A QUANTITATIVE PERFORMANCE MEASUREMENT FRAMEWORK FOR HEALTH CARE SYSTEMS

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by

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled.

A QUANTITATIVE PERFORMANCE MEASUREMENT FRAMEWORK FOR HEALTH CARE SYSTEMS

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And hereby certify that in their opinion it is worthy of acceptance.

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Writing this thesis has been an interesting experience for me. At times, research is exciting and enlightening, since it gives much freedom to explore what I find the most interesting within my field. On the other hand, it can be very frustrating, since it involves an endless search that leads to many dead ends. It is during such periods of times my supervisors and the people around me become really important.

First of all, I would like to thank my supervisor, Associate Professor James Noble, and also my committee members, Professor Lanis Hicks and Professor Cerry Klein for their wisdom and support when conducting this research. I am also grateful to University Physicians for allowing me to use the Green Meadows clinic as the site for my research. My thanks also go to all the people in the case study project, such as David Mountjoy, Eric Rosenhauer, and Tracy Hudson from the University Physicians, Philip Vinyard and Robin Cornelison from Green Meadows Clinic and Alan Arnold and Joann Perkins from IT Application Services for all their help and support.

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ABSTRACT

Performance measurement has been widely used in the manufacturing industry for years; although health care systems share many similarities with manufacturing systems, little has been done to adapt the performance measurements used in manufacturing systems for health care systems. Productivity is of vital importance to a health care system's ability to compete and survive over time. A health care system that is not able to efficiently utilize its resources in creating value for its patients will not survive with the ever increasing costs of care. However, the development of fully functional and suitable performance measurement systems (i.e. set of measures) to measure productivity has proven to be a very challenging task. This research has focused on the adaptation of a performance measurement system used in manufacturing for application in health care systems.

This research proposed a quantitative performance measurement system to apply in the health care industry. The main objective and critical factors to the system were first established to be included in the framework. The main objective and the critical factors were then decomposed in a top-down fashion to identify clearly the requirements of the system and the means to achieving those requirements. After breaking down the main factors to sub-components, these sub-components were then connected based on their qualitative relationships. The components are integrated using incremental calculus to analyze the system

components' relationship quantitatively. Based on the incremental calculus, a marginal analysis was conducted to measure the extent to which various criteria, the system as a whole, were affected by a given incremental change of each variable.

The proposed framework was applied to Green Meadows Clinic to measure the effects of changing ten percent of the physician and nursing manpower, the clinic's expenses, as well as patients' turnout to the operating margin of the clinic. Data obtained from the IDX data system and performance trend reports were analyzed using the proposed framework. The results showed that increasing ten percent of the physicians will bring about an increase in operating margin, while increasing ten percent of medical expenses and nursing staff reduces the operating margin. The analysis also showed that by improving patients 'no show' and the ratio of new and established patients resulted in an increase in operating margin for the clinic. The major accomplishments of this work included the incorporation of a system engineering tool to health care system performance measurement and the ability to show the overall effects to the system as a whole by making marginal changes to the inputs, thus helping health care managers to make better decisions.

CHAPTER 1 INTRODUCTION

The purpose of this chapter is to describe the background and objective of the research detailed in this thesis. The chapter begins by explaining the importance and complexity of the performance measurement in health care systems. Then, the problem area for the research, the objective, and research questions are described.

1.1 Changes in Health Care Systems

In the 1990s, health care experienced a magnitude of change in its structure, process, and relationship to society greater than ever before (Berwick, Godfrey and Rossner, 1990). Many changes were made altering the payment systems, delivery systems, technology, professional relations, and societal expectations of the health care industry (Shortell, Gillies and Devers, 1995). This is partially caused by the continued escalation in health care costs in the United States, which exceeded those for all other goods and services (Beck and Larrabee, 1995). People became frustrated with the health care systems in the United States for the high out-of-pocket expenses and the fragmented design of the system. Even the states and federal governments were no longer able to fund the high medical costs.

Hospitals have not altered their basic organizational structures in the last fifty years (Auton, 1994). This one fact is identified as a primary barrier preventing the hospital industry from successfully responding to the pressures of the external environment (Kissler, 1996). Inefficient structures and the continued centrality of inpatient services are significant sources of poor quality and excessive costs. Today's hospitals are beginning to realize the importance of changing their business model, improve their technology, and implement integrated systems of care delivery (Shortell et. al., 1993).

1.2 Performance Measurement in Health Care Systems

Hospitals are aggressively redesigning their organizations through the strategy of systems redesign. System redesign requires the organization to rethink and redesign traditional structure, work roles, and critical systems and related processes used to produce, deliver, or support patient care (Moss et. al., 1994).

Prior to the initiation of a formalized program of systems redesign, many organizations have done cost reductions, utilizing such strategies as hiring freezes, position eliminations, and reductions in budgets. Many such strategies are carried out without measuring the impact on productivity, quality, and efficiency of the delivery of care. Often, not having a performance measurement and using it to evaluate the impact of system redesign will result in poor decision making. Performance measurement is an efficient decision making tool for any health care organization planning to redesign or evaluate its systems.

During the past decade, increasing attention has been focused on performance measurement in the health care systems. This performance measurement helps to evaluate the impact on systems redesign, for example, how the performance will be affected when budgets or manpower is reduced. This attention has centered on the various relationships among organizational structure, clinical practices, and patient outcomes, with the strong recognition that the practice of medicine should be evidence based. Although there are many conceptual frameworks that explicate the relationships among the various components of the public health system, no system has yet to provide a quantitative base for the study of health care system performance.

Researchers and practitioners interested in the science base of the health care systems have used many different function frameworks to conceptualize the practice of health care and to assess aspects of operations performance. These efforts, however, were of limited value for several reasons, including their focus on only one aspect of health system performance, the key processes associated with public health practice. Most important, most of the conceptual framework that described the components of the public health system failed to measure how each component contributes to the desired outcome.

1.3 Problem Description

It is believed within this research that performance improvement is an essential criterion for the competitiveness and success of any health care system. Thus, without constantly working to improve the performance of the system, the health care organization will not be able to survive in a long-term perspective with health care costs ever increasing and as the baby boomers are fast approaching their retirement age. It is also believed that performance measurement should be used to support and encourage productivity improvement within a health care system.

Researchers and practitioners interested in the science base of the health care systems have used many different function frameworks to conceptualize the practice of health care and to assess aspects of operations performance. These efforts, however, were of limited value for several reasons, including their focus on only one aspect of health system performance, the key processes associated with public health practice. Most important, most of the conceptual framework that described the components of the existing health system failed to measure how each component contributes to the desired outcome. We attempt to understand the effects of each component on the overall health care systems or its subsystems, or to examine the relationships among the different system components.

In the health care systems, the medical supplies inventory, movements of materials, staffs and patients, rate of turnaround of medical facilities, quality of service, and costs can also utilize the same concepts in manufacturing to apply in any health care systems. Similarly, in any manufacturing systems to maximize efficiency, the system must control levels of inventory, movement of material, production rates, product quality, and cost. It is crucial to make decisions in a way that supports a company's high-level objectives, which requires an understanding of how detailed design issues affect the interactions among various components of a system.

1.4 Objective

Our study aims to apply some manufacturing systems best practices to health care systems to measure the different variables affecting the performance of the health delivery system and the relationship between the variables to the outcomes. We will develop a new framework to be used as the basis for measurement of the performance of any health system as a whole. It can be applied at multiple levels to examine health systems. Our model can also be applied to examine the performance of a specific part within a health care organization such as the pediatrics or outpatient clinics. However, we feel that the most important aim of this research project is to produce research results that are directly of interest to the health care industry, specifically: *To develop a* *systematic method that can assist health care managers in decision making to evaluate and improve the performance of the health care systems.*

1.5 Scope of the Thesis

According to Bourne et al (2000), the development of a performance measurement system can be divided into three main phases:

1. The design of the performance measures framework
2. The implementation of the performance measures
3. The use of the performance measures

The first phase, *the design of the performance measure framework*, can be subdivided again into identifying the key objectives to be measured and designing the measures themselves. There is a strong consensus among researchers in this field that performance measures should be derived from strategy (Tangen, 2004). In other words, this phase often begins with defining important strategic objectives of the organization, which are later broken down to more concrete key objectives to be achieved on minor levels in the organization. Then, the actual performance measures are designed in accordance to the key objectives.

The second phase, *the implementation of the performance measures*, is defined as when system and procedures are put in place to collect and process the data that enable the measurements to be made regularly (Tangen, 2004). This may involve completely new initiatives using computer programming to improve on the data used in the system and present them in a more meaningful form. (Bourne et al, 2000).

The third phase, *the use of the performance measures*, is split into two main subdivisions. First, as the measures are derived from strategy, the initial use to which they should be put is that of measuring the success of the implementation of that strategy. Second, the information and feedback from the measures should be used to challenge the assumptions and test the validity of the strategy.

CHAPTER 2 LITERATURE REVIEW

The results of this literature review are presented as follows: First, we will explore the role of engineering in the health care industry; following this section, literature related to health care systems performance measurements is examined. It will then be followed with literature related to the definition of quality in health care systems. Finally, the introduction to manufacturing systems and engineering systems design techniques, which we will utilize to formulate our performance measurement framework for health care systems, will be presented.

2.1 The Role of Engineering in the Transformation of Health Care

Given the complexity of health care delivery, which involves the coordination and management of large numbers of highly specialized, distributed personnel, multiple streams of information, and material and financial resources across multiple care settings, it is astounding that health care has not made better use of the design, analysis and control tools of systems engineering (IOM, 1995). The experiences of other major manufacturing and services industries, which have relied heavily of systems-engineering concepts and tools to understand, control, manage, and optimize performance of cost, safety, and other objectives, can provide valuable lessons for health care.

Many manufacturing corporations have benefited from comprehensive information systems and the extensive use of engineering tools for the design, analysis, and control of complex production and distribution systems. Similar operations can be found within the health care systems. Hence, it is reasonable to suggest that tools used in manufacturing firms can be applied to health care systems can lead to higher productivity, better quality care, and improved patient satisfaction (NAE, 2003).

However, over simplifying the parallel between health care systems and manufacturing systems will not lead to improving the health care processes. Due to the complexities within the health care systems, such as variations in human physiology and the complexities of disease services, just to name a few, innovative uses of system engineering principles and techniques is required to meet the challenges of health care systems.

In 2001, IOM set a new vision for a transformed, twenty-first century, patient centered health care system. IOM identified six interrelated dimensions of quality for health that must be improved. They are (IOM, 2001):

1) Safe- avoiding injuries to patients from the care that is intended to help them.
2) Effective- providing services based on scientific knowledge to all who could benefit and avoid providing services to those unlikely to benefit.

3) Patient-centered- Ensure patient values guide all clinical decisions.
4) Timely- Reducing waiting times and harmful delays.
5) Efficient- Avoiding waste.
6) Equitable- Providing care that does not vary in quality.

The IOM report emphasizes the importance of identifying proven, fundamental engineering concepts that could be brought to bear immediately to redesign and improve care processes (IOM, 2001). Information and communication technology, which is the product of engineering, has been widely used to improve the administrative aspect of the health care industry. However, the principles, tools, and research from engineering associated with the analysis, design, and control of complicated systems, which helped to transform many manufacturing corporations, are largely unknown in the clinical operations of health care delivery.

Because of the extensive experience of systems engineers in dealing with manufacturing and other technology intensive service industries, they are adept with the tools, methods, and knowledge base to grasp the deep functions and dynamics of complex systems and processes. Engineering tools and technologies can be used to measure and optimize system performance to meet performance goals, such as the six goals established by IOM (IOM, 2001).

2.2 Systems Redesign of Health Care Organizations

The aim of the performance measurement is to aide health care managers in their decision making process for systems redesign purposes. Systems redesign is a broad term that addresses the redesign of the organizations to prepare them for the future (Dienemann and Gessner, 1992). Given the integration and interdependencies of systems, systems redesign applied to hospitals affect everything. Systems redesign is defined as the fundamental rethinking and revamping of traditional structures, work roles, and critical systems and related processes used to produce, deliver, or support patient care (Moss et. al. 1994). The term “structure” refers to the pattern of interrelationships among the key components of the system (Senge et. al., 1994). This includes management hierarchy, decision-making processes, clinical and business processes, attitudes and perceptions. The hospital industry is heavily involved in systems redesign activities. Hence, it is crucial to develop a framework for performance measurement to help managers in their decision making (Walker, 1998).

While most health care providers have approached redesign in an iterative manner, the end result calls for the complete re-conceptualization of the hospital as it exists in America (Porter-O’Grady, 1995). Despite persistent and compelling pressures from the external environment for redesign, most of today’s hospitals have made little changes from their fundamental structure and management processes in the last fifty years (Upenieks, 2003). Today's complexity, technology, and speed of change have outrun the bureaucracy's ability to organize and manage it.

Typically, prior to the initiation of a program of systems redesign, an organization has done across-the-board cost reductions, utilizing such strategies as hiring freezes, manager and care-giver positions elimination, and non personnel-related reductions, such as use of joint contracting for materials management (Nowicki, 1995). Most hospitals mainly look at nursing benefits and salary when situations call for cost reductions and little attention is given to changing the actual systems and processes of care even though, the changes in the system will bring about better results in cost reduction (Tangen, 2004). Budget cost reductions without concomitant systems redesign is self-limiting in that the organization will reach the quality/cost dilemma, e.g., to take more cost out would reduce the personnel to the point that there is a greater risk that quality will suffer. It is at this time that most organizations are compelled to begin systems redesign initiatives. It is also important to have a good performance measurement system to evaluate the impact of downsizing to the quality of care delivery (Walker, 1998).

2.3 Health Care Systems Performance Measures

Decision-makers, at all levels, need to quantify the variation in health system performance, identify factors that influence it and target to achieve better results in a variety of settings. The performance of system sub-components, such as public health services, also needs to be assessed. We believe that a convincing and operational framework for quantitatively assessing health system performance is vital for the any health care institution.

Several frameworks, as shown in Table 1, for measuring health system performance have been proposed (Jee and Or, 1999) (Knowles, et. al., 1997) (Hsiao, 1998) and are testimony to the importance given to this enterprise. Taken together, these frameworks are a rich source of ideas and approaches. Approaches to health system performance often fall into two related problems (Hurst, 1999). Some are inclusive lists of multiple, and often overlapping, desirable attributes of health systems. Various frameworks, for example, have included goals related to health, health inequalities, coverage, equitable financing, quality, consumer satisfaction, allocating efficiency, technical efficiency, cost containment, political acceptability, and financial sustainability. Other approaches start from a consideration of which indicators are readily available, and construct a performance assessment that replicates the conceptual and technical inadequacies of available measures. Both approaches are unsatisfactory for a comprehensive and meaningful assessment of health system performance.

	Measures	Methods	References
1	Nursing staff restructuring	Survey	Urden, L.D. and Walston, S. L. (2001)
	Medical Errors		
2	Administrative costs	Medicare Cost Report for each of 6400 hospitals	Woolhandler,S., Himmelstein,D.U. and Lewontin, J.P.(1993)
3	Quality of medical care	population-based measures with case-based measures	Eddy, D. M. (1998)
	Health plans		
4	Quality of care	Patients data	Coye, M. J. (2001)
	Pateints' Needs		
5	Leadership	Survey	Ferlie E B and Shortell SM (2001)
	Organizational culture		
	Teamwork		
	IT		
6	Supply chain	Review of literature	Klein, S. and Schad, Heike (1996)
7	IT		
	organizational attitudes	Survey, data	Berg, M. (2001)
	worker and patient satisfaction		
8	Public Health System		
	Medical Outcomes	Review of prvious model	Handler, A., Issel, M. and Turnock, B. (2001)
9	Costs of nursing staffs	Surveys, interviews	Provan, K. G; Milward, H. B. (1995)
	Information systems		

Table 1 References of health care systems performance frameworks

2.4 Conceptual Aspects of Performance Framework

The issue of a performance framework can be considered at two levels: conceptual and technical. The technical aspect is often the focal point in many research and journals. However, performance measurement is more than just a set of measures; it also implies a mode of management (Power, 1997). The conceptual level of the performance framework provides a foundation for initiatives in quality management seen in the private sector, and increasingly the public sector, requiring organizations to be accountable and that they set down benchmarks for the legitimacy of organizational action. Performance measurements can create a quality assurance industry in health care systems like what it has done to the manufacturing industry.

All indicators embody a system of values and social goals (MacRae, 1985). Different indicators produced by different organizations or processes will reflect different values. Performance indicators are not simply technical entities, but they have programmatic or normative elements, which relate to the ideas and concepts that shape the mission of practice (MacRae, 1985). The potential impact of applying a set of indicators depends not only on their technical characteristics, but also on the degree to which those managing, working in, and using healthcare organizations support the program, the existing professional cultures, and what change in the culture the introduction of performance management may produce.

Governments and the public tend to focus excessively on outlying poor performers (Smith, 1998). These mechanisms are often built on notions of trust and professionalism, and are often organized outside of the influence of formal management (Power, 1997). A danger of introducing the new performance management structure is that it may support abstract managerial values at the expense of other cultures of performance evaluation, both formal and informal. This depends, among other things, on the degree to which the framework builds on or uses such relations of trust and makes use of the quality promoting activities which are already established and go on within professions and healthcare teams. It is not surprising that the introduction of external performance management in which judgments about quality are made by measuring performance based on precise standards can contribute to feelings of fear and loss of control by health professionals.

Measurement alone does not improve quality, and indeed, when seen primarily as a way to improve accountability and to make judgments, may cause the collapse of other quality enhancing activities not part of the performance management strategy (MacRae, 1985). A performance management structure constitutes a “health technology”, which has effects on people, organizations, and system behavior (Power, 1997). However, like all interventions applied to complex systems, the effects are often unexpected and difficult to control and may even produce net adverse outcomes. There is a need, therefore, for a greater empirical understanding of the consequences and the costs of performance management. However, there is little conclusive evidence about the impact of organizational performance assessment (Leggat, 1988).

Performance of the entire health system must be related to the performance of various subcomponents within the health system. Work on the performance of providers of health services is converging with work assessing the overall performance of health systems (Handler et. al., 2001). The key would be to compare the level of goal attained for the entire population to the level of goal attainment that would be achieved with the best and worst performance of that sub-system organization. The challenge is to define the best and worst attainable lines for a given sub-system or organization (Handler et. al., 2001).

2.5 Definition of Quality in Health Care Systems

Since we are implementing manufacturing best practices in health care systems, it is worth considering what is meant by quality. We will align the term 'quality' in both contexts to make sure that the performance indicators for measuring aspects of quality do not conflict with each other. Quality is now given such prominence in health care, as well as in the manufacturing industry, but unless it is defined and sensibly used, calls for quality improvement will become merely fashion statements. In health care, quality is defined as to ensuring appropriate use of health services, correcting oversupply and undersupply of healthcare resources, and reducing healthcare errors (The President's Advisory, 1998). Notions of cost effectiveness or efficiency used commonly in manufacturing are absent. Cost effectiveness definitely must lie at the heart of quality. If health care services are about maximizing human health and welfare within the resources available, then if these resources are not used efficiently quality will not be optimized (Sheldon, 1998).

Under this broad concept of quality, care would have to be clinically effective and medically appropriate, clinicians would need to be competent, and errors minimized and the systems for delivering care run smoothly and efficiently. However, isolating these elements from their resource implications is not rational (Sheldon, 1998). No one would allocate all the resources to preventing just one more medical accident or to provide more support for a surgery. There is some point at which the opportunity cost of investing more in one area of care generates such little benefit relative to the resources needed that it is not deemed efficient relative to the other beneficial uses to which they can be put. Simply increasing appropriateness and access or reducing errors, without reference to the cost of so doing, cannot optimize well-being and, therefore, cannot, by themselves, constitute quality. That it is not easy to use the cost effectiveness concept of quality does not make it less important. Very few quality improvement schemes either look at the efficiency of the strategy or include cost effectiveness as part of quality or performance indicators just as few clinical practice guidelines integrate evidence on resource use.

2.6 Adapting Manufacturing Systems to Health Care

As mentioned above, the tools used by systems engineers can be adapted to health care industry to improve their operations. For the second part of this literature review, we will introduce manufacturing systems, which can be used in the health care industry. Three manufacturing system parameters: lifetime, complexity, and performance requirements have shown a trend of the system lifetime getting shorter due to the decrease in product lifetime and quick introduction of new products. The rate of introduction of new products is increasing rapidly. Competition and quick changes in market structure require flexibility in the system layout structure. System complexity is increasing as requirements make planning and design activities more difficult and complex. Van Leeuwen and Norrie (1997) suggest that new generations of manufacturing systems will be based on distributed and reconfigurable units where different modules interact in a dynamic way in autonomy and collaboration fashion. Rozenfeld et. al. (1994) defines a workflow as a way by which individual tasks come together to represent a clearly defined business process within an enterprise. Focusing on industrial companies, four different workflows can be identified as material, information, energy, and economical flow (Wang et. al., 2002). A design stage starts with a stakeholder analysis to identify the constraints and degrees of freedom for the design. Results from the analysis can be divided into four different groups. They are (Jacobsen et. al., 2002):

1. Technological reflections: Cover items such as core capabilities, degree of automation, and how the manufacturing system fits into the logistics flow of supply chain management.
2. Environmental and ethical reflections: Deal with environmental issues of the surroundings, the working environment for the employees, and the responsibility for the parts produced.
3. Market reflections: Deal with meeting the expectations from the market with agility.
4. Organizational reflections: Deal with the human integration in and influence on the production.

We can view these four different groups as four equally valued building blocks. Around the manufacturing system are the stakeholders, and their interest sets the limitation for the development of the system. The entire manufacturing system must be controlled in order to control levels of inventory, movement of material through the plant, production (output) rates, product quality, and cost. These four different groups are equally important to health care industry. Figure 1 gives a general picture of the production system that houses the manufacturing system. All manufacturing systems are serviced by a production system. Because the oldest and most common manufacturing system is functionally organized, most production systems are functionally organized, too, and walls separate the people in these functional areas from all other areas. We will attempt to functionally organize the health care system using manufacturing systems mentioned here.

Manufacturing system is the arrangement and operation of machines, tools, material, people and information to produce a value-added physical, informational, or service product whose success and cost is characterized by measurable parameters (Cochran and Dobbs, 2002). In Figure 1, the manufacturing system takes inputs and produces products for the customer as its output. The production system (the enterprise) includes the manufacturing system plus all the other functional areas of the plant for information, design, analysis, and control. The job shop is a functionally designed manufacturing system where like processes are put together. Designing a manufacturing system to achieve a set of strategic objectives involves making a series of complex decisions over time (Hayes and Wheelwright, 1979).

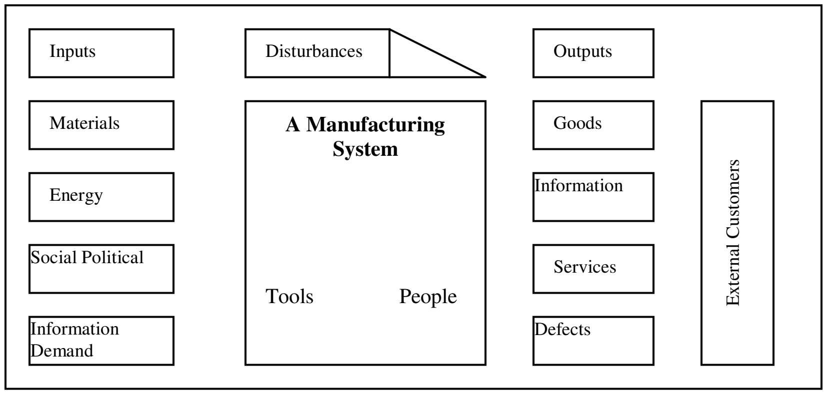


Figure 1 A manufacturing system with physical elements and characterized by measurable parameters (Black, 2002)

In today's rapid changing environment, companies are constantly confronted with decision problems with far-reaching consequences. Survival and long-term success will often depend on finding the right decision. It is often not a simple matter to find the right decision, as most decisions are highly complex in nature. This complexity is due to a number of factors (Grunig and Kuhn, 2005):

- The problem may have numerous dimensions, many of which can only be described in qualitative terms.
- Relationships between the different dimensions may be unclear so that the structure of the problems is obscured.
- The problem may involve more than one division or department of the company or organization.
- The problem may have a large number of possible alternative solutions.

- Future developments in the relevant environment may be uncertain.

The same problems are faced by not only the health care industry, but many other industries as well. It is crucial to make decisions in a way that supports a company's high-level objectives, which requires an understanding of how detailed design issues affect the interactions among various components of a manufacturing system. Designing the details of manufacturing systems, such as equipment design and specification, layout, work content, information flow, etc. in a way that is supportive of a company's strategy is becoming a challenge (Cochran et. al., 2002). Because manufacturing systems are complex entities involving many interacting elements, it can be difficult to understand the impact of detailed, low-level deficiencies and change the performance of a manufacturing system as a whole. Shingo (1998) discusses the problem of optimizing individual operations as opposed to the overall process, while Hopp and Spearman (1996) describe the same problem as reductionist approach. The approach described by Hopp and Spearman is to focus on breaking down a complex system into simple components and then analyzing each component separately. They point out that too much emphasis on individual component leads to a loss in perspective and that a holistic approach is needed to lead a better off overall system performance. Cochran et. al. (2002) propose a decomposition framework to help manufacturing system designers to clearly separate objectives from the means of achieving them, relate low-level activities and decisions to high-level goals and requirements, understand the interrelationships among different elements of a design system design and effectively communicate this information across the organization. The structure of the framework is based on axiomatic design. The decomposition framework for manufacturing system design and control integrates several disciplines, such as plant layout design and operations, use for information and performance measurement, etc. The framework is targeted at medium to high volume repetitive manufacturing companies.

2.7 Manufacturing System Design Decomposition

Carrus and Cochran (1998) introduced the Manufacturing System Design Decomposition (MSDD). The MSDD is the result of a design decomposition process that identifies clearly the requirements of a manufacturing system and the means to achieve those requirements. The ability of the system design to achieve its requirements can be evaluated with measurable parameters or measures (Suh, Cochran, and Lima, 1998). A mass system optimizes specific parts of a system, instead of the whole. The term "lean" can be interpreted in many different ways and has often been misinterpreted and misunderstood. The purpose of the manufacturing system design decomposition is to eliminate this ambiguity by providing a foundation that states clearly the requirements and means to achieve the requirements that exist within a system design.

The Manufacturing System Design Decomposition (MSDD), shown in Figure 2, has been developed according to the axiomatic design methodology

(Cochran et al. 2000). Axiomatic design is defined as the synthesized solutions in the form of products, processes, or systems that satisfy the perceived customer needs through mapping between Functional Requirements (FRs) and Design Parameters (DPs).

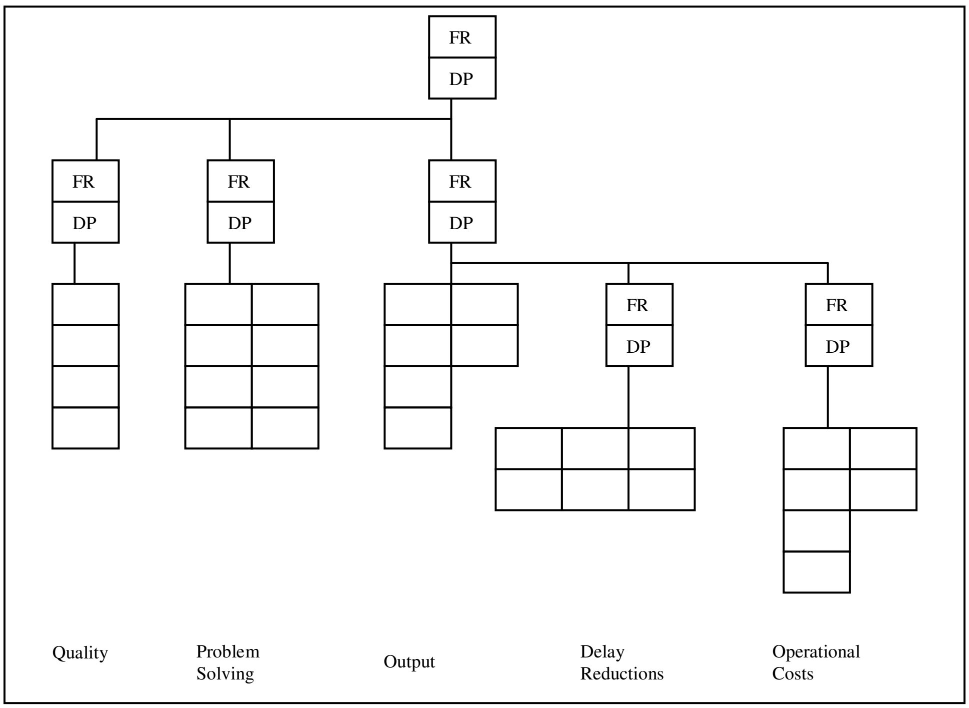


Figure 2 The manufacturing system design decomposition (MSDD) (Cochran et. al., 2002).

Two design axioms are specified: the Independence Axiom and the Information Axiom. The Independence Axiom (Axiom 1) states that a good design must "maintain the independence of the functional requirements." The Information Axiom (Axiom 2) requires minimizing the information content of the design. The axiomatic design (AD) methodology begins with the identification of customer needs and the conversion of these needs into a set of high-level functional requirements. The goal is to develop the minimum set of independently achieved requirements that completely characterize the desired functions of the design (Suh, 1990). The process starts with mapping from the customer domain to the functional domain to state (objectives) functional requirement (FRs) in solution-neutral terms. Next, determine how the FRs will be met by the design parameters (DPs). Decomposition proceeds until all FRs and DPs have been decomposed to an operational level of details.

In axiomatic design, the FRs and DPs are connected by means of design matrices; that is FRs are related to its associated vector of DPs according to the following equation (Cochran et. al., 2002):

$$\{FRs\} = [A]\{DPs\} \tag{2.1}$$

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix} \tag{2.2}$$

The binary elements of the design matrix, expressed as X's and 0's, indicate the presence or absence of a relationship between DPs and related FRs. The relationship between the FRs and DPs in the MSDD are more conceptual in nature and A_{ij} is related to the particular choice of DP_j affecting the system by FR_i.

To accomplish independence of the Functional Requirements requires defining a means-a Design Parameter (DP)-to affect only one Functional Requirement (FR). Independence also means that the selection of the DPs ensures that the FRs are independently satisfied. The selection of DPs limits the choice of possible solutions for the next levels of FRs. The use of the design process to develop the MSDD provides the ability to communicate one's thinking rigorously and the result of the decomposition process provides a structured and adaptable communication tool. MSDD provides a framework to prove the effectiveness of a system design. The system design process with axiomatic design provides a tool to effectively communicate one's thought process and also forces rigorous thinking through the satisfaction of the axioms. Figure 3 describes the simplified flow of the axiomatic design decomposition process.

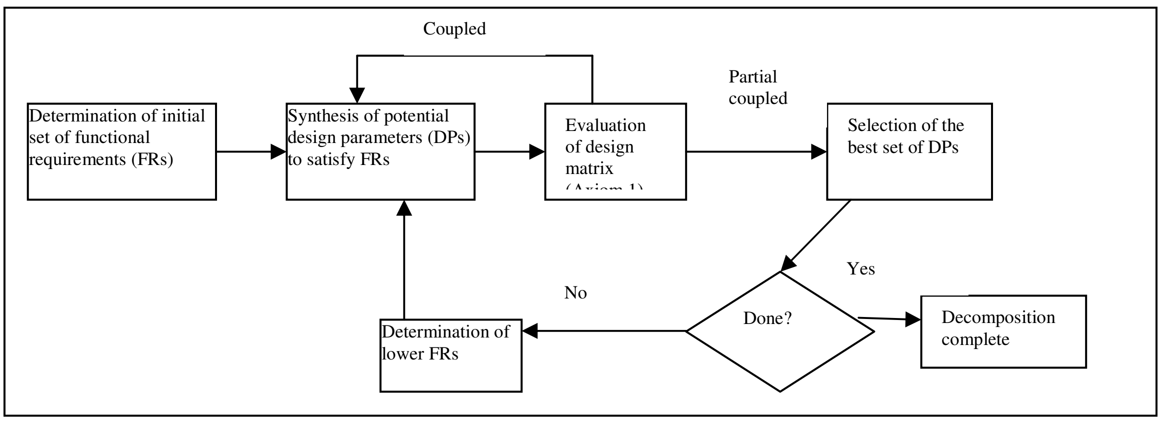


Figure 3 Simplified axiomatic design decomposition process.

2.8 Introduction to Process Modeling

Organizations usually measure only the output and outcomes, such as profits and customers' satisfaction. Although they believe that satisfied customers will lead to repeated sales or may help the organization to market their products through word of mouth, the organization does not know how the different variables from the inputs to the outputs are linked. It is because of this that firms need an in-process scorecard that shows the cause-effect linkages of the measures from inputs through the processing system, to outputs (Platts and Tan, 2002). In defining performance measurement of an organization, a process model is often used. This process model usually illustrates how goals and measures may be placed along a causal chain, from resource inputs to the outcomes obtained as shown in Figure 4. By defining linked sets of performance measures, managers will be able to better control and manage their businesses. Using a combination of input, process can do this linking of performance measures and output measures.

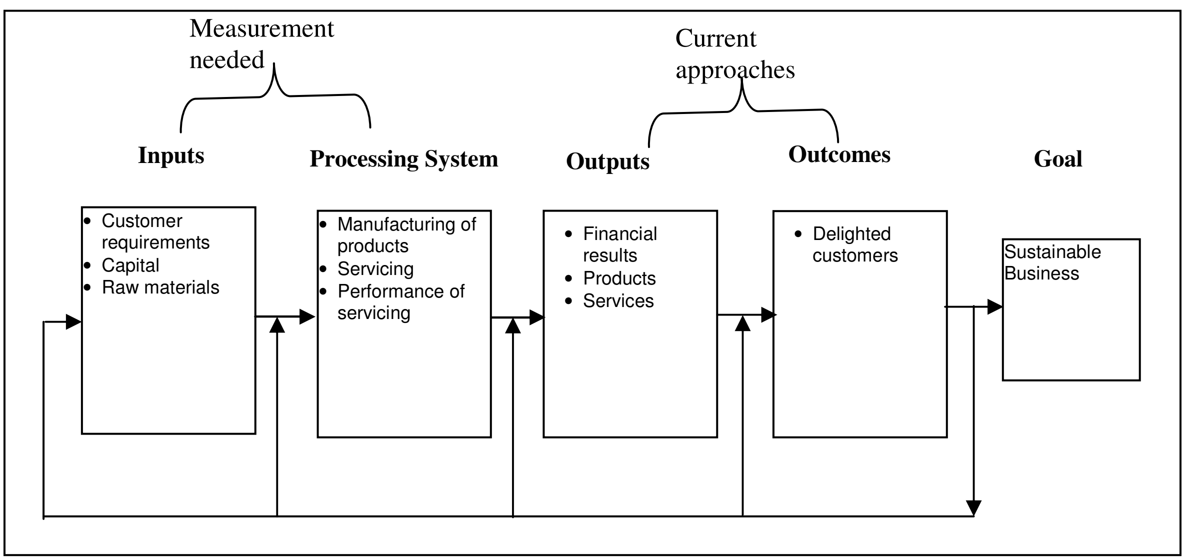


Figure 4 Gaps in current performance measurement systems (Tan, Platt and Noble, 2003)

2.9 The Connectance Concept

In order to make the process model applicable to organizations, we need to define inputs, processes and outputs, so that we can put measures on them, and also understand the relationships among them to interpret the measures and act accordingly. We have tackled this by adapting the Production System Variable Connectance Model developed by Professor John L Burbidge in 1984. This model is a generic causal model of a production system, based on qualitative relationships between variables. The Connectance Model (Burbridge, 1984) is based on the idea that if relationships between production system variables are specified in qualitative terms only, which excludes quantitative measures. Although the connectance concept will set as a good basis for research, a new model to include quantitative measures rather than just the direction of change is needed.

Burbridge illustrated the general scheme of classification for systems variables in Figure 5. In this figure, systems variables are divided between four main classes: system design parameters, regulatory parameters, uncontrollable input variables, and output variables. It is illustrated in the figure that a system variable will still remain as variable even if it has been assigned a particular fixed value as a policy, plan, or aim for the future, or has achieved a particular fixed value in some other way.

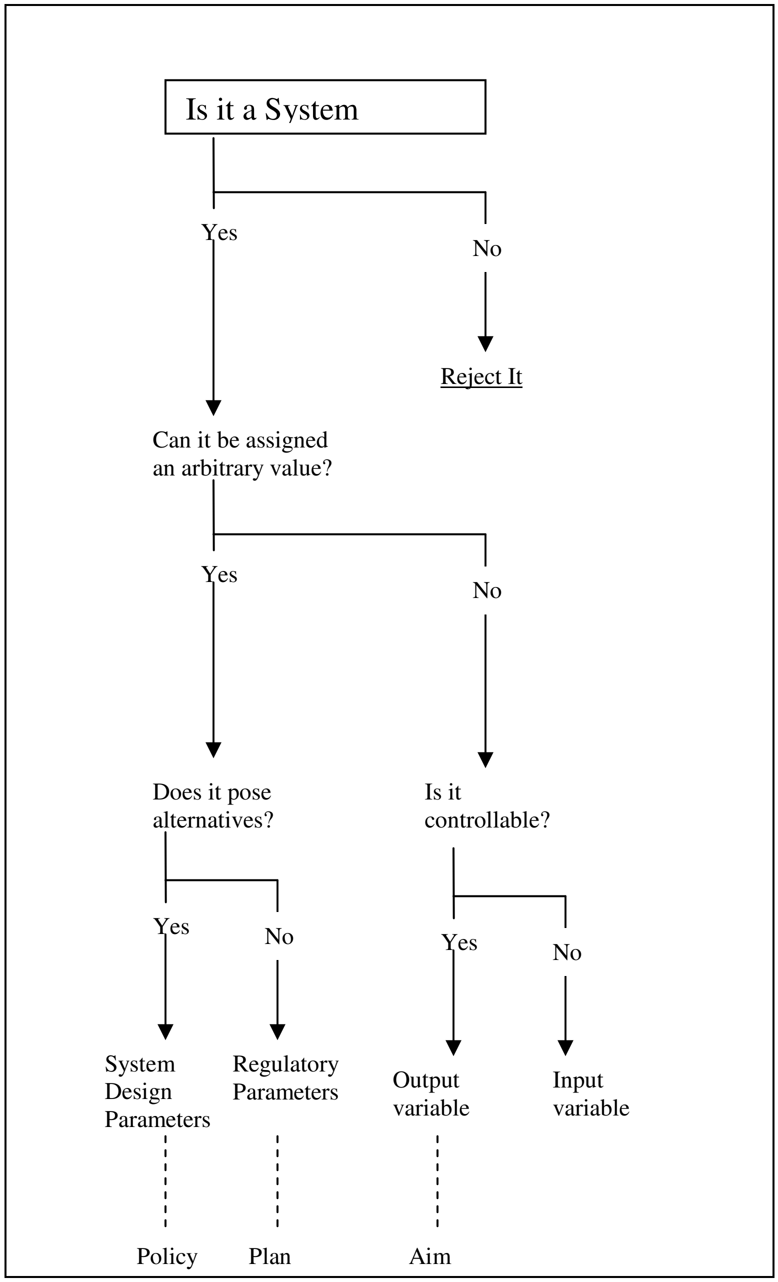


Figure 5 Scheme of classification (Burbridge, 1984)

Burbridge used a general model for production system as illustrated in figure 6. It shows the system, the four main types of system variables, and the feedback control loop between the manager and the sensor. The main difference between figure 6 and other conventional models available in the market is that it separates systems design parameters from other parameters, and by implication recognizes that the system is affected by the way it is designed. The system design (SD) in this case is also separated from operational management (MN).

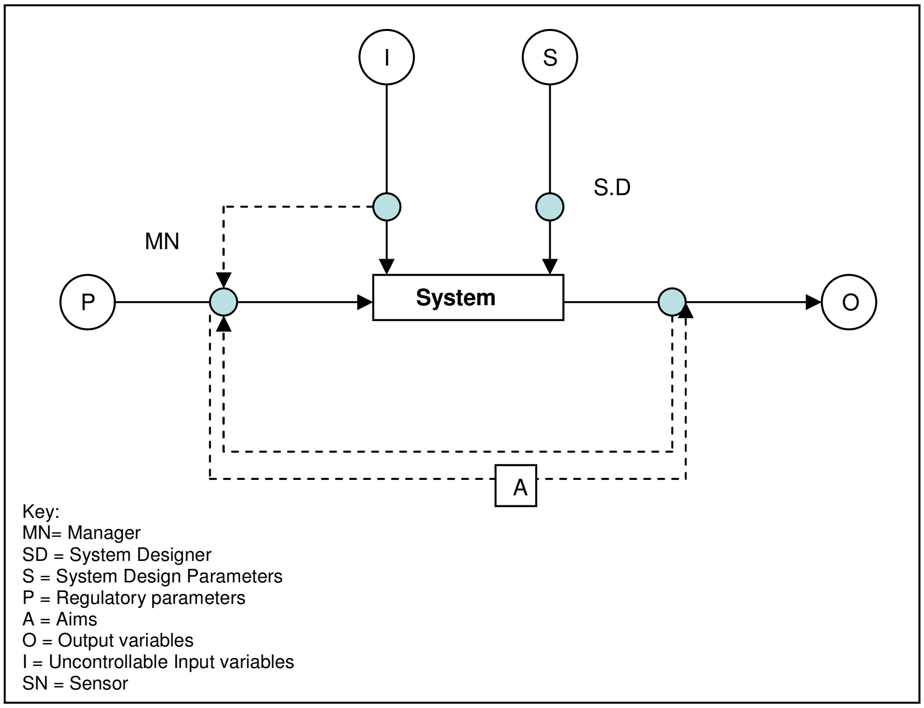


Figure 6 Model of production system (Burbridge, 1984)

Burbidge believes that through experience, managers learn the principles, which govern the relationships between changes of input variables and their effect on output variables. Thus, based on practical experience, industrial managers are able to form generalized inductive rules about variable relationships, such as an increase in factory overtime or number of working shifts could lead to increase in factory capacity, as shown in figure 7.

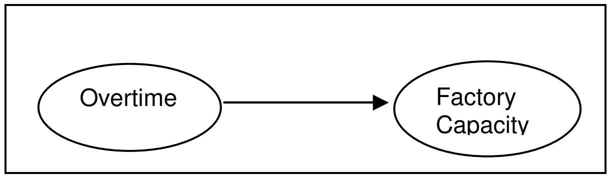


Figure 7 Connectance between overtime and factory capacity (Tan, Platt and Noble, 2003)

In designing the connectance model, Burbidge classified over 200 production variables and showed how a given direction of change in each, will induce a particular direction of change in related variables. There are two main types of connectance:

1. Limitation
2. Induction

In limitation, changes in the value of a system variable either fix the value, or change the limits to the possible range of values for some other variables. Where a parameter change affects the value of any other parameter, the relationship is treated as a "limitation" (Burbridge, 1984). In the case of "induction", changes in the value of a system variable induce changes in the values for some other variables.

Burbidge used the model for the design of new production systems (Burbidge, 1984), that is to find the input and system variables required in order to achieve a given combination of output variable requirements, which can be adapted to aid the design of performance measurement systems.

2.10 Incremental Calculus

The incremental calculus presented by Eilon (1984) focuses its attention on the relative or incremental changes that take place among a set of variables. The relative change in a variable is the ratio between the absolute change, or increment, in the variable and the original absolute value of the variable. The primary motivation for focusing on relative increments rather than the absolute values of the variables is that relationships of a more general nature can be developed from them. A secondary motivation is that incremental calculus is generally more robust than the absolute value. The increments are not constrained in their sign or in the manner, in which change takes place and the change that a variable undergoes can be continuous or discrete resulting in the same relative incremental change.

The incremental calculus is based on four main rules from which it is possible to derive other incremental relationships (Noble and Tanchoco, 1995). The four main rules are: addition, subtraction, multiplication, and division. Let y^* be the relative incremental change, y^*/y, where

$$y^* = y_{old} - y_{new.} \tag{2.3}$$

The additional rule in incremental calculus is:

$$y^* = (x_1 + x_2)^* = k_1 x_1^* + k_2 x_2^* \tag{2.4}$$

where,

$k_1 = \frac{x_1}{x_1 + x_2}$, $k_2 = \frac{x_2}{x_1 + x_2}$, $k_1 + k_2 = 1$

The subtraction rule in incremental calculus is:

$$y^* = (x_1 - x_2)^* = k_1x_1^* - k_2x_2^* \quad (2.5)$$

where,

$k_1 = \frac{x_1}{x_1 - x_2}$, $k_2 = \frac{x_2}{x_1 - x_2}$, $k_1 + k_2 = 1$

The multiplication rule in the incremental calculus is:

$$y^* = (x_1x_2)^* = x_1^* + x_2^* + x_1^*x_2^* \quad (2.6)$$

The division rule in incremental calculus is:

$$y^* = \left(\frac{x_1}{x_2} \right)^* = \frac{x_1^* - x_2^*}{1 + x_2} \quad (2.7)$$

The following is an example illustrating the fundamentals of incremental calculus.

Total revenue R is $\mathbf{R = R_1 + R_2}$ **(2.8)**

In table 2, the three cases where the absolute increase in R_1 is the same, the relative increase is smaller when the value of R is high than when it is small.

Case	R1	R2	R	Increase in R1	New total R	Increase in total R %
1	100	80	180	10	190	5
2	100	20	120	10	130	8
3	100	0	100	10	110	10

Table 2 Three examples of R from R1 and R2

The relative increase in R depends on the ratio of $\mathbf{R_1}$/ **R** and when this ratio is multiplied by the relative increase in $\mathbf{R_1}$, then the relative increase in the total is obtained as shown in the equation below.

$$\frac{\delta R}{R} = \frac{R_1}{R_2}\frac{\delta R_1}{R_1} \qquad (2.9)$$

Where,

$\frac{\delta R}{R} =$ relative increase in the total

$\frac{R_1}{R} =$ proportion of R in the total prior to the change

$\frac{\delta R_1}{R_1} =$ relative change in R_1

2.11 Summary

In this chapter, we discussed the complexity of health care systems and how engineering tools could be adapted to better understand and optimize the performance in a health care system. We also discussed various existing frameworks that measure health care system performance based on health inequalities, coverage, equitable financing, quality, consumer satisfaction, allocating efficiency, technical efficiency, cost containment, political acceptability, and financial sustainability. However, the approaches were incomplete and were unable to provide a comprehensive assessment of health care system performance.

The MSDD presented an axiomatic design-based decomposition of a general set of functional requirements and design parameters for a manufacturing system, which aid engineers and managers in the design and operation of manufacturing systems. The decomposition framework for manufacturing system design and control integrates several different disciplines, such as human work organization, use of information technology, and performance measurement, which shared the same disciplines in health care systems.

We also investigated the connectance model, we believed that the connectance concept could complement the MSDD to make our framework more comprehensive. The connectance model would help managers identify and study variable interrelationships. In solving a manufacturing problem, the relationships among production variables were not given to managers as facts; rather, they are discussed, defined, and labeled by managers using their own understanding of the production environment, as they attempt to make sense out of the complex interactions. The connectance concept, although simple, were used to analyze large complex model.

We then discussed the marginal and incremental analyses, which were techniques that helped to address issues, such as the cost effectiveness of different amounts of a particular treatment and the differential costs and benefits of competing strategies, respectively.

From the frameworks explored in this chapter, we were able to integrate the engineering tools developed for manufacturing systems and applied these to health care systems. This motivated us to develop a holistic approach to lead a better overall system performance by breaking a complex system into its more simple components and then analyzing each component separately. These engineering tools can help health care managers to emphasize on individual components and yet not losing the perspective for the overall system.

We believed that the engineering tools reviewed could be adapted to approach health care system issues by:

1. Understanding the relationships between high level system objectives and lower level design decisions.

2. Understanding the interrelations, precedence, and dependencies among various elements of a system design that determine its ability to meet high-level requirements and objectives.

CHAPTER 3 METHODOLOGY

3.1 Methodology Introduction

Our study is divided in two main parts:

1. Developing the performance framework
2. Applying the framework to an outpatient clinic

In order to appropriately analyze the performance measurement in a health care system, we need to ensure that the framework is practical. As reviewed, existing studies fail to alter their framework applicable to health care system. To rectify these issues, our framework is developed specifically to measure performance in health care system.

As mentioned in the introduction, the performance measurement framework is developed from some manufacturing best practices to decompose the primary inputs to subsystems and link them based on their relationship (connectance) to the objectives that we defined for the study. Figure 8 shows the phases of developing the proposed framework.

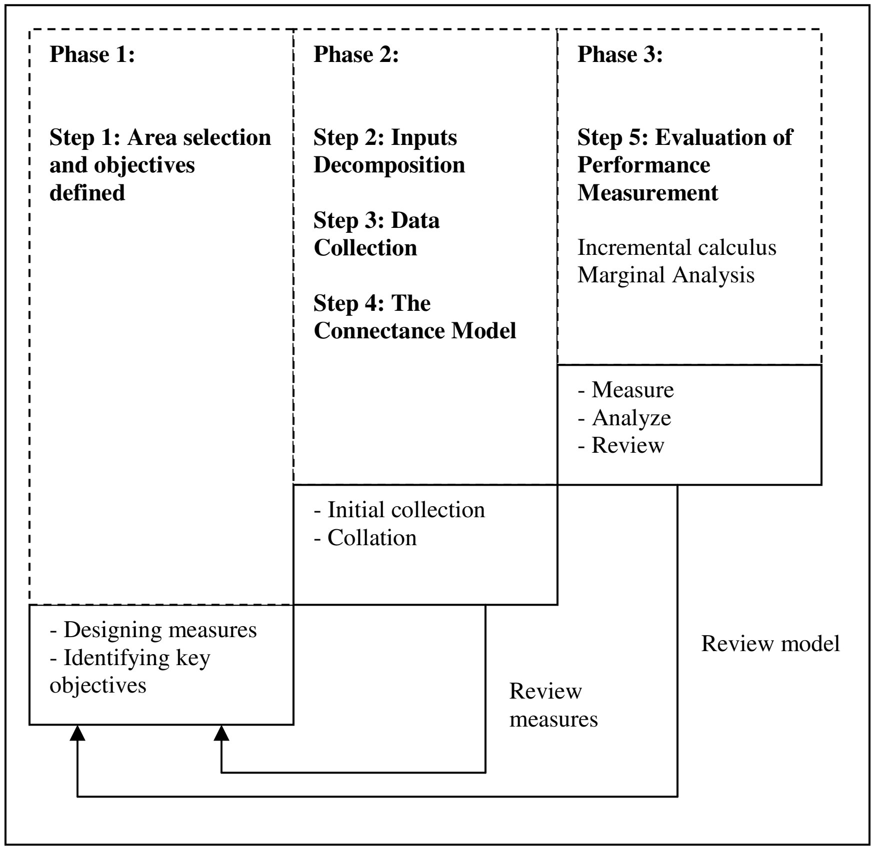


Figure 8 Phases in developing performance measurement

3.2 Area Selection and Defining Objectives

We will first establish the main objective and the inputs that will affect the objective for our study. With the inputs and objective established, we can then start decomposing the objectives to subcomponents and connect the sub-components to the primary inputs.

3.3 Inputs Decomposition

We will first attempt to decompose the operations using a modification of the Manufacturing System Design Decomposition (MSDD) introduced by Carrus and Cochran (1998) to breakdown the different components within a health care system, as shown in Figure 9. The MSDD is the result of a design decomposition process that identifies clearly the requirements of any system and the means to achieve those requirements. The ability of the system design to achieve its requirements can be evaluated with measurable parameters or measures. The purpose of the system design decomposition is to eliminate this ambiguity by providing a foundation that states clearly the requirements and means to achieve the requirements that exist within a system design. And, the same can be applied to health care systems.

The decomposition framework integrates several different areas, such as, staffing breakdown, patients' schedules, material supply, occupancy, and utilization and performance measurement. This decomposition requires the experience in the health care systems to effectively break down the primary inputs into subcomponents.

Based on the objectives and inputs, performance analysis using the ratio between the inputs and the outputs based on their relationships will be utilized.

These ratios will be measured using incremental calculus due to its robustness and flexibility.

Step 1 in the design process is to define the top level objectives and the primary inputs for the health care system that we wanted to study. Figure 8 shows the decomposition process. Step 2 in the design process is determining the Design Parameters that correspond to the Objectives. Step 3 connects the primary inputs to the design parameters based on their relationships. The primary inputs are connected to the design parameters when the result from primary inputs will affect the outcomes of the design parameters. For example, if objective 1 is costs, one of the design parameter might be number of RNs in the system, which may link to the primary input under staffing.

The design process continues by determining the design parameters to satisfy the objectives. The extensiveness of the decomposition heavily relies on the designer's experience with the health care system and judgments in communicating the necessary level of detail. Selection of objectives and design parameters is an iterative process and based heavily on the designer's experience in health care system analysis.

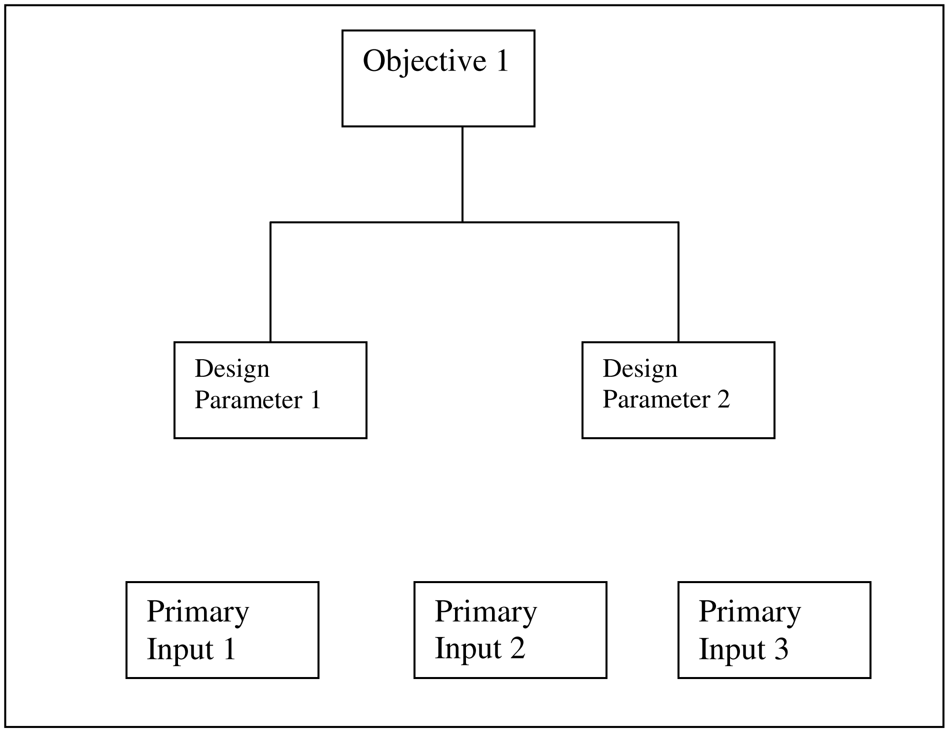


Figure 9 Decomposition Process

3.4 The Connectance Model

We will attempt to describe the relationships among the design parameters, primary inputs, and objectives that we defined. With the help of experienced managers in the health care systems, we can establish the principles that govern the relationships between changes of input variables and their effect on output variables and form generalized inductive rules about variable relationships. For example, an increase in RN overtime could lead to an increase in the clinic capacity. We believe that the model can be adapted to aid the design of performance measurement systems.

3.5 Incremental Calculus

The relative change in a variable is the ratio between the absolute change, or increment, in the variable and the original absolute value of the variable. This is of particular interest when attention is focused on the *relative* changes that take place on the ratio of an increment of a variable (or a function) to its original value prior to the change. Incremental calculus can help us in diagnosing past events and for planning and decision making. Although incremental calculus is mainly used in the business world, it is easily applied to our proposed network.

Bela Gold (1976) proposed the R model for managerial control ratios which we will utilize once the performance network is established. Based on his model:

$$\frac{profit}{Total\_investment} = \left(\frac{product\_value}{Output} - \frac{Total\_\mathrm{cost}}{Output}\right)\left(\frac{Output}{Capacity}\right)\left(\frac{Capacity}{Total\_investment}\right) \quad (3.1)$$

Or r = (p-c) e k

Where,

r= return on total investment = profit/total investment

p = unit price for the output

c = unit cost of the output

a = p-c= unit profit of the output

e = output/capacity = capacity utilization of the facility

k = capital/total investment

$$= \left(\frac{Capacity}{Fixed\_investment}\right)\left(\frac{Fixed\_investment}{Total\_investment}\right) \quad (3.2)$$

However, in our case, the equation will change based on the objectives and subcomponents of the primary inputs we developed earlier. At a given time, the rate of return is given by *r=aek* and, if after a certain time period the rate of return becomes r + δr, it may be expressed as :

$$r + \delta r = (a + \delta a)(e + \delta e)(k + \delta k) \quad (3.3)$$

where δa, δe and δk are the corresponding incremental changes in a, e and k respectively. The incremental change δr as follows:

$$\delta r = ek\,\delta a + ak\,\delta e + ae\,\delta k + e\,\delta a\,\delta k + k\,\delta a\,\delta e + a\,\delta e\,\delta k + \delta k\,\delta a\,\delta e \quad (3.4)$$

If we divide the left hand side by *r* and right hand side by *aek* and substitute the following:

$r^* = \delta r / r$ = change in *r* relative to the original value of *r*

$a^* = \delta a / a$ = change in *a* relative to the original value of *a*

$e^* = \delta e / e$ = change in *e* relative to the original value of *e*

$k^* = \delta k / k$ = change in *k* relative to the original value of *k*

we get:

$$r^* = a^* + e^* + k^* + a^*e^* + e^*k^* + k^*a^* + a^*e^*k^* \qquad (3.5)$$

where the relative changes of a*, e* and k* are small, hence the last four terms may be ignored and we get:

$$r^* = a^* + e^* + k^* \qquad (3.6)$$

Equations 3.5 and 3.6 indicate how a relative change in rate of return can be attributed to relative changes in the three factors in the equation and to the interactions between them. If (3.6) holds, the overall relative change in r is the sum of the relative changes a, e and k. The last four terms in (3.5) represent residuals due to the combined effect of these factors. Hence, if we want to identify the total effect of a change in a, then from (3.6), it would be:

$$a^* (1+e^*+k^*) \qquad (3.7)$$

The first term inside the bracket describe the direct contribution of *a**, the second term represents the relative effect of the interaction of *e**,* and the third is the relative effect of the interaction of *k**. Equation (3.5) mathematically represents the decomposition of the relative change in the rate of return into its different constituent parts. We will apply this theory to the health care systems. We will decompose the primary inputs and represent the same way as equation (3.5) to better appreciate the relative contributions of the subcomponents.

3.6 Marginal Analysis

The measurement of performance may help to answer questions about the expected response by different factors. These factors may be the result of management decisions that the manager of the facility is in a position to control or influence. This model and measurement may give indications or provide explicit predictions, as to how the system is likely to behave in the future under the given conditions.

		Effects on (in per cent)							
		Output unit cost							
	1% change in	Labor	Materials	Capital	Total	Unit profit margin a*	Output / Capacity e*	Capacity / Total Inv. k*	Return on inv. r*
Labor	M-hr/output unit								
	Wage rate								
Materials	Volume/output unit								
	Avrg unit cost								
	Output								

Table 3 An incremental Marginal Table

From the model developed, we realized that it involved many variables, and inter-relationships. Inevitably, some variables are likely to be more significant than others and the purpose of the marginal analysis is to establish the extent to which various criteria, as well as the system as a whole, are affected by a given incremental change of each variable. Thus, an incremental marginal table may be constructed, such as Table 3, where for an incremental change of 1 percent for each of the factors listed on the left the possible effect in percentage is recorded for each of the ratios enumerated at the top of the table. In some cases, the effect might be negligible, in others the relative impact could be significant; and this is precisely the purpose of this table, to identify the most important variables in the performance model. The table contains the major factors and ratios that are likely to be of interest. It should be emphasized that the incremental sensitivity table is strictly valid only at a given level of operations, usually identified as the current clinic activity.

Like the concept of marginal costing, the incremental marginal table depicts marginal values. If a ten percent increase in any given parameter takes place, the results will not necessary be ten times the values shown in the table. Nor do these values predict the incremental changes that would occur if the mode of operation of the clinic and the values of the major variables are significantly different from those assumed when the table was constructed. Consider the following example (Noble and Tachoco, 1995). A current health care system design has a capacity of 50 patients/hour and a total cost of $5000. A specific component of the system X_0 comprises of $200 of the total cost. An analysis of the component X_0 revealed two alternative design X_1 which cost $300 of the total cost and yields an overall increase in 10 patients/hour and X_2 which cost $700 of the total cost and yields an overall increase in 50 patients/hour. As we can see, the incremental cost of X_1 is 2% but the incremental capacity is 20% and the incremental cost of X_2 is 10% and the incremental capacity is 100%. The example given is admittedly trivial, but the insight gained from the marginal analysis is very valuable, especially in situations where a variety of integrated system decisions need to be analyzed concurrently like our proposed framework for the health care systems.

	Total cost	% cost increase	Capacity	% capacity increase
Current System with X_0	$5,000		50	
System with X_1	$5,100	2%	60	20%
System with X_2	$5,500	10%	100	100%

Table 4 Marginal cost/performance perspective

Nevertheless, the incremental sensitivity table is a useful tool for the purpose of managerial control, and it provides a systematic picture which highlights the most significant components in the model for any given situation.

CHAPTER 4 APPLICATION CASE STUDY

The framework presented in Chapter 3 was applied and tested empirically in a case study at Green Meadows Clinic under the University Physicians system in Columbia, Missouri. This clinic is located in Columbia and resembles a metropolitan group practice. With more than 50,000 visits annually, the clinic draws its large patient population from the Columbia area. The medical staff at Green Meadows Clinic is organized into three teams:

- **Blue Team**
- **Green Team**
- **Gold Team**

The health-care providers at the Family Medicine Clinic located at University Physicians—Green Meadows take a team approach to providing their patients with health care. Patients are seen by attending physicians, resident physicians and nurse practitioners. This is an outpatient clinic which provides health care for ambulatory patients. The patient visits are strictly by appointment only and do not handle emergency cases. The clinics function as a place for people with injuries or illnesses to come and be seen by medical professionals.

As this is an outpatient clinic, the injury or illness of the patients are usually not serious enough to warrant a visit to an emergency room. Treatment at the clinic is also less expensive than it would be at an emergency room. It operates on regular hours of 8:00 am to 4:30 pm from Monday to Friday with the exception of Monday, Tuesday and Wednesday which the Green Team will extend their operating hours to 8:00 pm. All the doctors in the clinic are in family practice and refer their patients to specialists when the need arises.

During the case study, the framework was applied to Green Meadows clinics according to the steps described in the Chapter 3. The data collection and its performance measures were done by conducting site visits and by studying documents. It should be noted that only the evaluation of the operations aspect of the clinic is presented in this research.

Step 1: Area selection and objectives defined

In this step, the area within the clinic where we will conduct our research was defined. The clinic is divided into four main area: 1.) Medical records, which consists of the supporting staff who help to update and maintain the medical records; 2.) front office, consisting of physicians, nurses and admin staff involved in managing, consulting and treating the patients; 3.) back office staff, consisting of the nurses in-charge of setting up appointments and answering general queries via the telephone, and 4.) pharmacy, for patients to purchase their prescriptions. The personnel were organized in various groups within these four main areas. Each group was then further breakdown into many subgroups.

During the site visits, several specific objectives that the management had set out to achieve as well as important productivity key factors were emphasized.

Figure 10 shows the framework for our study which we adapted from the framework developed by Slack et. al.(2002). These objectives were developed through a top-down process, which started with the University Physician management team's vision. From this vision, the objectives were designed to function within the operations aspect of the clinic.

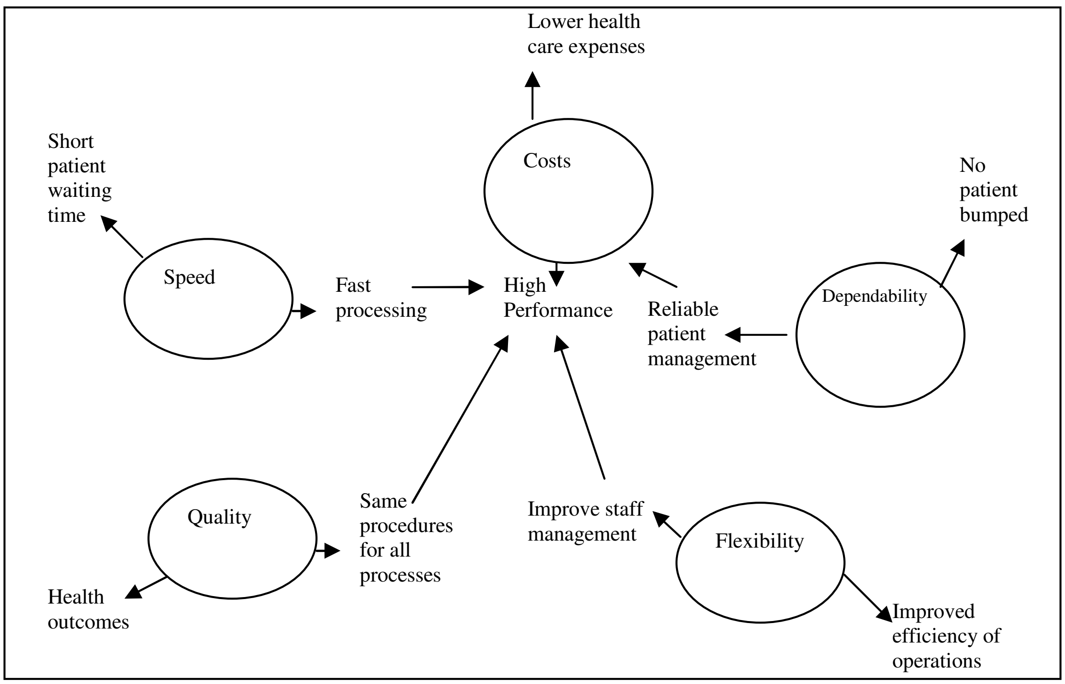


Figure 10 Performance objectives modified from Slack, et. al. (2001)

Step 2: Inputs Decomposition

The performance objectives were further decomposed using the MSDD technique as mentioned in previous chapter. Although the ultimate objective within the clinic is not profit, within the operations aspect, operating margin plays a crucial role in decision making for health care managers. Furthermore, with the increasing costs in health care delivery and the reduction in state funding for health care, operating margin within the operations aspect is crucial for the survival of any health care system.

As shown in figure 11, the main objective was designated as Function Requirement (FR) 1. It was then further broken down to FR 2, which were the main contributing factors of profit. Each FRs was broken down further and design parameters (DPs) were considered after each decomposition. In this case, we classified FRs as objectives that we wanted to achieve and DPs are the factors which we were able to collect data from. For example, when we consider the following equation, labor cost = labor rate x total working hours, we were unable to collect any raw data on labor cost, but raw data for labor rate and total working hours can be easily collected. Labor cost, in this case, is the objective we wanted to obtain; it is the FR for this equation. The DPs for this objective will be the labor rate and total working hours, which we can easily collect the raw data. When the FRs were unable to be broken down any further, the DPs affecting the FR will be developed in the lower level. Then, the DPs would then be decomposed to other

FRs until the decomposition reached the primary inputs. These FRs and DPs were developed based on existing performance measures that the clinic is currently using, as well as records and reports that can be utilized for this study.

Our main objective in this research was operating margin. We decompose the operating margin to its sub-components, which were revenue, capacity, and utilization. We continued to break down revenue to income and costs. We did not further breakdown the capacity and utilization because Green Meadows clinic did not have any utilization and capacity data within the system. We decomposed income and costs further to their DPs, materials, operating expenses, manpower and patients. We were able to calculate income from the patient data and obtain costs from manpower, operating expenses and manpower data. However, the patient data can be further decomposed in terms of schedule. From there, we decompose the four DPs to even smaller components until the primary inputs were achieved.

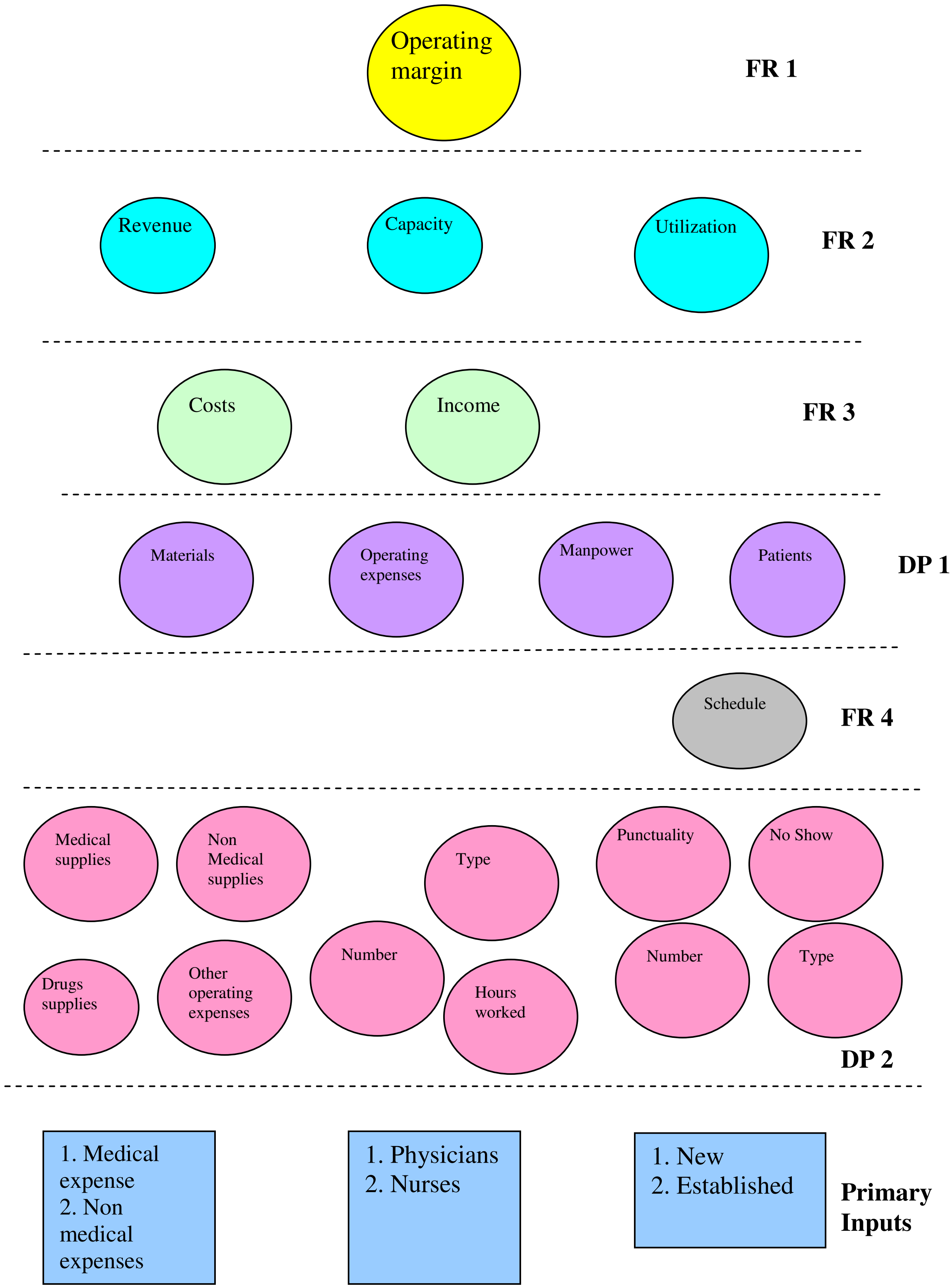


Figure 11 Decomposition of performance measurement at Green Meadows Clinic

Step 3: Data Collection

The performance framework was developed through a top-down process, which started out with the main objective we define. At this point, all the FRs and DPs were defined. We looked into the data that the clinic tracks for their present performance measurements.

Based on the framework we developed and the current data tracked by the IDX system, three main categories of data were defined:

1. Labor data
2. Patient data
3. Expense data

Labor data

The labor data were collected through the work schedules. The data were collected from 30 January, 2006 to 24 February, 2006. Due to the recent change in nurse schedule management, data before 30 January, 2006 were irretrievable. The physician and nurse schedules were planned on a monthly basis. The data were generated based on the schedules. Based on the number of hours each physician and nurse works in each team, the hours from each of them were accumulated respectively to generate the total man-hours each working day for physicians and nurses. The normal schedules for physicians are A.M. shift which is from 8:00 a.m. to 11:30 a.m. and PM shift which is from 12:30 p.m. to 4:30

p.m. from Monday to Friday. For Monday to Wednesday, the Green Team has extended operating hours from 5:30 p.m. to 7:30 p.m. For the nurses, their work schedules are different from the physicians as the nurses are usually scheduled based on 8 hour blocks, from 7:30 a.m. to 4:30 p.m. and extended hours schedules for the green team are planned from 12:30 p.m. to 7:30 p.m. for Monday to Wednesday.

From figures 12, 13, and 14, we can see that for Blue and Gold teams, the physician hours are more stable than that of Green Team. In figure 11, for the A.M. sessions, the Blue Team physician man-hours range between five and fifteen hours per day, and the Gold Team range between six and sixteen hours per day. The Green Team, which was the largest team in terms of manpower among all the three teams, and had the highest variability. The Green Team physician hours range from four to thirty-one hours per day.

The same trend was observed for the P.M. sessions, with the Green Team showing the highest variability as compared to the Blue and Gold Teams. As shown on figure 11, the Green Team physician working hours per day range from six to thirty- one. The Blue and Gold Teams showed less variability as compared to Green Team. For the Blue Team, physician total hours per day range from six to seventeen hours per day and for Gold Team, the working hours range from nine to seventeen.

In the Green Meadows clinic, the extended hours operates from 5:00 p.m. to 7:30 p.m. every Mondays to Wednesdays and the Green Team is the only team operating the extended hours. Physicians from all three teams who are scheduled to work during extended hours will move to the Green Team after the normal operating hours. From figure 14, we can see that the working hours range from six to fourteen hours per day.

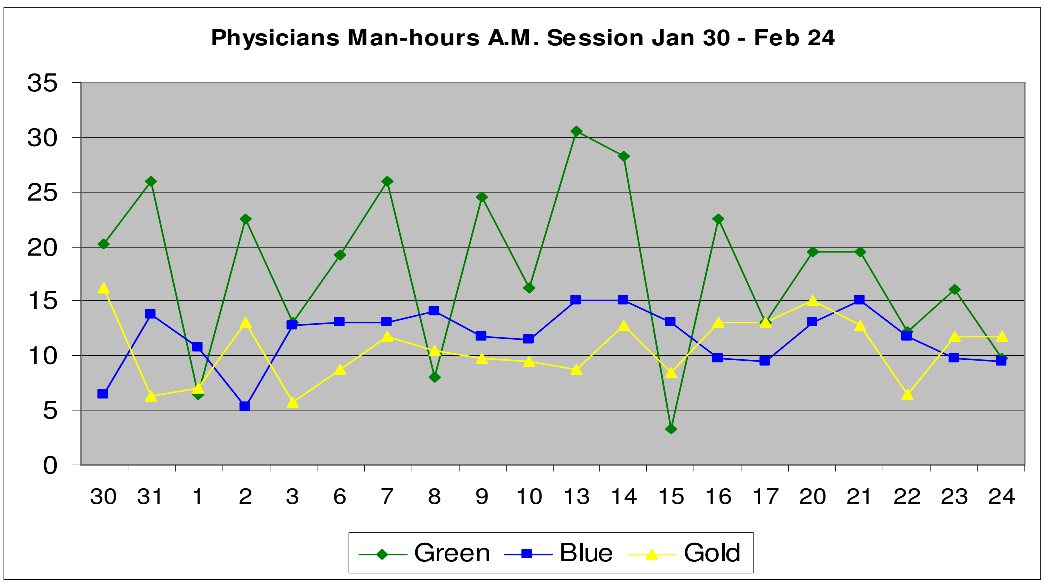


Figure 12 Physicians man-hours A.M. session Jan 30 - Feb 24

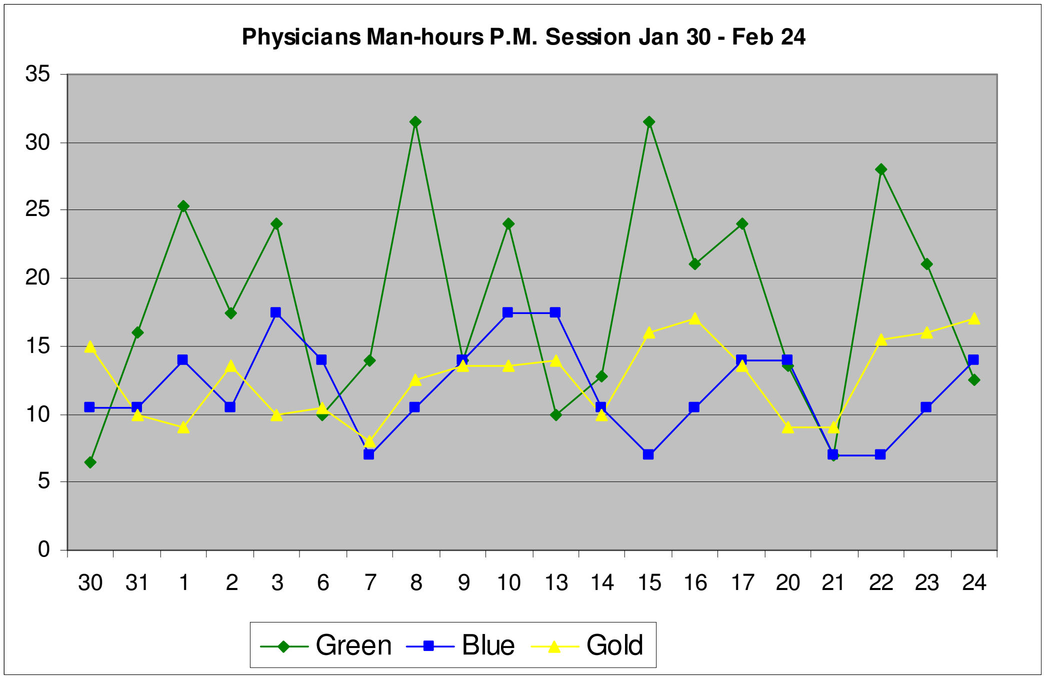


Figure 13 Physicians man-hours P.M. session Jan 30 - Feb 24

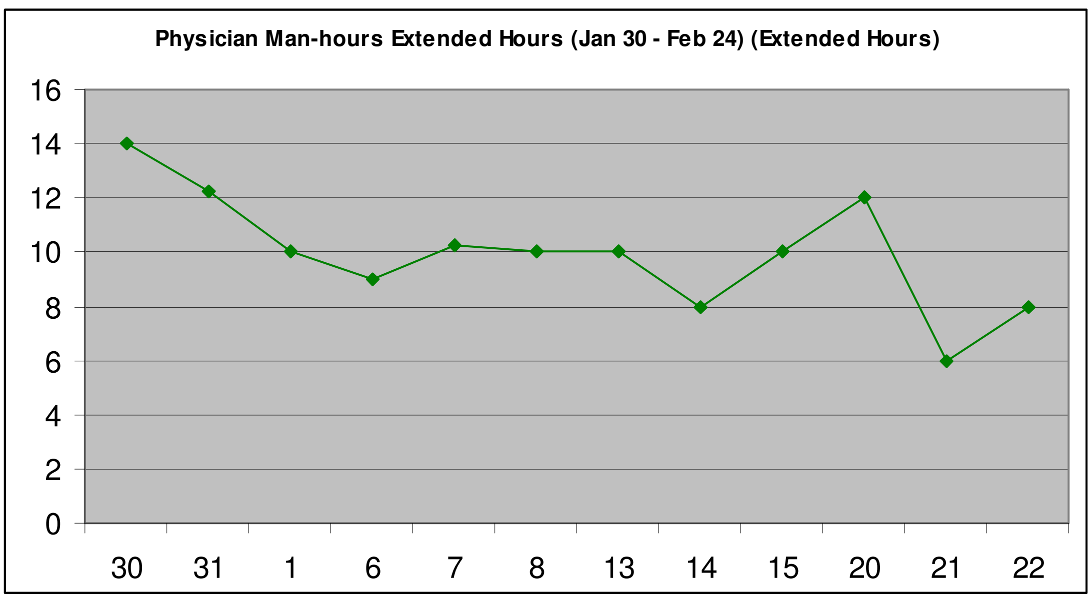


Figure 14 Physicians Man-hours extended hours Jan 30 - Feb 24, 2006

The nurse working schedules are slightly different from the physicians' schedule. Figure 15 shows that the nurse schedules show less variability as compared to the physician schedules. For the Green Team, except for every

Wednesday, the total working hours per day was thirty; the average was about fifty hours. For Blue and Gold Teams, the total hours per day were very similar which range from eighteen to thirty-one hours. Figure 16 shows that except for January, 30 to February, 1, the total hours during the extended hours were about fifteen hours. For January 30 and 31, the total working hours per day is twenty-two hours and February 1, the total hours was four hours per day, which was the lowest total hours during our data collection period.

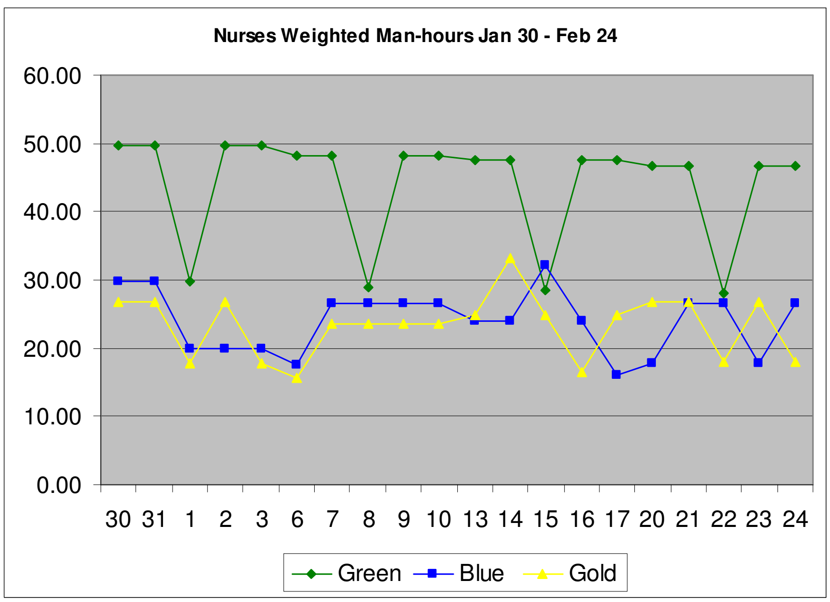


Figure 15 Nurses weighted regular man-hours Jan 30- Feb 24

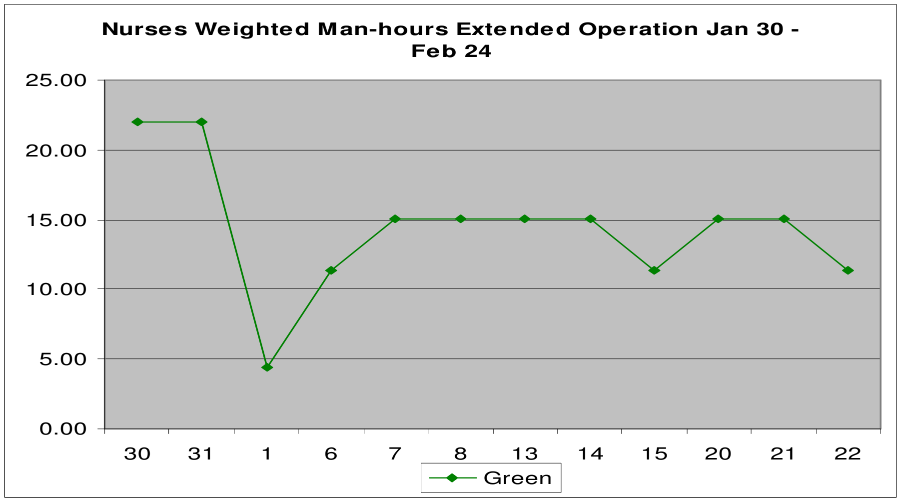


Figure 16 Nurses Man-hours extended hours Jan 30 - Feb 24, 2006

Patient Data

The patient data showed a very erratic trend and more so for the Green Team as compared to the Blue and Gold Teams. This trend was very similar to the physician data. The same trend was observed in both the patient A.M. and the P.M. sessions as we can see in Figures 17 and 18. The extended hours data was less erratic as compared to the A.M. and P.M. sessions as shown on Figure 19.

When we divided the physicians' hours to number of patients, we should see a relatively constant value, to show that the patient trend follows that of the physician trend. Our findings will be presented in the next chapter on the numbers of patients affected by the hours physicians scheduled for a given day.

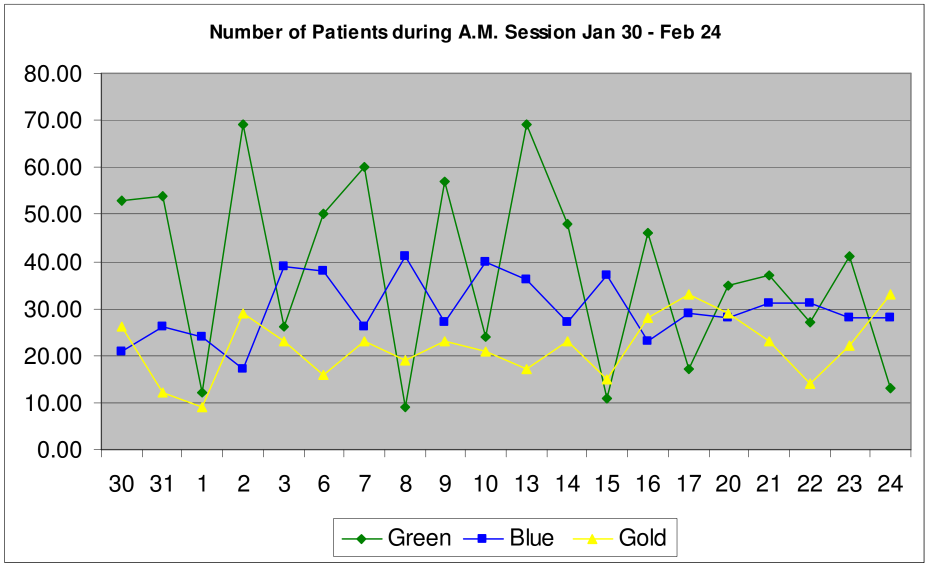


Figure 17 Number of patients during A.M. session Jan 30 - Feb 24

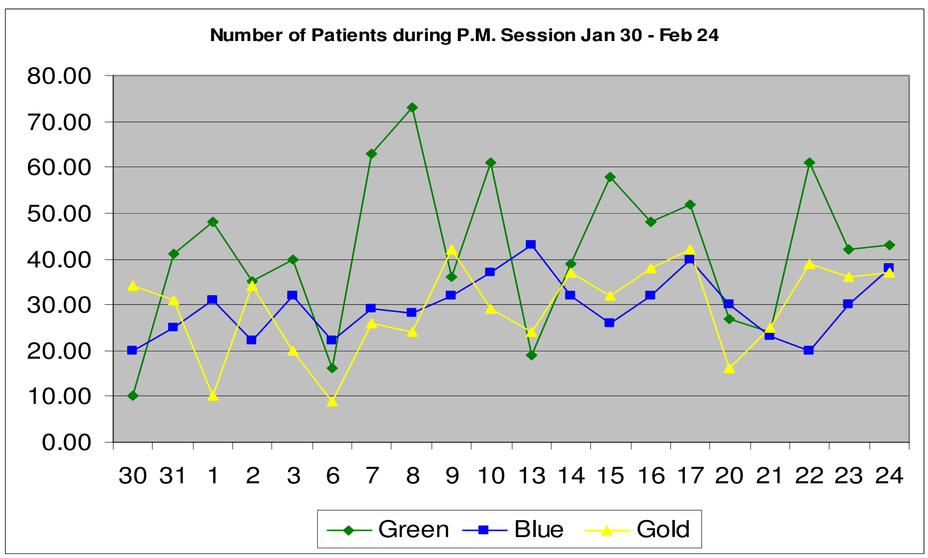


Figure 18 Number of patients during P.M. session Jan 30 - Feb 24

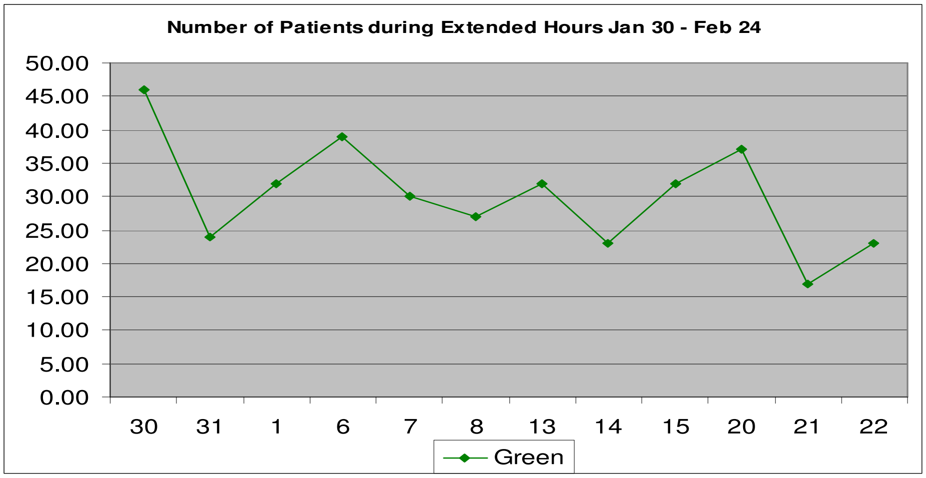


Figure 19 Number of Patients in Each Session from 30 Jan - 24 Feb, 2006

The patient data were gathered based on the records from the IDX system. The IDX system is a health care information system, which integrate delivery networks, group practices, management service organizations, hospitals and health plans. The IT software automates patient registration, billing, scheduling and data management functions.

The number of patients from each period, namely, the A.M. session, P.M. session, and the extended hours was recorded. On top of that, patient punctuality was also recorded in Figures 20 and 21. Patients were considered as arriving early if they appear before or at the scheduled time and deemed as late if the arrive 1 minute after their scheduled appointment. The number of patients 'bumped' and not showing up for the appointments were recorded as well.

Green Meadows Clinic Attendance

Date	ARRIVED	BUMPED	CANCELLED	NO SHOW	PENDING	REMINDER	RESCHEDULED	Total Appointments Scheduled
Jul, 2005	1995	268	691	351	0	0	0	3305
Aug, 2005	2529	161	868	410	1	0	0	3969
Sep, 2005	2245	141	748	418	0	1	0	3553
Oct, 2005	2492	133	779	380	1	0	0	3785
Nov, 2005	2995	159	888	441	0	0	0	4483
Dec, 2005	2245	98	737	393	0	1	0	3474
Jan, 2006	2268	169	715	335	0	0	0	3487
Feb, 2006	2310	86	714	347	1	0	0	3458
Mar, 2006	1323	159	581	259	676	2	153	3153
Total	20402	1374	6721	3334	679	4	153	32667

Figure 20 Green Meadows Clinic Attendance

		Dec, 2005	Jan, 2006	Feb, 2006	Dec, 2005 + Jan, 2006 + Feb, 2006
	Total Early	Dec, 2005	Jan, 2006	Feb, 2006	Dec, 2005 + Jan, 2006 + Feb, 2006
	FAMILY MEDICINE CLINIC AT GREEN MEADOWS	1702	1746	1778	5226
	FAMILY PRACTICE B	924	1009	1029	2962
	FAMILY PRACTICE G	820	893	862	2575
	Total Late	Dec, 2005	Jan, 2006	Feb, 2006	Dec, 2005 + Jan, 2006 + Feb, 2006
	FAMILY MEDICINE CLINIC AT GREEN MEADOWS	539	520	528	1587
	FAMILY PRACTICE B	448	468	453	1369
	FAMILY PRACTICE G	314	339	342	995
FAMILY MEDICINE CLINIC AT GREEN MEADOWS		Dec, 2005	Jan, 2006	Feb, 2006	Dec, 2005 + Jan, 2006 + Feb, 2006
	Total Early	1702	1746	1778	5226
	Total Late	539	520	528	1587
	Total Visits	2245	2268	2310	6823
FAMILY PRACTICE B	**Total Early**	924	1009	1029	2962
	Total Late	448	468	453	1369
	Total Visits	1373	1478	1485	4336
FAMILY PRACTICE G	**Total Early**	820	893	862	2575
	Total Late	314	339	342	995
	Total Visits	1134	1232	1204	3570
	% Late	Dec, 2005	Jan, 2006	Feb, 2006	Dec, 2005 + Jan, 2006 + Feb, 2006
	FAMILY MEDICINE CLINIC AT GREEN MEADOWS	24.01%	22.93%	22.86%	23.26%
	FAMILY PRACTICE B	32.63%	31.66%	30.51%	31.57%
	FAMILY PRACTICE G	27.69%	27.52%	28.41%	27.87%
			Weighted Average % Late		26.82%

Figure 21 Green Meadows Clinic Patients' Punctuality Dec 2005 - Feb 2006

Expense Data

Based on the performance trend reports, the monthly Green Meadows clinics expenses were recorded from July, 2004 to January 2006. These expenses exclude labor and benefits expenses and are divided into four main categories:

1. Medical supplies such as medical equipments, bandages, gauze, dressings, IV sets, needles and syringes.

2. Non medical supplies such as housekeeping supplies, office type supplies, linens, patient apparel, and hospital acquired scrubs and uniforms.
3. Drug supplies expenses such as oxygen and related medical gases, dialysis supplies and fluids and drugs.
4. Other operating such as expenses travel, education training, and provision for bad debts and doubtful collections

The average of these expenses was calculated to get a good approximation of each month's expenses base for the four categories.

	Green Meadows Clinc Expenses (excluding labor) Report							
	2004							
	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	
Medical Supplies	$2,719.00	$4,479.00	$4,326.00	$6,977.00	$5,496.00	$5,318.00	**$29,315.00**	
Non Medical Supplies	$4,612.00	$3,819.00	$2,846.00	$6,921.00	$5,125.00	$4,662.00	**$27,985.00**	
Drug Supply Expenses	$13,132.00	$6,212.00	$15,117.00	$6,828.00	$20,822.00	$8,479.00	**$70,590.00**	
Other Operating expenses	$529.00	$596.00	$508.00	$662.00	$795.00	$542.00	**$3,632.00**	
	2005							
	Jan	Feb	Mar	Apr	May	Jun	**Total**	
Medical Supplies	**$3,588.00**	$3,613.00	$2,647.00	$3,312.00	$5,646.00	$3,304.00	**$22,110.00**	
Non Medical Supplies	$4,264.00	$5,128.00	$4,474.00	$4,863.00	$3,592.00	$4,344.00	**$26,665.00**	
Drug Supply Expenses	$22,309.00	$7,013.00	$17,648.00	$9,031.00	$19,388.00	$8,377.00	**$83,766.00**	
Other Operating expenses	$3,163.00	($16,295.00)	$8,385.00	($10,944.00)	$53,022.00	$3,994.00	**$41,325.00**	
	2005						2006	
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	**Total**
Medical Supplies	$6,020.00	$5,218.00	$3,632.00	$6,092.00	$4,001.00	$5,258.00	$2,605.00	**$26,806.00**
Non Medical Supplies	$4,273.00	$3,824.00	$3,166.00	$7,122.00	$4,093.00	$5,494.00	$5,494.00	**$29,193.00**
Drug Supply Expenses	$0.00	$26,282.00	$11,135.00	$12,375.00	$47,313.00	$11,230.00	$6,136.00	**$114,471.00**
Other Operating expenses	$243.00	$259.00	$624.00	$250.00	$620.00	$312.00	$310.00	**$2,375.00**
Overall	**Total**	**Average**						
Medical Supplies	**$52,504.00**	**$2,763.37**						
Non Medical Supplies	**$83,843.00**	**$4,412.79**						
Drug Supplies Expenses	**$268,827.00**	**$14,148.79**						
Other operating expenses	**$47,332.00**	**$2,491.16**						

Figure 22 Green Meadows Clinic Expenses

Step 4: The Connectance Model

As described in Figure 12, in total four classes of FR for the performance measurement framework are suggested: FR 1, FR 2, FR 3 and FR 4 and two classes of DP are described: DP1 and DP 2. The FRs and DPs together with the primary inputs describes the functions and the components within the front office operation of Green Meadows clinic. Based on the relationships between the FRs and DPs were connected accordingly. Components were connected in black arrows if the components had positive relationships and blue arrows when the relationships were negative. In our model, the only two negative relationships were revenue connecting to cost and schedule connecting to no show. Since revenue = income – cost and schedule of patients = type of patients + number of patients + punctuality of patients – patients ‘no show’. The other components were connected by black arrows as they had positive relationships. We connected the components based on their relationship, for example, capacity is a function of utilization and manpower while cost is a function of materials and manpower.

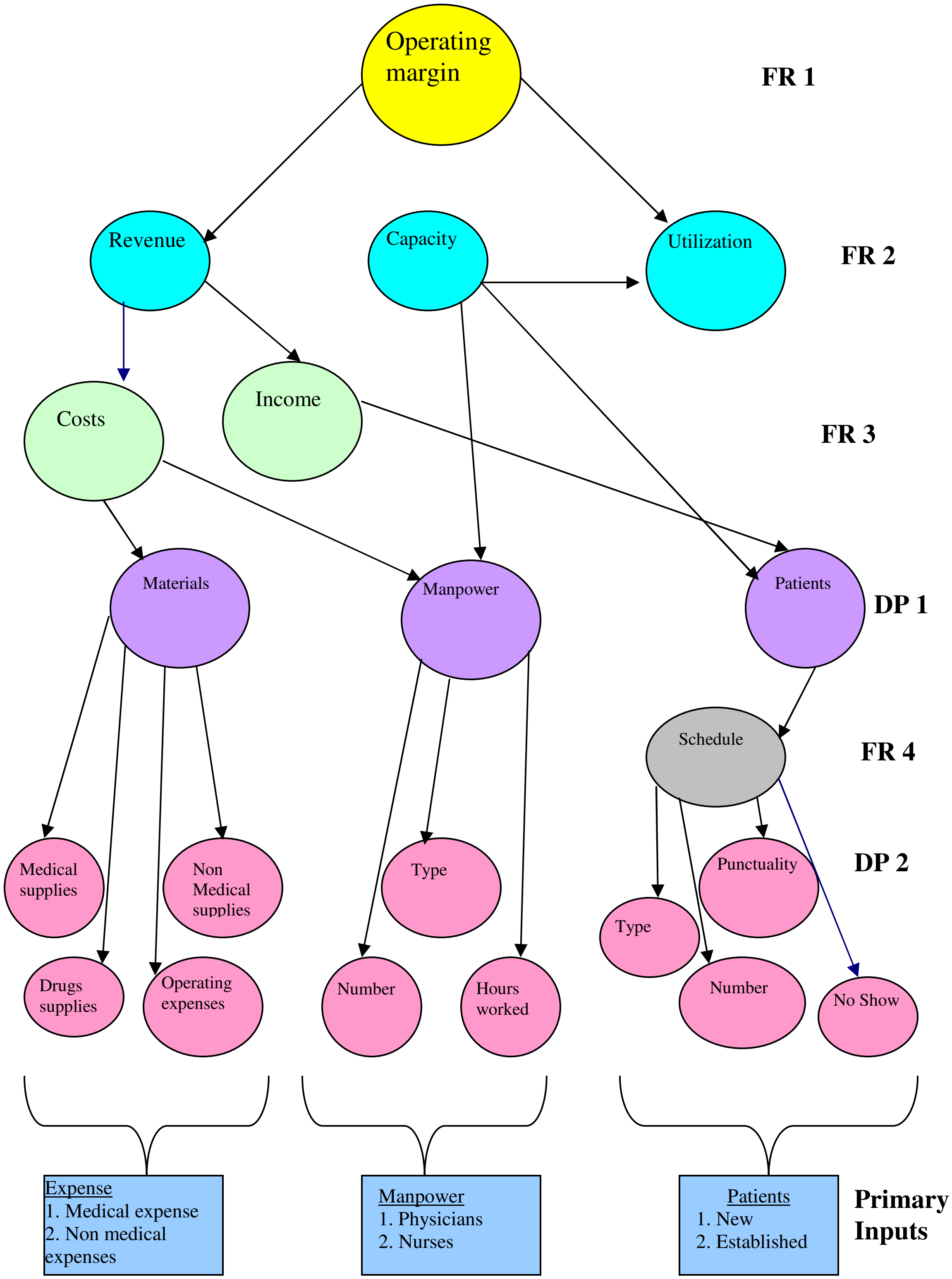


Figure 23 The Connectance Model of Performance Framework

Step 5: Evaluation of Performance Measurement

In this step, the studied performance measures were analyzed based on the network developed and a functional equation was developed based on the performance framework and the connections among each factor.

The equation had the ultimate objective as the primary goal and the equation was decomposed until the primary factors were reached.

$$\text{Operating margin} = \text{Revenue} - \text{Costs} \tag{2.1}$$

Where,

Revenue = Charges x number of patients attended

Costs = Labor costs + Medical expenses + Non medical expenses + Drug supplies expenses + Other Operating Expenses

Labor Charges = (Physician man- hour/ patient) x rate of physicians x number of patients attended + (Nurse man- hour/ patient) x rate of nurses x number of patients attended

= Number of patients attended {(Physician man- hour/ patient) x rate of physicians + (Nurse man- hour/ patient) x rate of nurses}

Number of patients attended = (1- percentage no show – percentage bumped) x total number of patients scheduled

Operating Margin = (1- percentage no show – percentage bumped) x [(average charges for established patients per invoice x ratio of established patients x total number of patients scheduled) + (average charges for new patients per invoice x (1- ratio of established patients) x total number of patients scheduled] (2.2)

= (1- percentage no show – percentage bumped) x (total number of patients scheduled) x [(average charges for established patients per invoice x ratio of established patients) + (average charges for new patients per invoice x (1- ratio of established patients)] (2.3)

Therefore,

Operating margin *= (1- percentage no show – percentage bumped) x (total number of patients scheduled) x [(average charges for established patients per invoice x ratio of established patients) + (average charges for new patients per invoice x (1- ratio of established patients)]*

= (1– percentage no show – percentage bumped) x (total number of patients scheduled) x {(Physician man-hour/ patient) x rate of physicians + (Nurse man- hour/ patient) x rate of nurses}

= (1– percentage no show – percentage bumped) x (total number of patients scheduled) x (Medical expenses + Non medical expenses + Drug supplies expenses + Other Operating Expenses) (2.4)

Or

$$\mathbf{O = P (r) - P (C_p + C_n) - P E} \qquad \mathbf{(2.5)}$$

Further simplifying the equation, we have:

$$\mathbf{O = P [r - (C_p + C_n) - E]} \qquad \mathbf{(2.6)}$$

Where,

O = Operating Margin

P = Total number of patients who turned up at Green Meadows Clinic = *(1- percentage no show – percentage bumped) x (total number of patients scheduled)*

r = Revenue received from each patient = *(average charges for established patients per invoice x ratio of established patients) + (average charges for new patients per invoice x (1- ratio of established patients)*

C_p = Charges by physicians/patient = *(Physician man- hour/ patient) x rate of physicians*

C_n = Charges by nurses/patient = (*Nurse man- hour/ patient) x rate of nurses*

E = Expenses excluding labor/patient = *(Medical expenses + Non medical expenses + Drug supplies expenses + Other Operating Expenses)/Total number of patients*

Using the four incremental calculus rules illustrated in Chapter 2, the relative incremental operating margin:

$$O^* = P^* + k_r\, E^* - k_e\, E^* - (k_p\, C_p^* + k_n\, C_n^*) \qquad (2.7)$$

Where,

$$k_r = \frac{r}{r-E} \qquad k_e = \frac{E}{r-E} \qquad , k_r - k_e = 1$$

$$k_p = \frac{p}{p+n} \qquad k_n = \frac{n}{p+n} \qquad , k_p + k_n = 1$$

The equation was formulated based on the performance framework and the connectance model. This equation helped us to analyze the data collected from Green Meadows Clinic and use the marginal analysis to measure performance, which answer the questions about the expected response by different factors. These factors were the result of management decisions, which the manager of the facility was in a position to control or influence. This model and measurement provided indications, or provided explicit predictions about how the system will behave in the future under the given conditions. We will discuss the application of marginal analysis using incremental calculus.

CHAPTER 5 RESULTS AND DISCUSSION OF FINDINGS

In this chapter, based on the model we developed in Chapter 4, we measured the operating margin of Green Meadows clinic using the data we collected on the physicians, nurses and patients. A further analysis using marginal analysis to measure the performance of the system was also be conducted. The effects of changes in the primary inputs to the operating margin were measured and discussed. The assumptions and the limitation of our proposed framework were stated in this chapter.

5.1 Costs and Expenses per Patient Analysis

From the trend of the physician hours per patient in Figure 24, we can see that the patient's appointment was determined by the schedules of the physician based on the relatively constant value. The rate was between 0.3 to 0.6 hour per patient for the A.M. session, 0.2 to 0.5 hour per patient for the P.M. session and about 0.3 hours per patient for extended hours, except certain days. The sudden spike in some of the days may be caused by an over supply of physicians for the given day or patients failed to show up for their appointments. However, due to the scope of this research, we will not go into details to discuss the causes.

For the A.M. session, the Green Team showed spikes on 8, 10, 17, and 24 February and the Gold Team showed a spike on 1 February. The P.M. sessions, other than the gold team showing a spike on 1 and 6 February, the other two teams showed a relatively constant trend. For the extended hours, the spike was on 31 January, jumping from average of 0.3 hours to 0.5 hours. The Gold Team had spikes on 1 February on both A.M. and P.M. sessions. At times, the clinic might benefit from reassigning some of the physicians from Gold Team to the other two teams for similar situations in future. However, this might not hold true, since the patient turnout rate is not constant for any given day.

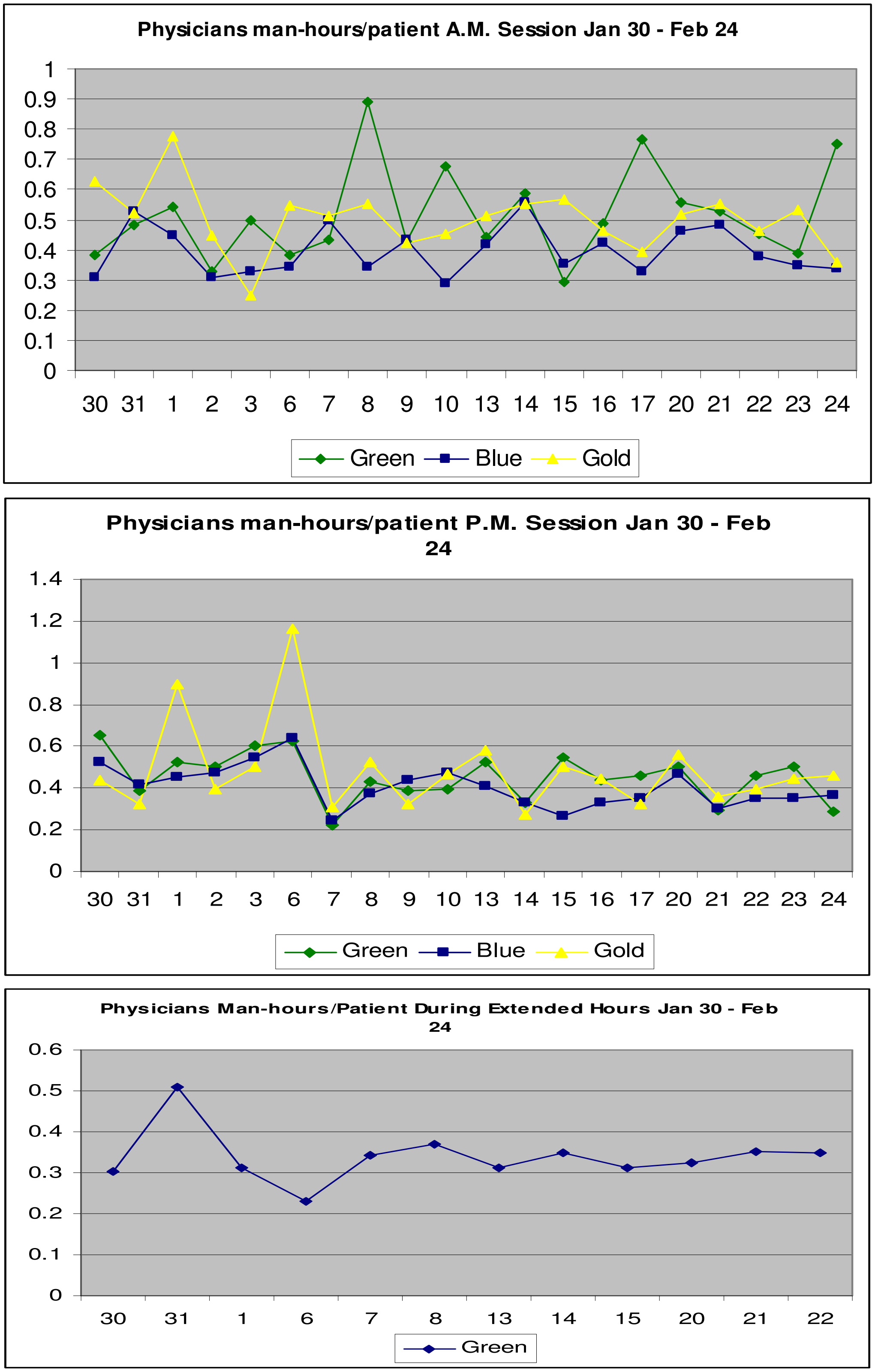
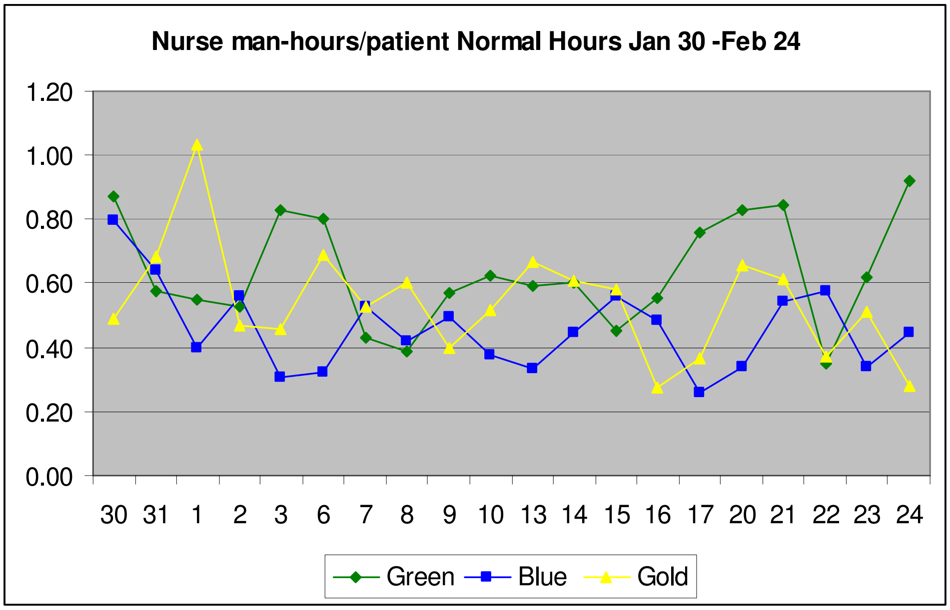


Figure 24 Physician hours/patient Jan 30 - Feb 24

In Figure 25, the nurse rate of man-hours per patient was erratic, as the nurse schedules were fairly regular everyday, while the total number of patients fluctuated, as it was dependent on the physician schedules.



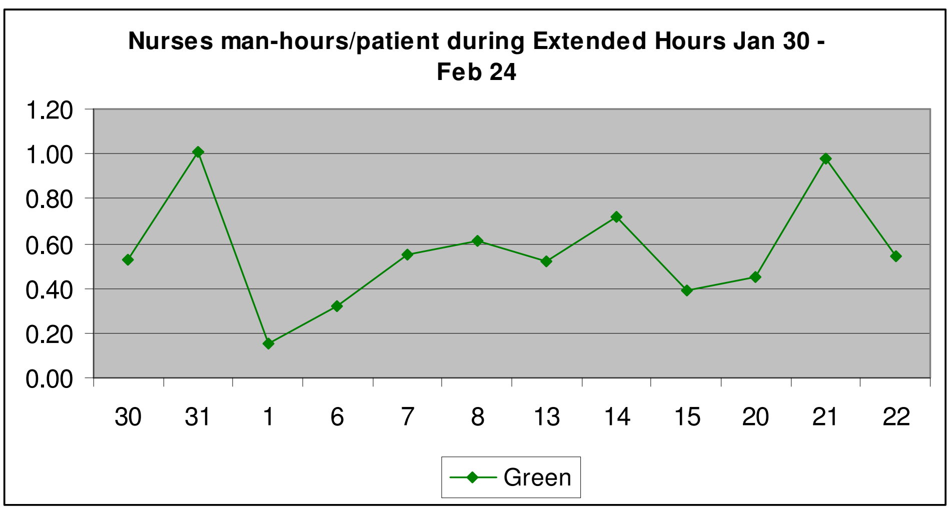


Figure 25 Nurses hours/patient Jan 30 - Feb 24

Since the values of expenses and nurse charges were very much smaller compared to the physician rates, Figure 26 followed the trend of physician man-hours per patient as shown in figure 24. The trend observed in figure 26 consisted of spikes, mainly from Gold Team on 1 and 6 February for the P.M. sessions and four days on the Green Team and one day on Gold Team on the A.M. sessions. We based the hourly rates of Physicians and Nurses on the compensation survey developed by researching the physicians and from the Bureau of Labor Statistics for the nurses. We were unable to collect the exact rate from the clinic because all the physicians in the clinic had secondary responsibilities, which were also added into their compensation, and the nursing staff compensation included nurses in the triage system, which we did not consider in our measurement. Furthermore, we were not interested in the absolute value, but the marginal effects and the data collected from the Bureau of Labor were close to the actual data.

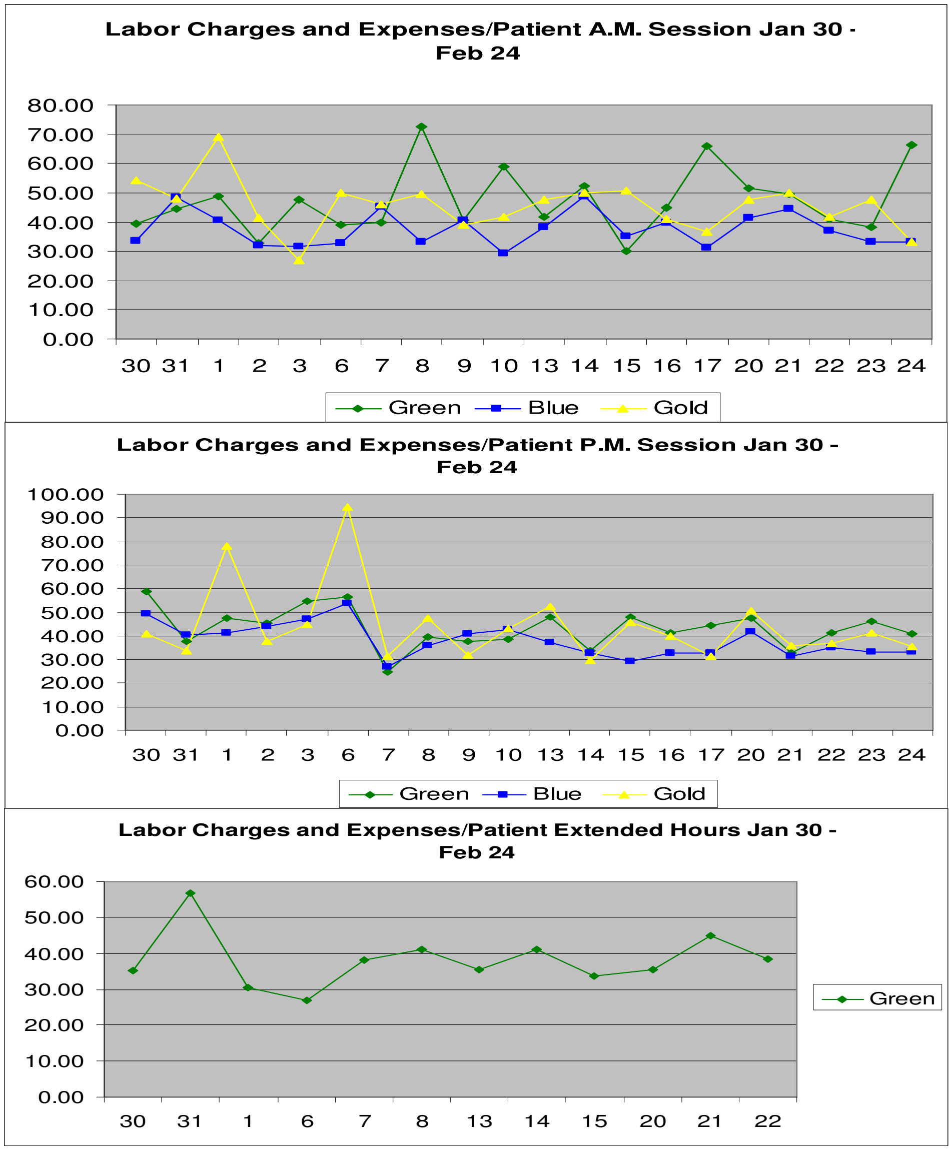


Figure 26 Labor charges and expenses per patient

5.2 Operating Margin per Patient Analysis

As we investigate the operating margin of each patient in Figures 27, 28, and 29, the trends were the same for the labor and expenses charges per patient, except that the trend was inversely proportional. Where it used to be a spike, it is now a sharp drop. This is expected, since the revenue per patient is a constant rate of $93 based on the weighted average of the invoices charged for established and new patients.

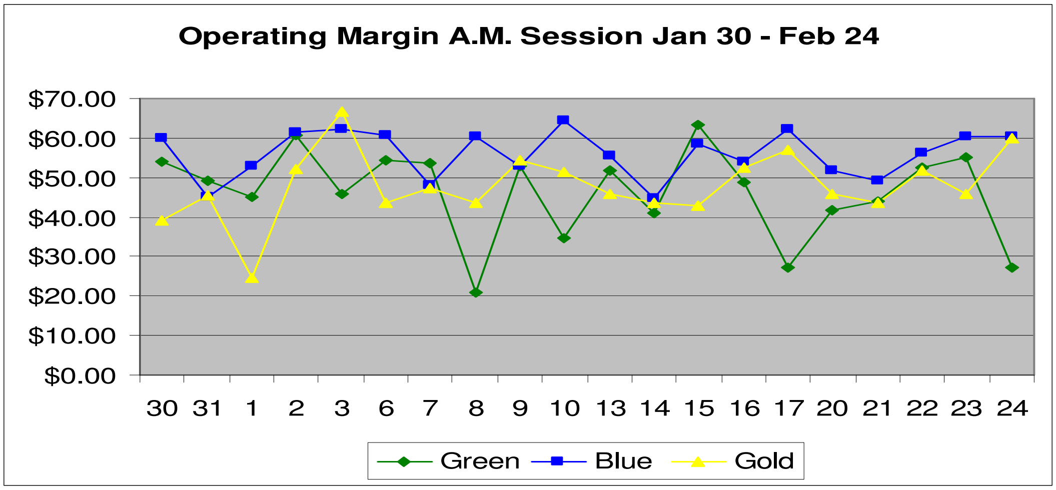


Figure 27 Operating margin per patient A.M. session Jan 30 - Feb 24

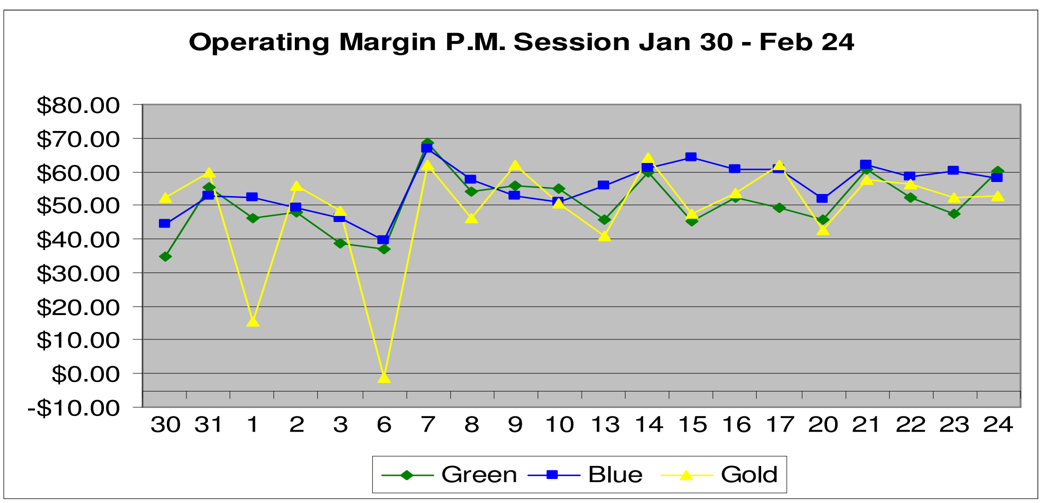


Figure 28 Operating margin per patient P.M. session Jan 30 - Feb 24

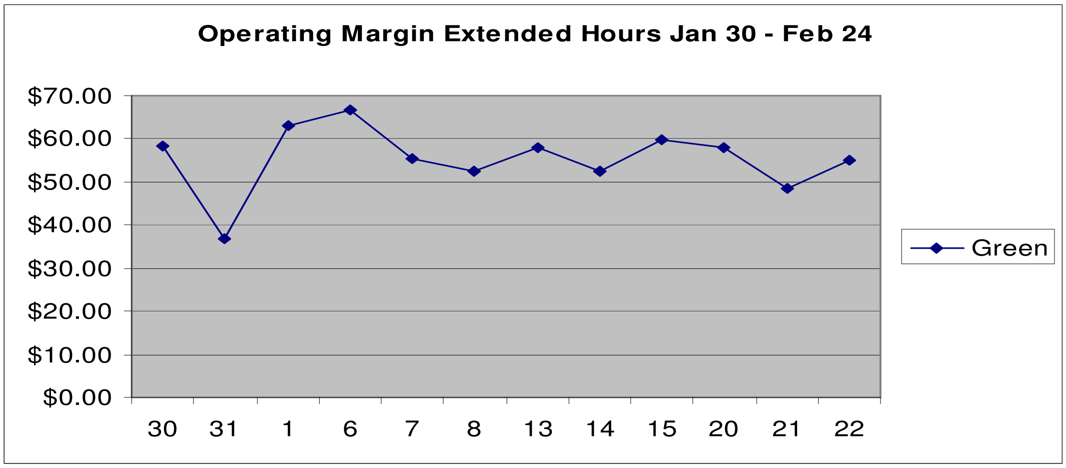


Figure 29 Operating margin per patient during extended hours Jan 30 - Feb 24

5.3 Case Study Assumptions

In this case study, the following assumptions were made:

- That the quality of care does not change with the changes involving the number of staff, such as physicians and nurses, medical or non-medical supplies, and the number of patients scheduled made.
- The differences in date for the data collected do not effect the accuracy of the analysis drawn from different reports. It is assumed that for the same period of time taken from different month or year represent the same trends in the analysis.
- The performance measurement is a simplified look into measuring selected factors, which will affect the operating margin. Not all the factors are included in these measurements; however, the main factors perceived by the authors are measured in this study.

- This performance measurement aims to maximize operating margin, it is not the main objective of the health care system. However, a healthy operating margin is important for any public or private health care system.
- We do not measure depreciation rate and inflation involved when measuring financial status of the clinic and how these factors affect the operating margin of the clinic.
- We do not measure the physical capacity, such as medical facilities and consulting rooms, although it is one of the factors listed in our performance framework. We assume that physical capacity is not an issue during our measurement in the clinic, but may be measured as the clinic increases the size of its operations.
- From interviewing with the staff in Green Meadows clinic, physicians are the bottleneck for the clinic. Patients are scheduled based on the number of physicians present on a given day and the number of nurses available does not affect the number of patients scheduled in any given day. A change in number of physicians in the clinic will change the number of patients scheduled for the given day.
- We assume that overtime charges for labor are not charged for all labor and consider the labor rate as constant.
- We define quality as 1) Individual staff carries out the same procedure in the same fashion and there is no variability between different staff. 2) The outcome of care will not be measured in this study, due to time constraints.

- We assume that all payments by patients are made to the clinic and there are no bad debts, although this is not usually the case.
- We assume that each patient has one invoice, although this may not be true at times when patients go for lab tests.

5.4 Case Study Limitations

We were unable to measure the utilization and capacity of the resources within the Green Meadows clinic. During the clinic visits, Green Meadows clinic did not show that capacity was an issue in the facility and no data were available to study the utilization and capacity issue.

Our initial intention was to measure the punctuality of the different types of patients, i.e. new and established, during the different sessions of the clinic's operations, i.e. morning session, afternoon session, and extended hours. This analysis helped us to optimize the staff resources by proposing the ideal mix of the types of patients to schedule based on their punctuality. However, due to lack of data, we were unable to measure this aspect of the performance.

The rates by the nurses and physicians were calculated using their base salary only. Benefits were not considered in this analysis, although these expenses were part of the salary package received by the medical staff. The other staffs within the facility, such as administrative staff, lab technicians, and triage system staff, were also not measured in this case study.

The payment mechanisms are not considered in this case study, and we assume that all payments are made to the clinic in full. Other activities within the clinic are also not measured as well.

Lastly, only one effect is analyzed at any one situation. We do not analyze the effects on operating margin by changing more than one factor.

5.5 Marginal Analysis

Table 5 showed the marginal analysis (Eilon, Gold and Soesan, 1984) of Green Meadows clinic. From the equation we developed for our framework as shown earlier in this chapter, we analyzed the changes in overall result by changing marginally, one factor at a time. Since the Green Meadows clinic is a relatively small scale clinic with about four thousands visits a month, we alter the factors by ten percent instead of one percent as suggested by Eilon et. al. (1984), in order to observe the significant results that would be brought with the changes. We also analyzed how the factors change from the original value as recorded from the data we collected. These comparisons will help us to determine the causes, which affect the overall results. We will also measure the percentage change in operating margin, which will helps health care managers to rank the importance of each factor. This will then helps in planning to implement changes within the Green Meadows clinic.

Outputs

$O_{present}$	P	r	$Cp_{Average}$	$Cn_{Average}$	E
$206,615.03	4,168.00	$93.46	$33.02	$8.10	$5.71

$O = P [r - (C_p + C_n) - E]$

	Effects		Output Changes					Results	% Change in O
Factors	**Change (%)**	**Reason**	**ΔP**	**Δ r**	**$\Delta Cp_{Average}$**	**$\Delta Cn_{Average}$**	**ΔE**	**O_{new}**	**ΔO**
Physicians	10	increase physicians	331.1	$0.00	$0.64	-$0.65	$0.00	$222,871.47	7.87%
	-10	decrease physicians	-331.2	$0.00	-$0.73	$0.62	$0.00	$190,833.96	-7.64%
Nurses	10	increase nurses	0	$0.00	$0.00	$0.44	$0.00	$203,493.13	-1.51%
	-10	decrease nurses	0	$0.00	$0.00	-$0.44	$0.00	$209,736.92	1.51%
Expenses	10	increase inventory buffer	0	$0.00	$0.00	$0.00	$0.57	$204,235.10	-1.15%
	-10	decrease inventory buffer	0	$0.00	$0.00	$0.00	-$0.57	$208,994.95	1.15%
Patients	10% of 'no show'	improve 'no show'	81.41	$0.00	-$1.26	$0.40	$0.00	$209,146.70	1.23%
	New patients increase to 10%	Increase new patients	0	$2.04	$0.00	$0.00	$0.00	$211,995.85	2.60%

Table 5 Sensitivity Analysis of Green Meadows Clinic

5.5.1 Change in physician manpower

As discussed earlier, the increase in physician manpower led to an increase in the number of patients scheduled. By simulating a ten percent change in physician manpower, we expected a ten percent increase in the number of patients scheduled. However, based on historical patients 'bumped' and 'no show' data as collected in Figure 19, about 16.34 percent of 'no show' and due to about 27 percent late, 6.73% will be bumped. Patients are bumped when their schedules are pushed to a later time, and eventually, do not get to see the doctor because of the patients earlier spent longer than the allocated time or are late. This will then push the other patients behind to a later time. When this happens, usually the last few patients of the day will be bumped because they are pushed after the operating hours of the clinic. These patients will then be rescheduled to another day. Based on this analysis, only about 77 percent of the total number of scheduled patients will turn up. A similar trend was expected when we reduced the physician manpower by ten percent.

When we increase the physician manpower, there would be an increase in the number of patients. However, since the increase for physician was higher than that of patients, the rate of physician man-hours per patient increased. As the rate of nurse man-hours remains constant while the number of patients increased, the rate for nurses decreased. This led to an overall increase in operating margin of 7.87%.

5.5.2 Change in nurse manpower

When the nursing manpower increased, we did not expect any increase in the number of patients scheduled. Since the number of nurses would not affect the number of patients scheduled, the change in the nurse manpower would not affect the number of patients in Green Meadows. This would be a good measure for costs analysis for the managers to determine the impact of increasing the nursing manpower. The problem with this analysis was we do not measure the costs of benefits of the nursing staff. When we increase the nursing staffs, the rate of nursing staff per patient would increase. When increasing the nurse manpower, it led to a drop in operating margin by 1.51%. The same trend was observed when we decrease the number of nursing staff by ten percent, operating margin also increased by 1.51%.

5.5.3 Change in expense

The patient expenses, excluding labor and including medical supplies, non medical supplies and drugs supplies. Based on historical data, the expenses for each patient excluding labor was about $5.71. An increase in the expenses by ten percent to simulate increasing the inventory buffer by ten percent led to a proportional change in the rate of expenses per patient. The increase of ten percent in expenses led to 1.15% drop in operating margin. It was interesting to observe the impact captured in this model, the increase in the supplies by ten percent was close to the impact of increasing the nursing staff excluding the benefits, by the same magnitude. This analysis also allowed managers to measure the impact of rising expenses excluding labor on the operating margin.

5.5.4 Change in patients

We analyzed the impact of improving the rate of ‘no show’ by ten percent from 17.63 % to 15.87 %. This led to an increase in the number of patient visits by 81.41. This, in turn, reduced the rate of physician and nurse man-hours per patient. With the increase in patients and corresponding reduction in the rate of nursing and physician labor, we will improve the operating margin by 1.23 percent. However, we do not measure the costs involved in implementing the measures in order to improve ‘no show’. The managers will have to decide if implementing the measures to ensure the ‘no show’ performance improved by ten percent is worth spending to achieve the improvement in operating margin as a result.

Next, we studied the effect of improving the proportion of new patients to old patients from the current 5.7 percent to 10 percent. Even though the total number of patient visits did not change, the operating margin increased by 2.76 percent. This happened because, for new patient, the average invoice charge is $138.54, while established patients charged about $90.72, as seen in table 6. By improving the proportion of new patients, we will increase the revenue, while the costs remain constant. However, we do not calculate the amount needed to spend in order to improve the proportion of new patients as well as the difference in time spent between new and established patients.

FY Posting Period,Group,Division,Billing Area,Location,Provider,Secondary Provider,Tertiary Provider,Diagnosis,Procedure,Charge Amount

GREEN MEADOWS BUILDING A

	Dec, 2005			Jan, 2006			Feb, 2006			Dec, 2005+Jan, 2006+Feb, 2006			
	Charge Amount	Invoice Count	Avg Charge per Invoice	Charge Amount	Invoice Count	Avg Charge per Invoice	Charge Amount	Invoice Count	Avg Charge per Invoice	Charge Amount	Invoice Count	Avg Charge per Invoice	
NEW PT OV-LEVEL I	$116.00	2	$58.00	$116.00	2	$58.00	$290.00	5	$58.00	$522.00	9	$174.00	
NEW PT OV-LEVEL II	$6,760.00	71	$95.21	$6,864.00	66	$104.00	$11,336.00	109	$104.00	$24,960.00	246	$303.21	
NEW PT OV-LEVEL III	$13,330.00	90	$148.11	$13,485.00	91	$148.19	$15,810.00	106	$149.15	$42,625.00	287	$445.45	weighted avrg
NEW PT OV-LEVEL IV	$4,003.00	20	$200.15	$7,293.00	33	$221.00	$6,630.00	30	$221.00	$17,926.00	83	$642.15	$138.56
NEW PT OV-LEVEL V	$562.00	2	$281.00	$281.00	1	$281.00	$281.00	1	$281.00	$1,124.00	4	$843.00	
		185									629		$87,157.00
EST PT OV-LEVEL I	$1,872.00	39	$48.00	$1,152.00	35	$32.91	$1,536.00	31	$49.55	$4,560.00	105	$130.46	
EST PT OV-LEVEL II	$7,991.00	139	$57.49	$8,052.00	139	$57.93	$7,259.00	121	$59.99	$23,302.00	399	$175.41	
EST PT OV-LEVEL III	$183,260.00	2,227	$82.29	$181,985.00	2,170	$83.86	$206,210.00	2,467	$83.59	$571,455.00	6,864	$249.74	weighted avrg
EST PT OV-LEVEL IV	$77,158.00	632	$122.09	$79,328.00	609	$130.26	$77,452.00	594	$130.39	$233,938.00	1,835	$382.74	$90.72
EST PT OV-LEVEL V	$772.00	4	$193.00	$772.00	4	$193.00	$1,544.00	8	$193.00	$3,088.00	16	$579.00	
		3041									9219		$836,343.00

New Patients to Established patients ratio
0.057347

Average charges $93.46

Average charge when new patients =10%
$95.50

Table 6 Invoice charges of patients

5.6 Comparison between marginal analysis and performance trend report

The aim of this analysis was to measure how the factors within the equation are sensitive to marginal changes. Our analysis would complement the current performance trend report used in Green Meadows Clinic, as this analysis used the current data to predict future impacts instead of using past data to show current performance. The performance trend report shown in Table 7 displayed the monthly data of the Green Meadows clinic operation and the Hunter's group standard of the Worked hours/Volume index. This report plainly showed the data and did not provide information of how operations within the Green Meadows clinic could be improved. The marginal analysis would be a valuable add-on to the performance trend report to provide a complete picture to improve the operating margin. The data on the performance trend report would show the areas needed for improvements and the marginal analysis could be conducted on those areas to suggest the improvements to be made and the impacts to the operating margin.

The aim of our proposed performance measurement was to improve on the current performance trend report used by the Green Meadows clinic for developing indicators that report on the accomplishments and progress. Using both reports, we were able to use the performance trend report for the setting of targets for desired performance and the review of performance against these targets using our proposed framework. Through analyzing trends, peaks, and valleys in the performance using our proposed framework, we were able to find out the causes of fluctuations in their performance.

The key to effectiveness of our proposed performance measurement was to identify the unique measures that can gauge the health and efficiency of Green Meadows clinic operations and to use the information to take appropriate actions. We then re-examined the performance and provided suggestions to improve the performance and also impact the overall system. Our proposed framework was able to be used to systematically identify the root cause of the problem. Our performance measurement was used to guide organizational change and development. It can be used to provide objective, factual data to make more informed day-to-day decisions in running the organization. Our proposed performance measurement provided an objective view of the efficiency and effectiveness of the organization as a system. Using our proposed performance measurement and the performance trend report, we were able to identify the measures to use to gain a more balanced view of performance as compared to using only the current performance trend report.

Facility:	Corporate
Associate:	MountjoyD
Manager:	MulhollandP
Date Printed:	Friday, March 04, 2005
Time Printed:	12:35:00PM

University of Missouri HEALTH CARE

Department Performance Trend Report

H3007001 - Clinic-Family Practice

June 2004

Report Number:	Not Assigned
Report Location:	Not Assigned
Data Source:	SRC Budget Advisor

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	YTD Actual	YTD Budget	YTD Prior Act
Utilization Statistics															
Clinic Visits	4,296	4,247	4,797	5,737	4,763	4,991	4,472	4,539	4,785	5,181	4,318	4,571	56,699	59,256	54,610
Revenues															
Gross Patient Revenue	$ 2,432	$ 1,984	$ 2,384	$ 3,424	$ 2,240	$ 3,536	$ 2,688	$ 2,320	$ 3,440	$ 3,536	$ 1,984	$ 2,368	$ 32,336	$ 31,590	$ 30,233
Deductions	$ -1,055	$ -849	$ -1,050	$ -1,488	$ -907	$ -1,576	$ -975	$ -1,041	$ -1,502	$ -1,563	$ -876	$ -1,041	$ -13,923	$ -14,968	$ -13,117
Net Patient Revenue	$ 1,377	$ 1,135	$ 1,334	$ 1,936	$ 1,333	$ 1,960	$ 1,713	$ 1,279	$ 1,938	$ 1,973	$ 1,108	$ 1,327	$ 18,413	$ 16,622	$ 17,116
Other Revenue	$ 281	$ 476	$ 334	$ 570	$ 575	$ 560	$ 548	$ 416	$ 377	$ 513	$ 475	$ 204	$ 5,328	$ 62	$ -355
Total Net Revenue	$ 1,658	$ 1,611	$ 1,667	$ 2,506	$ 1,908	$ 2,520	$ 2,261	$ 1,695	$ 2,315	$ 2,485	$ 1,583	$ 1,531	$ 23,742	$ 16,683	$ 16,760
Operating Expenses															
Salary Expense	$ 94,254	$ 89,238	$ 93,385	$ 94,682	$ 96,589	$ 98,408	$ 90,320	$ 101,115	$ 105,052	$ 93,976	$ 104,774	$ 98,650	$ 1,160,442	$ 1,175,755	$ 1,091,280
Contract Labor	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 272	$ 2,147	$ 6,812	$ 1,701	$ 6,926	$ 17,857	$ 0	$ 3,798
Total Salary	$ 94,254	$ 89,238	$ 93,385	$ 94,682	$ 96,589	$ 98,408	$ 90,320	$ 101,387	$ 107,199	$ 100,787	$ 106,474	$ 105,576	$ 1,178,299	$ 1,175,755	$ 1,095,078
Benefit Expense	$ 36,641	$ 25,821	$ 27,304	$ 28,233	$ 28,409	$ 29,315	$ 26,209	$ 32,125	$ 32,289	$ 28,899	$ 32,406	$ 23,518	$ 351,166	$ 323,803	$ 275,874
Total Salary & Benefits	$ 130,895	$ 115,059	$ 120,689	$ 122,915	$ 124,998	$ 127,723	$ 116,529	$ 133,511	$ 139,488	$ 129,686	$ 138,880	$ 129,093	$ 1,529,465	$ 1,499,558	$ 1,370,953
Medical Supply Expense	$ 3,242	$ 3,390	$ 3,054	$ 5,486	$ 4,502	$ 5,151	$ 4,022	$ 4,887	$ 8,605	$ 3,113	$ 3,658	$ 5,328	$ 54,437	$ 46,176	$ 41,515
Drug Supply Expense	$ 5,525	$ 3,169	$ 6,020	$ 9,053	$ 6,432	$ 8,733	$ 8,939	$ 15,237	$ 6,186	$ 5,879	$ 2,917	$ 10,353	$ 88,442	$ 99,510	$ 94,596
Non Medical Supply Expense	$ 6,170	$ 4,459	$ 4,451	$ 5,019	$ 4,343	$ 5,031	$ 4,732	$ 5,002	$ 6,189	$ 3,641	$ 3,931	$ 3,687	$ 56,654	$ 45,210	$ 39,260
Total Supply Expense	$ 14,937	$ 11,018	$ 13,525	$ 19,558	$ 15,277	$ 18,915	$ 17,693	$ 25,125	$ 20,980	$ 12,633	$ 10,506	$ 19,367	$ 199,534	$ 190,896	$ 175,371
Purchased Patient Services	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Institutional Expense	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Other Operating Expense	$ 7,604	$ 3,799	$ 4,089	$ 4,940	$ 4,845	$ 4,669	$ 3,014	$ -41,121	$ 2,914	$ 4,359	$ 5,917	$ -25,302	$ -20,275	$ 16,223	$ 1,319
Total Operating Expense	$ 153,435	$ 129,875	$ 138,303	$ 147,413	$ 145,120	$ 151,306	$ 137,236	$ 117,516	$ 163,382	$ 146,678	$ 155,303	$ 123,158	$ 1,708,724	$ 1,706,678	$ 1,547,643
Net Operating Income (Loss)	$ -151,777	$ -128,264	$ -136,636	$ -144,907	$ -143,213	$ -148,786	$ -134,975	$ -115,820	$ -161,067	$ -144,192	$ -153,719	$ -121,627	$ -1,684,983	$ -1,689,994	$ -1,530,882
NonOperating Rev/Exp	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Financial Indicators															
Revenue Net to Gross %	56.6%	57.2%	55.9%	56.5%	59.5%	55.4%	63.7%	55.1%	56.3%	55.8%	55.9%	56.0%	56.9%	52.6%	56.6%
Gross Patient Rev / Volume	$ 0.57	$ 0.47	$ 0.50	$ 0.60	$ 0.47	$ 0.71	$ 0.60	$ 0.51	$ 0.72	$ 0.68	$ 0.46	$ 0.52	$ 0.57	$ 0.53	$ 0.55
Supply Expense / Volume	$ 3.48	$ 2.59	$ 2.82	$ 3.41	$ 3.21	$ 3.79	$ 3.96	$ 5.54	$ 4.38	$ 2.44	$ 2.43	$ 4.24	$ 3.52	$ 3.22	$ 3.21
Total Operating Exp / Volume	$ 35.70	$ 30.58	$ 28.83	$ 25.70	$ 30.47	$ 30.32	$ 30.69	$ 25.89	$ 34.14	$ 28.31	$ 35.97	$ 26.94	$ 30.14	$ 28.80	$ 28.34
Labor Productivity Statistics & Indicators															
Paid FTEs (incl agency & cap)	43.6	41.4	42.6	41.5	43.5	41.7	41.0	42.6	44.4	41.8	44.5	45.2	42.9	44.8	43.0
Net Worked FTEs (incl agency)	38.2	35.7	35.6	40.1	39.9	36.1	30.7	38.1	40.9	39.1	41.5	37.5	37.9	39.3	37.6
Agency FTEs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capitalizated / Sold FTEs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paid Hours (incl agency & cap)	7,704	7,305	7,275	7,332	7,435	7,363	7,234	7,041	7,838	7,139	7,867	7,719	89,251	93,111	89,519
Net Worked Hours (incl agency)	6,743	6,311	6,084	7,077	6,817	6,364	5,422	6,294	7,229	6,693	7,325	6,412	78,793	81,704	78,323
Agency Hours	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capitalizated / Sold Hours	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overtime Hrs as % Total Paid Hrs	2.4%	1.7%	2.0%	1.2%	1.9%	2.1%	2.1%	2.0%	3.3%	3.7%	2.5%	1.5%	2.2%	2.3%	1.3%
Agency Hrs as % Net Worked Hrs	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Salary Expense / Volume	$ 21.93	$ 21.01	$ 19.47	$ 16.50	$ 20.28	$ 19.72	$ 20.20	$ 22.34	$ 22.40	$ 19.45	$ 24.66	$ 23.10	$ 20.78	$ 19.84	$ 20.05
Avg Hourly Rate (Incl Agency)	$ 12.23	$ 12.22	$ 12.84	$ 12.91	$ 12.99	$ 13.37	$ 12.49	$ 14.40	$ 13.68	$ 14.12	$ 13.54	$ 13.68	$ 13.20	$ 12.63	$ 12.23
Worked Hours / Volume	1.5688	1.4861	1.2683	1.2336	1.4313	1.2792	1.2125	1.3867	1.5108	1.2918	1.6963	1.4028	1.3897	1.3788	1.4342
The Hunter Group Standard	1.2503	1.3092	1.3092	1.3680	1.3533	1.2062	1.1123	1.2390	1.2531	1.2531	1.1567	1.2668			

Table 7 Performance Trend Report

5.7 Conclusion

In conclusion, this marginal analysis actually helped health care managers to analyze the impact factors to the main objective, in this case, operating margin when they make marginal changes. The main factors were determined by the framework and corresponding equations defined. This marginal analysis also helped managers to prioritize these impacts. The data helped them to justify their spending to implement new ideas by showing the impacts quantitatively. However, this analysis did not measure the costs involved in getting their ideas implemented. Sometimes, the costs involved may not justify for the little increase as propose in the marginal analysis.

CHAPTER 6 CONCLUSION AND FUTURE WORK

This final chapter begins with a summary of the most important results from the research, followed by a review of the thesis. The industrial value of the research results is discussed. Finally, areas for further research are suggested.

6.1 Summary

In this study, the developments of performance measures for health care systems using engineering techniques were addressed. The main objective was *to develop and apply the performance measurement systems for health care systems*. In order to reach this objective, several obstacles that contributed to the complexity of the research area were treated.

In Chapter 3, we introduced the method of MSDD to decompose our main objectives to different contributing factors and connecting these factors based on their relationships with each other. The way we suggest to measure the performance of the health care systems was by incremental calculus. Using incremental calculus, we were able to observe the impact of small changes to the main objective using the marginal analysis. In marginal analysis, we focused on how sensitive each factor will affect the main objective.

In Chapter 4, we applied the developed performance measurement framework on Green Meadows clinic, an out-patient clinic consisting of three teams. Furthermore, we collected data from Green Meadows clinic to measure their performance based on the techniques we developed.

In Chapter 5, key-factors found to affect the performance of the Green Meadows clinic were discussed. The key-factors were divided into three groups: (1) *physicians;* (2) *nurses;* (3) *patients*. We observed the effects on the performance by changing each key-factor. We analyze the effects using the marginal analysis. We also discussed about the limitations and stated the assumptions for the applicability of the case study.

6.2 Conclusion

There are several issues that should be discussed concerning the research presented in this study. On the one hand, the proposed method has several strengths when it comes to evaluating and revising the performance of health care systems. First, it is rather simple to understand and to use, which made it suitable for assisting management in reviewing the performance of their systems. Second, it broke down the main objective to smaller contributing factors, which makes it easy to identify the problem areas and pin-point the area to focus on, in order to improve performance. Third, it allows health care managers to prioritize and slowly implement changes without making any dramatically overhaul of the system. Fourth, the conceptual framework can be used to study the effects of each contributing factor.

However, this method has its limitations. The method has not yet been fully tested on a more complex health care system, such as hospital systems and nursing homes in reality.

Furthermore, from a practical point of view, it also is necessary to describe the method in more detail before it can be directly used by the industry. Many of the tools within the method force its user to rely on experience. Especially during the decomposition stage, it requires the user to understand the system well enough to decompose the factors correctly. The method also leaves much to the user, which must come up with own ideas about how to make improvements. It can also be very time-consuming to decompose the factors within a large system to measure performance measures.

In conclusion, it is believed that this study will help Green Meadows Clinic to better measure their performance. The proposed conceptual framework and analysis helps health care managers to look into every factor and their resultant effects. As compared to the current performance trend report which the clinic used to measure the performance which shows the overall performance within the facility, our performance analysis were able to look into each factor and their effects in order to prioritize the improvements and measure the importance of each improvement.

There are still some issues within the research area that needs further attention and they are explained in future research. The *industrial relevance* of the research can be described from various perspectives. In the last few years, there is much focus on the performance of health care systems as costs of health care rises. Although a manufacturing system is similar to a health care system in many ways, there are many changes that need to be done before we can successfully implement engineering techniques the health care systems. By studying the problems, this research has made important contributions to the industry by, for example:

- Describing how each factors affects the performance of the health care systems, in this case, operating margin
- Describing various key-factors that influence a health care system's performance

Furthermore, the research has also adopted several tools, such as MSDD, the connectance model, incremental calculus, and marginal analysis to be used in practice when evaluating and revising the performance of the health care systems. These tools are, in turn, simple to understand and to use and make it easier to conduct the process of continuously updating the performance measures within the health care systems.

6.3 Future Work

As implementing engineering techniques on health care systems performance measurement is relatively new research topic, there are many issues in the field that have not yet been developed and solved. Considering the scope of this research, it is suggested that the following areas should be further explored.

• The performance measurement framework presented in this thesis has not yet been developed to the stage where measurement practitioners in industry can directly use it. At the time, it provides important guidelines of how to measure and evaluate the performance of a health care system, but there are still many details that should be further explained and specified.

• The performance measurement framework has also not been fully tested from an empirical point of view. It would, therefore, be beneficial to make further case studies in a larger scope such as studying a hospital system to assure its applicability and improve its usefulness as well as studying its limitations.

• In order to design a successful performance measurement framework, it is vital that the key-factors influencing performance at the each individual health care system are identified and considered. Factors for one health care system may not be applicable to another even though both systems may have the same main objective. However, this area is far from being fully explored. More detailed and useful tools for identifying such key-factors should be developed.

• How to effectively implement new performance measures into a health care system which probably have their own existing methods is a question with significant importance. This issue has not been considered in this research. However, without an effective implementation, there will be a high risk that the performance measures are neglected or used improperly. The process of implementation should be studied in order to formulate industrial guidelines that can be used in the proposed method.

• The variability of the key-factors which affects the main objective was shown but no study was made on how to improve the variability. It is important to study the causes and ways to improve the variability of the key factors.

• Our study is essentially a quantitative based study, which analyzed the effects of how the changes of one key-factor affect the performance of the main objective. A detailed study which, further decompose the key-factors and focus on both the quantitative and qualitative aspects is recommended.

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APPENDICES

Physician and Nurses Compensation Survey

In Practice Three Plus Years — **Primary Care**

Physicians

Specialty	**Lowest**	**Highest**	**Average**	Rate/hr
Family Practice	147,516	160,318	149,754	$72.00
Internal Medicine	111,894	117,984	111,113	
Pediatrics	197,025	205,096	201,086	

http://www.physicianssearch.com/physician/salary2.html

Median hourly earnings of the largest occupations in health services, May 2004 Occupation	Ambulatory health care services	Hospitals	Nursing and residential care facilities	All industries
Registered nurses	$23.69	$25.66	$22.93	$25.16
Licensed practical and licensed vocational nurses	15.59	15.71	16.95	16.33
Medical secretaries	12.88	12.6	12	12.76
Medical assistants	11.77	12.03	10.85	11.83
Office clerks, general	11.07	11.08	9.62	10.5
Receptionists and information clerks	10.76	11.79	10.4	10.95
Nursing aides, orderlies,and attendants	9.82	10.43	9.78	10.09
Home health aides	8.58	9.69	8.84	8.81
Personal and home care aides	7.05	8.54	8.85	8.12

http://stats.bls.gov/oco/cg/cgs035.htm#earnings

Table 8 Physicians and nurses compensation survey

	Number of patients attended by physicians in each team			
Date		Green	Blue	Gold
12/1/2005	AM	37	31	21
12/1/2005	PM	40	28	32
12/1/2005	Extended			
12/2/2005	AM	34	29	43
12/2/2005	PM	37	38	27
12/5/2005	AM	55	42	25
12/5/2005	PM	39	28	21
12/5/2005	Extended	36		
12/6/2005	AM	42	12	35
12/6/2005	PM	42	21	23
12/6/2005	Extended	27		
12/7/2005	AM	18	26	7
12/7/2005	PM	53	34	19
12/7/2005	Extended	34		
12/12/2005	AM	52	39	23
12/12/2005	PM	20	26	25
12/12/2005	Extended	33		
12/13/2005	AM	70	21	23
12/13/2005	PM	49	21	12
12/13/2005	Extended	17		
12/14/2005	AM	9	36	9
12/14/2005	PM	45	33	31
12/14/2005	Extended	30		
12/15/2005	AM	53	25	21
12/15/2005	PM	29	24	28
12/15/2005	Extended			
12/16/2005	AM	26	38	28
12/16/2005	PM	49	32	38
12/16/2005	Extended			
12/19/2005	AM	68	38	27
12/19/2005	PM	34	32	17
12/19/2005	Extended	36		
12/20/2005	AM	40	16	22
12/20/2005	PM	23	9	29
12/20/2005	Extended	31		
12/21/2005	AM	24	30	2
12/21/2005	PM	40	23	26
12/21/2005	Extended	20		
12/22/2005	AM			
12/27/2005	AM	30	18	18
12/27/2005	PM	4	11	13
12/27/2005	Extended	23		
12/28/2005	AM	8	24	14
12/28/2005	PM	56	13	30
12/28/2005	Extended	11		

12/29/2005	AM	49	17	20
12/29/2005	PM	15	23	7
12/29/2005	Extended			
12/30/2005	AM	35	21	15
12/30/2005	PM	35	17	21

Number of patients Jan 30 - Feb 24

Date		Green	Blue	Gold
30	Am	53.00	21.00	26.00
	PM	10.00	20.00	34.00
	Ext	46.00		
31	AM	54.00	26.00	12.00
	PM	41.00	25.00	31.00
	Ext	24.00		
1	AM	12.00	24.00	9.00
	PM	48.00	31.00	10.00
	Ext	32.00		
2	AM	69.00	17.00	29.00
	PM	35.00	22.00	34.00
3	AM	26.00	39.00	23.00
	PM	40.00	32.00	20.00
6	AM	50.00	38.00	16.00
	PM	16.00	22.00	9.00
	Ext	39.00		
7	AM	60.00	26.00	23.00
	PM	63.00	29.00	26.00
	Ext	30.00		
8	AM	9.00	41.00	19.00
	PM	73.00	28.00	24.00
	Ext	27.00		
9	AM	57.00	27.00	23.00
	PM	36.00	32.00	42.00
10	AM	24.00	40.00	21.00
	PM	61.00	37.00	29.00
13	AM	69.00	36.00	17.00
	PM	19.00	43.00	24.00
	Ext	32.00		
14	AM	48.00	27.00	23.00
	PM	39.00	32.00	37.00
	Ext	23.00		
15	AM	11.00	37.00	15.00
	PM	58.00	26.00	32.00
	Ext	32.00		
16	AM	46.00	23.00	28.00
	PM	48.00	32.00	38.00
17	AM	17.00	29.00	33.00
	PM	52.00	40.00	42.00
20	AM	35.00	28.00	29.00
	PM	27.00	30.00	16.00
	Ext	37.00		
21	AM	37.00	31.00	23.00
	PM	24.00	23.00	25.00
	Ext	17.00		

22	AM	27.00	31.00	14.00	
	PM	61.00	20.00	39.00	
	Ext	23.00			
23	AM	41.00	28.00	22.00	
	PM	42.00	30.00	36.00	
24	AM	13.00	28.00	33.00	
	PM	43.00	38.00	37.00	
		1956.00	1189.00	1023.00	4168.00

			Nurses	
			Weighted hours	
	Date			
		Date	Green	Blue
8am-5pm	1/30/2006	30	49.78	29.75
Extended hours (530-730pm)	1/30/2006	Extended	22.05	
8am-5pm	1/31/2006	31	49.78	29.75
Extended hours (530-730pm)	1/31/2006	Extended	22.05	
8am-5pm	2/1/2006	1	29.87	19.83
Extended hours (530-730pm)	2/1/2006	Extended	4.41	
8am-5pm	2/2/2006	2	49.78	19.83
8am-5pm	2/3/2006	3	49.78	19.83
8am-5pm	2/6/2006	6	48.26	17.64
Extended hours (530-730pm)	2/6/2006	Extended	11.32	
8am-5pm	2/7/2006	7	48.26	26.46
Extended hours (530-730pm)	2/7/2006	Extended	15.09	
8am-5pm	2/8/2006	8	28.96	26.46
Extended hours (530-730pm)	2/8/2006	Extended	15.09	
8am-5pm	2/9/2006	9	48.26	26.46
8am-5pm	2/10/2006	10	48.26	26.46
Extended hours (530-730pm)	2/13/2006	13	47.50	24.10
8am-5pm	2/14/2006	14	15.09	
Extended hours (530-730pm)	2/14/2006	Extended	47.50	24.10
8am-5pm	2/15/2006	15	15.09	
Extended hours (530-730pm)	2/15/2006	Extended	28.50	32.13
8am-5pm	2/16/2006	16	11.32	
Extended hours (530-730pm)	2/16/2006	Extended	47.50	24.10
Extended hours (530-730pm)	2/17/2006	17	47.50	16.07
8am-5pm	2/20/2006	20	46.74	17.77
Extended hours (530-730pm)	2/20/2006	Extended	15.09	
8am-5pm	2/21/2006	21	46.74	26.65
Extended hours (530-730pm)	2/21/2006	Extended	15.09	
8am-5pm	2/22/2006	22	28.04	26.65
Extended hours (530-730pm)	2/22/2006	Extended	11.32	
8am-5pm	2/23/2006	23	46.74	17.77
8am-5pm	2/24/2006	24	46.74	26.65