest) (Figure 5.33).

Discussion The Honor Roll hospitals are displayed as a single quadrant in recognition of the fact that these are all *Leaders* among hospitals. These hospitals represent the top 0.4 % of all U.S. hospitals in quality and clinical outcomes. *The Mayo Clinic and Ronald Reagan UCLA hospital rank highest in both quality and efficiency*.

5.5.4 Ranking of Pennsylvania Hospitals

The State of Pennsylvania has the largest number of hospitals represented in the national study and has the same hospital cost as the national average [Kaiser Family Foundation,

Hospital	State	HRE	U.S. News Rank	HPI	Rank Score
Massachusetts General	MA	$1,206	1	0.43	1.00
Johns Hopkins Hospital	MD	$1,729	2	0.30	0.94
Mayo Clinic	MN	$712	3	0.88	0.88
Cleveland Clinic	OH	$1,144	4	0.49	0.82
Ronald Reagan UCLA	CA	$351	5	1.37	0.76
Barnes-Jewish	MO	$878	6	0.73	0.71
NY Presbyterian	NY	$1,169	7	0.47	0.65
Duke University	NC	$620	8	0.97	0.59
Brigham and Women's	MA	$1,245	9	0.40	0.53
U Pittsburgh	PA	$388	10	1.31	0.47
Hospital of the Univ of Pennsylvania*~	PA	$576	10	1.02	0.47
NYU Langorne Medical Center**	NY		11		
Northwestern Hospital**	IL		12		
UC San Francisco	CA	$947	13	0.67	0.29
University of Washington*~	WA		13	0.36	0.29
Vanderbilt*~	TN	$882	14	0.73	0.24
Mount Sinai	NY	$941	14	0.68	0.24
Indiana University Health**	IN		16		
University of Michigan	MI	$151	17	1.70	0.06

*~ = not ranked in 2012-2013 Honor Roll, 2011-2012 ranking displayed ** = not ranked in 2011 - 2012

Figure 5.32 Honor Roll hospitals' data.
Source: [U.S.News, 2011; U.S.News, 2012].

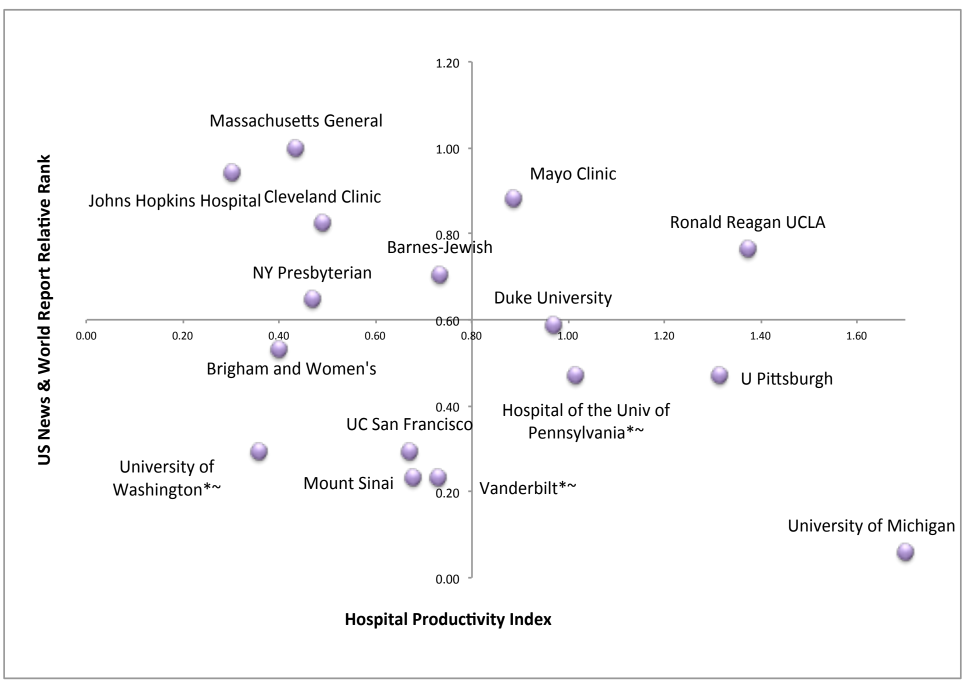


Figure 5.33 Distribution of Honor Roll hospitals.

2011]. Pennsylvania is selected for detailed quality and efficiency analysis through the hospital-modified Total Performance Matrix.

Dataset The 85 hospitals included in this study are the same as Chapter 4.

Research Study Procedure

1. Select hospitals (Dataset).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
4. Calculate Hospital Productivity Index (Section 5.5.1).
5. Convert U.S. News Rank to Rank Score.
   Rank Score =1-((y - 1)/z). where y = U.S. News Rank and z = Lowest rank in list.
6. Generate table of HPI versus Rank Score (Figure 5.34).
7. Generate table of Quality (Rank Score where 1 = highest) versus Efficiency (HPI where 1.7 = highest) (Figure 5.35).

Total Performance Matrix The four quadrants of the Total Performance Matrix are determined by the intersection of the midpoints of the two axes - U.S. News & World Report Relative Rank and Hospital Productivity Index. Hospitals in the first quadrant (Upper Right) are considered to be 'Leaders' as they are able to deliver high quality care in an efficient manner - the aim of all hospitals. hospitals in the second quadrant (Upper Left) are considered to be 'Quality Stars' as they deliver high quality care at a high cost but are still able to serve a population because of their quality. Hospitals in the third quadrant are considered to be 'Laggards' and this is an undesirable position as these hospitals deliver lower than average quality at a lower than average level of quality. Hospitals in the fourth quadrant are considered to be 'Efficiency Stars' and the hospitals which are more productive than average. As these hospitals deliver care in an efficient manner - the assumption is that they will be able to improve their quality of care and become 'Leaders.'

Discussion The 33 hospitals in Pennsylvania with U.S. News & World Report ranking and which fit with the inclusion criteria for this study (short-term, acute care hospitals above 70 beds) are clustered toward the right side of the chart. These results indicate that Pennsylvania is a model state for productivity as most of their hospitals are in the two most efficient quadrants. *The 'best hospitals in Pennsylvania' are UPMC - University of Pittsburgh Medical Center (PA 10) and The Hospital of the University of Pennsylvania (PA 41).*

Hospital	Hospital Code	HRE Rank	HRE	U.S. News Rank	HPI	Rank Score
UPMC U Pittsburgh Presbyterian	PA 10	3	$388	1	1.19	1.00
U Pittsburgh Keesport	PA 48	18	$615	1	0.87	1.00
Hospital of the Univ of Pennsylvania	PA 41	16	$576	2	1.14	0.98
Thomas Jefferson Univ Hospital	PA 78	32	$827	3	0.78	0.95
Magee-Womens	PA 64	27	$696	4	0.90	0.93
Lehigh Valley Hospital - Cedar Crest	PA 70	29	$726	5	0.87	0.90
Allegheny General Hospital	PA 52	20	$642	6	1.18	0.88
Albert Einstein	PA 66	28	$704	10	0.89	0.78
Penn State Milton S. Hershey MC	PA 5	2	$345	14	0.86	0.68
Geisinger	PA 15	4	$424	15	1.34	0.65
Lancaster General	PA 77	31	$819	15	0.79	0.65
Hahnemann Univ Hospital	PA 19	5	$457	18	1.26	0.58
Temple Univ Hospital	PA 31	10	$527	18	0.92	0.58
Western Pennsylvania Forbes	PA 40	15	$575	18	0.84	0.58
St Luke's Hospital - Bethlehem	PA 63	26	$692	18	0.90	0.58
The Western Pennsylvania Hospital	PA 39	14	$575	22	0.90	0.48
St Vincent Health Center	PA 2	1	$294	23	1.04	0.45
Lankenau Hospital	PA 54	22	$648	23	1.20	0.45
Lehigh Valley Hospital - Muhlenberg	PA 20	6	$457	26	0.99	0.38
York Hospital	PA 56	23	$652	26	1.00	0.38
Paoli Hospital	PA 72	30	$729	28	0.87	0.33
U Pittsburgh Passavant	PA 38	13	$573	29	1.20	0.30
Delaware Cty Mem Hospital	PA 23	8	$473	30	1.20	0.28
U Pittsburgh St Margaret	PA 33	11	$541	30	0.96	0.28
Robert Packer Hospital	PA 42	17	$583	30	1.28	0.28
Bryn Mawr Hospital	PA 62	25	$689	30	0.91	0.28
Regional Hospital of Scranton	PA 21	7	$461	34	0.98	0.18
U Pittsburgh - Mercy	PA 34	12	$555	34	0.79	0.18
Aria Health - Torresdale	PA 51	19	$640	34	0.89	0.18
Alle-Kiski	PA 53	21	$646	34	1.05	0.18
The Reading Hospital	PA 85	33	$913	34	0.70	0.18
Crozer-Chester	PA 25	9	$478	39	0.98	0.05
Holy Spirit Hospital	PA 61	24	$687	39	0.71	0.05

Figure 5.34 The best hospitals in Pennsylvania.
Source: [U.S.News, 2012].

5.5.5 Ranking of New Jersey Hospitals

The State of New Jersey has the second largest number of hospitals represented in the national study and is in the highest quadrant of hospital cost compared national average [Kaiser Family Foundation, 2011]. It is also a state with the highest density of hospitals in the nation. New Jersey is therefore selected for detailed quality and efficiency analysis through the hospital-modified Total Performance Matrix.

Dataset The 55 hospitals included in this study are the same as Chapter 4.

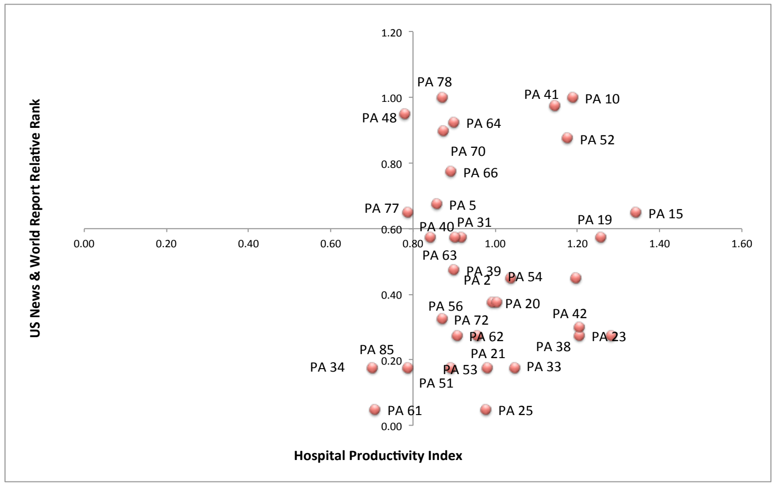


Figure 5.35 Total performance chart of best hospitals in Pennsylvania.

Research Study Procedure

1. Select hospitals (Dataset).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
4. Calculate Hospital Productivity Index (Section 5.5.1).
5. Convert U.S. News Rank to Rank Score.
   Rank Score =1-((y - 1)/z) where y = U.S. News Rank; z = lowest rank in list.
6. Generate table of HPI versus Rank Score (Figure 5.36).
7. Generate graph of Quality (Rank Score where 1 = highest) versus Efficiency (HPI where 1.7 = highest) (Figure 5.37).

Total Performance Matrix The four quadrants of the Total Performance Matrix are determined by the intersection of the midpoints of the two axes - U.S. News & World Report Relative Rank and Hospital Productivity Index. Hospitals in the first quadrant (Upper Right) are considered to be 'Leaders' as they are able to deliver high quality care in an efficient manner - the aim of all hospitals. Hospitals in the second quadrant (Upper Left) are considered to be 'Quality Stars' as they deliver high quality care at a high cost but are still able to serve a population because of their quality. Hospitals in the third quadrant are considered to be ‘Laggards’ and this is an undesirable position as these hospitals deliver lower than average quality at a lower than average level of quality. Hospitals in the fourth quadrant are considered to be ‘Efficiency Stars’ and the hospitals which are more productive than average. As these hospitals deliver care in an efficient manner - the assumption is that they will be able to improve their quality of care and become ‘Leaders.’

Discussion The 23 hospitals in New Jersey with U.S. News & World Report ranking and which fit with the inclusion criteria for this study (short-term, acute care hospitals above 70 beds) are clustered toward the center of the chart. This indicates that most New Jersey hospitals are at an average productivity level with just a few exceptions and that quality varies widely. *The ‘best hospitals in New Jersey’ are a close tie between Morristown Medical Center (NJ 1) and Robert Wood Johnson University Hospital (NJ 2).*

Hospital	Hospital Code	HRE Rank	HRE	U.S. News Rank	HPI	Rank Score
Hackensack Univ MC	NJ 18	6	$677	1	0.92	1.00
Robert Wood Johnson Univ Hosp	NJ 2	2	$405	2	1.29	0.96
Morristown MC	NJ 1	1	$384	3	1.32	0.91
Jersey Shore Univ MC	NJ 25	8	$705	5	0.89	0.83
Englewood Hosp and MC	NJ 34	12	$747	5	0.85	0.83
AtlantiCare Regional MC - City	NJ 30	10	$738	5	0.86	0.83
Holy Name Hosp	NJ 38	15	$775	6	0.83	0.78
St Barnabas MC	NJ 9	3	$613	9	0.98	0.65
Overlook MC	NJ 45	18	$818	9	0.79	0.65
Newark Beth Israel MC	NJ 10	4	$616	9	0.97	0.65
The Valley Hosp	NJ 36	14	$758	12	0.84	0.52
Monmouth MC	NJ 40	16	$783	12	0.82	0.52
St Joseph's Regional MC	NJ 33	11	$747	14	0.85	0.43
Capital Health Sys - Fuld	NJ 41	17	$786	14	0.82	0.43
UMDNJ The Univ Hosp	NJ 54	23	$988	16	0.63	0.35
Hunterdon MC	NJ 27	9	$721	16	0.88	0.35
Riverview MC	NJ 47	19	$821	19	0.79	0.22
St Michael's MC	NJ 35	13	$757	20	0.84	0.17
Our Lady of Lourdes MC	NJ 50	21	$843	20	0.77	0.17
Ocean MC	NJ 48	20	$828	20	0.78	0.17
Jersey City MC	NJ 53	22	$974	20	0.65	0.17
East Orange General Hosp	NJ 12	5	$618	20	0.97	0.17
Clara Maass MC	NJ 20	7	$681	20	0.91	0.17

Figure 5.36 The best hospitals in New Jersey.
Source: [U.S.News, 2012].

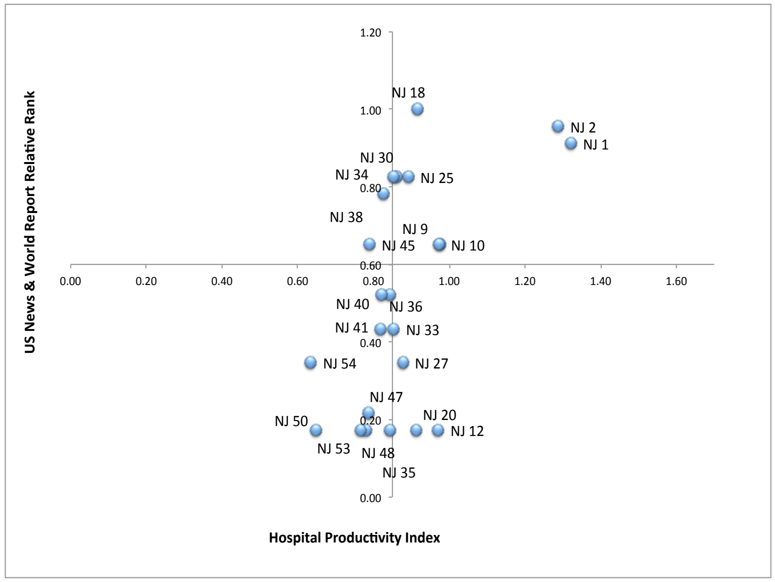


Figure 5.37 Total performance chart of the best hospitals in New Jersey.

5.5.6 Ranking of National Hospitals

The Total Performance Matrix is uniquely derived for each state. The study in this section is carried out in order to create a national ranking of 'best hospitals' as represented by the national subset of states - Nebraska, New Jersey, Pennsylvania, South Dakota, and Washington.

Dataset The 200 hospitals included in this study are the same as Chapter 4.

Research Study Procedure

1. Select hospitals (Dataset).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate Hospital Resource Efficiency (HRE) (Equation 5.4).
4. Calculate Hospital Productivity Index (Section 5.5.1).
5. Convert U.S. News Rank to Rank Score for each hospital by state.
   Rank Score =1-((y - 1)/z) where y = U.S. News Rank; z = lowest rank in list.

6. Generate table of HPI versus Rank Score (Figure 5.39) by state.
7. Generate graph of Quality (Rank Score where 1 = highest) versus Efficiency (HPI where 1.7 = highest) (Figure 5.38) whereby the state charts are overlaid on each other.

Total Performance Matrix The four quadrants of the Total Performance Matrix are determined by the intersection of the midpoints of the two axes - U.S. News & World Report Relative Rank and Hospital Productivity Index. Hospitals in the first quadrant (Upper Right) are considered to be 'Leaders' as they are able to deliver high quality care in an efficient manner - the aim of all hospitals. Hospitals in the second quadrant (Upper Left) are considered to be 'Quality Stars' as they deliver high quality care at a high cost but are still able to serve a population because of their quality. Hospitals in the third quadrant are considered to be 'Laggards' and this is an undesirable position as these hospitals deliver lower than average quality at a lower than average level of quality. Hospitals in the fourth quadrant are considered to be 'Efficiency Stars' and the hospitals which are more productive than average. As these hospitals deliver care in an efficient manner - the assumption is that they will be able to improve their quality of care and become 'Leaders.'

Discussion The 69 hospitals in the national dataset with U.S. News & World Report state ranking and which fit with the inclusion criteria for this study (short-term, acute care hospitals above 70 beds) are distributed through three of the four quadrants of the Total Performance Matrix. Visually, there is a tendency for the hospitals to cluster toward right quadrants (leaders) and the center of the chart and along the anti-diagonal. All of the hospitals in Washington State are in the left quadrant of the chart, indicating there is a lower than average level of productivity in this state's hospitals. Only two of Nebraska's hospitals are included in the study (met the criteria for no. of beds and are ranked by U.S. News &World Report) - and both are of average productivity. Likewise, only two South Dakota hospitals met the criteria for inclusion in the study and one is of average productivity and one is ranked as a 'Leader.' *The 'four best hospitals in the national study' are a close tie amongst Morristown Medical Center (NJ 1) and Robert Wood Johnson University Hospital (NJ 2) and UPMC - University of Pittsburgh Medical Center (PA 10) and The Hospital of the University of Pennsylvania (PA 41).*

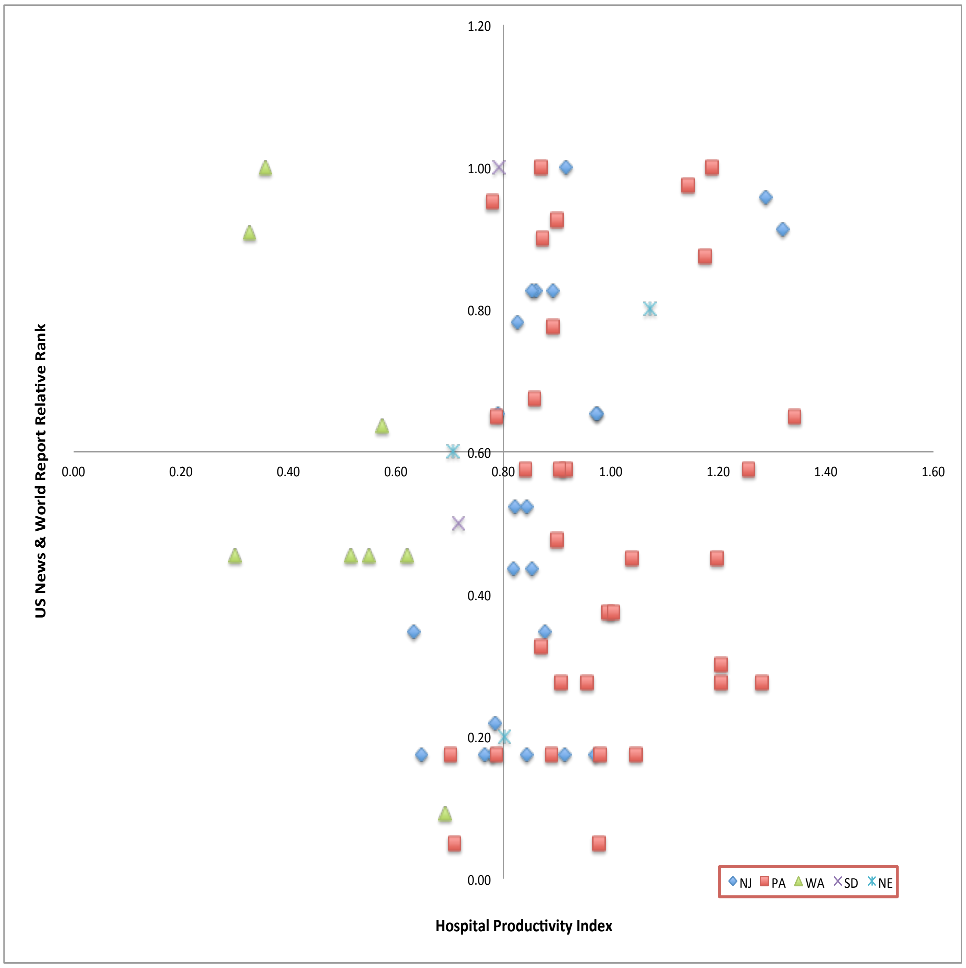


Figure 5.38 Total performance chart of the distribution of national hospitals.

Hospital	Hospital Code	HPI	Rank Score
Morristown Medical Center	NJ 1	1.32	0.91
Robert Wood Johnson Univ Hosp	NJ 2	1.29	0.96
St Barnabas Medical Center	NJ 9	0.98	0.65
Newark Beth Israel Medical Center	NJ 10	0.97	0.65
East Orange General Hosp	NJ 12	0.97	0.17
Hackensack Univ Medical Center	NJ 18	0.92	1.00
Clara Maass Medical Center	NJ 20	0.91	0.17
Jersey Shore Univ Medical Center	NJ 25	0.89	0.83
Hunterdon Medical Center	NJ 27	0.88	0.35
AtlantiCare Regional Medical Center - City	NJ 30	0.86	0.83
St Joseph's Regional Medical Center	NJ 33	0.85	0.43
Englewood Hosp and Medical Center	NJ 34	0.85	0.83
St Michael's Medical Center	NJ 35	0.84	0.17
The Valley Hosp	NJ 36	0.84	0.52
Holy Name Hosp	NJ 38	0.83	0.78
Monmouth Medical Center	NJ 40	0.82	0.52
Capital Health Sys - Fuld	NJ 41	0.82	0.43
Overlook Medical Center	NJ 45	0.79	0.65
Riverview Medical Center	NJ 47	0.79	0.22
Ocean Medical Center	NJ 48	0.78	0.17
Our Lady of Lourdes Medical Center	NJ 50	0.77	0.17
Jersey City Medical Center	NJ 53	0.65	0.17
UMDNJ The Univ Hosp	NJ 54	0.63	0.35
St Vincent Health Center	PA 2	1.04	0.45
Penn State Milton S. Hershey Medical Center	PA 5	0.86	0.68
UPMedical Center U Pittsburgh Presbyterian	PA 10	1.19	1.00
Geisinger	PA 15	1.34	0.65
Hahnemann Univ Hospital	PA 19	1.26	0.58
Lehigh Valley Hospital - Muhlenberg	PA 20	0.99	0.38
Regional Hospital of Scranton	PA 21	0.98	0.18
Delaware Cty Mem Hospital	PA 23	1.20	0.28
Crozer-Chester	PA 25	0.98	0.05
Temple Univ Hospital	PA 31	0.92	0.58
U Pittsburgh St Margaret	PA 33	0.96	0.28
U Pittsburgh - Mercy	PA 34	0.79	0.18
U Pittsburgh Passavant	PA 38	1.20	0.30
The Western Pennsylvania Hospital	PA 39	0.90	0.48
Western Pennsylvania Forbes	PA 40	0.84	0.58
Hospital of the Univ of Pennsylvania	PA 41	1.14	0.98
Robert Packer Hospital	PA 42	1.28	0.28
U Pittsburgh Keesport	PA 48	0.87	1.00
Aria Health - Torresdale	PA 51	0.89	0.18
Allegheny General Hospital	PA 52	1.18	0.88
Alle-Kiski	PA 53	1.05	0.18
Lankenau Hospital	PA 54	1.20	0.45
York Hospital	PA 56	1.00	0.38
Holy Spirit Hospital	PA 61	0.71	0.05
Bryn Mawr Hospital	PA 62	0.91	0.28
St Luke's Hospital - Bethlehem	PA 63	0.90	0.58
Magee-Womens	PA 64	0.90	0.93
Albert Einstein	PA 66	0.89	0.78
Lehigh Valley Hospital - Cedar Crest	PA 70	0.87	0.90
Paoli Hospital	PA 72	0.87	0.33
Lancaster General	PA 77	0.79	0.65
Thomas Jefferson Univ Hospital	PA 78	0.78	0.95
The Reading Hospital	PA 85	0.70	0.18
Providence Regional Medical Center	WA 3	0.69	0.09
Swedish Medical Center / First Hill	WA 9	0.62	0.45
Southwest Washington Medical Center	WA 12	0.57	0.64
Tacoma General Hosp	WA 13	0.55	0.45
Swedish Medical Center / Cherry Hill	WA 15	0.52	0.45
Univ of Washington Medical Center	WA 22	0.36	1.00
Harborview Medical Center	WA 23	0.33	0.91
Valley Medical Center	WA 24	0.30	0.45
Avera Kennan Health Center	SD 1	0.79	1.00
Sanford USD Sioux Falls	SD 2	0.72	0.50
Methodist Hospital	NE 1	1.07	0.80
Immanuel	NE 4	0.80	0.20
Bergan Mercy	NE 5	0.71	0.60

Figure 5.39 Total performance table (HPI) - distribution of national hospitals.
Source: [U.S.News, 2012].

CHAPTER 6

ANALYSIS OF INPATIENT CASE MIX VERSUS LENGTH OF STAY AND CORRELATION BETWEEN OUTPATIENT SERVICES

This chapter presents two studies (i) an analysis of the relationship between the two major descriptors of inpatient service - Case Mix Index and Length of Stay for a single state and (ii) a correlation study of volume amongst outpatient services categories for in a national study represented by five states. These two studies, with the studies in Section 5.4, which examine efficiency variance, complete Research Objective 4.

6.1 Inpatient Case Mix Index and Length of Stay

The United States uses a *case mix system* for classifying hospital inpatients as detailed in Section 2.2.2. This system categorizes patients into segments or diagnosis related groups (DRGs) based on clinical information abstracted from patient records (charts). The purpose of this classification is to reimburse hospitals through a system which acknowledges cost differences associated with the range of patient conditions and levels of criticality. Each DRG is associated with a relative cost weight which is combined with a constant dollar multiplier to represent the mean cost of patients in the group (mean DRG cost).

This system is critical to hospital accounting as hospitals are reimbursed by payers (typically insurance companies or Medicare/Medicaid) based on cost weight which is the mean patient cost of the patient's case mix group [Sutherland and Botz, 2006]. Under this system, hospitals receive a pre-determined reimbursement rate for service packages based on DRG. When actual costs exceed the pre-determined rate, hospitals are expected to absorb the extra cost and in this way, theoretically, hospitals are disincentivized from over prescribing treatment for the sake of increasing reimbursement [Lehtonen, 2007]. Colloquial wisdom holds that case mix index is directly related to length of stay, i.e., patients who are more critically ill require a longer inpatient stay. The following study was performed to test this belief.

Dataset The six hospitals in South Dakota which fit the study criteria (short-term, acute care hospitals above 70 beds) are listed in Appendix B and are the same hospitals used in the national studies in Chapters 4 and 5. Inpatient Service Categories: Cardiology, Cardiovascular Surgery, Gynecology, Medicine, Neurology, Neurosurgery, Obstetrics and Oncology, Orthopedic Surgery, Orthopedics, as well as Pulmonology, Surgery, Surgery for Malignancy, Urology and Vascular Surgery and Psychiatry.

Research Study Procedure

1. Select hospitals (Dataset).
2. Convert inpatient days to Hospital Units of Care (Equation 5.5).
3. Calculate average Case Mix Index and average length of stay data for each hospital by inpatient service category.
4. Perform a two variable correlation study for each Case Mix Index/average length of stay data pair.
5. Generate table of significant 'R' values (Table 6.1).

Results For the sixteen categories of inpatient services, thirteen significant pairs are found as shown in Table 6.1. Same service pairs are Obstetrics, Medicine, Neurosurgery, Gynecology, Surgery for Malignancy, Orthopedics, Vascular Surgery, Surgery, Oncology and Psychiatry. In Obstetrics, the strongest relationship, there is a perfect correlation between the average Case Mix Index and average length of stay.

The weakest relationship, Psychiatry had an R value of 0.86 indicating that at $R^2 = 0.74$, up to 74% of the variation in average length of stay could be explained by the case mix index. Surgery case mix index and Medicine average length of stay are strongly correlated (R = 0.93, $R^2 = 0.86$). Vascular Surgery and Cardiovascular surgery are also closely related for both services' case mix index and average length of stay (R = 0.9, $R^2 = 0.81$). All other services' results are inconclusive.

Discussion The results of this study constitute a significant finding and addition to the current body of knowledge in that this is one of the first studies to produce a correlation matrix for inpatient services. This information can be used by hospitals to anticipate volume increase and capacity planning.

Table 6.1 South Dakota Inpatient Correlation Study

Variable 1: Case Mix Index	Variable 2: Length of Stay	R
Obstetrics	Obstetrics	1.
Medicine	Medicine	0.97
Neurosurgery	Neurosurgery	0.96
Gynecology	Gynecology	0.94
Surgery for Malignancy	Surgery for Malignancy	0.93
Surgery	Medicine	0.93
Orthopedics	Orthopedics	0.92
Vascular Surgery	Vascular Surgery	0.91
Vascular Surgery	Cardiovascular Surgery	0.9
Cardiovascular Surgery	Cardiovascular Surgery	0.89
Surgery	Surgery	0.88
Oncology	Oncology	0.86
Psychiatry	Psychiatry	0.86

6.2 Outpatient Volume Correlation Study

The United States uses an *Ambulatory Payment Classification System (APC)* for classifying hospital outpatients as detailed in Section 2.2.2. The Medicare Outpatient Prospective Payment System (OPPS), went into effect on August 1, 2000. Prior to OPPS, Medicare reimbursed hospitals based on actual costs incurred in outpatient care delivery. Under OPPS, Medicare classifies hospital outpatient services into approximately 800 ambulatory payment classifications (APCs) based on clinical and cost similarity. Centers for Medicare and Medicaid Services (CMS) establishes a relative weight for each APC; this weight reflects the resource costs associated with services in the APC.

The relative weight is then multiplied by a conversion factor to arrive at a national unadjusted payment rate for each APC. The labor portion (60%) of this national rate is adjusted for local wage differences using the hospital wage index. Hospitals also receive other adjustments for certain new technologies (called pass-through payments) and for unusually costly services (called outlier payments).

All services in the same APC are reimbursed at the same predetermined amount, regardless of the actual treatment cost, with adjustments for local labor costs, certain hospitals, and outlier cases [He and Mellor, 2012]. The Service Mix Index is the average of APC relative weights for all claims (based only on APCs with non-zero relative weights) [American Hospital Association, 2011]. A single outpatient visit can generate multiple units of service. For instance, one outpatient pharmacy visit can be associated with multiple units of pharmacy service or a single visit to the emergency department can result in several units of service of Diagnostic Laboratory service, IV Therapy service and other services. As hospitals encounter increasing outpatient volume, the question arises *are different outpatient services correlated?*

Dataset The 203 (short-term, acute care, above 70 bed) hospitals included in this study are the same as in the Chapter 5 Benchmark and National Productivity Studies (no initial exclusions): Benchmark/Excellence - 14, Nebraska - 11, New Jersey - 57, Pennsylvania - 89, South Dakota - 6, Washington - 26.

Research study procedure

1. Select hospitals (Dataset).
2. Generate list of outpatient services (Table 6.2).
3. Generate dataset of units of service per outpatient service type.

4. Remove hospitals with incomplete data (services with volume information missing i.e., units of service).
5. Generate list of 42 hospitals with complete data (units of service for 33 types of outpatient service) (Figure 6.3).
6. Run Minitab regression model for outpatient units of service (Figure 6.1) to display p values for significant correlations. Services with no significant correlation to another service are removed from the results chart (Example, Service 2: IV Therapy).

Results There are 23 types of outpatient services with significant correlations to other services. Figure 6.1 identifies the significant correlations (p values). IV Therapy, Laboratory for Pathology, Operating Room Services, Anesthesia, Other Imaging Services, Respiratory Service, Occupational Therapy, Pulmonary Function, Magnetic Resonance, Gastrointestinal Services and Treatment Room - these are not significantly correlated to any other service types.

Service	1	3	4	6	7	8	9	12	15	16	17	18	20	21	22	24	25	26	27	29	31	32	33
1		0.034										0.015		0.019				0.003					
3	0.034																						
4																		0.032			0.024		
6					0.001		0.002				0.023	0.004					0.045						
7				0.001			0.001		0.029		0.005	0.001		0.025			0.008			0.008		0.029	
8											0.002				0.02	0.038							
9				0.002	0.001				0.016			0.004		0.041			0.007					0.012	
12											0.022											0.024	
15					0.029		0.016				0.005			0.043			0.004					0.004	
16																							
17				0.023	0.005		0.002	0.022	0.016			0.009		0.018			0.003					0.003	0.008
18	0.015			0.004	0.001		0.004				0.009			0.047			0.045	0.015		0.008			
20																			0.048				0.04
21	0.019				0.025		0.041		0.043		0.018	0.047						0.004					
22						0.02										0.043							
24						0.038									0.043								
25				0.045	0.008		0.007		0.004		0.003	0.045										0.012	0.041
26	0.003		0.032									0.015		0.004									
27													0.048										
29					0.008							0.023											
31			0.024																				
32					0.029		0.012	0.024	0.004		0.003						0.012						0.016
33							0.039				0.008		0.04				0.041					0.016	

Figure 6.1 Statistical study of outpatient services.

Discussion The results of this study constitute a significant finding and addition to the current body of knowledge in that this is one of the first studies to produce a correlation matrix for outpatient services. This information can be used by hospitals to anticipate volume increase and capacity planning.

Subscript	Outpatient Service Type	Subscript	Outpatient Service Type
k = 1	Pharmacy	k = 17	Speech-Language Pathology
k = 2	IV Therapy	k = 18	Emergency Room
k = 3	Medical Surgical Supplies	k = 19	Pulmonary Function Service
k = 4	Laboratory	k = 20	Cardiology
k = 5	Laboratory - Pathology	k = 21	Cardiac Cath Lab
k = 6	Radiology - Diagnostic	k = 22	Clinic
k = 7	Radiology - Therapeutic	k = 23	Magnetic Resonance
k = 8	Nuclear Medicine	k = 24	Drugs with Specific Identification
k = 9	CT Scan	k = 25	Magnetic Resonance Technology
k = 10	Operating Room Service	k = 26	EKG/ECG (Electrocardiograph)
k = 11	Anesthesia	k = 27	EEG (Electroencephalograph)
k = 12	Blood Storage and Processing	k = 28	Recovery Room
k = 13	Other Imaging Service	k = 29	Observation Room
k = 14	Respiratory Service	k = 30	Treatment Room
k = 15	Physical Therapy	k = 31	Other Diagnostic Service
k = 16	Occupational Therapy	k = 32	Other Therapeutic Service

Figure 6.2 Outpatient services list.

No	Hospital	State
1.	The Cleveland Clinic	OH
2.	Las Palmas Medical Center	TX
3.	Massachusetts General Hospital	MA
4.	Saint Luke's Hospital	IA
5.	Ronald Reagan UCLA Medical Center	CA
6.	BryanLGH Medical Center East	NE
7.	Regional West Medical Center	NE
8.	Saint Elizabeth Regional Medical Center	NE
9.	Englewood Hospital and Medical Center	NJ
10.	Jersey Shore University Medical Center	NJ
11.	Monmouth Medical Center	NJ
12.	Morristown Medical Center	NJ
13.	Robert Wood Johnson University Hospital	NJ
14.	Saint Barnabas Medical Center	NJ
15.	Somerset Medical Center	NJ
16.	Southern Ocean Medical Center	NJ
17.	Altoona Hospital	PA
18.	Chambersburg Hospital	PA
19.	Easton Hospital	PA
20.	Geisinger Medical Center	PA
21.	Grand View Hospital	PA
22.	University of Pittsburgh Medical Center Horizon - Greenville	PA
23.	Harrisburg Hospital	PA
24.	Heritage Valley Beaver	PA
25.	Lancaster General	PA
26.	Memorial Medical Center - Main Campus	PA
27.	Paoli Hospital	PA
28.	University of Pittsburgh Medical Center Passavant - McCandless	PA
29.	Sacred Heart Hospital	PA
30.	Saint Luke's Hospital - Bethlehem Campus	PA
31.	Regional Hospital of Scranton	PA
32.	Sharon Regional Health System	PA
33.	Thomas Jefferson University Hospital	PA
34.	University of Pittsburgh Medical Center Presbyterian	PA
35.	Saint Vincent Health Center	PA
36.	Geisinger Wyoming Valley Medical Center	PA
37.	Avera Saint Luke's Hospital	SD
38.	Southwest Washington Medical Center	WA
39.	Saint Joseph Medical Center	WA
40.	Tacoma General Hospital	WA
41.	Virginia Mason Medical Center	WA
42.	University of Michigan Hospitals and Health Centers	MI

Figure 6.3 Hospitals included in outpatient services study.

CHAPTER 7

SIGNIFICANT FINDINGS AND FUTURE WORK

Significant Findings The research conducted in the production of this dissertation accomplishes the following significant research objectives:

1. Creates a Hospital Operations Excellence Model (HOSx), a flexible, scalable model to measure and evaluate operations efficiency and productivity.
2. Defines a new measure of hospital volume, the Hospital Unit of Care (HUC).
3. Creates a new measure of hospital efficiency, the Hospital Resource Efficiency (HRE).
4. Shows statistically for a cross-section of national hospitals that the HUC is a better predictor of Cost than the traditional inpatient days and adjusted patient days (APD) measures.
5. Shows that the HRE measure can be used to study and benchmark hospital operations performance.
6. Creates a benchmarking scale, the Hospital Productivity Index (HPI) for ranking hospitals operationally.
7. Creates a Total Performance Matrix to be used in benchmarking clinical quality versus operational efficiency for U.S. hospitals.
8. Shows statistically that for New Jersey hospitals, there is no correlation between productivity and size, location, and teaching status.
9. Shows statistically that for South Dakota hospitals, there is a relationship between inpatient case mix index and average length of stay for specific inpatient services.
10. Shows statistically that for a cross-section of national hospitals, there is a correlation between outpatient services for some types of services.

Future Work The research conducted in the production of this dissertation has laid the groundwork for the following future research opportunities:

1. Explore improvements to the HUC Model.

2. Analyze issues with the HUC, such as finding activities that are hidden/currently unaccounted for and perform direct tracing of activities.

3. Explore improvements to the HRE model, such as removal of depreciation, interest and capital cost in the calculation of total cost.

4. Refine the HOSX model to include hospitals that are not recording data in a manner consistent with other hospitals (estimate 20% of U.S. hospitals are non-standardized).

5. Create and distribute to all hospital CEOs in New Jersey a scorecard showing a compendium of the productivity study for the state of New Jersey and offer results and analysis for their hospital.

6. Contribute to Data Envelopment Analysis (DEA) studies which focus on cost inefficiencies in hospitals. The HUC model can be used by researchers in Healthcare Finance to understand cost inefficiencies.

7. Contribute to Hospital IT studies which focus on topics such as the impact of IT budgets on average length of stay, processes and patient outcomes.

APPENDIX A

ELEMENTS OF THE HOSPITAL UNIT OF CARE

Figure A.1 presents the symbol table of indices for the Hospital Unit of Care (HUC) load equation.

Subscript	Ancillary Service Type
p=1	Operating Room
p =2	Recovery Room
p =3	Delivery/Labor Room
p =4	Anesthesiology
p =5	Radiology-Diagnostic
p =6	Radiology-Therapeutic
p =7	Radioisotope
p =8	Laboratory
p =9	PBP Clinical Lab Services
p =10	Whole Blood/Packed RBC
p =11	Blood Stor, Process, Trans
p =12	IV Therapy
p =13	Respiratory Therapy
p =14	Physical Therapy
p =15	Speech Pathology
p =16	Electrocardiology
p =17	Electroencephalography
p =18	Renal Dialysis
p =19	ASC (non-distinct part)
p =20	Other

Subscript	Inpatient Service Type
i=1	Cardiology
i=2	Cardiovascular Surgery
i=3	Gynecology
i=4	Medicine
i=5	Neurology
i=6	Neurosurgery
i=7	Obstetrics
i=8	Oncology
i=9	Orthopedic Surgery
i=10	Orthopedics
i=11	Psychiatry
i=12	Pulmonology
i=13	Surgery
i=14	Surgery for Malignancy
i=15	Urology
i=16	Vascular Surgery

Subscript	Intensive Care Type
j = 1	General
j = 2	Coronary
j = 3	Burn
j = 4	Surgical
j = 5	Psychiatric
j = 6	Pediatric
j = 7	Neonatal
j = 8	Trauma
j = 9	Detox
j = 10	Premature

Subscript	Outpatient Service Type
k = 1	Pharmacy
k = 2	IV Therapy
k = 3	Medical Surgical Supplies
k = 4	Laboratory
k = 5	Laboratory - Pathology
k = 6	Radiology - Diagnostic
k = 7	Radiology - Therapeutic
k = 8	Nuclear Medicine
k = 9	CT Scan
k = 10	Operating Room Service
k = 11	Anesthesia
k = 12	Blood Storage and Processing
k = 13	Other Imaging Service
k = 14	Respiratory Service
k = 15	Physical Therapy
k = 16	Occupational Therapy
k = 17	Speech-Language Pathology
k = 18	Emergency Room
k = 19	Pulmonary Function Service
k = 20	Cardiology
k = 21	Cardiac Cath Lab
k = 22	Clinic
k = 23	Magnetic Resonance
k = 24	Drugs with Specific Identification
k = 25	Magnetic Resonance Technology
k = 26	EKG/ECG (Electrocardiograph)
k = 27	EEG (Electroencephalograph)
k = 28	Recovery Room
k = 29	Observation Room
k = 30	Treatment Room
k = 31	Other Diagnostic Service
k = 32	Other Therapeutic Service

Figure A.1 Inpatient case mix category types (i), Intensive care types (j), Outpatient service types (k), and Ancillary service types (p).

APPENDIX B

HOSPITAL DATASET

Figures B.1, B.2, B.3 show selected data for all hospitals in Nebraska, South Dakota, Washington, New Jersey, Pennsylvania and the *U.S. News* Honor Roll set.

Identifier Code	Nebraska Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE	Scaled BRE	Scaled NRE	Scaled HRE
NE X	BryanLGH MC East	295	83,774	132,816	$433,572,254	$432,596,222	2,228,406	$5,164	$3,257	$194	16.78	0.06	1.08	1.17	0.23
NE Y	The Nebraska MC	509	141,403	231,395	$773,621,131	$730,646,401	2,389,064	$5,167	$3,158	$306	10.32	0.10	1.08	1.13	0.37
NE 1	Methodist Hosp	423	90,229	166,611	$379,223,000	$401,265,000	744,358	$4,447	$2,408	$539	4.47	0.22	0.93	0.86	0.65
NE 2	Creighton Univ MC - St Joseph Hosp	208	46,180	65,256	$182,264,053	$185,147,477	283,884	$4,009	$2,837	$652	4.35	0.23	0.84	1.02	0.78
NE 3	St Elizabeth Regional MC	265	63,309	105,265	$236,980,995	$214,919,530	284,749	$3,395	$2,042	$755	2.71	0.37	0.71	0.73	0.91
NE 4	Immanuel MC	194	47,679	72,518	$206,026,421	$187,282,863	233,033	$3,928	$2,583	$804	3.21	0.31	0.82	0.92	0.97
NE 5	Bergan Mercy MC	461	87,579	139,900	$307,016,575	$322,777,827	355,909	$3,686	$2,307	$907	2.54	0.39	0.77	0.83	1.09
NE 6	Good Samaritan Hosp	179	39,139	60,199	$185,554,503	$171,006,089	173,644	$4,369	$2,841	$985	2.88	0.35	0.91	1.02	1.18
NE 7	St Francis MC	137	26,278	56,914	$149,343,287	$136,090,857	117,817	$5,179	$2,391	$1,155	2.07	0.48	1.08	0.86	1.39
NE 8	Regional West MC	123	25,139	48,848	$174,532,096	$165,971,670	135,269	$6,602	$3,398	$1,227	2.77	0.36	1.38	1.22	1.47
NE 9	Fremont Area MC	90	13,861	26,840	$96,692,864	$94,455,467	57,805	$6,814	$3,519	$1,634	2.15	0.46	1.42	1.26	1.96
State Total		2884	664,570	1,106,561	$3,124,827,179	$3,042,159,403	7,003,939								
State Average		262	60,415	100,596	$284,075,198	$276,559,946	636,722	$4,796	$2,795	$833			1.00	1.00	1.00

Identifier Code	Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE	Scaled BRE	Scaled NRE	Scaled HRE
SD 1	Avera McKennan Hosp & Univ Health Center	407	97,562	159,880	$379,981,884	$343,292,326	421,424	$3,519	$2,147	$815	2.64	0.38	0.70	0.82	0.70
SD 2	Sanford USD MC Sioux Falls	453	109,637	164,114	$528,650,201	$480,178,276	535,180	$4,380	$2,926	$897	3.26	0.31	0.87	1.12	0.77
SD 3	Rapid City Regional Hosp	304	77,709	124,948	$346,244,966	$311,691,943	342,512	$4,011	$2,495	$910	2.74	0.36	0.80	0.95	0.78
SD 4	Avera St Luke's Hosp	113	21,456	47,364	$141,506,097	$140,177,178	105,872	$6,533	$2,960	$1,324	2.24	0.45	1.30	1.13	1.13
SD 5	Avera Sacred Heart Hosp	100	16,059	29,621	$91,581,343	$90,585,207	67,092	$5,641	$3,058	$1,350	2.27	0.44	1.12	1.17	1.15
SD 6	Avera Queen of Peace Hosp	88	12,560	36,360	$76,393,931	$76,685,437	44,612	$6,106	$2,109	$1,719	1.23	0.82	1.21	0.81	1.47
State Total		1465	334,983	562,288	$1,564,358,422	$1,442,610,367	1,516,692								
State Average		244	55,831	93,715	$260,726,404	$240,435,061	252,782	$5,031	$2,616	$1,169			1.00	1.00	1.00

Indentifier Code	Washington Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE	Scaled BRE	Scaled NRE	Scaled HRE
WA X	Virginia Mason MC	230	64,522	203,930	$790,485,676	$802,286,673	1,536,604	$12,434	$3,934	$522	7.53	0.13	2.12	1.20	0.49
WA 1	Auburn Regional MC	114	28,638	47,065	$135,192,716	$127,932,571	167,851	$4,467	$2,718	$762	3.57	0.28	0.76	0.83	0.71
WA 2	Providence St Peter Hosp	306	84,660	122,132	$377,136,671	$339,235,774	416,557	$4,007	$2,778	$814	3.41	0.29	0.68	0.85	0.76
WA 3	Providence Regional MC	353	102,822	168,844	$504,809,015	$495,304,050	535,421	$4,817	$2,933	$925	3.17	0.32	0.82	0.89	0.87
WA 4	Kadlec Regional MC	229	56,870	99,451	$268,111,164	$258,929,383	276,767	$4,553	$2,604	$936	2.78	0.36	0.78	0.79	0.88
WA 5	St Joseph MC	294	98,518	167,614	$571,928,692	$526,700,580	559,920	$5,346	$3,142	$941	3.34	0.30	0.91	0.96	0.88
WA 6	Sacred Heart MC	567	143,126	203,802	$646,334,718	$674,651,918	698,943	$4,714	$3,310	$965	3.43	0.29	0.80	1.01	0.90
WA 7	Deaconess MC	257	63,869	98,002	$237,452,791	$245,920,586	250,749	$3,850	$2,509	$981	2.56	0.39	0.66	0.76	0.92
WA 8	Overlake Hosp MC	293	72,767	126,385	$382,411,210	$360,964,469	362,537	$4,961	$2,856	$996	2.87	0.35	0.85	0.87	0.93
WA 9	Swedish MC / First Hill	619	148,973	285,770	$1,031,261,504	$901,830,623	900,997	$6,054	$3,156	$1,001	3.15	0.32	1.03	0.96	0.94
WA 10	Yakima Valley Mem Hosp	203	54,982	121,302	$281,288,307	$278,373,571	274,769	$5,063	$2,295	$1,013	2.27	0.44	0.86	0.70	0.95
WA 11	Good Samaritan Hosp	198	54,112	79,441	$310,387,966	$262,254,471	252,427	$4,847	$3,301	$1,039	3.18	0.31	0.83	1.00	0.97
WA 12	Southwest Washington MC	383	93,477	97,547	$470,570,238	$476,633,165	452,275	$5,099	$4,886	$1,054	4.64	0.22	0.87	1.49	0.99
WA 13	Tacoma General Hosp	361	85,517	159,751	$650,773,195	$603,711,290	559,268	$7,060	$3,779	$1,079	3.50	0.29	1.20	1.15	1.01
WA 14	Holy Family Hosp	176	35,273	73,447	$179,813,100	$184,810,014	166,647	$5,239	$2,516	$1,109	2.27	0.44	0.89	0.77	1.04
WA 15	Swedish MC / Cherry Hill	152	34,330	58,785	$328,145,688	$321,710,276	288,141	$9,371	$5,473	$1,117	4.90	0.20	1.60	1.66	1.05
WA 16	Harrison MC - Bremerton	299	63,305	105,166	$339,454,662	$325,368,434	289,272	$5,140	$3,094	$1,125	2.75	0.36	0.88	0.94	1.05
WA 17	Northwest Hosp & MC	162	36,446	68,432	$198,536,636	$219,729,755	193,069	$6,029	$3,211	$1,138	2.82	0.35	1.03	0.98	1.07
WA 18	St John MC	170	39,446	102,926	$236,438,920	$225,492,554	196,181	$5,716	$2,191	$1,149	1.91	0.52	0.98	0.67	1.08
WA 19	Legacy Salmon Creek Hosp	192	38,857	66,021	$174,195,404	$168,427,976	142,501	$4,335	$2,551	$1,182	2.16	0.46	0.74	0.78	1.11
WA 20	St Joseph Hosp	221	56,801	101,790	$371,917,297	$365,215,642	292,502	$6,430	$3,588	$1,249	2.87	0.35	1.10	1.09	1.17
WA 21	Highline MC	214	38,564	81,875	$198,354,528	$205,892,491	162,343	$5,339	$2,515	$1,268	1.98	0.50	0.91	0.77	1.19
WA 22	Univ of Washington MC	326	100,453	161,725	$764,013,655	$742,289,086	574,232	$7,389	$4,590	$1,293	3.55	0.28	1.26	1.40	1.21
WA 23	Harborview MC	326	104,601	149,848	$645,593,959	$715,493,675	540,150	$6,840	$4,775	$1,325	3.60	0.28	1.17	1.45	1.24
WA 24	Valley MC	265	61,896	120,370	$383,980,532	$410,309,207	296,919	$6,629	$3,409	$1,382	2.47	0.41	1.13	1.04	1.29
WA 25	Evergreen Hosp MC	261	58,466	116,078	$354,940,009	$388,466,032	279,356	$6,644	$3,347	$1,391	2.41	0.42	1.13	1.02	1.30
State Total		7171	1,821,291	3,187,497	$10,833,528,253	$10,627,934,266	10,666,395								
State Average		275.81	70,050	122,596	$416,674,164	$408,766,703	410,246	$5,861	$3,287	$1,067			1.00	1.00	1.00

Hospital Code	Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE
EX A	Johns Hopkins Hospital, MD	918	279,417	421,333	$1,727,733,094	$1,525,850,066	882,280	$5,461	$3,621	$1,729	2.09	0.48
EX 5	Mount Sinai, NY	1,032	328,393	415,646	$6,705,342,013	$1,485,467,817	1,578,068	$4,523	$3,574	$941	3.8	0.26
EX 3	Barnes-Jewish, MO	1,168	290,060	465,497	$3,352,261,230	$1,405,407,643	1,600,644	$4,845	$3,019	$878	3.44	0.29
EX 10	Brigham and Women's, MA	763	266,601	422,800	$4,576,101,356	$2,082,986,055	1,673,611	$7,813	$4,927	$1,245	3.96	0.25
EX 6	UCSF, CA	660	184,438	287,252	$5,946,735,288	$1,637,175,538	1,728,527	$8,877	$5,699	$947	6.02	0.17
EX 9	Massachusetts General Hospital, MA	883	279,299	558,434	$5,638,983,396	$2,098,887,000	1,740,484	$7,515	$3,759	$1,206	3.12	0.32
EX 4	Vanderbilt University, TN	754	246,782	435,089	$4,523,130,818	$1,553,191,480	1,761,810	$6,294	$3,570	$882	4.05	0.25
EX B	Stanford University, CA	436	125,556	220,153	$6,705,342,013	$1,824,591,373	11,516,180	$14,532	$8,288	$158	52.31	0.02
EX C	University of Michigan, MI	818	256,512	489,117	$4,117,209,611	$1,921,949,133	12,691,053	$7,493	$3,929	$151	25.95	0.04
EX 1	Duke University, NC	789	252,873	502,819	$3,923,265,234	$1,269,555,874	2,048,541	$5,021	$2,525	$620	4.07	0.25
EX 8	NY-Presbyterian, NY	1,849	601,519	797,712	$8,058,136,000	$3,299,473,879	2,822,023	$5,485	$4,136	$1,169	3.54	0.28
EX D	Ronald Reagan UCLA, CA	439	160,699	220,749	$3,284,974,333	$1,098,900,000	3,132,051	$6,838	$4,978	$351	14.19	0.07
EX 7	Cleveland Clinic, OH	1,284	348,847	947,496	$9,857,534,601	$3,683,893,828	3,218,909	$10,560	$3,888	$1,144	3.4	0.29
EX 2	St Mary's (Mayo Clinic), MN	802	188,422	243,955	$1,336,822,871	$686,834,159	964,778	$3,645	$2,815	$712	3.95	0.25

Figure B.1 Data for Nebraska, South Dakota, Washington and Honor Roll hospitals.

Identifier Code	New Jersey Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE	Scaled BRE	Scaled NRE	Scaled HRE
NJ X	RWJ Univ Hosp Hamilton	248	66,305	105,163	$198,576,437	$201,993,218	1,045,802	$3,046	$1,921	$193	9.94	0.10	0.80	0.74	0.27
NJ Y	Southern Ocean MC	146	27,165	50,932	$120,342,590	$126,221,665	520,440	$4,646	$2,478	$243	10.22	0.10	1.23	0.96	0.35
NJ 1	Morristown MC	554	164,032	233,076	$701,269,618	$707,772,926	1,842,378	$4,315	$3,037	$384	7.90	0.13	1.14	1.17	0.55
NJ 2	Robert Wood Johnson (RWJ)	610	185,115	225,182	$721,753,055	$719,892,755	1,776,920	$3,889	$3,197	$405	7.89	0.13	1.03	1.24	0.58
NJ 3	Meadowlands Hosp MC	200	29,038	37,579	$61,651,698	$68,625,182	168,145	$2,363	$1,826	$408	4.47	0.22	0.62	0.71	0.58
NJ 4	Cooper Univ Hosp	488	123,351	189,186	$542,106,000	$555,219,000	1,077,912	$4,501	$2,935	$515	5.70	0.18	1.19	1.13	0.73
NJ 5	Mountainside Hosp	195	46,877	86,292	$197,628,072	$192,704,341	334,160	$4,111	$2,233	$577	3.87	0.26	1.08	0.86	0.82
NJ 6	South Jersey Healthcare Regional	284	76,271	139,236	$276,644,058	$281,447,674	486,726	$3,690	$2,021	$578	3.50	0.29	0.97	0.78	0.82
NJ 7	Raritan Bay MC	298	76,237	110,007	$230,679,183	$237,230,858	406,610	$3,112	$2,157	$583	3.70	0.27	0.82	0.83	0.83
NJ 8	Palisades MC	202	46,814	62,710	$127,033,000	$131,472,420	217,526	$2,808	$2,096	$604	3.47	0.29	0.74	0.81	0.86
NJ 9	St Barnabas	585	160,658	214,329	$548,448,510	$524,384,506	855,559	$3,264	$2,447	$613	3.99	0.25	0.86	0.95	0.87
NJ 10	Newark Beth Israel MC	451	136,985	178,218	$407,889,300	$512,826,527	831,956	$3,744	$2,878	$616	4.67	0.21	0.99	1.11	0.88
NJ 11	St Peter's Univ Hosp	393	116,398	162,268	$369,558,195	$390,123,396	632,513	$3,352	$2,404	$617	3.90	0.26	0.88	0.93	0.88
NJ 12	East Orange General Hosp	175	42,198	59,057	$106,850,782	$113,325,515	183,424	$2,686	$1,919	$618	3.11	0.32	0.71	0.74	0.88
NJ 13	Cape Regional MC	242	38,410	61,222	$104,282,545	$106,930,817	171,639	$2,784	$1,747	$623	2.80	0.36	0.73	0.68	0.89
NJ 14	Community MC	473	137,937	182,413	$336,821,992	$343,316,269	533,699	$2,489	$1,882	$643	2.93	0.34	0.66	0.73	0.92
NJ 15	Christ Hosp	227	55,644	78,696	$125,144,762	$159,754,867	245,408	$2,871	$2,030	$651	3.12	0.32	0.76	0.78	0.93
NJ 16	St Mary's Hosp	264	50,333	72,783	$173,585,000	$170,970,968	258,379	$3,397	$2,349	$662	3.55	0.28	0.90	0.91	0.94
NJ 17	Bayshore Community Hosp	140	39,744	55,847	$101,044,505	$102,566,829	152,667	$2,581	$1,837	$672	2.73	0.37	0.68	0.71	0.96
NJ 18	Hackensack Univ MC	677	230,196	341,424	$1,118,412,543	$1,205,639,475	1,779,955	$5,237	$3,531	$677	5.21	0.19	1.38	1.36	0.96
NJ 19	Our Lady of Lourdes MC	370	89,953	111,716	$274,343,675	$300,859,647	443,601	$3,345	$2,693	$678	3.97	0.25	0.88	1.04	0.97
NJ 20	Clara Maass MC	291	82,022	114,884	$247,815,570	$239,344,329	351,543	$2,918	$2,083	$681	3.06	0.33	0.77	0.81	0.97
NJ 21	Somerset MC	274	82,637	107,077	$619,028,796	$261,694,104	382,677	$3,167	$2,444	$684	3.57	0.28	0.84	0.94	0.97
NJ 22	Virtua Mem Hosp Burlington Cty	307	84,170	125,054	$307,945,000	$293,758,000	429,518	$3,490	$2,349	$684	3.43	0.29	0.92	0.91	0.97
NJ 23	St Francis MC	180	37,227	52,045	$129,287,964	$129,781,494	185,609	$3,486	$2,494	$699	3.57	0.28	0.92	0.96	1.00
NJ 24	Kimball MC	294	67,972	91,818	$117,482,625	$144,740,686	205,568	$2,129	$1,576	$704	2.24	0.45	0.56	0.61	1.00
NJ 25	Jersey Shore Univ MC	504	143,362	181,027	$559,729,000	$535,354,000	758,893	$3,734	$2,957	$705	4.19	0.24	0.99	1.14	1.00
NJ 26	Univ MC at Princeton	206	59,048	116,250	$319,420,592	$313,122,554	434,182	$5,303	$2,694	$721	3.73	0.27	1.40	1.04	1.03
NJ 27	Hunterdon MC	170	37,397	86,666	$223,258,328	$218,393,104	302,779	$5,840	$2,520	$721	3.49	0.29	1.54	0.97	1.03
NJ 28	Underwood-Mem Hosp	219	55,517	80,962	$170,864,464	$176,066,425	243,002	$3,171	$2,175	$725	3.00	0.33	0.84	0.84	1.03
NJ 29	Chilton Mem Hosp	256	49,281	76,268	$155,194,489	$160,245,525	217,335	$3,252	$2,101	$737	2.85	0.35	0.86	0.81	1.05
NJ 30	AtlantiCare Regional MC - City	533	145,767	221,665	$612,487,236	$594,780,341	805,762	$4,080	$2,683	$738	3.64	0.28	1.08	1.04	1.05
NJ 31	Capital Health Sys - Mercer	202	48,270	91,854	$224,959,646	$231,333,734	311,285	$4,792	$2,518	$743	3.39	0.30	1.26	0.97	1.06
NJ 32	Virtua West Jersey Hosp Voorhees	525	170,679	251,984	$593,068,801	$573,925,204	769,627	$3,363	$2,278	$746	3.05	0.33	0.89	0.88	1.06
NJ 33	St Joseph's Regional MC	667	189,124	247,138	$591,810,439	$605,580,707	810,412	$3,202	$2,450	$747	3.28	0.30	0.84	0.95	1.06
NJ 34	Englewood Hosp and MC	335	82,005	120,658	$328,489,707	$332,546,955	444,908	$4,055	$2,756	$747	3.69	0.27	1.07	1.07	1.06
NJ 35	St Michael's MC	259	71,937	110,848	$207,201,906	$286,150,245	378,113	$3,978	$2,581	$757	3.41	0.29	1.05	1.00	1.08
NJ 36	The Valley Hosp	427	137,151	190,015	$574,662,627	$541,075,119	713,676	$3,945	$2,848	$758	3.76	0.27	1.04	1.10	1.08
NJ 37	RWJ Univ Hosp at Rahway	141	33,528	46,281	$103,098,519	$108,714,849	142,693	$3,243	$2,349	$762	3.08	0.32	0.86	0.91	1.08
NJ 38	Holy Name Hosp	284	72,683	123,407	$258,044,711	$264,233,264	340,783	$3,635	$2,141	$775	2.76	0.36	0.96	0.83	1.10
NJ 39	Bayonne MC	236	28,832	37,803	$140,105,000	$137,805,792	177,067	$4,780	$3,645	$778	4.68	0.21	1.26	1.41	1.11
NJ 40	Monmouth MC	279	75,183	108,026	$257,828,512	$286,741,299	366,117	$3,814	$2,654	$783	3.39	0.30	1.01	1.03	1.11
NJ 41	Capital Health Sys - Fuld	172	44,846	64,032	$258,938,047	$249,189,840	317,080	$5,557	$3,892	$786	4.95	0.20	1.47	1.50	1.12
NJ 42	Hoboken Univ MC	194	40,054	68,286	$118,446,332	$158,884,008	202,091	$3,967	$2,327	$786	2.96	0.34	1.05	0.90	1.12
NJ 43	JFK MC	343	107,767	161,900	$413,398,234	$430,017,365	531,565	$3,990	$2,656	$809	3.28	0.30	1.05	1.03	1.15
NJ 44	CentraState MC	245	61,458	88,862	$203,075,932	$211,423,356	260,938	$3,440	$2,379	$810	2.94	0.34	0.91	0.92	1.15
NJ 45	Overlook MC	480	107,289	161,567	$427,204,059	$417,503,378	510,700	$3,891	$2,584	$818	3.16	0.32	1.03	1.00	1.16
NJ 46	St Clare's Hosp - Denville	341	78,889	129,281	$260,944,748	$301,993,475	367,693	$3,828	$2,336	$821	2.84	0.35	1.01	0.90	1.17
NJ 47	Riverview MC	214	58,049	82,536	$225,022,000	$212,808,092	259,069	$3,666	$2,578	$821	3.14	0.32	0.97	1.00	1.17
NJ 48	Ocean MC	259	72,007	102,032	$218,684,000	$211,696,005	255,712	$2,940	$2,075	$828	2.51	0.40	0.78	0.80	1.18
NJ 49	Shore Mem Hosp	296	54,676	82,029	$191,701,019	$196,710,976	234,402	$3,598	$2,398	$839	2.86	0.35	0.95	0.93	1.19
NJ 50	Lourdes MC of Burlington Cty	171	27,078	38,592	$102,557,798	$108,993,936	129,360	$4,025	$2,824	$843	3.35	0.30	1.06	1.09	1.20
NJ 51	Kennedy Mem Hosps	482	133,648	183,994	$470,112,000	$464,563,000	542,168	$3,476	$2,525	$857	2.95	0.34	0.92	0.98	1.22
NJ 52	Trinitas Hosp	249	72,594	114,184	$221,302,229	$302,961,464	311,233	$4,173	$2,653	$973	2.73	0.37	1.10	1.03	1.39
NJ 53	Jersey City MC	264	72,802	99,095	$265,948,298	$292,785,947	300,676	$4,022	$2,955	$974	3.03	0.33	1.06	1.14	1.39
NJ 54	The Univ Hosp	413	103,350	150,927	$598,421,000	$605,250,008	612,664	$5,856	$4,010	$988	4.06	0.25	1.55	1.55	1.41
NJ 55	Bergen Regional MC	105	25,801	28,004	$146,239,758	$206,053,761	182,472	$7,986	$7,358	$1,129	6.52	0.15	2.11	2.84	1.61
State Total		18039	4,753,761	6,894,387	$17,707,844,906	$17,959,501,196	27,754,788								
State Average		316	83,399	120,954	**$310,663,946**	**$315,078,968**	**$486,926**	**$3,790**	**$2,587**	**$702**			1.00	1.00	1.00

Figure B.2 New Jersey data.

Identifier Code	Pennsylvania Hospital Name	Beds	Inpatient Days	Adjusted Patient Days (APD)	Net Patient Revenue	Total Cost	HUC	BRE	NRE	HRE	HUC/APD	HRE/NRE	Scaled BRE	Scaled NRE	Scaled HRE
PA X	Univ of Pittsburgh MC - Hamot	351	84,540	123,016	$315,248,739	$273,351,453	1,802,185	$3,233	$2,222	$152	14.65	0.07	0.82	1.03	0.26
PA 1	St Mary MC	306	100,072	165,429	$395,428,544	$331,338,643	1,453,972	$3,311	$2,003	$228	8.79	0.11	0.84	0.93	0.39
PA Y	Penn Presbyterian MC	265	70,092	106,283	$432,046,000	$442,942,000	1,770,804	$6,319	$4,168	$250	16.66	0.06	1.60	1.94	0.43
PA 2	St Vincent Health Center	384	87,908	153,716	$259,890,669	$268,918,310	915,336	$3,059	$1,749	$294	5.95	0.17	0.78	0.81	0.51
PA 3	Butler Mem Hosp	212	53,567	117,542	$196,649,617	$186,798,538	566,057	$3,487	$1,589	$330	4.82	0.21	0.88	0.74	0.57
PA 4	Schuylkill - South Jackson Street	134	29,135	66,274	$83,009,823	$95,119,221	282,267	$3,265	$1,435	$337	4.26	0.23	0.83	0.67	0.58
PA 5	Penn State Milton S. Hershey MC	454	139,909	245,714	$770,549,849	$744,809,905	2,156,995	$5,324	$3,031	$345	8.78	0.11	1.35	1.41	0.60
PA 6	The Williamsport Hosp & MC	193	47,087	78,336	$183,721,802	$175,429,466	488,578	$3,726	$2,239	$359	6.24	0.16	0.94	1.04	0.62
PA 7	Holy Redeemer Hosp and MC	231	61,398	99,371	$156,984,812	$164,629,880	447,334	$2,681	$1,657	$368	4.50	0.22	0.68	0.77	0.64
PA 8	Moses Taylor Hosp	174	50,035	106,293	$144,238,142	$151,700,575	410,002	$3,032	$1,427	$370	3.86	0.26	0.77	0.66	0.64
PA 9	Sacred Heart Hosp	165	20,276	39,842	$102,214,799	$105,976,965	283,503	$5,227	$2,660	$374	7.12	0.14	1.32	1.24	0.65
PA 10	U Pittsburgh MC Presbyterian	1,262	349,330	513,581	$1,772,917,739	$1,841,754,790	4,746,944	$5,272	$3,586	$388	9.24	0.11	1.34	1.67	0.67
PA 11	Easton Hosp	199	49,946	82,111	$206,326,655	$158,458,125	404,750	$3,173	$1,930	$391	4.93	0.20	0.80	0.90	0.68
PA 12	Sharon Regional Health Sys	159	39,294	87,039	$154,273,876	$161,776,766	404,563	$4,117	$1,859	$400	4.65	0.22	1.04	0.86	0.69
PA 13	Mercy Fitzgerald Hosp	348	85,662	132,987	$297,276,945	$372,078,216	910,866	$4,344	$2,798	$408	6.85	0.15	1.10	1.30	0.71
PA 14	Chambersburg Hosp	197	43,021	89,675	$245,106,649	$227,921,333	550,994	$5,298	$2,542	$414	6.14	0.16	1.34	1.18	0.72
PA 15	Geisinger MC	400	121,122	264,733	$774,165,398	$726,042,483	1,711,217	$5,994	$2,743	$424	6.46	0.15	1.52	1.28	0.73
PA 16	Monongahela Valley Hosp	148	38,427	81,255	$102,356,519	$103,659,801	239,235	$2,698	$1,276	$433	2.94	0.34	0.68	0.59	0.75
PA 17	Bradford Regional MC	87	16,069	52,214	$64,008,372	$65,250,447	145,825	$4,061	$1,250	$447	2.79	0.36	1.03	0.58	0.77
PA 18	Armstrong Cty Mem Hosp	139	28,953	82,064	$90,806,579	$88,785,229	195,602	$3,067	$1,082	$454	2.38	0.42	0.78	0.50	0.78
PA 19	Hahnemann Univ Hosp	476	106,825	141,412	$383,185,197	$415,159,657	908,337	$3,886	$2,936	$457	6.42	0.16	0.98	1.37	0.79
PA 20	Lehigh Valley Hosp - Muhlenberg	176	49,350	89,190	$213,465,282	$195,155,000	426,667	$3,955	$2,188	$457	4.78	0.21	1.00	1.02	0.79
PA 21	Regional Hosp of Scranton	198	43,405	73,031	$145,555,258	$147,994,469	320,709	$3,410	$2,026	$461	4.39	0.23	0.86	0.94	0.80
PA 22	Carlisle Regional MC	145	25,234	53,069	$112,785,379	$88,112,534	188,542	$3,492	$1,660	$467	3.55	0.28	0.88	0.77	0.81
PA 23	Delaware Cty Mem Hosp	222	50,404	80,861	$178,469,000	$180,008,245	380,250	$3,571	$2,226	$473	4.70	0.21	0.90	1.04	0.82
PA 24	Pocono MC	209	45,110	101,521	$215,854,141	$201,373,078	424,081	$4,464	$1,984	$475	4.18	0.24	1.13	0.92	0.82
PA 25	Crozer-Chester MC	485	130,712	191,391	$549,564,000	$555,014,435	1,161,065	$4,246	$2,900	$478	6.07	0.16	1.08	1.35	0.83
PA 26	Jeanes Hosp	156	41,115	83,587	$145,211,224	$149,527,657	310,214	$3,637	$1,789	$482	3.71	0.27	0.92	0.83	0.83
PA 27	Community MC	273	48,401	77,999	$157,699,152	$152,957,843	316,522	$3,160	$1,961	$483	4.06	0.25	0.80	0.91	0.84
PA 28	Westmoreland Regional Hosp	343	94,906	165,903	$241,859,088	$234,205,605	477,091	$2,468	$1,412	$491	2.88	0.35	0.63	0.66	0.85
PA 29	Doylestown Hosp	247	55,524	110,410	$209,949,683	$210,243,489	424,983	$3,787	$1,904	$495	3.85	0.26	0.96	0.89	0.86
PA 30	Mem MC - Main	463	114,896	201,950	$356,481,275	$354,302,832	716,060	$3,084	$1,754	$495	3.55	0.28	0.78	0.82	0.86
PA 31	Temple Univ Hosp	596	144,923	212,420	$752,804,367	$785,832,659	1,492,529	$5,422	$3,699	$527	7.03	0.14	1.37	1.72	0.91
PA 32	DuBois Regional MC West	185	39,692	102,054	$196,706,093	$199,244,142	376,102	$5,020	$1,952	$530	3.69	0.27	1.27	0.91	0.92
PA 33	U Pittsburgh MC St Margaret	234	68,355	133,098	$247,365,009	$228,642,008	422,792	$3,345	$1,718	$541	3.18	0.31	0.85	0.80	0.93
PA 34	U Pittsburgh MC - Mercy	391	105,040	172,205	$350,809,381	$366,239,788	660,222	$3,487	$2,127	$555	3.83	0.26	0.88	0.99	0.96
PA 35	Pottstown Mem MC	168	40,886	80,824	$187,597,667	$150,758,310	271,072	$3,687	$1,865	$556	3.35	0.30	0.93	0.87	0.96
PA 36	Altoona Hosp	404	80,519	162,773	$300,038,456	$301,120,488	535,706	$3,740	$1,850	$562	3.29	0.30	0.95	0.86	0.97
PA 37	Brandywine Hosp	200	34,925	53,654	$100,090,313	$111,979,280	195,817	$3,206	$2,087	$572	3.65	0.27	0.81	0.97	0.99
PA 38	U Pittsburgh MC Passavant	325	81,699	161,660	$311,060,169	$275,513,465	480,774	$3,372	$1,704	$573	2.97	0.34	0.85	0.79	0.99
PA 39	The Western Pennsylvania Hosp	455	90,181	151,552	$313,388,767	$396,771,108	690,060	$4,400	$2,618	$575	4.55	0.22	1.11	1.22	0.99
PA 40	Western Pennsylvania Forbes	262	63,834	105,903	$171,403,275	$160,499,872	278,999	$2,514	$1,516	$575	2.63	0.38	0.64	0.70	0.99
PA 41	Hosp of the Univ of Pennsylvania	694	232,816	381,710	$1,557,024,000	$1,421,284,000	2,467,459	$6,105	$3,723	$576	6.46	0.15	1.55	1.73	1.00
PA 42	Robert Packer Hosp	234	59,381	109,976	$239,840,566	$209,445,942	359,152	$3,527	$1,904	$583	3.27	0.31	0.89	0.89	1.01
PA 43	Heritage Valley Sewickley	148	35,943	74,897	$130,591,547	$134,955,047	230,793	$3,755	$1,802	$585	3.08	0.32	0.95	0.84	1.01
PA 44	The Chester Cty Hosp	219	64,945	113,736	$198,755,498	$203,795,971	348,107	$3,138	$1,792	$585	3.06	0.33	0.80	0.83	1.01
PA 45	Geisinger Wyoming Valley MC	222	50,000	140,642	$315,431,384	$311,389,825	526,001	$6,228	$2,214	$592	3.74	0.27	1.58	1.03	1.02
PA 46	Gnaden Huetten Mem Hosp	85	12,183	33,476	$57,559,362	$58,104,040	95,805	$4,769	$1,736	$606	2.86	0.35	1.21	0.81	1.05
PA 47	Heritage Valley Beaver	246	69,965	138,670	$212,072,321	$220,428,728	361,205	$3,151	$1,590	$610	2.60	0.38	0.80	0.74	1.05
PA 48	U Pittsburgh McKeesport	180	51,481	89,788	$125,579,676	$124,799,131	203,079	$2,424	$1,390	$615	2.26	0.44	0.61	0.65	1.06
PA 49	Jefferson Regional MC	332	76,111	117,155	$204,707,658	$221,955,963	350,453	$2,916	$1,895	$633	2.99	0.33	0.74	0.88	1.09
PA 50	Riddle Mem Hosp	207	51,376	78,347	$164,829,623	$176,633,616	276,833	$3,438	$2,254	$638	3.53	0.28	0.87	1.05	1.10
PA 51	Aria Health - Torresdale	460	139,632	199,453	$409,751,422	$392,390,939	613,213	$2,810	$1,967	$640	3.07	0.33	0.71	0.92	1.11
PA 52	Allegheny General Hosp	568	149,421	252,568	$651,387,188	$630,718,353	982,926	$4,221	$2,497	$642	3.89	0.26	1.07	1.16	1.11
PA 53	Alle-Kiski MC	218	40,429	85,877	$121,871,954	$117,293,422	181,511	$2,901	$1,366	$646	2.11	0.47	0.74	0.64	1.12
PA 54	Lankenau Hosp	331	98,263	133,255	$369,824,948	$366,871,487	566,331	$3,734	$2,753	$648	4.25	0.24	0.95	1.28	1.12
PA 55	U Pittsburgh Horizon - Greenville	136	34,725	82,451	$123,169,776	$122,812,340	188,939	$3,537	$1,490	$650	2.29	0.44	0.90	0.69	1.12
PA 56	York Hosp	500	130,317	275,676	$740,819,905	$696,826,288	1,069,197	$5,347	$2,528	$652	3.88	0.26	1.35	1.18	1.13
PA 57	Wilkes-Barre General Hosp	392	83,807	148,464	$245,395,043	$245,990,021	368,828	$2,935	$1,657	$667	2.48	0.40	0.74	0.77	1.15
PA 58	U Pittsburgh MC Northwest	127	27,637	61,769	$91,366,793	$86,417,373	127,764	$3,127	$1,399	$676	2.07	0.48	0.79	0.65	1.17
PA 59	Jameson Hosp - North	210	40,689	79,357	$109,864,405	$110,154,953	162,804	$2,707	$1,388	$677	2.05	0.49	0.69	0.65	1.17
PA 60	Lancaster Regional MC	185	21,515	36,846	$88,328,835	$85,618,264	126,183	$3,979	$2,324	$679	3.42	0.29	1.01	1.08	1.17
PA 61	Holy Spirit Hosp	295	60,158	108,156	$260,939,916	$255,613,985	372,286	$4,249	$2,363	$687	3.44	0.29	1.08	1.10	1.19
PA 62	Bryn Mawr Hosp	303	77,598	107,086	$311,512,547	$295,930,471	429,812	$3,814	$2,763	$689	4.01	0.25	0.97	1.29	1.19
PA 63	St Luke's Hosp - Bethlehem	560	145,243	240,725	$614,081,829	$582,060,380	841,110	$4,007	$2,418	$692	3.49	0.29	1.02	1.12	1.20
PA 64	Magee-Womens	312	103,564	212,107	$393,898,588	$359,269,093	516,358	$3,469	$1,694	$696	2.43	0.41	0.88	0.79	1.20
PA 65	Indiana Regional MC	132	30,836	84,695	$125,666,356	$129,754,153	184,561	$4,208	$1,532	$703	2.18	0.46	1.07	0.71	1.22
PA 66	Albert Einstein MC	450	129,925	207,912	$659,046,379	$677,110,943	961,835	$5,212	$3,257	$704	4.63	0.22	1.32	1.51	1.22
PA 67	Pennsylvania Hosp	384	113,162	156,650	$444,377,000	$463,992,000	657,477	$4,100	$2,962	$706	4.20	0.24	1.04	1.38	1.22
PA 68	St Clair Hosp	267	67,161	122,091	$211,750,014	$202,165,638	280,534	$3,010	$1,656	$721	2.30	0.44	0.76	0.77	1.25
PA 69	Montgomery Hosp MC	150	25,302	53,050	$108,250,000	$111,656,743	154,608	$4,413	$2,105	$722	2.91	0.34	1.12	0.98	1.25
PA 70	Lehigh Valley Hosp - Cedar Crest	741	198,850	294,906	$888,524,893	$899,735,000	1,239,068	$4,525	$3,051	$726	4.20	0.24	1.15	1.42	1.26
PA 71	Nazareth Hosp	173	44,661	68,936	$165,675,958	$166,411,982	229,153	$3,726	$2,414	$726	3.32	0.30	0.94	1.12	1.26
PA 72	Paoli Hosp	226	55,043	84,729	$228,696,753	$203,598,844	279,396	$3,699	$2,403	$729	3.30	0.30	0.94	1.12	1.26
PA 73	Mount Nittany MC	187	48,697	90,424	$205,801,791	$183,760,525	247,812	$3,774	$2,032	$742	2.74	0.36	0.96	0.95	1.28
PA 74	Berwick Hosp Center	83	12,257	24,534	$65,791,138	$57,612,895	77,684	$4,700	$2,348	$742	3.17	0.32	1.19	1.09	1.28
PA 75	Meadville MC	142	29,408	80,303	$125,966,929	$129,366,137	170,324	$4,399	$1,611	$760	2.12	0.47	1.11	0.75	1.31
PA 76	Grand View Hosp	192	38,865	88,799	$172,496,432	$173,654,883	225,950	$4,468	$1,956	$769	2.54	0.39	1.13	0.91	1.33
PA 77	Lancaster General	615	162,574	268,179	$788,908,475	$767,603,052	937,001	$4,722	$2,862	$819	3.49	0.29	1.20	1.33	1.42
PA 78	Thomas Jefferson Univ Hosp	805	224,693	312,401	$1,167,383,652	$1,109,329,132	1,341,183	$4,937	$3,551	$827	4.29	0.23	1.25	1.65	1.43
PA 79	Harrisburg Hosp	526	136,582	211,180	$547,530,951	$554,758,000	660,976	$4,062	$2,627	$839	3.13	0.32	1.03	1.22	1.45
PA 80	The Good Samaritan Hosp	131	32,821	73,334	$161,243,680	$168,444,267	199,459	$5,132	$2,297	$845	2.72	0.37	1.30	1.07	1.46
PA 81	Elk Regional Health Center	70	12,110	39,719	$65,256,018	$66,793,885	78,034	$5,516	$1,682	$856	1.96	0.51	1.40	0.78	1.48
PA 82	Uniontown Hosp	181	39,745	75,964	$116,993,158	$124,059,874	141,484	$3,121	$1,633	$877	1.86	0.54	0.79	0.76	1.52
PA 83	The Washington Hosp	197	56,042	103,333	$241,743,433	$218,054,397	246,387	$3,891	$2,110	$885	2.38	0.42	0.99	0.98	1.53
PA 84	St Joseph MC	212	41,969	91,322	$188,321,209	$184,012,384	203,009	$4,384	$2,015	$906	2.22	0.45	1.11	0.94	1.57
PA 85	The Reading Hosp and MC	464	132,179	230,465	$708,001,072	$669,865,167	733,661	$5,068	$2,907	$913	3.18	0.31	1.28	1.35	1.58
State Total		25913	6,561,860	11,459,056	27,714,593,779	$27,239,897,643	52,361,366								
State Average		298	75,424	131,713	318,558,549	$313,102,272	601,855	$3,947	$2,150	$578			0.78	0.82	0.49

Figure B.3 Pennsylvania data.

APPENDIX C

HOSPITAL PRODUCTIVITY INDEX

Figures C.1 and C.2 show the hospitals in the upper and lower quadrant of the Hospital Productivity Index.

Hospital Name	Rank	State	Total Operating Cost	HUC	X: Individual HRE	$HPI_{upper} = (1+(x-A)*(0.5/(B-A)))$
Univ of Michigan Hosps and Health Centers	1	EX	$1,921,949,133	12691053	$151	1.68
Univ of Pittsburgh MC - Hamot	2	PA	$273,351,453	1802185	$152	1.68
Univ of Pittsburgh MC - Hamot	3	EX	$273,351,453	1802185	$152	1.68
Stanford Hosp	4	EX	$1,824,591,373	11516180	$158	1.67
Robert Wood Johnson Univ Hosp Hamilton	5	NJ	$201,993,218	1045802	$193	1.62
BryanLGH MC East	6	NE	$432,596,222	2228406	$194	1.61
St Mary MC	7	PA	$331,338,643	1453972	$228	1.56
Southern Ocean MC	8	NJ	$126,221,665	520440	$243	1.54
Penn Presbyterian MC	9	PA	$442,942,000	1770804	$250	1.53
St Vincent Health Center	10	PA	$268,918,310	915336	$294	1.46
The Nebraska MC	11	NE	$730,646,401	2389064	$306	1.44
Butler Mem Hosp	12	PA	$186,798,538	566057	$330	1.40
Schuylkill MC - South Jackson Street	13	PA	$95,119,221	282267	$337	1.39
Penn State Milton S. Hershey MC	14	PA	$744,809,905	2156995	$345	1.37
Ronald Reagan UCLA MC	15	EX	$1,098,900,000	3132051	$351	1.37
The Williamsport Hosp & MC	16	PA	$175,429,466	488578	$359	1.35
Holy Redeemer Hosp and MC	17	PA	$164,629,880	447334	$368	1.34
Moses Taylor Hosp	18	PA	$151,700,575	410002	$370	1.34
Sacred Heart Hosp	19	PA	$105,976,965	283503	$374	1.33
Morristown MC	20	NJ	$707,772,926	1842378	$384	1.31
Univ of Pittsburgh MC Presbyterian	21	PA	$1,841,754,790	4746944	$388	1.31
Easton Hosp	22	PA	$158,458,125	404750	$391	1.30
Sharon Regional Health Sys	23	PA	$161,776,766	404563	$400	1.29
Robert Wood Johnson Univ Hosp	24	NJ	$719,892,755	1776920	$405	1.28
Meadowlands Hosp MC	25	NJ	$68,625,182	168145	$408	1.28
Mercy Fitzgerald Hosp	26	PA	$372,078,216	910866	$408	1.28
Chambersburg Hosp	27	PA	$227,921,333	550994	$414	1.27
Geisinger MC	28	PA	$726,042,483	1711217	$424	1.25
Monongahela Valley Hosp	29	PA	$103,659,801	239235	$433	1.24
Bradford Regional MC	30	PA	$65,250,447	145825	$447	1.21
Armstrong Cty Mem Hosp	31	PA	$88,785,229	195602	$454	1.20
Hahnemann Univ Hosp	32	PA	$415,159,657	908337	$457	1.20
Lehigh Valley Hosp - Muhlenberg	33	PA	$195,155,000	426667	$457	1.20
Regional Hosp of Scranton	34	PA	$147,994,469	320709	$461	1.19
Carlisle Regional MC	35	PA	$88,112,534	188542	$467	1.18
Delaware Cty Mem Hosp	36	PA	$180,008,245	380250	$473	1.17
Pocono MC	37	PA	$201,373,078	424081	$475	1.17
Crozer-Chester MC	38	PA	$555,014,435	1161065	$478	1.17
Jeanes Hosp	39	PA	$149,527,657	310214	$482	1.16
Community MC	40	PA	$152,957,843	316522	$483	1.16

Figure C.1 Upper quadrant of Hospital Productivity Index.

Hospital Name	Rank	State	Total Operating Cost	HUC	X: Individual HRE	HPI $_{lower}$ =(0.5+(x-C)*(0.5/(A-C)))
St Joseph MC	41	WA	$526,700,580	559920	$941	0.68
Mount Sinai MC	42	EX	$1,485,467,817	1578068	$941	0.68
Univ of California San Francisco MC at Parnassus	43	EX	$1,637,175,538	1728527	$947	0.67
Sacred Heart MC	44	WA	$674,651,918	698943	$965	0.66
Trinitas Hosp	45	NJ	$302,961,464	311233	$973	0.65
Jersey City MC	46	NJ	$292,785,947	300676	$974	0.65
Deaconess MC	47	WA	$245,920,586	250749	$981	0.64
Good Samaritan Hosp	48	NE	$171,006,089	173644	$985	0.64
UMDNJ The Univ Hosp	49	NJ	$605,250,008	612664	$988	0.64
Overlake Hosp MC	50	WA	$360,964,469	362537	$996	0.63
Swedish MC / First Hill	51	WA	$901,830,623	900997	$1,001	0.63
Yakima Valley Mem Hosp	52	WA	$278,373,571	274769	$1,013	0.61
Good Samaritan Hosp	53	WA	$262,254,471	252427	$1,039	0.59
Southwest Washington MC	54	WA	$476,633,165	452275	$1,054	0.58
Tacoma General Hosp	55	WA	$603,711,290	559268	$1,079	0.56
Holy Family Hosp	56	WA	$184,810,014	166647	$1,109	0.53
Swedish MC / Cherry Hill	57	WA	$321,710,276	288141	$1,117	0.52
Harrison MC - Bremerton	58	WA	$325,368,434	289272	$1,125	0.51
Bergen Regional MC	59	NJ	$206,053,761	182472	$1,129	0.51
Northwest Hosp & MC	60	WA	$219,729,755	193069	$1,138	0.50
Cleveland Clinic	61	EX	$3,683,893,828	3218909	$1,144	0.50
St John MC	62	WA	$225,492,554	196181	$1,149	0.49
St Francis MC	63	NE	$136,090,857	117817	$1,155	0.49
New York-Presbyterian Hosp/Weill Cornell MC	64	EX	$3,299,473,879	2822023	$1,169	0.47
Legacy Salmon Creek Hosp	65	WA	$168,427,976	142501	$1,182	0.46
Massachusetts General Hosp	66	EX	$2,098,887,000	1740484	$1,206	0.44
Regional West MC	67	NE	$165,971,670	135269	$1,227	0.42
Brigham and Women's Hosp	68	EX	$2,082,986,055	1673611	$1,245	0.41
St Joseph Hosp	69	WA	$365,215,642	292502	$1,249	0.40
Highline MC	70	WA	$205,892,491	162343	$1,268	0.39
Univ of Washington MC	71	WA	$742,289,086	574232	$1,293	0.36
Avera St Luke's Hosp	72	SD	$140,177,178	105872	$1,324	0.34
Harborview MC	73	WA	$715,493,675	540150	$1,325	0.34
Harborview MC	74	EX	$715,493,675	540150	$1,325	0.34
Avera Sacred Heart Hosp	75	SD	$90,585,207	67092	$1,350	0.31
Valley MC	76	WA	$410,309,207	296919	$1,382	0.28
Evergreen Hosp MC	77	WA	$388,466,032	279356	$1,391	0.28
Fremont Area MC	78	NE	$94,455,467	57805	$1,634	0.06
Avera Queen of Peace Hosp	79	SD	$76,685,437	44612	$1,719	-0.02
Johns Hopkins Hosp	80	EX	$1,525,850,066	882280	$1,729	-0.03

Figure C.2 Lower quadrant of Hospital Productivity Index.

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