Real Options Analysis of Flexibility in a Hospital Emergency Department Expansion Project, a Systems Approach

by

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Submitted to the System Design and Management Program in partial
Fulfillment of the Requirements for the Degree of

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ABSTRACT

Hospital Emergency Departments across the United States have been experiencing demand in excess of their capacity to treat patients for the last two decades. This research considers a hypothetical case inspired by a hospital in the Greater Boston undergoing an ED expansion to meet existing and projected demand. A traditional infrastructure expansion project approach to plan, design and immediately build for expected demand 10 to 15 years into the future is compared to a flexible design able to meet short term demands and then adapt to future demand realization. It is the overall objective of this research to identify, characterize and quantify the parameters that should be considered in ED expansion projects and provide useful modeling techniques to drive investment decisions that best allow hospital administrators to provide expected level of service to their patient population.

Thesis Supervisor: Dr. Richard de Neufville
Title: Professor of Engineering Systems

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Table of Contents

List of Figures

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List of Tables

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Chapter 1. Introduction

"The future ain't what it used to be"

Yogi Berra

The purpose of this thesis is to provide hospital administrators with methods to manage the uncertain future of an ED engineering system with only the benefit of today's perspective. More precisely, this work takes a systems approach to the application of Real Options (RO) analysis to manage uncertainty as it relates to a hospital Emergency Department (ED) expansion project.

This work is inspired by a hospital in the Greater Boston area that is undertaking an ED expansion project of a 20 year old facility to address current capacity issues and meet future demand. A traditional deterministic approach to facility design and project valuation (i.e. NPV or IRR) is compared to a flexible design and RO framework appropriate for the healthcare context. The hospital is referred to as Greater Boston Hospital (GBH) for purposes of discretion.

This research compares a traditional infrastructure expansion project approach to plan, design and immediately build for expected demand 15 to 20 years into the future with a flexible design able to meet short term demands and then adapt to future demand realization. The traditional approach creates an initial excess in capacity and ties up funds that could be better invested in other more present and pressing needs of the enterprise. Specifically in the case of an ED, these spent funds could be directed to address system hospital system constraints that cause ED issues. The flexible approach provides a way to allocate investments to meet immediate needs and to then allocate future funds as uncertainty is resolved over time. It is the overall objective of this research to identify, characterize and quantify the parameters that should be considered in ED expansion projects and provide a useful modeling technique to drive investment decisions that best allow hospital administrators to provide expected level of service to their patient population.

There are plenty of examples in the literature of RO analysis of big industry projects such as ore mining and the oil field development. Well known examples of RO analysis also exist in aviation, pharmaceuticals, and various other manufacturing industries. Examples of RO analysis in hospital projects, and specifically in the design of an ED expansion, are uncommon or unheard of. This work attempts to expand upon the limited examples of RO analysis in healthcare infrastructure to help further advance the practice of RO analysis and provide a holistic framework for the evaluation and design of healthcare facility expansion projects.

As such, the objective of this research is threefold:

1. To describe the complexity of the ED system as it relates to operational and capacity planning uncertainty
2. Introduce the concepts of design flexibility in a healthcare context; specifically, Emergency Department design.
3. Contribute a healthcare infrastructure case to the growing body of knowledge of Real Options analysis of flexible designs.

1.1 Current State of Emergency Care

It is useful to introduce the current state of Emergency Care in the United States to fully understand the scope of this work. It should become apparent throughout this introduction that the ED is a complex engineering system heavily influenced by its local context.

The United States has been facing an impending healthcare crisis rooted in demographic driven increases in demand for services, unaffordable costs, facility capacity shortfalls, inefficient processes and lagging infrastructure investment. This has been especially the case when it comes to Emergency Care and Emergency Departments (ED) across the nation. The issues are readily observable at most any ED where waiting times frustrate patients and lengths of stay are longer than they need be. These strains on capacity lead EDs to regularly go on diversion for periods of time that essentially shuts the door to any patients incoming via emergency service transport. The causes of these capacity issues are numerous and vary from hospital to hospital;

some of the commonly cited causes are regional ED closures, abuse of ED services and under investment in staff and infrastructure.

The following terms are used throughout this work and defined as follows by the American College of Emergency Physicians (2003):

ED Overcrowding: A situation in which the identified need for emergency services exceeds the available resources in the ED. Evidence of ED overcrowding is typically found when the number of patients receiving care exceeds the number of staffed ED beds, which may lead to the use of hallways and other non-treatment areas to assess or monitor patients and is usually associated with lengthy waiting times for treatment.

ED Saturation: A situation in which patient needs, including timely evaluation and treatment, as defined by patient acuity or triage level, cannot be met for existing or new patients because of fully committed ED resources.

ED Boarder: A patient who remains in the ED beyond the time of disposition after the decision has been made for either inpatient admission or transfer to another facility.

Boarder burden: the proportion of the ED functional treatment spaces or beds occupied by boarding patients.

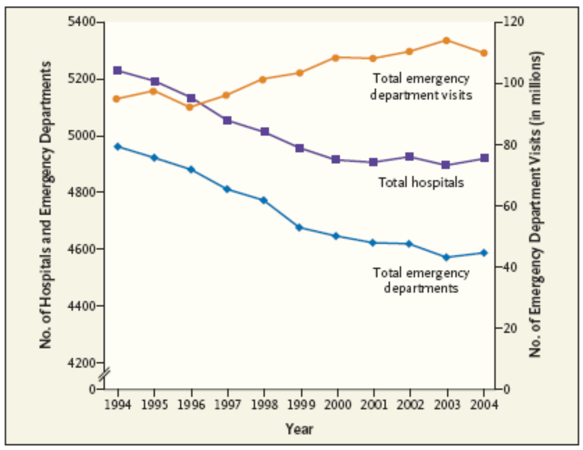
ED treatment station (ED bed): A gurney or bed in a space designed to be a treatment area in the ED. Beds in such areas as the hallway, waiting room, conference rooms, etc, are not ED beds.

Hospital ED or ambulance diversion: A situation in which a hospital has determined that it does not or will not have the required capacity or capability to accept additional patients from pre-hospital or EMS ambulance transports. Diversion can be for a specified category of patients (e.g., trauma, critical care) or all pre-hospital or inter-hospital ambulance transfers.

Increasing volume drivers at the national level are anecdotally believed to be as follows:

- Loosening of managed care restrictions on ED use

- The number of EDs has declined by 6% between 1997 and 2007 due to hospital closures and mergers while demand has increased by 16% over the same time period. American College of Emergency Physicians President Linda Lawrence reacts to these trends by stating: "The number of emergency patients is increasing while the number of hospital beds continues to drop. It is a recipe for disaster." Lawrence adds, "National health care reform must strengthen the nation's emergency departments and provide additional resources for hospital emergency departments" (Lopes, *Washington Times*).



Trends in Emergency Department Visits, Number of Hospitals, and Number of Emergency Departments in the United States, 1994–2004.

Visits to the emergency department represent about 10% of all outpatient visits in the United States. Data are from the National Health Policy Forum.

Figure 1-1 Trends in EDs, visits and hospitals in the US.

- Payer policy for ED visits is expected to remain unchanged which will not deter demand.
- Continued decline in Primary Care Physician (PCP) use and closure of state run mental health clinics is expected to have local effects in some markets that will drive up ED use.
- Rise in unemployment, and hence of the uninsured, rates will increase ED use.

The following excerpt from a CDC article exemplifies the national perspective and policy driven view of the ‘ED crisis’ (CDC 2005):

“Emergency departments are a safety net and often the place of first resort for health care for America’s poor and uninsured,” said Linda McCaig of CDC’s National Center for Health Statistics and the report’s lead author. “This annual study of the nation’s emergency departments is part of a series of surveys of health care in the United States and provides current information for the development of policies and programs designed to meet America’s health care needs.”

The prevalence of these stories and dire national statistics create an impression that all EDs are experiencing similar problems rooted in the same fundamental causes. This, as may be expected, is not the case.

The GBH ED is an example of a case where many of the national issues are present (demand outstripping capacity, long wait times, extended length of stay, boarding and overcrowding) yet the root causes are not necessarily the same. Root causes must be understood as they affect the GBH ED’s service region which spans multiple towns. Properly understanding the local, and even regional, context is paramount to being able to appropriately define design requirements and flexibility elements in the design. Project teams must temper and challenge information found in high profile reports, potentially generic advice from renowned consulting firms or any other of the typically influential sources that could lead a team to implement unsuitable generalities.

Although design guidelines for EDs are available from various sources, extensive literature searches have not produced a framework to identify flexibility in the design and deployment of an ED expansion project. This work sets out to provide this framework along with a means to value its economic benefit.

1.2 National and Local Context

The national context is presented to set the stage for the importance of defining local factors that affect individual ED operations. Many EDs observe the same issues reported at the national level, but not necessarily for the same reasons.

A U.S. Department of Health and Human Services survey, National Hospital Ambulatory Medical Care Survey (NHAMCS), in 2003 estimated 113.9 million visits were made to hospital EDs, about 38.9 visits per 100 persons in the country. Increasing trends in ED utilization were observed for the following age groups: 22-49, 50-64 and 65 years of age and over. Of the almost 114 million visits, 14.2 percent (16 million) arrived by ambulance. In order of prevalence, the following were chief complaints at time of registration accounted for almost 20% of the ED volume: abdominal pain, chest pain, fever and cough. Other telling statistics for the 2003 study period:

- From 1993 through 2003, the number of ED visits increased 26 percent from 90.3 million visits in 1993 to 114 million in 2003. The U.S. population rose 12.3 percent during this period, and the 65-and-over population rose 9.6 percent.
- The average waiting time to see a physician was 46.5 minutes, the same as it was in 2000. The wait time was unchanged despite increased visits. EDs have implemented a number of efficiencies, including “fast track” units, which may have kept the wait time constant. On average, patients spent 3.2 hours in the ED, which includes time with the physician as well as other clinical services.
- Injury, poisoning, and the adverse effects of medical treatment accounted for over 35 percent of ED visits. The leading causes of injuries were falls, being struck by or striking against objects or persons, and motor vehicle traffic incidents, accounting for 41 percent of injury-related visits. Some 1.7 million visits were for adverse effects of medical treatment.
- In 2003, patients arrived at the ED by ambulance in 14 percent of the visits, representing over 16 million ambulance transports. More than a third of patients who arrived at the ED by ambulance were 65 years of age and over.
- X-rays, CT scans, or other imaging tests were provided in about 43 percent of visits. Medications were provided in over 77 percent of visits, with painkillers being the most frequent prescription, accounting for just over 14 percent of medications reported.
- About 58 percent of all EDs were located in metropolitan areas, and they represented 82 percent of the annual usage. Board-certified emergency medicine physicians were available at 64 percent of EDs.

Understanding the national context is interesting when considering local hospital issues, but not very useful in planning and decision making. National issues are not necessarily the same as local issue even though on the surface they make look the same. One of these national issues experienced at a local level is ED overcrowding partly driven by increased utilization. A report by the General Accounting Office (GAO) in 2003 provides evidence that hospital overcrowding varies by community and hospital (Yamane 2003). It was found that although most EDs across the country experienced some degree of crowding, the problem is much more pronounced in some hospitals and areas than in others. The hospitals reporting the most problems with crowding were in the largest (population > 2.5 million) metropolitan service areas (MSA). This reinforces the importance of understanding the local context.

The ED utilization is Massachusetts between 1990 and 2000 declined significantly until 1998 despite a modest population increase 0.35 million over the same period (McManus 2001). One proposed correlate that does not presume to definitively determine causality is the penetration of managed care during the same period as shown in Figure 1-2.

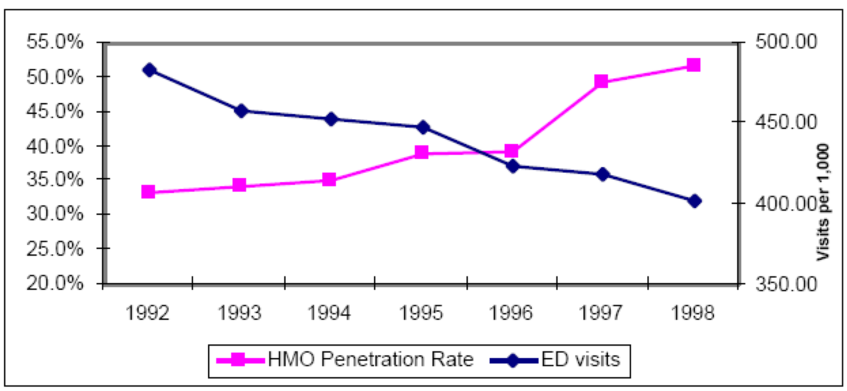


Figure 1-2 ED visits and HMO Penetration rates in MA (McManus 2001)

The national, local and hospital specific context are all useful to understand, albeit to varying degrees. This research describes a systems approach to defining context and understanding the inputs required to make design decisions in an ED expansion project.

1.3 Organization of Thesis and General Approach

This thesis is organized into three main areas: Overview of Real Options and Traditional Valuation Methods and a Real Options analysis of the GBH case. A description of the ED as an Engineering System is included as an appendix.

Overview of Real Options

This section of thesis starts with a historical background of Real Options (RO) analysis and its existing applications. The distinction between Real Options ‘on’ projects versus Real Options ‘in’ designs is made to frame the purpose of this thesis which is to introduce the concept of RO ‘in’ the design of healthcare infrastructure projects; specifically using an ED expansion example. Traditional project valuation methods are discussed, along with their strengths and weaknesses, to better understand the merits of RO analysis versus these traditional valuation methods. Lastly, an overview of the approach to identify and analyze RO ‘in’ projects is introduced to be extended in the healthcare context.

Real Options Analysis

A Real Options analysis is done to value flexibility in the design of the GBH ED expansion. Methods and factors developed throughout this work are incorporated into a model that illustrates the applicability of RO in the Healthcare context. Various expansion scenarios were developed and compared to the base case using VARG curves and other pertinent metrics.

Appendix: The ED as an Engineering System

This section frames the ED as engineering system and hospital networks as systems of systems. Various system engineering tools are used to identify the elements of flexibility that exist within an ED design and to understand which are significant in RO modeling. The complexity of ED capacity is understood beyond it being seen as an issue of scale. These various systems engineering approaches also serve to generate a holistic view of the ED within its operating context. Possible solutions to ED issues are discussed such as facility expansion and patient flow process improvement to understand their potential benefits, detriments and risks. The concept of level of service is discussed to support modeling decisions related to capacity and satisfying demand.

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Chapter 2. Real Options Background, Traditional Project Valuation Methods and Real Options ‘in’ Engineering Systems

2.1 Real Options Background

The modern breakthrough in valuation of options was made in the early 1970s by Robert Merton, Fischer Black, and Myron Scholes, whose Nobel Prize winning work solved a tough problem that had been a challenge since the early 1900s (Copeland and Antikarov 2001). Thousands of papers, both theoretical and empirical have followed. The early applications were mainly in securities pricing due to the wide availability of data and the directly observable market pricing of the underlying assets(Borison 2005).

Stewart Myers coined the term ‘real options’ in 1977 to describe the application of option pricing theory to the valuation of non-financial or “real” investments with learning and flexibility, such as multi-stage R&D, modular manufacturing plant expansion and the like (Myers 1977). Most of these early efforts used complex mathematical modeling which limited is accessibility mostly to applied mathematicians. The advent of powerful desktop computers and spreadsheet software over the last decade has allowed a broader base of users to model options using lattices and algebraic solutions. As the adoption of real options increased beyond the securities realm, practitioners realized that real options can be applied to any situation where the Net Present Value (NPV) of a project without flexibility can be calculated. Thus, the underlying risk asset becomes the free cash flows generated by the project (Copeland and Antikarov 2001).

A real option is the ‘right’, but not the obligation, to invest in a project at a later date. The following list provides examples of simple real options commonly found in projects:

- Deferral option. This is an American call option to delay the start of a project. The exercise price is the money invested to get the project started.
- Option to Abandon. Is akin to an American put option where the exercise price is the money required to terminate a project. This could be in the form of a contract penalty or forfeited deposit for originally anticipated work.

- Option to Expand. This is an American call option where additional money is paid to enable the project to be scaled-up.

One can combine simple options to create portfolios of options. One case is to have options on options which are known as compound options. A phased project is an example of a compound option where one has the right to abandon, stop or defer the project at the completion of each phase. Later phases of the project are contingent on options exercised in previous phases; these later phase options become options on options.

More recently, real options analysis has been extended by de Neufville to include the valuation of options 'in' engineering systems rather than on projects. In effect, real options analysis in design is the valuation of design flexibility. This is a departure from conventional options analysis rooted in the analysis of financial markets which arguably do not seem adequate for engineering systems. As pointed out by de Neufville 2002, the real options analysis of engineering system as compared to financial markets does not have the benefit of historical risk volatility data as it applies to the particular design interest and decision points at which the exercise price of the real option is known may also be unavailable (de Neufville 2002). This supports the idea that a real options analysis approach to valuation of flexibility in engineering systems requires a different approach.

The next section will discuss traditional project evaluation methods along with their shortcomings to support the case for real options analysis as the appropriate method to value ED expansion projects with designed flexibility.

2.2 Traditional Project Evaluation Methods

Traditional project evaluation criteria include:

- Net Present Value (NPV)
- Benefit-Cost Ratio
- Internal Rate of Return

- Pay-Back period

The following sections provide an overview of these methods and an assessment of their advantages and disadvantages.

2.2.1 Net Present Value

Net Present Value (NPV) is the most widely used investment valuation method today. This approach considers the time value money when making investment decision. It provides the net equivalent amount at the present for the life of the project that represents the difference between the equivalent negative cash outflows (expenses) and the equivalent positive cash inflows (revenue) for a selected discount rate.

$$\mathrm{NPV} = C_0 + \sum_{t=1}^{N} \frac{C_t}{(1+r)^t}$$

Equation 2-1

Co: Initial investment

N : Useful life of project

R: Discount rate

t: Time period of a particular cash flow

Ct: Net cash flow at time t

NPV has many advantages as evidenced by its wide use. The following list of advantages is proposed by Mun:

- Clear, consistent decision criteria for all projects
- Same results regardless of risk preferences of investors
- Quantitative, decent level of precision, and economically rational
- Not as vulnerable to accounting conventions (depreciation, investing, valuation, and so forth)
- Relatively simple, widely taught, and widely accepted
- Simple to explain to management: “If benefits outweigh the costs, do it!”

There are also many conceptual issues related to using NPV for valuation of investments in real projects. The most important issue with NPV is that all investment decisions are assumed to be made solely at the beginning of the project and that future states of nature will remain unchanged. This is a deterministic view of the world that fails to adequately account for uncertainty. Therefore NPV fails to recognize that management has the strategic flexibility to make and change decisions as project risks and uncertainties present themselves or are further understood. Failure to recognize and account for the stochastic nature of real projects effectively ignores the value of flexibility.

Other issues arise in analysts' use of discounted cash flow models which are important to resolve given NPV is an integral part of ROA; one such issue is discount rate selection and use. Discount rates commonly used are the risk free rate, Weighted Average Cost of Capital (WACC) or some other risk adjusted rate selected by the analyst. There is a conceptual error commonly seen in NPV analysis whereby both benefits and costs are discounted using a single identical market risk-adjusted discount rate. The benefits of a project should be discounted at a market risk-adjusted discount rate (i.e. WACC) and its cost should be discounted at a reinvestment rate similar to the risk-free rate. Thus, cash flows that have market risks should be discounted using the firm's WACC and cash flows that have private risks should be discounted at the risk-free rate because the market will only compensate the firm for taking on market risks. This discipline of matching discount rates to costs and benefits appropriately recognizes the economic benefits of difference between market and private risk (Thuesen and Fabrycky 2001).

2.2.2 Benefit-Cost Analysis and Benefit-Cost Ratio

Benefit-Cost Analysis (BCA) is a useful economic tool for selecting among alternatives where benefits of the possible project alternatives may not generate identical benefits. It considers life-cycle benefits as well as life-cycle costs.

BCA attempts to capture all benefits and costs from a project or course of action, regardless of which particular party realizes the benefits or costs, or the form these benefits and costs take. BCA sets out to find the economically efficient investment alternative. The efficient alternative is the one that maximizes the net benefits to the firm from its allocation of resources. The benefit-cost ratio (BCR) is used to select the most efficient alternative among competing projects. The BCR is calculated by placing the net present value of benefits in the numerator and the net present value of the initial project investment cost in the denominator. The ratio is then expressed as a quotient, for example: $200/$100= 2.0. The logic follows that projects with the highest BCRs can be selected to form a portfolio of projects that in aggregate yield the greatest benefits to costs.

Care must be taken when relying on the BCR as the primary benefit-cost analysis (BCA) measure. Guidelines state to only include the initial project investment cost in the denominator of the ratio. All other BCA values, including project lifecycle costs, should be included in the ratio's numerator. This approach is necessary to be consistent in project comparisons and not bias against projects with significant operational costs. BCR must also be compared to the net benefit of the projects being selected to assure that high benefit projects are not selected out (FHA 2007).

In summary, the BCA process is as follows:

1. Define project goals, constraints and assumptions
2. Define base case and identify alternatives
3. Set analysis period
4. Analyze economic drivers, i.e. patient demand
5. Estimate benefits and costs relative to base case (BCR)
6. Evaluate risk
7. Compare net benefits and rank alternatives
8. Make recommendations

2.2.3 Internal Rate of Return

The internal rate of return (IRR) is a capital budgeting metric. It is an indicator of the efficiency of an investment, as compared to NPV, which indicates value or magnitude of an investment.

The IRR is the annualized effective compounded return rate which can be earned on the invested capital, i.e., the yield on the investment. A project is a good investment if its IRR is greater than the rate of return that could be earned by alternate investments such as other projects or risk-free investments such as bonds. IRR must include an appropriate risk premium to adequately compare the project being analyzed to any alternate costs of capital.

Mathematically the IRR is defined as any discount rate that results in a net present value of zero of a series of cash flows. If the IRR is greater than the project's cost of capital, or hurdle rate, the project will add value for the company.

Year	**0**	**1**	**2**	**3**	**4**
Cash Flow	-100	+30	+35	+40	+45

Internal Rate of Return (IRR):

$$\mathrm{NPV} = -100 + \frac{30}{(1+r)^1} + \frac{35}{(1+r)^2} + \frac{40}{(1+r)^3} + \frac{45}{(1+r)^4} = 0 \Rightarrow r \approx 17.09$$

IRR = r,

IRR = 17.09%

Net Present Value (NPV), using r = IRR = 17.09%:

$$\mathrm{NPV} = -100 + \frac{30}{(1+17.09\%)^1} + \frac{35}{(1+17.09\%)^2} + \frac{40}{(1+17.09\%)^3} + \frac{45}{(1+17.09\%)^4} = 0.00$$

(Example drawn from www.wikipedia.com)

2.2.4 Payback Period

Payback period is probably the most popular method used by industry for assessing the economic desirability of an investment. The payback period without interest is commonly defined as the length of time required to recover the first cost of an investment from the net cash flow produced by that investment for an interest rate of zero. Represented as an equation, if F_0 equals the first cost of the investment and if F_1

equals the net cash flow in period t, then the payback period is defined as the smallest value of n that satisfies the equation:

$$\sum_{t=0}^{n} F_t \geq 0$$

Equation 2-2

When comparing the payback period for investment proposals it is usually more desirable to have a short payback period than a longer one. A short payback period can be viewed as having a higher degree of liquidity than one with a longer payback period.

There are two fundamental deficiencies of the payback period; this method fails to consider the time value of money since no discounting is used and is shortsighted in that it does not consider the timeframe post payback period (Thuesen and Fabrycky 2001).

Ultimately, no single one method of project valuation is perfect. Common industry practice is to employ multiple methods of project valuations and then compare them in a process that relies heavily on decision maker judgment.

2.3 Real Options Analysis in Engineering Systems

Traditional System Engineering project planning and valuation does not adequately account for uncertainty. There are implicit assumptions in the traditional approach that users understand their needs, and that requirements have been adequately defined and are unchanging for the life of the project. This approach is not without many successes, but can be improved.

Architecting engineering systems from a real options point of view requires three activities according to de Neufville (2002):

- **Valuate Flexibility**. Identify the various kinds of flexibility that could be included in the architecture of the system.
- **Compare Cost to Value**. The value of each element of design flexibility is compared to the value it provides the overall system. This enables the architect

to include flexibility elements that increase the overall value of the system and exclude those that do not.

- **Describe Stages of System Evolution**. The system's evolution over time is described to be able to benefit from exercising design flexibility options.

The methodology further allows hospital administration to develop:

- A recognition that the value of an ED expansion design is associated with the fluctuations of patient demand and market forces, and thus requires active management over the life of the project with keen attention towards exploiting design flexibility as uncertainty is resolved;
- An understanding that uncertainty can be advantageous once one gets beyond the notion that unknowns are risks to be avoided;
- Employing Real Options as a way to manage risk and efficiently allocate capital dollars.

The analysis of Real Options in projects is not without its challenges. These challenges include:

1. Operating knowledge of the system along with a technical understanding of its complexity must be understood by the analyst in order to define the available real options in the ED system. In an ED expansion project, this level of knowledge can be reached through a team approach that includes nurses, physicians, technicians from the specific ED in question along with process engineers and financial analysts that have become familiar with the ED being analyzed.
2. The obviousness of when to exercise an option or what is its exercise price is not readily apparent in real options as it is in financial options. This realization requires management teams to make best judgment decisions that are informed by the indicators identified, and possibly even bounded, by the real options analysis. For example, an option to expand will not necessarily be exercised when a metric such as left without being seen (LWBS) increases by X%. The complexity and combination of factors that drive particular metrics must be actively managed and their interdependencies understood to drive decisions.

3. Real options in an ED system are highly interdependent due the very nature of an ED system. For example if a competing ED closes in the same service area, an option to expand would be exercised. If the closed ED had provided a specialized service that is no longer available to community such as a pediatric emergency medicine specialty, an option to switch a number of treatment areas would be exercised in conjunction with the expansion option.

Real options in this way are “building blocks to describe flexibility”. It drives hospital administrators to think, organize, understand and quantify flexibility in a way that has been previously unavailable with traditional project valuation methods.

2.3.1 Evaluating Flexibility

Evaluating flexibility is the primary distinction between Real Options Analysis and other traditional project valuation methods. The value of flexibility is the net between the investment required to create the design option and the realizable benefit of exercising that option in an uncertain future. This is an especially valuable approach for an ED expansion project that will be making decisions today that will determine the effectiveness and efficiency of the for 15 to 20 years into the future. A flexible design approach with built in options has the additional advantage of efficiently allocating present funds that can be better used elsewhere within the hospital enterprise.

The cost of creating design flexibility is the same as any project costing activity. The estimation of the value of flexibility in an uncertain future has three major elements (de Neufville 2002):

- Risk Estimation. The risks associated with the inflexible project drives volatility which is the essential driver of flexibility value. The elements of volatility within an ED project are described in Appendix A.
- Option Value Calculation. The option value is calculated using decision analytics or other methods such as binomial lattices in conjunction with Black-Scholes equation. These methods are presented in Chapter 4.
- Option exercising strategy. The method and timing of exploiting options in designs must be understood to reap the benefits of flexibility. These methods are presented in Chapter 4 as well.

The estimation of risks associated with an ED system is best approached by simulation of system behavior. This is the case for a new ED system because historical data do not exist for which to calculate volatility for the new design in the environment of the future. Calculation of system behavior risk should not be confused with calculating the volatility of factors affecting the system such as in the ED case: patient volume, patient treatment times, and hospital capacity. Calculating the value of system flexibility could reasonably be approached through the use of decision analytics, i.e. decision trees. Although a binomial lattice approach using Black-Scholes equation may provide a more economically correct answer, its complexity and increased resolution arguably outweighs its benefit. Exercising options in a system is not intuitively obvious and timing is not as well defined as some financial options such as European calls and puts. In system design the profitability of exercising options is not always easily determined.

2.3.1 .1 Comparing Cost to Value

Once the cost of flexibility in an ED design is understood it must be compared to the economic benefits of having the option. This comparison can range from a simple mathematical higher-is-better decision rule to considering the value of flexibility as just one input to a judgment based decision process. Flexibility that when exercised provides intangible or difficult to value benefits such as better health, improved public image or good faith pose a quantification challenge for analysts. These unquantifiable, or at least not readily or consistently quantifiable, benefits abound in the healthcare context, but will not be treated in this work beyond recognition of their presence.

2.3.1.2 Value at Risk and Gain (VARG) Analysis

Value at risk analysis displays the cumulative density function of the possible outcomes of a design. Future demands on the ED system, emergence and obsolescence technology, market shifts and new entrants, and policy changes are inevitably uncertain. The VARG itself is the minimum loss or maximum gain that might exist at any probability. Said differently, it defines a loss that will not be exceeded at some specified confidence level. The comparison of VARG curves for two ED design solutions shows the differences both in maximum possible loss and gain between them. This method in effect provides the valuation of flexibility between alternatives. The difference between the expected NPV, E(NPV), of a flexible and a rigid ED design is:

$$flexibility\ value = E(NPV)_{flexible} - E(NPV)_{rigid}$$ **Equation 2-3**

The E(NPV) can be calculated from present values of revenues and costs of any ED design as provided by financial revenue and cost estimations (Hassan, de Neufville et al. 2005). The flexible design provides value by decreasing downside risk and increasing upside potential; this is the asymmetric value of design flexibility.

The spreadsheet based analysis described by de Neufville to calculate value at risk is as follows:

1. Examine the design without flexibility (base case)
2. Introduce variability through simulation
3. Introduce flexibility
4. Compare results

2.4 Decision Tree Analysis

Decision Tree Analysis (DTA) is another useful tool for strategic decision-making because it accounts for uncertainty and managerial flexibility (de Neufville 1990). Additional stated benefits are that DTA provides:

1. Strategies for altering choices as unknowns become known. Other methods provide optimal choices against a set of ED specifications that may or may not reflect future system needs.
2. A second best choice is an inherent part of DTA which offers insurance against downside and opportunities to exploit the upside.
3. Insight to stakeholders about the range and distribution of possible results (i.e. Value at Risk).

DTA provides an efficient means for decision makers to overcome the difficulty of dealing with complex, uncertain situations where multiple choices exist between ED designs. Without a suitable framework such as DTA, managers tend to oversimplify situations (best case, worst base, etc…) at the expense of system performance.

The use of DTA is broadly understood in its basic sense by stakeholders from multiple backgrounds. DTA provides manageable graphical representation of a wide range of choices over several time periods, along with associated uncertainties and even customer satisfaction as proposed by de Neufville. Figure 2-1 shows how DTA can readily illustrate the difference between a static NPV approach and a Real Options Approach (Williams, Mammes et al. 2007)

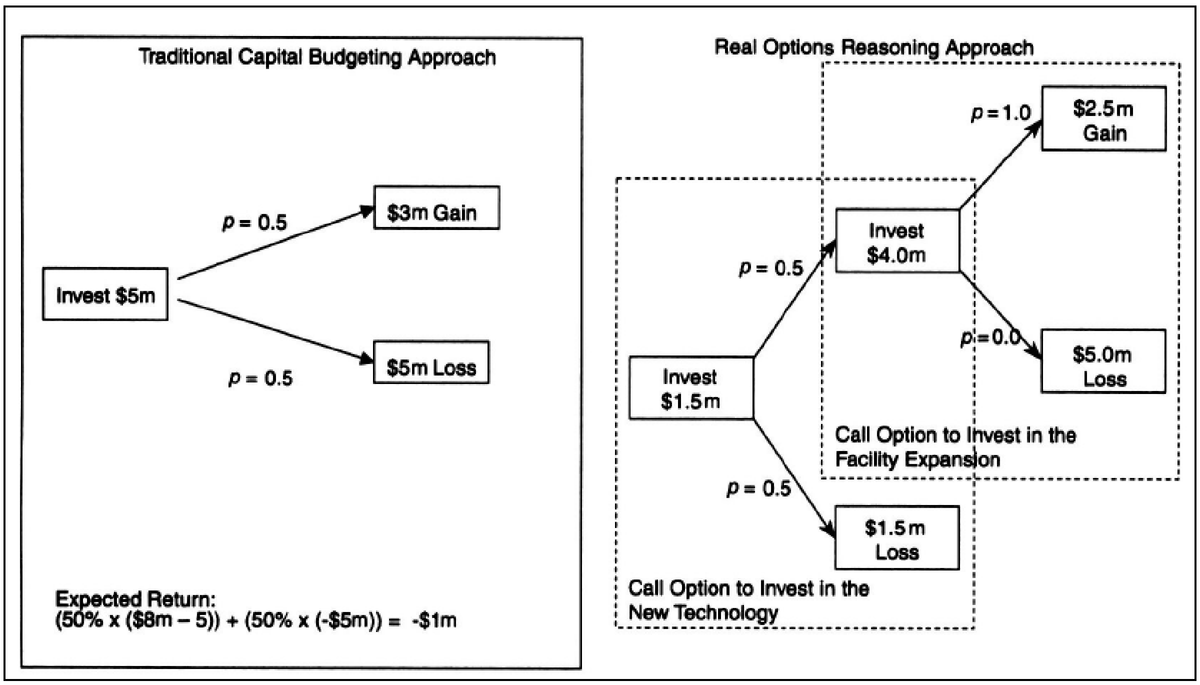

Figure 2-1 Comparison of NPV and Real Options Analysis using decision trees (Williams, Mammes et al. 2007).

Decision trees offer advantages to other methods of analyzing alternatives. Decision trees are:

- **Graphic**. You can represent decision alternatives, possible outcomes, and chance events schematically. The visual approach helps with comprehending complex decision sequences and dependencies.
- **Efficient**. You can quickly express a complex decision problem clearly. You can easily modify a decision tree as new information becomes available. After a

decision tree is set up you can use it to compare how changing input values affect the decision alternatives. Standard decision tree notation is easy to adopt.

- **Revealing**. You can compare competing alternatives in terms of risk and probable value. The expected value (Grenadier) term combines relative anticipated payoffs and uncertainties into a single numerical value. The EV reveals the overall merits of competing decision alternatives.
- **Complementary**. You can use decision trees in conjunction with other project management tools. For example, project scheduling information can be evaluated by the decision tree method (www. projectsphinx.com).

The multiple choices necessary to be made in an ED design to serve the needs of an uncertain future patient population create the prototypical case that can benefit from a flexible approach. The flexibility provided has several advantages:

- Reduces the maximum loss of over-building the ED
- Reduces the initial capital costs
- Increases the expected value of the project
- Increases the maximum possible gain and expected gain in financial terms and delivered service level to the community

Since the identification of worthwhile flexibility design elements in an ED is not trivial, it is useful to develop a holistic view of the ED and its operating context.

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Chapter 3. Real Options Analysis of the ED System

The GBH Administrators have made a strategic decision to expand their existing ED to meet the current and future needs of their patients; this is specifically motivated by the current capacity shortfalls being experienced in the ED. The level of investment required for this expansion requires the project team to find the most economically desirable method to approach this expansion project.

The value of real options becomes apparent when one accepts that forecasts are always wrong. The multiple factors described in this work that influence ED demand and throughput will inevitably conspire to create conditions different from that originally anticipated. In this simple spreadsheet model demand is uncertain and ED throughput remains constant on a per capacity (bed) basis. Hospital effects such as admissions rate are ignored, but can be brought into consideration by the team when discussing model outputs.

A basic real options analysis spreadsheet can provide direction to bring capacity into service when and where it is needed. This avoids building excess capacity long before it is needed and avoids tying up funds that can be better utilized elsewhere. An example of using funds elsewhere as it relates to the ED is to invest a nominal amount in reconfiguring an existing ED to have better throughput and use excess funds to expand in-hospital capacity to avoid ED boarding.

The Real Options Analysis for the GBH ED is done using spreadsheet based simulation of infrastructure expansion scenarios (de Neufville, Scholtes et al. 2006) adapted for hospital use. The underlying model in this example was chosen since it avoids complex financial procedures which are inappropriate for most design issues and would be a distraction to the introduction of Real Options in design to the healthcare context. Simplifications aside, the substantial improvement in performance afforded by real options over the deterministic approach is readily apparent.

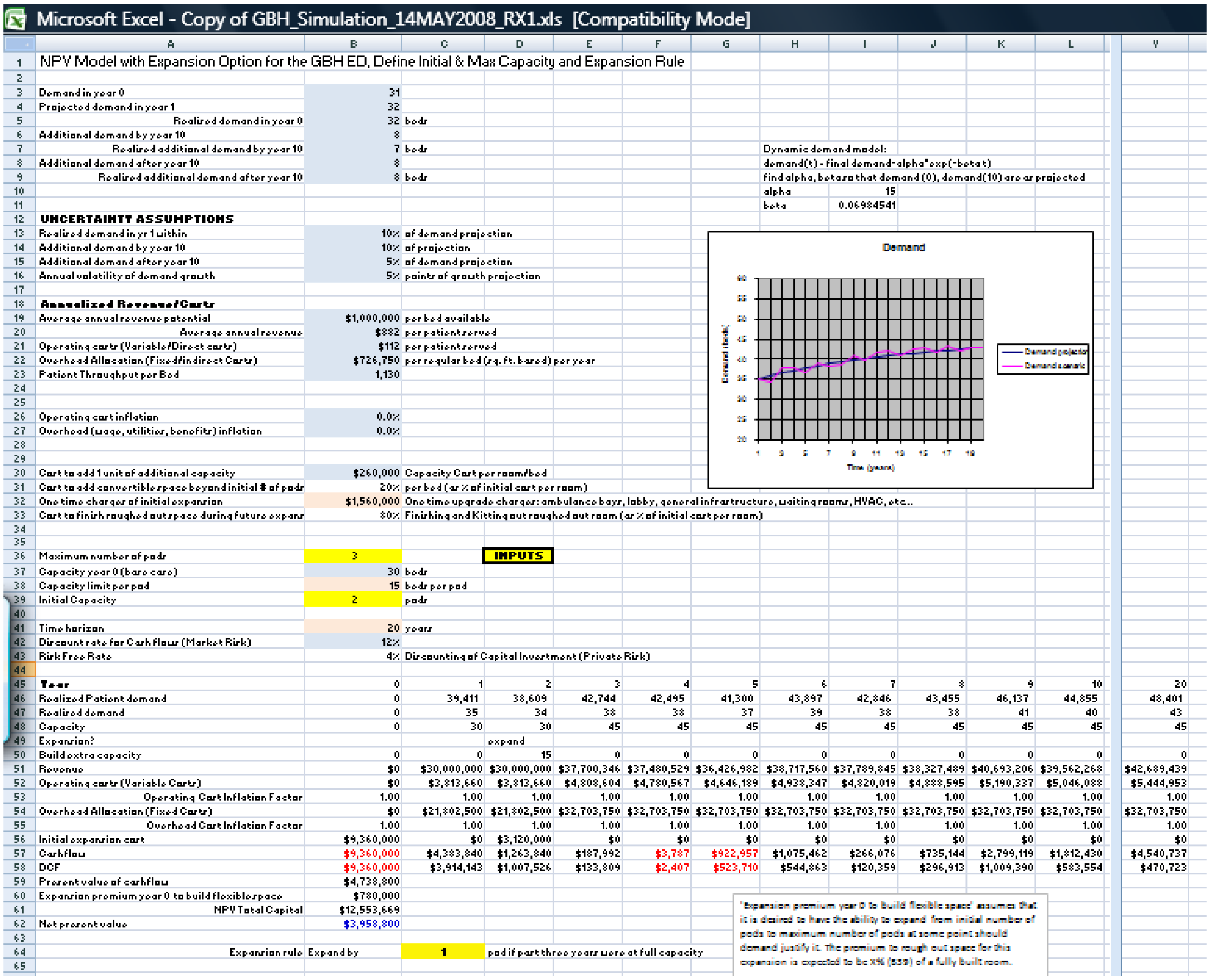
3.1 The spreadsheet model

The model is fundamentally based on a discounted cash flow (DCF) analysis. The advantage of using DCF is that anyone with basic financial training will readily become familiar with the calculation mechanics and the implications of the results. The other fundamental aspect of the model is the simulation that drives demand forecasts for the non-deterministic cases and the ENPV calculations. These are simple simulations as far as simulations go, yet serve the purpose of introducing the reality of uncertainty into the modeling exercise. The model users need not be distracted by the intricacies of the simulation since only simple, familiar inputs are required to obtain useful results.

The inputs that represent the driving assumptions for the model are:

1. Expected initial demand, demand at year 10 and uncertainty around the same
2. Operational Costs: Fixed and Variable
3. Expansion Costs: Cost per bed and cost for expandable space
4. Project Time Horizon and Discount Rates

An example of model a screen shot is shown in Figure 3-1 and a working Excel version is available for use on Professor Richard de Neufville's Real Options Website: http://ardent.mit.edu/real_options/Common_course_materials/papers.html. The inputs are organized in the upper left corner of the sheet and the discounted cash flow calculations extend across columns towards the right as typically seen in financial spreadsheets. The model also generates a chart to graphically represent how demand evolves over time. After setting up the base assumptions, only three or four inputs (initial number of pods, maximum number of pods, number of beds per pod and/or number of pods to add during each expansion) need be varied to test different build strategies



Microsoft Excel - Copy of GBH_Simulation_14MAY2008_RX1.xls [Compatibility Mode]

NPV Model with Expansion Option for the GBH ED, Define Initial & Max Capacity and Expansion Rule

Demand in year 0	31	
Projected demand in year 1	32	
Realized demand in year 0	32	beds
Additional demand by year 10	8	
Realized additional demand by year 10	7	beds
Additional demand after year 10	8	
Realized additional demand after year 10	8	beds
UNCERTAINTY ASSUMPTIONS		
Realized demand in yr 1 within	10%	of demand projection
Additional demand by year 10	10%	of projection
Additional demand after year 10	5%	of demand projection
Annual volatility of demand growth	5%	points of growth projection
Annualized Revenue/Costs		
Average annual revenue potential	$1,000,000	per bed available
Average annual revenue	$882	per patient served
Operating costs (Variable/Direct costs)	$112	per patient served
Overhead Allocation (Fixed/indirect Costs)	$726,750	per regular bed (sq. ft. based) per year
Patient Throughput per Bed	1,130	
Operating cost inflation	0.0%	
Overhead (wage, utilities, benefits) inflation	0.0%	
Cost to add 1 unit of additional capacity	$260,000	Capacity Cost per room/bed
Cost to add convertible space beyond initial # of pods	20%	per bed (as % of initial cost per room)
One time charges of initial expansion	$1,560,000	One time upgrade charges: ambulance bays, lobby, general infrastructure, waiting rooms, HVAC, etc...
Cost to finish roughed out space during future expans	80%	Finishing and Kitting out roughed out room (as % of initial cost per room)
Maximum number of pods	3	INPUTS
Capacity year 0 (base case)	30	beds
Capacity limit per pod	15	beds per pod
Initial Capacity	2	pods
Time horizon	20	years
Discount rate for Cash flows (Market Risk)	12%	
Risk Free Rate	4%	Discounting of Capital Investment (Private Risk)

Dynamic demand model:
demand(t) - final demand-alpha*exp(-beta t)
find alpha, beta so that demand (0), demand(10) are as projected

alpha	15
beta	0.06984541

Demand

Year	0	1	2	3	4	5	6	7	8	9	10	20
Realized Patient demand	0	39,411	38,609	42,744	42,495	41,300	43,897	42,846	43,455	46,137	44,855	48,401
Realized demand	0	35	34	38	38	37	39	38	38	41	40	43
Capacity	0	30	30	45	45	45	45	45	45	45	45	45
Expansion?			expand									
Build extra capacity	0	0	15	0	0	0	0	0	0	0	0	0
Revenue	$0	$30,000,000	$30,000,000	$37,700,346	$37,480,529	$36,426,982	$38,717,560	$37,789,845	$38,327,489	$40,693,206	$39,562,268	$42,689,439
Operating costs (Variable Costs)	$0	$3,813,660	$3,813,660	$4,808,604	$4,780,567	$4,646,189	$4,938,347	$4,820,019	$4,888,595	$5,190,337	$5,046,088	$5,444,953
Operating Cost Inflation Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Overhead Allocation (Fixed Costs)	$0	$21,802,500	$21,802,500	$32,703,750	$32,703,750	$32,703,750	$32,703,750	$32,703,750	$32,703,750	$32,703,750	$32,703,750	$32,703,750
Overhead Cost Inflation Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Initial expansion cost	$9,360,000	$0	$3,120,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cashflow	$9,360,000	$4,383,840	$1,263,840	$187,992	$3,787	$922,957	$1,075,462	$266,076	$735,144	$2,799,119	$1,812,430	$4,540,737
DCF	$9,360,000	$3,914,143	$1,007,526	$133,809	$2,407	$523,710	$544,863	$120,359	$296,913	$1,009,390	$583,554	$470,723

Present value of cashflow	$4,738,800
Expansion premium year 0 to build flexible space	$780,000
NPV Total Capital	$12,553,669
Net present value	$3,958,800
Expansion rule	Expand by 1 pod if past three years were at full capacity

'Expansion premium year 0 to build flexible space' assumes that it is desired to have the ability to expand from initial number of pods to maximum number of pods at some point should demand justify it. The premium to rough out space for this expansion is expected to be X% (55?) of a fully built room.

Figure 3-1 Real Options Model screenshot example for the GBH ED simulation.

Other assumptions are coded into the model such as demand growth, expansion rules and ENPV simulation.

The growth in demand is taken to be exponential which is an acceptable approximation of population growth, but could have been modeled as linear growth or any other reasonable approximation. This dynamic model permits fluctuations to take place as would be expected under real circumstances to calculate demand for any given year.

The expansion rule (when to expand) is based on previous year observations. The model tests capacity for the previous X years against demand over the same period, if for each of the previous X years demand is exceeded then an expansion would be triggered. This X can be any number smaller than the life of the project. The examples provided in this work used X = 3 years as a reasonable and optimum time frame. This expansion rule is coded into the model, but can be changed by the users familiar with editing functions in electronic spreadsheets.

The ENPV is an average of possible NPV under the given model assumptions. Each possible development strategy is tested to see how it performed over the range of possible future demands. This was done by running 2000 iterations of possible NPV outcomes to arrive at an average NPV or ENPV. These 2000 calculations happen automatically every time the model is refreshed by pressing F9 in the Excel version of this model. The spreadsheet then randomly varies the simulation inputs and calculates a resulting NPV and stores the value as a possible outcome. The outcomes are then aggregated into a distribution of possible NPVs that can then be statistically analyzed to make some inferences about minimum, maximum and average NPV as well as confidence level statements for the mean (ENPV). A Histogram and the Cumulative Distribution Function (CDF) for the distribution is also provided. A screenshot example of the ENPV simulation outputs (Histogram and CDF) are shown in Figure 3-2.

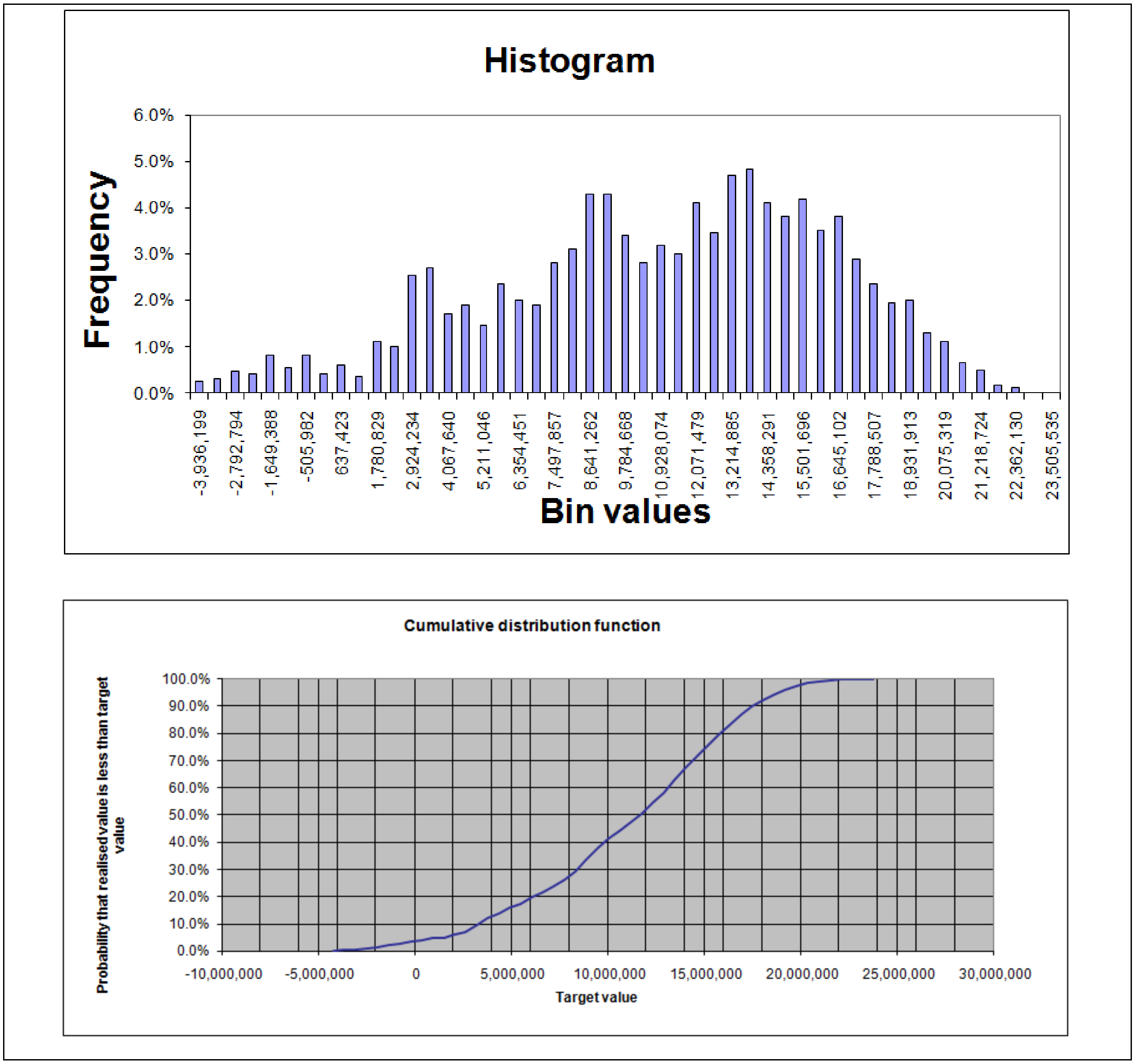


Figure 3-2 Examples of NPV simulation Histogram and CDF simulation.

3.2 Simulation steps

The following steps were taken to analyze the GBH ED expansion project using an adapted garage case model:

1. Determine expansion strategy/configuration and model the static expansion case with no flexibility

2. Model the static base case using randomized demand

3. Analyze various expansion scenarios using randomized demand and Monte Carlo simulation to obtain the ENPV.

4. Compare results using VARG curves and summary metrics. The cumulative distribution of the scenario simulations gives the Value at Risk and Gain (VARG) which shows the probability that an NPV might be less or equal to a threshold.

3.3 ED Expansion Configurations

ED physical configurations can be generally lumped into four types: racetrack, pods, interlocking pods and linear model. Each of these configurations has its advantages and disadvantages related to patient flow, staff flow, space utilization, expansion flexibility and staffing flexibility. The Advisory Board Company Innovation Center published an assessment of ED configurations in 2007 shown in Figure 3-3 (2007).

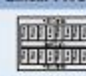
	Racetrack	Pods	Interlocking Pods	Linear Model
				
Description	• Treatment rooms lining outside perimeter with a central nursing station in the middle	• Treatment rooms arranged in small groups around a central nursing station • Units contiguous to each other	• Treatment rooms arranged in small groups around a central nursing station • Pods offset from each other across hallways to increase visibility	• Two rows of treatment rooms aligned along staff-only corridor with separate public circulation space along the outside perimeter
Patient Flow	• Patients, staff, and equipment move in space around central nursing station • Patients, staff, and materials share same hallways	• Patients, staff, and equipment share same circulation space within pods • Compact patient circulation	• Patients, staff, and equipment share same circulation space within pods • Compact patient circulation	• Patients, families move in exterior corridors • Enter ED rooms from perimeter spaces
Staff Flow	• Staff moves in and out of central nursing station • Share same traffic patterns as patients, families, and materials	• Direct flow to ED rooms from central nursing station • Compact staff flow	• Direct flow to ED rooms from central nursing station • Compact staff flow	• Staff share central corridor with equipment, materials • Staff enter treatment rooms from central corridor
Degree of Flexibility for Future Expansion	• Relatively flexible, but requires expansion of nursing station or creation of new station	• Moderate level of flexibility • Design allows for future expansion	• Moderate level of flexibility • Design allows for future expansion	• Extremely flexible—rooms built onto the end of the corridor • Design unwieldy if room count along corridor exceeds 50 spaces
Advantages	• Simple patient circulation • Good line of sight to patients • Staff can congregate easily	• Permits closer monitoring of patients • Enables segregation of patients by acuity level or illness	• Permits closer monitoring of patients • Enables segregation of patients by acuity level or patient type	• Easily expands, contracts depending on patient volumes • Less congested corridors for staff • Staff core can serve as semi-sterile core during outbreak/disaster surge
Disadvantages	• Line of sight diminishes as treatment rooms added • Mixes patient, staff, equipment flows	• Incapable of flexing up/down depending on patient volumes • Pods can become specialized silos	• More flexible than traditional pod arrangement, but still locked into rigid pod formation	• Staff communication difficult along long corridor • Poor visibility of public circulation space for staff • Patients may be stranded at end of corridor as rooms close
Innovations Center Assessment	• A good fit for EDs with fewer than 20 beds, but has significant growth and traffic challenges	• Layout promotes specialization at the expense of patient flow	• Layout allows specialization, but still the potential for substandard patient flow	• A flexible option that adapts to hourly volume fluctuations, but poses staff communication, patient monitoring challenges

Figure 3-3 Comparison of ED configurations from The Advisory Board Company Innovations Center "Emergency Department Design" (2007)

Physical limitations at times may not allow a particular type of configuration to fit in a particular building site. For example, the GBH site has a land feature that prevents an elongated design such as a linear model or long racetrack. The current GBH ED can be considered a short racetrack, with a pod capping either end of the racetrack. This works marginally well and can be improved upon as part of an expansion. Taking this into consideration the expansion configurations in this research are interlocking pod designs due to the site geometry and them providing a nice balance of flexibility and efficient patient flow. The GBH site is estimated to be able to fit the equivalent of 50 beds independent of how many are distributed into each pod grouping. Too many small pods chop up the space and impeding patient flow. Pods that are too big prevent flexibility and make direct patient monitoring difficult. The pod groupings will be between 10 and 20 beds per pod to avoid these operational limitations.

3.4 The Analysis

The base case and two flexible expansion scenarios analyzed in this work were as follows:

Scenario	Physical Configuration	Comments
Static Expansion – 45 beds	Interlocking pods	Full capacity built at year zero (three 15 bed interlocking pods)
Flex Expansion 2/4/14*	Interlocking pods	Two pods built at year zero with an option to expand to four by year 20. Each pod has 14 beds.
Flex Expansion 3/5/10*	Interlocking pods	Three pods built at year zero with an option to expand to five by year 20. Each pod has 10 beds.

***Expansion Abbreviation Example**: 3/5/10 is 3 initial pods with an option to expand to 5. Each pod has 10 beds.

Table 3-1 Summary of expansion scenarios modeled

Hospital administrators such as in GBH feel, if not have, an obligation to provide for the emergency care needs of their community. Thus, the first step of the analysis was to set up a static expansion base case which is aligned with the GBH expansion strategy.

The deterministic base case assumed expansion occurs once at year zero to satisfy expected demand over the life of the project and that demand follows a deterministic path. In the case of GBH, it is assumed that the project team would decide to build a 45 bed facility at year zero. Taking this approach creates over capacity over the near term where demand does not match up well with capacity until about year 12, nearly mid way through the life of the project, as seen in Figure 3-4. Well matched capacity is taken to be when demand is approximately 85% to 90% of capacity; this is high enough to offset fixed costs, yet allows a sufficient buffer to handle spikes in demand or modest drops in patient throughput for unforeseen reasons. In this scenario there is a dozen year excess capacity carrying cost associated with the deterministic expansion approach. Tying up resources for a decade or so before the investment was actually needed is a wasteful practice. Having shown that ED boarding and overcrowding is a hospital issue, it would seem that these tied funds could have been routed to in-hospital wards to expand capacity that could be specifically reserved for ED use unless released by ED staff.

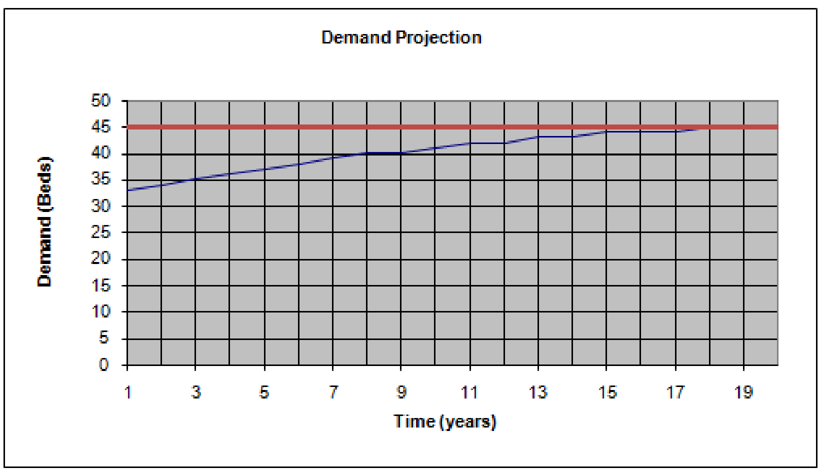


Figure 3-4 Comparison of demand and capacity over the life of the 45 bed deterministic expansion case scenario.

Conducting the 2000 run randomized simulation on the 45 bed scenario produces significantly different outcomes from the deterministic 45 bed case as seen below in Table 3-2. This type of randomized analysis is necessary as mentioned earlier because the deterministic case is just one of an infinite number of scenarios that can occur. It is useful because it shows the range of risks, min NPV and Max NPV, associated with each expansion strategy.

Scenario	Total No. of Beds at Year 20	CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Deterministic Expansion - 45 Beds	45	$13,260,000	$811,682	-	-	-
Randomized Expansion - 45 Beds	45	$13,260,000	$3,498,877	($27,689,967)	$23,032,228	$11,729,523

Table 3-2 Comparison of deterministic 45 bed expansion and randomized simulation.

The NPV values are contingent upon simulated demand realization. The negative part of the range was a result of the carrying costs of excess capacity when demand does not grow as expected and the positive NPV was a result of demand scenarios being sufficiently high to offset fixed costs. The randomized case has a higher ENPV than the deterministic case since demand turns out to be better matched to capacity over various instances of the 2000 simulation runs. This creates a greater number of more favorable NPV scenarios than less favorable ones which averages to a higher ENPV than the deterministic demand scenario. Similarly, the randomized case shows that it is possible to have a substantial loss over some demand scenarios as well. Different runs of the simulation generated ENPVs that could range from positive to negative due to the nature of the resulting distribution and the high standard deviation which is about 20% of the range between minimum and maximum NPV values. The randomized simulation approach provides hospital administrators a more complete picture of possible outcomes and, in this scenario, a higher ENPV due to the expected demand realization. However, since all forecasts are wrong the rigid expansion approach seems very risky and potentially financially catastrophic. A better approach exists.

The flexible expansion scenarios attempt to capitalize on the uncertainty of demand realization and the ability management has to make expansion decisions at the right time in a project's life. This again is the power of a real options approach, management has the ability to choose as uncertainty is resolved. Two flexible expansion scenarios were developed to showcase this approach and find a scenario that was financially attractive and which served the emergency care needs of GBH's community over the life of the project; something the rigid expansion strategy not been able to accomplish.

The following notation is used to describe the flexible scenario X/Y/Z where X = starting number of pods, Y = maximum number of pods and Z = number of beds per pod. The first scenario tested was one in which two 14 bed pods are built initially and pods can be added as demand uncertainty is resolved up to a total of four pods (2/4/14) over the life of the project. This scenario deliberately started with a capacity level slightly under exepected demand to assure no excess capacity ocurred even during possible fluctuations. This demand scenario can be seend in Figure 3-4.

This would initially maximize cash flows and prevent any carrying costs of surplus capacity. The results of this simulation are shown below in Table 3-3.

Scenario	Total No. of Beds at Year 20	Initial CAPEX	PV of CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Expansion Option 2/4/14	42	$10,192,000	$12,444,757	$3,290,333	($14,293,080)	$21,602,333	$8,765,644

Expansion Option Abbreviation Example: 3/5/10 is 3 pods initially built with an option to expand to 5 with each pod having 10 beds.

Table 3-3 Summary of 2/4/14 expansion simulation results.

This scenario had an expansion rule that expansion would occur if demand out paced capacity for the previous three years. This served to attenuate premature expansion due to unsustained spikes in demand and thus prevent adding beds prior to demand levels being sufficiently high to offset fixed costs. Expanding too soon (when one previous year of demand is higher than capacity) or too late (four years of demand higher than capacity) results in lower ENPVs than the three year. Expanding too late also results in lower levels of service; something to be avoided in emergency medicine. Another parameter that was varied was how many pods to add during each expansion step. It was found that adding one pod at a time resulted in the highest ENPV. Adding two or three pods at a time resulted in excessive capacity and hence excessive carrying costs that reduced ENPV without increasing level of service.

An alternate expansion scenario was modeled to build upon the success of the 2/4/14 scenario. The 3/5/10 scenario was intended to match initial demand with the same capacity currently in place. The smaller pods were crafted to be more flexible and manageable by a smaller number of staff. This scenario also provides the greatest operational flexibility by shutting down pods during slow days or seasons and opening them back up during busy times. This operational benefit was not included in the model and provides an additional economic advantage to the already attractive 3/5/10 expansion option. From a construction standpoint this pod size of 10 also allows smaller expansion investments spread out over larger periods of time. The results of this simulation are summarized in Table 3-4.

Scenario	Total No. of Beds at Year 20	Initial CAPEX	PV of CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Expansion Option 3/5/10	40	$10,400,000	$11,889,112	$10,980,562	($4,222,051)	$23,791,387	$5,419,719

Expansion Option Abbreviation Example: 3/5/10 is 3 pods initially built with an option to expand to 5 with each pod having 10 beds.

Table 3-4 Summary of flexible scenario 3/5/10

The ENPV was positive at $11,900,000 with a standard deviation of $5,420,000. This stacks nicely against the results of the deterministic expansion case.

This is the point in the analysis where readers may wonder if RO is still prevails if the number of beds were to be built was the same as the rigid case instead of letting the RO model select the optimum expansion strategy given the model input assumptions. To answer this question the model was forced to select an expansion scenario that would end up with the same number of beds as the rigid expansion case. A summary of the results is shown in Table 3-5. The flexible expansion case maintains the higher ENPV and minimizes the dowside risk as well as project initial and total discounted CAPEX.

Scenario	Total No. of Beds at Year 20	CAPEX Over Life of Project	Initial CAPEX	ENPV	MinNPV	MaxNPV	Std Dev Returns
Deterministic Expansion - 45 Beds	45	$13,260,000	$13,260,000	($5,316,487)	-	-	-
Randomized Expansion - 45 Beds	45	$13,260,000	$13,260,000	($4,486,363)	($33,114,148)	$18,221,474	$12,518,757
Expansion Option 2/3/15	45	$12,553,669	$10,140,000	$2,299,068	($2,006,113)	$6,906,937	$1,450,137

Expansion Option Abbreviation Example: 2/3/15 is 2 pods initially built with an option to expand to 3 with each pod having 15 beds.

Expansion Scenario Simulations	2/3/15 45 Beds	45 Static
Average ENPV	$2,299,068	($5,555,357)
ENPV Std dev	$1,450,137	$12,518,757
95% Confidence Interval for Average ENPV	$2,266,654	($5,835,285)
	$2,331,481	($5,275,429)
Real option value	$7,854,424	N/A
Real option cost	$780,000	N/A
Acquire the option?	Yes	N/A

Table 3-5 Comparison of equal end number of beds

The VARG curves for the equal number of beds case is shown in Figure 3-5. The illustration of what is presented in Table 3-5 can be readily seen in these VARG curves. The rigid case has a substantial portion of possible outcomes in the negative NPV range while the flexible case is mostly in the positive NPV range.

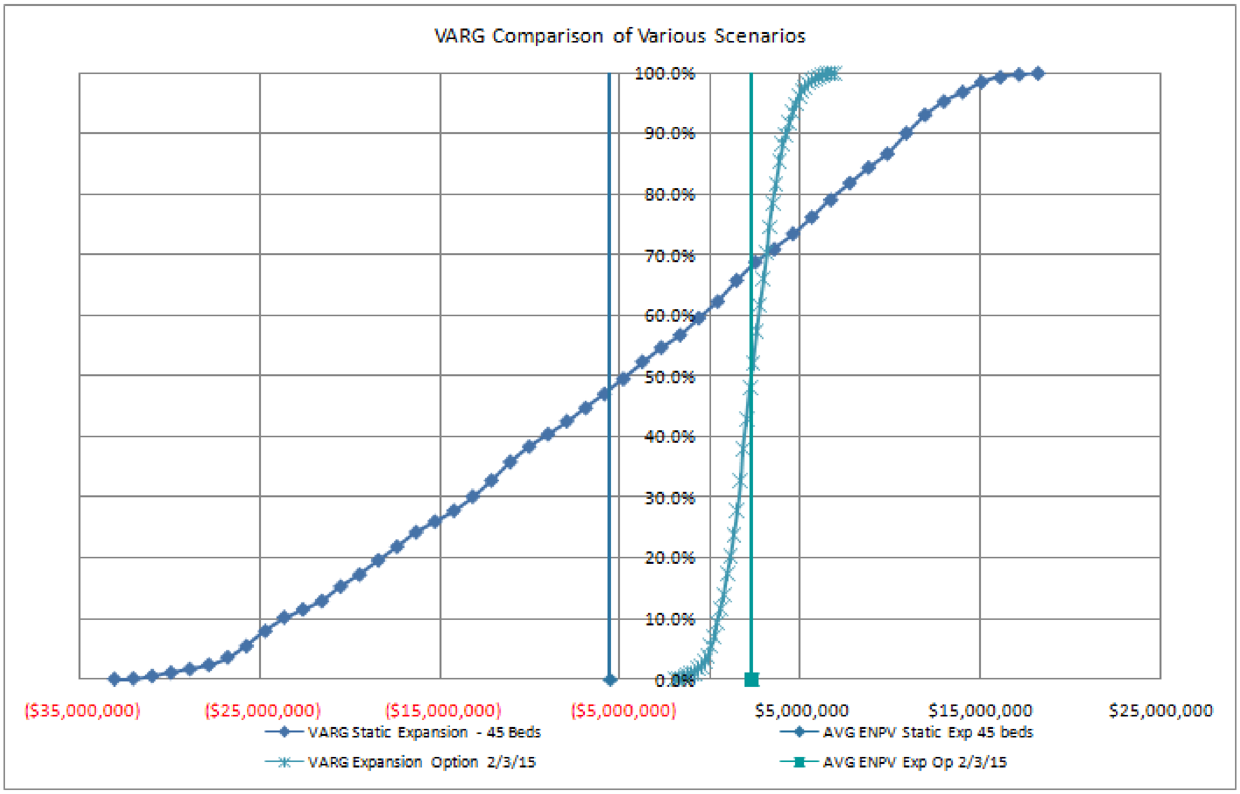


Figure 3-5 VARG curves for same total number of bed rigid and flexible expansion.

Another question that arises is the effect of varying the number of beds per pod and expansion rules on the value of each scenario. Table 3-6 shows the results of having equal pod sizes for two different flexible expansion strategies. Normalizing each expansion scenario to 10 bed pods favors the 2/4/10 expansion over the previously higher 3/5/10. This result although interesting, does not pass the minimum level of service test since 'expanding' an ED to have two thirds of the orginal size isn't a rational approach given present patient demand.

Scenario	Total No. of Beds at Year 20	CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Expansion Option 2/4/10	40	$10,667,105	$14,229,513	($553,643)	$27,021,369	$7,358,211
Expansion Option 3/5/10	50	$13,138,307	$10,939,230	($6,272,234)	$22,794,142	$5,604,803

Expansion Option Abbreviation Example: 3/5/10 is 3 pods initially built with an option to expand to 5 with each pod having 10 beds.

Table 3-6 Flexible expansion scenarios normalized to an equal pod size.

The VARG comparion of the scenarios discussed is shown below in Figure 3-6.

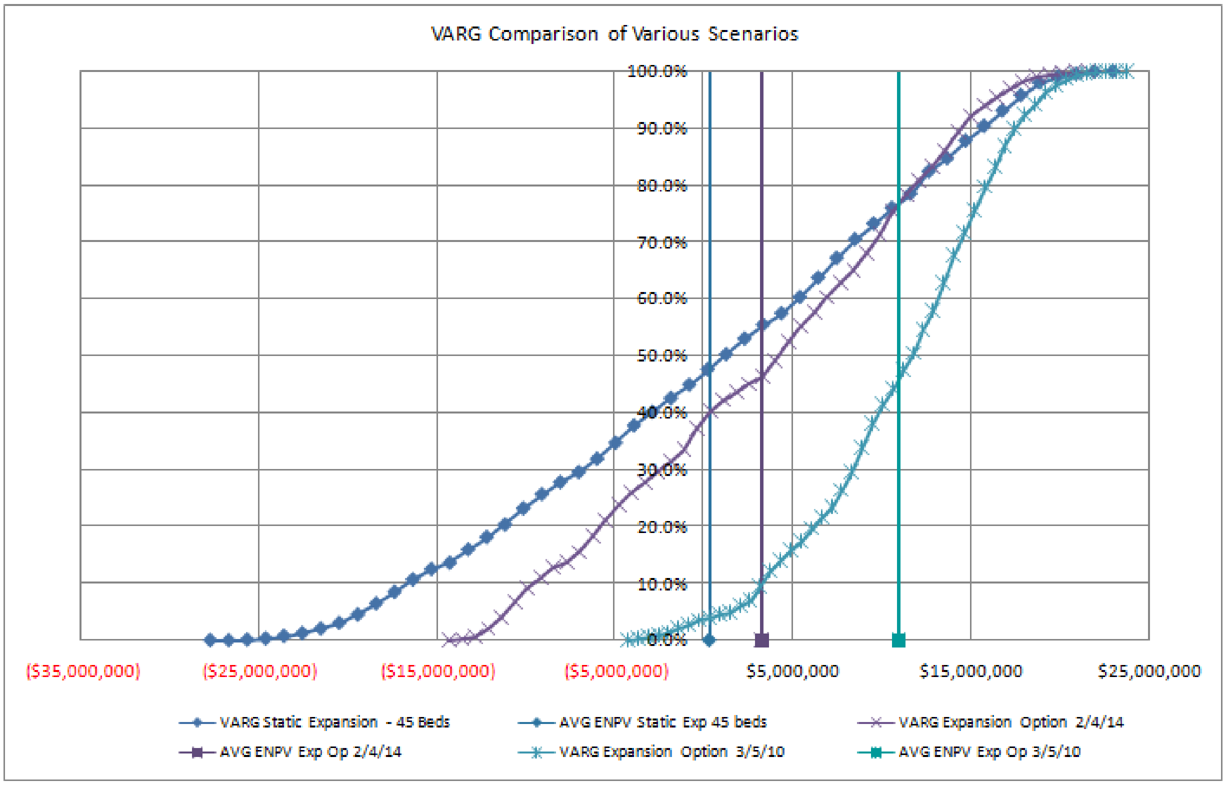


Figure 3-6 VARG comparison of static and flexible expansion strategies.

The Value at Risk and Gain (VARG) curves readily compare the scenarios considered in this analysis. The difference both in maximum possible loss and gain between each scenario is readily observable. This also leads to valuation of the flexibility provided by the different project scenarios. The value of the options in the flexible expansion projects is the difference between the ENPV of the flexible design minus the ENPV of the rigid design.

$$flexibility\ value = E(NPV)_{flexible} - E(NPV)_{rigid}$$

Equation 3-1

The asymmetric nature of options in design can be appreciated by considering the following results shown in Table 3-7. Average ENPV is the average of the 2000 simulation runs, the ENPV standard deviation is the standard deviation of the distribution, the 95% confidence interval bounds the possible values of the average ENPV to a high confidence level, the real option value is the difference between the flexible ENPV and the static case ENPV and the real option cost is the investment required to have access to the element of design flexibility. The decision to acquire the option compares the value of the option against zero; any positive value option should be acquired. For example, in the 3/5/10 scenario an investment of $1,040,000 in a flexible design options has a value of $11,404, 927 which indicates that the option should be acquired solely based on financial criteria. This $1,040,000 investment is how much needs to be invested in roughing out the expandable space; the cost of the real option. This is the asymmetric nature of options.

Expansion Scenario Simulations	3/5/10	45 Static	2/4/14
Average ENPV	$10,980,562	$354,195	$3,290,333
ENPV Std dev	$5,419,719	$11,729,523	$8,765,644
95% Confidence Interval for Average ENPV	$10,859,468	$91,915	$3,094,285
	$11,101,657	$616,475	$3,486,381
Real option value	$10,626,367	N/A	$2,936,138
Real option cost	$1,040,000	N/A	$1,456,000
Acquire the option?	Yes	N/A	Yes

Table 3-7 Summary of simulation runs for each flexible expansion strategy.

The following table summarizes metrics for all expansion scenarios considered:

Scenario	Total No. of Beds at Year 20	CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Deterministic Expansion - 45 Beds	45	$13,260,000	$811,682	-	-	-
Randomized Expansion - 45 Beds	45	$13,260,000	$3,498,877	($27,689,967)	$23,032,228	$11,729,523
Expansion Option 2/4/14	42	$12,444,757	$3,290,333	($14,293,080)	$21,602,333	$8,765,644
Expansion Option 3/5/10	40	$11,889,112	$10,980,562	($4,222,051)	$23,791,387	$5,419,719

Expansion Option Abbreviation Example: 3/5/10 is 3 pods initially built with an option to expand to 5 with each pod having 10 beds.

Table 3-8 Summary of all modeled expansion strategies.

The simple financial argument would select the 3/5/10 expansion option since it has the highest ENPV with a tight standard deviation. This case would indeed seem to maximize financial value for GBH. This scenario has the added benefit to maintain level of service as demand grows, rather than by building premature surplus that could lead to operational inefficiencies. It is not difficult to imagine that if ED boarding is an issue today when hallway beds need to be used, what would the boarding issue look like if there were an additional 30-40% surplus of ED beds?

GBH should choose the 3/5/10 expansion under the given assumptions. The 3/5/10 scenario provides a robust average ENPV as compared to other scenarios, minimizes downside risk and maximizes potential upside gain.

Running the 3/5/10 scenario multiple times results in a 40-bed or 50-bed configuration being chosen as optimum depending on demand realization. While still producing the highest ENPV of all scenarios considered, the 50 bed configuration is the only scenario of those considered that after twenty years is still able to provide a high level of service by having a modest amount of excess capacity to meet community needs. In fact, from a queuing standpoint the 3/5/10 alternative is running at 85% capacity which provides the ability to met demand during surge times. Lastly, this scenario maximizes patient access to in-hospital services due to its ability to meet expected future demand. The comparison to previous scenarios can be seen in Table 3-9 below (note: numbers may not be the same as in previous tables given each run of the simulation recalculates fields).

Scenario	Total No. of Beds at Year 20	CAPEX Over Life of Project	ENPV	MinNPV	MaxNPV	Std Dev Returns
Deterministic Expansion - 45 Beds	45	$13,260,000	$811,682	-	-	-
Randomized Expansion - 45 Beds	45	$13,260,000	$12,284,156	($25,696,930)	$23,032,228	$11,694,904
Expansion Option 2/4/14	42	$12,444,757	$3,788,547	($14,158,147)	$20,871,369	$8,781,933
Expansion Option 3/5/10	50	$12,999,641	$11,230,270	($4,081,697)	$22,844,104	$5,391,200

Expansion Option Abbreviation Example: 3/5/10 is 3 pods initially built with an option to expand to 5 with each pod having 10 beds.

Table 3-9 Comparison of 50 bed 3/5/10 configuration to other expansion strategies.

These results should motivate hospital administrators and expansion project teams to consider real options analysis as part of their project evaluation tool box. The advantages over traditional project evaluation metrics have been discussed and shown through the use of VARG curves and summary ENPV simulation metrics.

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Chapter 4. Conclusion and Suggestion for Future Work

4.1 Conclusion

There are two main points made in this work:

1. The future is unknowable and teams engaging in the expansion of an ED would benefit from taking a systems approach to manage this uncertainty through flexibility in design.

2. Real options analysis through spreadsheet simulation is a useful tool that provides hospital administrators and teams with an understanding of the cost of flexibility along with a comprehensive picture value at risk and gain (VARG) to drive the economic component of the investment decision.

The application of the spreadsheet modeling to the healthcare infrastructure context shows that real options can be easy to use and provides insight into the way that flexibility minimizes exposure to risk and maximizes potential for gain under favorable circumstances. The widespread availability of spreadsheet use and type of data required as input to the model makes the tool further accessible to hospital administrators and project teams.

Being able to do the right thing at the right time can lead to significant improvements in ENPV of an ED or other hospital infrastructure expansion project. This opportunity is made available to individuals and teams incorporating flexibility in their design and evaluating the value of this flexibility using real options analysis.

4.2 Recommendations for Future Work

Future work should consider extensions of the spreadsheet model that address the following factors:

Demand Factors

- Model the influence of community factors (hospital closures, demographics—aging population) on volume of patients presenting to the ED.

- Model patient throughput as a function of patient acuity.
- Model effect of increased diagnostic and treatment capability on ED efficiency.

Supply Side Factors

- Model effect of regional hospital closures/openings on volume and type of patient demand.

Internal Hospital Operations

- Model influence of hospital inpatient beds on ED throughput assumptions.
- Include various staffing models to test influence on operational costs.

The model can be extended to include the hospital level effects.

- Develop a framework to quantify the interdependencies of different ED indicators (Patient volumes, wait times, LWOBS, LOS, Diversions, hospital inpatient bed utilization, etc.) such that more rigorously defined triggers can be provided to exercise options.

- Expand financial analysis to include revenue generated by ED patients being admitted to the hospital and the value of ED expansion policies in this regard.

These recommendations would provide quantitative support for the system engineering concepts discussed in this work to assure a holistic view of the ED.

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Bibliography

(2003). Hospital Emergency Departments, Crowded Conditions Vary among Hospitals and Communities. USA, General Accounting Office (GAO)**:** 71.

(2007). "Emergency Department Design."   Retrieved June, 2007, from www.advisoryboardcompany.com.

Asplin, B. R., D. J. Magid, et al. (2003). "A conceptual model of emergency department crowding." Annals of Emergency Medicine **42**(2): 173-180.

Borison, A. (2005). "Real Options Analysis: Where Are the Emperor's Clothes?" Journal of Applied Corporate Finance **17**(2): 16.

CDC. (2005). "Visits to U.S. Emergency Departments at All-Time High; Number of Departments Shrinking."   Retrieved 15FEB2008, 2008, from http://www.cdc.gov/nchs/PRESSROOM/05news/emergencydept.htm.

CIHF (2005). Understanding Emergency Department Wait Times. C. I. f. H. Information. Ottawa, ON, Canadian Institute for Health Information.

Colatat, P., L. Maseda, et al. (2007). Greater Boston Hospital Project, an Enterprise Architecture Project. Cambridge, MA, Massachusetts Institute of Technology**:** 87.

Cooke, D. L., H. Yang, et al. (2007). Introducing System Dynamics Modeling to Health Care in Alberta. 25th International Conference of the System Dynamics Society. Boston, MA (USA).

Copeland, T. E. and V. Antikarov (2001). Real Options : a practitioner's guide. New York, Texere.

de Neufville, R. (1991). Understanding and Using Forecasts. Cambridge, MA, Massachusetts Institute of Technology**:** 30.

de Neufville, R. (2002). Architecting/Designing Engineering Systems Using Real Options. Working Paper Series. Cambridge, MA, Massachusetts Institute of Technology**:** 13.

de Neufville, R., S. Scholtes, et al. (2006). "Valuing Options by Spreadsheet: Parking Garage Case Example." ASCE Journal of Infrastructure Systems **12**(2): 4.

FHA. (2007). "Economic Analysis Primer."   Retrieved March 10, 2008, from http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm.

Grenadier, S. R. (2000). Game Choices : the intersection of real options and game theory. London, Risk Books.

Hassan, R., R. de Neufville, et al. (2005). Value-at-Risk Analysis for Real Options in Complex Engineered Systems. IEEE International Conference on Large Scale Infrastructures. Hawaii.

Henry, M. C. (2001). "Overcrowding in America's Emergency Departments: Inpatient Wards Replace Emergency Care." Academic Emergency Medicine **8**(2): 2.

Hodges, J. (2003). Smoothing the Flow. Hospitals and Health Networks**:** 3.

Katz, D., G. Williams, et al. (2005). "Emergency Physicians' Fear of Malpractice in Evaluating Patients with Possible Acute Cardiac Ischemia." Annals of Emergency Medicine **46**(6): 8.

McManus, M. (2001). Emergency Department Overcrowding in Massachusetts: Making Room in Our Hospitals. The Massachusetts Health Policy Forum.

Myers, S. (1977). "Determinants of Corporate Borrowing." Journal of Financial Economics **5**: 28.

Nightingale, D. and D. Rhodes (2004). Enterprise Systems Architecting: Emerging Art and Science within Engineering Systems. MIT Engineering Systems Symposium. Cambridge, MA.

Thuesen, G. J. and W. J. Fabrycky (2001). Engineering Economy. Saddle River, NJ, Prentice Hall.

Williams, D. R., P. H. Mammes, et al. (2007). "Real Options Reasoning in Healthcare: An Integrative Approach and Synopsis." Journal of Healthcare Management **52**(3): 17.

Wilson, M. J. and K. Nguyen (2004). Bursting at the Seams, Improving Patient Flow to Help America's Emergency Departments, The George Washington University Medical Center, School of Public Health and Health Services, Department of Health Policy**:** 23.

Yamane, K. (2003). Hospital Emergency Departments - Crowded conditions vary among hospitals and communities. Washington, U.S. General Accounting Office (GAO).

Appendix A. ED as an Engineering System

This research considers the design and expansion of a Suburban Emergency Department (ED) as an engineering system. This thesis is inspired by an ED in the greater Boston area and will be referred to as Greater Boston Hospital (GBH) for confidentiality purposes. The ED as an engineering system is one element of the Hospital Engineering System in which it operates which in turn resides within a greater Engineering System of regional healthcare network of care providers. This perspective frames healthcare networks as a system of systems. The lifecycle of an ED is measured in years, if not decades, which is the case for the almost 20 year old GBH ED. The complexity of this system, along with its relative long lifecycle, makes it an interesting case study for the application of flexibility in design to maximize value.

Real Options analysis provides a useful approach to valuation of flexibility in the design of healthcare infrastructure projects in its own right, but especially true when compared to traditional valuation methods (NPV, IRR, ROI) that do not get at the intrinsic value of opportunities created by flexibility in design. The useful insights one derives from a Real Options analysis process uncover management's ability to create, execute and abandon options in their infrastructure projects and designs. The inherent uncertainty associated with the delivery of care to a particular patient population demands the need for flexibility.

There are many interacting factors that influence healthcare environment such as policy, regulations, technology, demographics, market trends, competition and individual perceptions to name a few. Each of these factors influence to varying degrees both the level and type of service that a healthcare provider will need to be able to provide its served population and the revenues and expenses associated with delivery of that service. In the case of this research, uncertainty of future demand for ED services is the driver of flexibility options in design. An important point to make for this project is that although creating economic value is a need of any business, it is not the primary guiding force of the healthcare enterprise. Delivery of patient care and the ability to respond to evolving patient population needs is the ultimate determinant of healthcare investment and management decisions. The dynamic nature of this environment is tractable in that certain metrics and trends can be monitored by management whereby decisions can be made that adapt hospital operations to future needs of their patients.

The availability, if not necessity, of a dynamic series of future decisions in healthcare operations completes the argument for an adaptive Real Options approach to valuation of flexibility on, and in, infrastructure projects as compared to one time static decision making approaches such as DCF, ROI or IRR. Traditional valuation methods do not get at:"the intrinsic attributes of the asset opportunity". Specifically, the useful insights one derives from a Real Options analysis process that uncovers management's ability to create, execute and abandon options on/in their infrastructure projects and designs.

Delivery of emergency care is a service business much like any other in many ways. However, the criticality of its safety, efficiency and effectiveness is unique in very specific ways. Expansion planning in a healthcare setting must always have patient care as a primary driver. That said, non-governmental hospitals have a need to at the very least break even from a financial perspective. Posting gains, i.e. earnings, allows hospitals to invest in newer technologies that increase their capabilities which in turn improve their ability to deliver patient care. This means that earnings from an operations standpoint can be leveraged to improve patient care. In an environment where profitability is sometimes construed as exploitation, a robust argument can be made that profitable hospitals can be better hospitals due to increased resource availability.

The scope of this work is limited to the operations of an ED within the hospital system context. Considering a simple input-throughput-output model presented in Figure X as described by the Urgent Matters Learning Network from the George Washington University School of Public Health, input will be community demand for emergency care, the process will patient care in the ED and output will be patient discharge to in-hospital care, discharge to the community or death. The drivers and constraints associated with each element of this simple model will be considered, but issues related to those factors outside of the ED itself will be identified and understood rather than resolved.

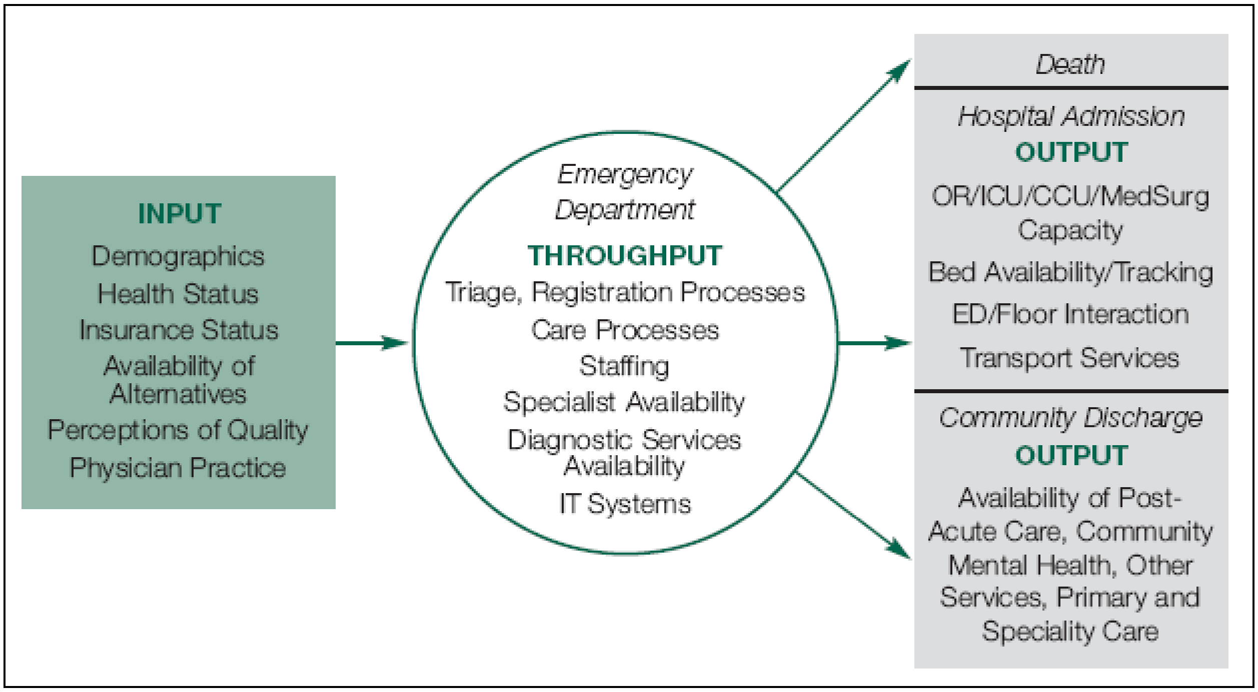

Figure A-1. Input-Throughput-Output model (Wilson and Nguyen 2004)

Patient factors leading to national overcrowding numbers were patient complexity (age, urgency, discharge diagnosis and disposition), and time and day of arrival. Time and day were retained factors due to issues caused by daily volume surges in EDs. The effect of daily surges is present at the GBH ED and a consideration used in capacity planning. The daily surges not only lead to overcrowding, but also cause patients to leave without being seen. It cannot be assumed that all LWBS patients aren't sick enough to merit emergency care. The GBH experience anecdotally supports that some LWBS patients return to the ED in a worsened state. In any case, these are lost opportunities to serve patient's needs and collect rents to support ED operations. Figure X shows how LWBS numbers are highest during GBH's busy periods between noon and 1 a.m.

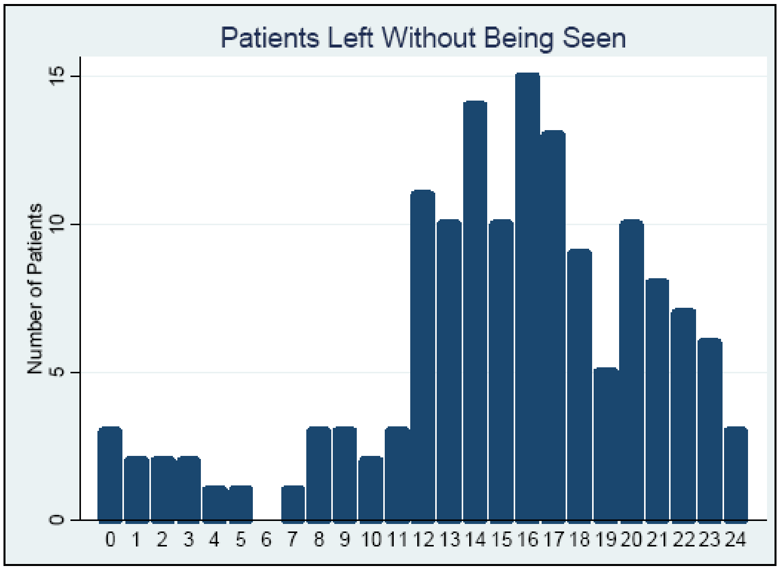

Figure A-2. GBH average number of patients LWBS (Colatat, Maseda et al. 2007)

Emergency Department factors included number of boarded patients, intermittent surges in number of newly arriving ambulances and ambulatory patients, ED Physician staffing, ED physician characteristics (decision making, pace of work and use of ancillary services), ED Nurse staffing, ED Nurse profiles, availability of ED social work and geriatric teams, response time to ED consult requests, the enforcement of ED consultation timeline policies, ED design, and availability of radiological imaging off-hours (especially ultrasound).

Hospital Factors leading to overcrowding included: number of staffed acute care beds (telemetry and ICU), overall bed occupancy rate, length of stay of admitted patients, and occupancy rate of acute beds by alternate level of care patients.

Some contributors to ED overcrowding issues are institution or caregiver behavior specific. For example, GBH admits roughly 40% of patients presenting at the ED. This could be driven by demographic composition, but is more likely driven by mental models of patient care. During one interview it was mentioned that patients above 65 presenting at the ED with anything more than the common cold are 'almost always' admitted for observation. This is just one example of the many individual institution nuances that make the use of national averages unsuited for forecasting. The influence mental models of care can have profound effects on the operation of an ED. A study by Katz et al (2005) reports that of the 7 million people who arrive at U.S. emergency departments with chest pain or other symptoms of possible heart attack or unstable angina, about half are hospitalized or admitted for observation. The majority of these patients will end up not having either problem; however, since a missed heart attack is one of the most frequent reasons for medical malpractice in adult medicine, doctors are reluctant to send low-risk patients home (Katz, Williams et al. 2005).

The ED overcrowding issue is well described in the national context. Care must be taken when translating national averages and assumptions to an institution specific context. The nationally reported factors leading to ED overcrowding are most useful as a checklist to review specific ED opportunities for flexibility in design and to define tracking metrics that trigger exercising of design options. The levels and combination of metrics that lead to the exercise of an option have to be defined through a rigorous understanding of and correlation to patient treatment capacity and flow through the ED and Hospital system. System Dynamics models, Value Stream Mapping and Queuing theory are suitable tools to determine the correlation between operational metrics and exercise of options.

The Healthcare Enterprise

It is important to recognize the complexity of a healthcare enterprise to be able to understand the greater context in which decisions related to an ED design are made. One of the inherent complexities of the healthcare enterprise is how perception and individual stakeholder behavior affects the dynamics of the hospital system as whole and individual operation and needs of departments such as the ED.

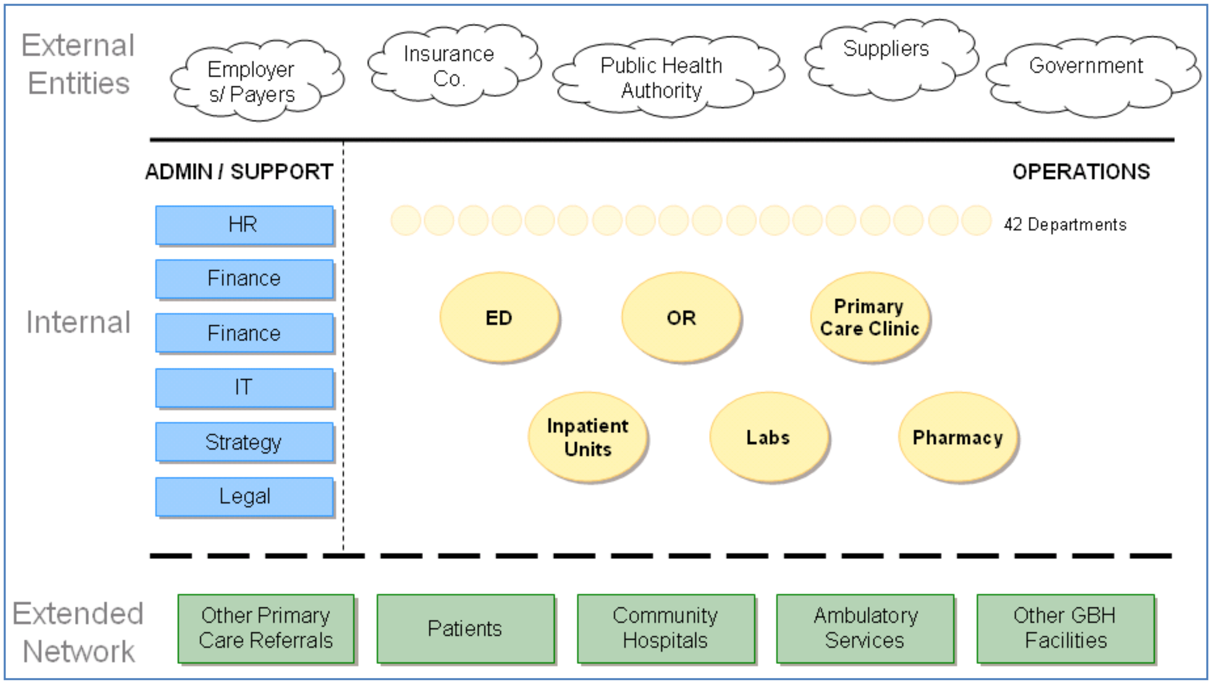

Figure A-3. GBH Enterprise Architecture (Colatat, Maseda et al. 2007)

Figure A-3 provides an overview of the GBH enterprise architecture to appreciate its complexity (Colatat, Maseda et al. 2007). The top layer of the diagram represents external entities which influence and affect hospital operations. The bottom layer represents the extended network with which the hospital has more frequent interactions, all of which directly interact with the ED. The central left part of the architecture is comprised of administrative and support functions that allow for the hospital to sustain its operations. The central right part includes the ED as well as all other hospital elements that factor into ED operations. If GBH is representative of other hospitals, these departments work in their own silos and calculate value on an individual basis. This leads to policies and actions that leave value of the table.

Enterprise Systems Architecture view of the ED

Enterprise Systems Architecture (ESA) is an emerging field in the engineering, and managing of complex social, technical, and infrastructure dimensions of an enterprise critical to achieving and sustaining its performance. ESA takes a systems perspective, viewing the entire enterprise as a holistic system encompassing multiple views such as organization view, process view, knowledge view, and enabling information technology view in an integrated framework (Nightingale and Rhodes 2004). A hospital ED certainly meets the criteria of having complex social, technical, and infrastructure dimensions necessary to meet its performance objectives. This holistic framework is useful in identifying alternatives in the design of an ED enterprise and in understanding the uncertainties related to its operating context and lifecycle. Nightingale and Rhodes propose seven ESA views: Strategy, Organization, Process, Information Technology, Service, Knowledge and Policy. These views are developed in sections to follow.

Strategy View

As in any well functioning organization, hospitals must ensure that all departments are strategically aligned and that not only each department understands its individual role in realizing the strategy, but also how its actions support or impede others from fulfilling their commitments.

Strategic goals for hospitals such as GBH typically include elements of recognition for leadership in delivery of care, workplace satisfaction goals, revenue and earnings targets and patient volume growth. Increasing high margin surgical procedures and growing exotic specialties is the default action plan some hospitals implement to achieve these types of strategic goals (Henry 2001). Not that these actions are incorrect, it is that they are incomplete. The ED, at least in the case of GBH, is one of the last considerations in strategic discussions and goal setting. Henry goes on to state that “the ED is seen as a “loss leader” in the marketplace. In a publication by the Association of American Medical Colleges, changes in teaching and nonteaching hospitals were analyzed over the past few years. There is seemingly no problem finding capital to expand revenue-enhancing product lines such as PET and MRI imaging or cardiac services in hospitals across America. This is in sharp contrast to the decline in hospitals offering emergency care such as Level 1 trauma.”

It is a lost opportunity to miss the strategic importance the ED to hospitals such as GBH. Approximately 30 to 40% of hospital in-patients are admitted through the ED. The ED is also first point of contact many community members have with a hospital. It is also the admissions portal for patients coming from other institutions within the regional healthcare network that require those high margin and exotic procedures that are strategically intuitive to GBH leadership.

To understand the strategic importance of the ED, hospitals should investigate and quantify the following:

- **Service area**. It is important to understand the magnitude and extent of influence a hospital's ED has on the patient base. Patients that have a negative ED experience are less likely to seek other services from the hospital making the ED a projection of the hospital's reputation and standing in the community. Much as hospital services are matched to their community, such must ED services be matched to enable departmental synergies. This would support strategic goals such as patient volume growth and recognition for leadership in delivery of care.
- **Number of in-patients** (patient days) **sourced from the ED**. This number is not commonly appreciated by GBH hospital administrators and high margin departments that benefit from the ED's patient source. In the case of GBH, many were surprised by the number of in-patients generated by the ED. In this way the ED directly supports multiple strategic goals of the organization.
- **ED revenue**. In the case of GBH, a suburban hospital surrounded by mainly middle class to affluent neighborhoods, ED revenues are a significant part of the hospital's top line. Privately insured patients, over ¾ of GBH's ED patients, are required to co-pay from $40 to $100 for ED visits at time of service; additional revenues are recovered from providers at time of billing. This payment schedule makes the ED one of the highest daily cash collectors of the hospital.
- **ED Contribution margin**. Common bias at GBH is that the ED is a money loser. This is mostly true in metropolitan settings where a large proportion of the population is uninsured. In the case of the GBH ED, its contribution margin is equivalent to that of other similar clinic services providing urgent community or primary care. Understanding the EDs individual financial contribution per patient boosts its standing in the enterprise and facilitates recognition of its strategic importance.

- **Patient loyalty generated**. This is the number of new patients introduced into the hospital system who use services other than the ED 60 days after initial ED contact. It can be considered a measure of 'patient loyalty' generated by a positive experience in the ED. In this way, the ED is a feeder of patients who will consume other higher margin hospital services. For GBH, this translates into millions of dollars in patient revenue beyond that collected for the ED service itself.

The Strategy View does not immediately uncover a specific element of flexibility to incorporate into the design of the ED, but instead emphasizes the need for flexibility to meet the strategic demands of the evolving hospital enterprise. This need for flexibility in the design of an ED is implicit due to the interdependencies between an ED and its hospital system where changes in one element of the Hospital system can change the ED operating environment and, hence, needs. For example, say in the near future GBH increases its inpatient capacity through expansion or process improvement to the degree where ED patients are instantaneously admitted to in-hospital beds at the order of an ED physician. However, the ED planners had taken a traditional approach to system design and had built a facility capable of meeting demand 15 years out into the future with the assumption that 40% of their beds would be consumed by boarders. This would lead to an immediate overcapacity situation and tying up of funds that could have been deployed to other areas of the hospital enterprise. Alternatively, a flexible design that had planned for capacity 5 years out with an option to expand, would have a much lower capacity surplus and could abandon or postpone the expansion option until the environment changed once again.

Policy View

The influence of policy, specifically lack of government funded universal insurance coverage, is anecdotally offered as the cause of ED services misuse and overuse, and ultimately ED overcrowding. Insurance, or lack of, is particularly relevant to the ED since by law, services must be made available to all persons regardless of economic or social status.

The Emergency Medical treatment and Active Labor Act (EMTALA) was enacted by congress in 1985 to protect the rights of indigent patients seeking emergency care. This law requires that all Medicare participating hospitals accept and provide a medical screening examination for all patients who arrive at the ED regardless of their ability to pay for services. Interpretation of the law has since expanded the scope of medical screening examination to include all ancillary services routinely available to the ED, such as physician consultation and inpatient care if required (Diekema 1995). The EMTALA is often cited as a de facto universal healthcare program due to its guarantees of care and consequent heavy utilization of EDs by the uninsured. This has lead to the nation's EDs being considered as the last stop in the nation's healthcare system safety net.

The GBH patient distribution is almost the opposite of what was observed in the AHMACS survey with private insurance and Medicare accounting for the majority of patients treated and uninsured patients accounting for single digit percentages.

As of July 1, 2007, Massachusetts is the first state mandating that all residents secure health insurance. This law is supported by state and federal funding to provide subsidized coverage for low income residents. The effect of this first-of-kind policy on ED use remains unknown and arguments have been made for all possible effects: increase, decrease and not affect ED patient volumes. This is a case where flexibility in the design of an ED can accommodate the effects of patient increases or decreases due to the policy. This case is especially interesting since funding for policies of this kind can dry up and revert the market dynamics or put into motion a new dynamic that could make demand for ED services difficult to predict. The benefit of being able to respond to this uncertainty is accessible by through a flexibility designed into the ED system.

The Policy View identifies flexibility opportunities to expand of contract depending on the state of reimbursement and insurance coverage policies. Exercising these options would be triggered by the enactment of policy that directly affects the population of GBH's service area.

Process View

From a Process View, the GBH ED has basic established processes for diagnosing and admitting patients. However, these processes have not been sufficiently analyzed to determine where value resides and are optimized based on tribal knowledge; individuals who carry out the processes make improvements and changes as they see fit. Each individual believes that their local optimization benefits the entire process and the patient when, in reality, they are unaware of the unintended system consequences.

There is much room for improvement of patient throughput which would increase the effective capacity of the ED. This is an important consideration when planning and analyzing flexibility in the ED design. The importance of understanding, implementing and harvesting the benefits of process improvement prior to planning and expanding a facility should be self evident. However, projects under time pressures such as in the case of the GBH ED design and build facilities based on the dysfunctions of present state operations and carry forward many of their dysfunctions to be implement at a larger scale. Flexibility in the design of an ED system expansion becomes even more important in situations where the benefits of process improvement cannot be understood prior to expansion.

Information Technology View

The Institute of Medicine (IOM) report, *Crossing the Quality Chasm*, estimated that between 44,000 and 98,000 deaths per year are from medical injury. Dr. Burstin suggests several ways to improve ED quality of care and patient safety, such as use of electronic medication prescribing and stand-alone, hand-held decision support systems. She recommends developing effective ED reporting systems that could help reduce ED medical errors and near misses; examining areas of high risk for error within the ED, such as triage misdiagnosis or misreading of radiology films; and use of error analysis tools, such as root cause analysis, to learn from errors.

In addition, developing, testing, and evaluating ED information systems may help reduce diagnostic testing and get information to the primary care providers who need to continue the care of patients when they leave the ED. Making emergency care more patient-centered, for example, by not moving patients in pain from place to place and by involving families in ED care, will improve quality of care. Finally, Dr. Burstin calls for reducing disparities in care by ensuring that the patients with the highest need get high-technology, potentially lifesaving therapies, regardless of their race, ethnicity, language, or ability to pay. EDs need to provide more culturally and linguistically appropriate care. Trained interpreters must be available to patients when they need them in order to get adequate patient histories and avoid medical errors (Burstin 2002).

The Information Technology View identifies the importance of having design flexibility in IT systems and infrastructure to be able to incorporate future developments in electronic medical records and other IT based logistics tools. This translates into appropriately sized and cooled server rooms with room to expand, scalable server architecture to meet increasing processing and data transfer needs and installed bandwidth capable of scaling with needs. This work will not consider the details of IT flexibility in ED design, but its importance merits mention.

Determining Service Area

Hospital markets have traditionally been defined using geopolitical boundaries and with fixed-distance radii. Although a useful simplifying abstraction, such measures fail to account for competitor capabilities, accessibility and population density around hospital locale. Competitor capabilities to consider are mainly size and scope of services offered. Phibbs and Robinson (1993) offer a patient-origin approach to measure a hospital's market area by drawing a circle that captures 75 or 90 percent of the hospital's patients. A modified Phibbs and Robinson approach was followed in determining GBH's service area given its location and patient demographics. Two primary characteristics of the GBH ED context support a deviation from Phibbs and Robinson's approach: 1. Travel distance is a critical factor when considering an ED service area (rather than general Hospital services) and 2. The GBH ED is in a commercial center surrounded by suburban communities where people commute long distances to work or visit. The modified approach was as follows:

1. Sort and group ED patient visits by place of origin using address zip codes
2. Calculate percent contribution of each zip code to total ED visits for a given year
3. Identify 75% and 90% cut off levels according to Phibbs and Robinson's approach
4. Determine if service area list results are reasonable when considering geography, competition and overall contribution of town ED volume.

This approach resulted in a 70% cut off to determine the GBH ED service area. The results were intuitively valid given most included communities were geographically surrounding GBH or had direct access via major roadways. There was also steep drop offs in patient contribution by communities as competitor density and quality increased and as accessibility decreased due to longer travel time.

Once service area was identified it was possible to look up population demographics to support forecasting and draw comparisons to other hospitals.

Demand for ED Services

Models can take a 'supply' or 'demand' approach to determining forecasts. The 'supply' model would go about determining aggregate ED capacity in the GBH service region and assume this would constrain ED utilization. Thus, ED demand would be constrained by available capacity. This approach, although economically cogent when analyzing discretionary consumer needs, is not tractable due to the critical nature of emergency services. In short, people in true need of emergency services will require service no matter what economic disincentives are involved. A 'demand' model is more pertinent to this research given the nature of the service being provided and that necessary capacity is the value being determined. The initial assumption is that capacity is fully unconstrained such that GBH would theoretically build an ED to meet 100% of expected future needs. This assumption would then be tempered by overlaying more reasonable constraints driven by strategic, financial and operational factors.

Good forecasts should meet two kinds of criteria, technical and planning, according to de Neufville (de Neufville 1991). *Technical Criteria* relate to model mechanics and mathematics and *Planning Criteria* relate to its usefulness in a planning process.

de Neufville states that *Technical Criteria* include: Acceptable Theory, Appropriate Procedures, Correct Mathematics and Adequate Concordance with Historical Data. Acceptable theory would correctly define the effects of various model parameters. For example, an increase in elderly population would relate to an increase in healthcare needs. Appropriate Procedures would include the use of statistical methods suitable for the problem at hand. Correct Mathematics points out the importance of accurate computations and adequate concordance with historical data relates to results aligning with recent data relevant to ED demand.

Planning Criteria relate to the ease of understanding the model outputs and their usefulness to stakeholders. Three factors worth stressing according to de Neufville: Clarity of Assumptions, Adaptability of Model and Modesty about Accuracy. Clarity of assumptions requires that major modeling assumptions be explicitly identified. The adaptability of the model relates to how readily it can be modified to accommodate changing circumstances. Modesty about accuracy is a reminder that forecasts are inherently incorrect and that care is to be taken when making statements of precision and accuracy.

The GBH forecast is a demand based model which makes it necessary to understand the demand drivers for ED utilization. There is an extensive amount of literature related to ED demand and utilization. A study by Schull et al. (2002) convened an expert panel to identify factors believed to cause ED overcrowding. Hospital system bottlenecks aside, overcrowding is precipitated by demand outstripping capacity to process patients.

The most challenging aspect of planning and designing service infrastructure is demand forecasting. The ED visit volumes at GBH have shown a very modest increase in actual visits over the last 7 years and in fact has had years with decreasing volume, but statistical significance of these trends is unknown due to amount of available data. This modest increase breaks with national trends and, thus, presents an interesting aspect of this analysis. GBH ED follows state trends more closely on average, but still has its own unique behavior. As discussed earlier, research indicates that ED volumes are mostly driven by demographics; specifically, an aging population. Other literature sources source insurance coverage, or lack of, and favorable reimbursement policies are major contributor to ED volumes, but the results are contradictory at times or very context specific. Hospital closures also conspire to overburden remaining open EDs in the service area do to a reduction in the supply side of the equation. All these factors are present in the GBH environment, but to lesser degrees than reported at national or even state levels. In fact, the GBH ED has seen an increase in competition in the form of another hospital contained within its service remodeling and expanding their ED over the last few years.

The ED as the last stop in the healthcare system's safety net for those with no other treatment options due to lack of insurance coverage or access to care is uniformly reported as an issue and reconcilable with anecdotal reports. It is logically congruent that people misusing the ED for chronic ailments or minor illness consume resources (space, time and money) intended for people with emergent needs and slow down a system that is not intended to serve them. The GBH ED does not have the characteristics of a safety net hospital when using these criteria. The vast majority of patients are insured and its service area is mostly affluent and middle class. Another indication of intended ED use is emergency room visits per 100 people in GBH's service area. GBH currently experiences 21 visits per 100 people in its service area over the last seven years compared to a national average of 38.7 and a Massachusetts average of 44.6 as stated by a 2005 Kaiser Family Foundation Report (statehealthfacts.org). Since the demand for emergency care although in concept is elastic, in practice it turns out to be fairly inelastic baring a disaster situation or pandemic. GBH's lower utilization rates are indicative of an ED with a service area population that is primarily seeking intended emergency care. This is supported by GBH data showing that non-emergent care in the ED is below that reported at the national level. Thus, the overcrowding situation of the GBH ED is more of an operational issue than a service area crisis and should be treated accordingly.

As a simplification to demonstrate RO analysis in the healthcare context, growth of patient demand will be assumed to follow service area population and patient acuity proportions will be assumed to remain as they are today. Although inconclusive and not future predicting, these assumptions have held valid for the last seven years of available data for the GBH ED. There are no indications of new entrants or hospital closures that would disrupt today's market dynamics.

Expansion as the solution

It would follow common logic that expansion is the solution to an overcapacity situation. However, from the study of system dynamics it is known that complex systems tend to exhibit policy resistance whereby a seemingly straightforward solution has the exact opposite consequence. This is the case with knee-jerk expansion of an ED where evidence supports that expansion does not eliminate overcrowding problems. This can be readily seen in a System Dynamics model of an ED where the 'Patients Waiting for ED Consult or Discharge' stock relies on a 'Hospital Admitting' flow to reduce its levels (Cooke, Yang et al. 2007). Expanding an ED without addressing the 'Hospital Admitting' flow which in turn is controlled by the 'Patients in Hospital Ward' stock will only worsen the ED capacity issues. This is no more effective than trying to address traffic backing up on a highway on-ramp without doing something to address the congestion on the highway itself.

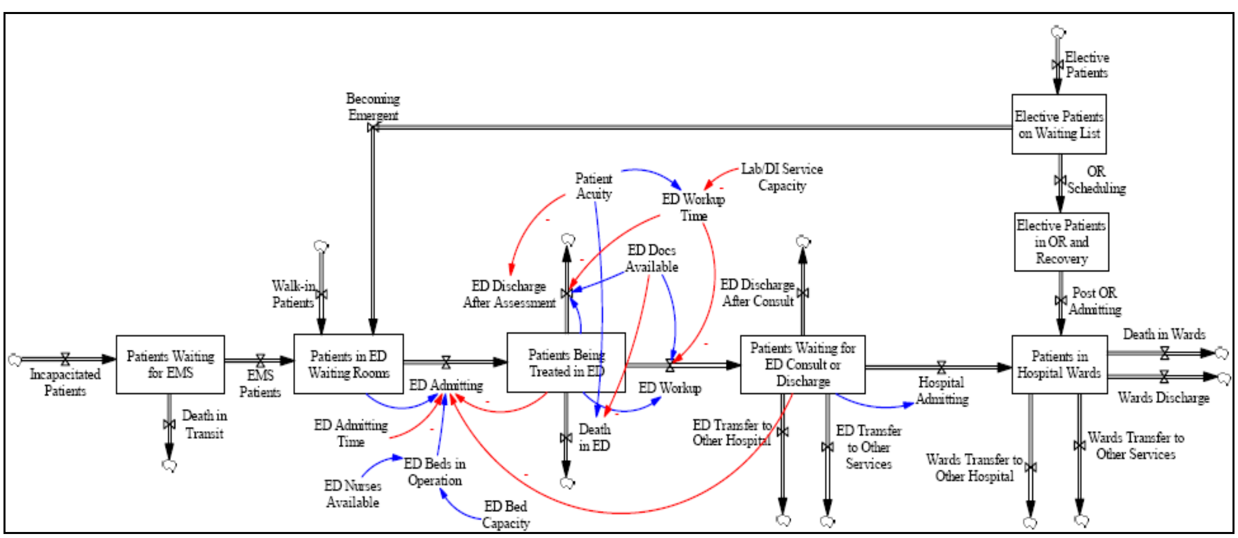

Figure A-4. System Dynamics model of an ED within a hospital system (Cooke, Yang et al. 2007)

A study by Han et al. (2007) examined an urban Level 1 trauma center pre and post expansion to determine the effects of expansion on ED overcrowding. The study period took place over one year to include a five month pre-expansion baseline and five month post-expansion observation period. The following parameters and definitions were used:

- Length of Stay (Asplin, Magid et al.). Time from patient registration to the time patient leaves the ED.
- Admissions hold LOS. Time from inpatient bed request to the time leaving the ED the ED for admitted patients.
- Diversion. Time ED turns away patients arriving via Emergency Medical Service (EMS) transport.

The ED in this study expanded from 28 to 53 licensed beds (~90% increase) with a commensurate addition of staff to maintain preexisting staff to patient ratios. The expansion numbers were driven by estimating that one bed would be required for every 1000 annual visits.

ED patient mean volumes increased significantly by 29 patients per day post-expansion and mean ED occupancy decreased by 7%. The mean waiting room count slightly increased, but no difference in waiting room LOS was noted. However, total and admission hold LOS significantly increased during the post-expansion period and the number of admissions holds in the ED rose by 67.7%. Although not statistically significant, there was a developing trend towards lower left without being seen (LWBS) patients. There was no significant effect on ambulance diversions even though ED available beds nearly doubled.

Han summarizes: “We found that a major ED expansion did not affect the amount of time spent on ambulance diversion. We observed an increase in total ED LOS. More importantly, admitted patients were boarding in the ED longer; consequently, more admission holds occurred during the post-expansion period. Diversion of inpatient did not change during the study periods, suggesting that there is a strong and direct association between inpatient bed availability and ambulance diversion that cannot be alleviated by an ED expansion alone. The expansion of the ED was an attempt to increase the patient throughput; more patients could be evaluated at one time. Although an increase in daily ED patient volume was observed, the absence of any changes in ambulance diversion and longer ED LOS were most likely driven by the higher number of admission holds and increased admission hold LOS during the post-expansion period." These findings reinforce the growing realization that ED overcrowding is a Hospital capacity issue rather than an ED capacity issue.

Multiple studies identify admission holds as the single most important factor leading to ED overcrowding and ambulance diversion given it is a proxy for hospital occupancy and inpatient bed availability. Forster (2003) found that ED LOS increased extensively when hospital occupancy exceeded a threshold of 90%; however, consultation and admissions rates were not influenced by hospital occupancy rates. These observations imply that the admissions decision is a clinical decision independent of the hospital's ability to accommodate the patient. As patients are admitted without a place to go they become part of the ED boarding phenomenon.

These hospital level effects conspire against ED throughput. One of these hospital effects is the current trend to increase revenue by encouraging more elective surgeries and transfers from outside hospitals. The result of this well intentioned, if not necessary, silo approach to service line growth is a decrease in available inpatient beds for ED patients. Thus, no matter how well the ED is able to manage patient throughput its effective capacity is determined by downstream factors out of its control. Process improvements that free up in-hospital beds are harvested by service lines other than the ED. This was the case in GBH where an addition of a significant number of in-hospital beds was overcome in short order by patients having elective or previously planned procedures. Hospital expansion of in-patient beds has been shown to alleviate ED overcrowding when a block of beds is reserved for ED and released for other purposes only with consent from ED staff. Some hospitals have gone as far as allocating surgery suite time, a highly valued hospital resource, as well to accommodate ED needs.

Effective alternatives to ED expansion include process improvements:

- Creating an ED managed acute care unit (fast track) for patients requiring prolonged evaluations and treatment. Impact: Decrease LWOBS and Diversions.
- Increase number of inpatient beds and surgical suites with a prioritized ‘ED allocation’ policy. Impact: Decrease ED boarding, LWOBS and Diversions.
- Physician triage at ED admissions step. Impact: Decrease ED LOS and LWOBS.
- Redistributing elective surgeries to Mondays and Fridays. Impact: Affected operating room availability and consequently ED boarding
- Stable patient observation area for those awaiting test results and discharge orders. Impact: Decrease in boarding.
- Doctor, Nursing and Technician scheduling during peak ED hours. Impact: Reduce LOS and LWOBS.

Process Improvement as the solution

As with most EDs, patients arrive at the GBH ED without appointments and require treatment over a large and varied set of ailments and conditions ranging from the common cold to life threatening trauma. The patient arrival rates are somewhat unpredictable, but follow a general pattern day by day and season by season. John Chessare, Chief Medical Officer at Boston Medical Center, puts this into perspective “If you stop acting like it is a surprise that you have more people on Sundays at 6 p.m. in the summer than on Tuesday mornings, you can start to plan” (Hodges 2003). Disaster situations notwithstanding, the ED must have a surge capacity to deal with periodic patterns and daily deviations from the norm. This is not to say that the ED should be sized to meet surges, but instead that it must have means with which to deal with surges by tapping into the broader hospital system. For example, Inova Fairfax Hospital in Falls Church, Virginia breaks with taboos in attempting to reduce ED boarders by tapping less-swamped departments to share the load during busy times “ We’re asking them to put boarders in their hallways instead of ours” (Hodges 2003). Although seemingly an attempt to shift the burden, forcing boarding into hospitals wards has been shown to motivate quicker turnover of empty beds to accommodate ‘hallway patients’.

Lean methodologies have shown positive results in dealing with overcrowding situations that seemed insurmountable. The Lean approach involves characterizing the EDs present state followed by defining a desired future state. The present state and future state is bridged by the transformation plan. The Lean methodologies must include the whole hospital system, and in some cases the regional healthcare network, to be able to bear any meaningful and lasting results. As discussed throughout this work, solely addressing ED process efficiency and effectiveness will not solve ED problems. Asplin makes this point "While increasing use of the ED, especially for non-urgent needs, causes significant problems in patient flow, staff burn-out, and ED operations, we do not think that it is those who seek care for non-urgent issues who are responsible for the recent crisis of ambulance diversions. It is really the acutely ill patient who is waiting in the ED for a hospital bed who creates the bottleneck that leads to overcrowding, diversions, and essentially a breakdown in the entire system" (Asplin, Magid et al. 2003).

George Washington University's Urgent Matters Learning Network reports multiple successful cases of increasing ED capacity through process improvements (Wilson and Nguyen 2004). One case is that of Grady Health System in Atlanta, Georgia. Between May 2003 and April 2004, average total ED throughput was reduced from almost 7.0 hours to approximately 5.25 hours. Two other critical metrics they were able to reduce through process improvement was Average time from arrival to bed placement (from 219 minutes to 94 minutes, 57%) and Average time of bed placement to initial exam (from 43 to 35 minutes, 19%). True to Lean methods, this was done without any expensive technological investments or changes to infrastructure. The ED staff implemented standardized processes and visual cues to establish patient pull. Another example provided incorporates a hospital system view of process improvement. University Hospital in San Antonio, Texas reduced inpatient bed turnaround from more than 160 minutes to less than 30 minutes (81%). This holistic approach opened hospital capacity to promptly accept ED patients to prevent ED boarding, a major capacity constraint that grind an ED to a halt in its most severe cases.

The effect of ED process improvement on expansion planning will be considered as it relates to modeling capacity using literature reported efficiency and effectiveness improvements. Reiterating an earlier point, the effects of process improvement must be understood, if not realized, prior to adequately being able to plan an ED expansion.

Level of Service

Level of Service can be simplified in the ED context to be the amount of time a patient waits to be seen given once a patient is seen treatment is expected to be adequate. (CIHF 2005)Ideally all patients seeking care in an ED would be treated immediately, efficiently and effectively. However, the reality is that resources and capabilities are bounded such that defining and understanding level of service becomes important. Level of service for EDs in the United States is not formally defined in the way of industry or government standards. There is a recognition that certain situations, such as overcrowding, lead to poor levels of service. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) provides a standard that requires leaders to develop and implement plans to identify and mitigate impediments to efficient patient flow throughout the hospital to prevent patient overcrowding, especially in the Emergency Department. An excerpt from JCAHO's accreditation manual that includes standard LD.3.11 describing overcrowding management in hospital level terms to maintain a system view of the problem is included in Appendix B.

This standard is a set of guidelines for hospital administration to follow and does not describe a level of service that is to be maintained.

Short of available standards to describe adequate level of service, the following guidelines are provided by the Canadian Health Ministry by CTAS level:

Establishing Goals for Time to Physician Initial Assessment

The time it takes to be seen by a physician can be critical for some conditions. When the Canadian Triage and Acuity Scale (CTAS) was established, goals or operating objectives of time to physician initial assessment were proposed. These times were:

- **CTAS I** Resuscitation: immediate
- **CTAS II** Emergent: 15 minutes (time to physician assessment)
- **CTAS III** Urgent: 30 minutes (time to physician assessment)
- **CTAS IV** Less-Urgent: 60 minutes (time to physician assessment)
- **CTAS V** Non-Urgent: 120 minutes (time to physician assessment)

Those who developed the CTAS were clear that these times are not established standards of care and might not make sense for all facilities (for example, those without on site physician coverage).[12] However, they do allow for some comparisons across different facility types and even with other countries that are using the same assessment goals.

Analyses of the 2003–2004 NACRS data according to these goals suggest that most patients are seen within these times. But that's not true for everyone. A higher proportion of those triaged as non-urgent (CTAS V) are seen within the proposed time (87% under 120 minutes) than those triaged as most severely ill (54% of CTAS I patients were seen in under 5 minutes). And, 10% of patients in this category waited 45 minutes or more for initial assessment by a physician. In Australia, where triage levels also use a five-level triage scale and assessment goals are the same, approximately 99% of patients visiting public hospital EDs who were triaged as "requiring resuscitation" were seen within the recommended time in 2003–2004. For other triage levels, the range was from 61% to 82% of patients.[14]

Figure A-5. CTAS Implementation goals and percent achieved (CIHF 2005)

Other regulatory attempts to define level of service are developing through the Centers for Medicare and Medicaid Services (CMS) pay for performance program (P4P). This CMS program scales reimbursement rates based on hospital performance scores. Typical ED performance metrics include length of stay (Asplin, Magid et al.), number of patients who leave without being seen (LWBS) and amount of time on diversion. It remains unclear what metrics will be used by CMS or how the payment schedule will be structured.

Appendix B. JCHAO Guidelines for ED Patient Flow Planning

Standard LD.3.11

The leaders develop and implement plans to identify and mitigate impediments to efficient patient flow throughout the hospital.

Rationale for LD.3.11

Managing the flow of patients through their care is essential to the prevention of patient crowding, a problem that can lead to lapses in patient safety and quality of care. The Emergency Department is particularly vulnerable to experiencing negative effects of inefficiency in the management of this process. For this reason, while Emergency Departments have little control over the volume and type of patient arrivals and most hospitals have lost the “surge capacity” that existed at one time to manage the elastic nature of emergency admissions, other opportunities for improvement do exist. Improved management of processes can ensure the wise use of limited resources and thereby reduce the risk to patients of negative outcomes from delays in the delivery of care, treatment, or services. To understand the system implications of the issues, leadership should identify all of the processes critical to patient flow through the hospital system from the time the patient arrives, through admitting, patient assessment and treatment, and discharge. Supporting processes are included if identified by leadership as impacting patient flow, e.g. diagnostic, communication, and patient transportation procedures. Relevant measurements are selected and implemented to enable monitoring of each process and supporting process(es) by the organization leaders. These critical processes should be modified for the purposes of improving patient flow.

Elements of Performance for LD.3.11

1. Leaders assess patient flow issues within the organization, the impact on patient safety, and plan to mitigate that impact.
2. Planning encompasses the delivery of appropriate and adequate care to admitted patients who must be held in temporary bed locations, e.g. Post Anesthesia Care Unit and Emergency Department areas.
3. Leaders and Medical Staff share accountability to develop processes that support efficient patient flow.
4. Planning includes the delivery of adequate care and services to those patients who are placed in overflow locations, such as hallways.
5. Specific indicators are used to measure components of the patient flow process and include:
    a. Available supply of patient bed space
    b. Efficiency of patient care and treatment areas
    c. Safety of patient care and treatment areas
    d. Support service processes that impact patient flow.
6. Indicator results are available to those individuals who are accountable for processes that support patient flow.
7. Indicator results are reported to leadership on a regular basis to support planning.
8. The organization improves inefficient or unsafe processes identified by leadership as essential in the efficient movement of patients through the organization.
9. Criteria are defined to guide decisions about initiating diversion.