12-2004

Developing a Lean Based Model for a Hospital Pharmacy Environment

Jason North
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Jason North entitled "Developing a Lean Based Model for a Hospital Pharmacy Environment." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

Rupy Sawhney, Major Professor

We have read this thesis and recommend its acceptance:

ARRAY(0x7f6ff7f2a8b0)

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Jason North entitled "Developing a Lean Based Model for a Hospital Pharmacy Environment." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

Rupy Sawhney, Major Professor

We have read this thesis
and recommend its acceptance.

Denise F. Jackson

Kenneth E. Kirby

Acceptance for the Council:

Vice Chancellor and
Dean of Graduate Studies

DEVELOPING A LEAN BASED MODEL FOR A HOSPITAL PHARMACY ENVIRONMENT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Jason North

December 2004

ABSTRACT

Lean strategies have become necessary in healthcare due primarily to two factors: a demand for efficiency and a need to reduce medical error. The case for the necessity of a lean program is based on trends of increasing costs and decreasing revenues resulting from government intervention. Profit margin per patient has been reduced, and therefore more patients per time period must be seen in order to meet profitability goals. Preventable medical error is shown to be a leading cause of death.

Current research in the area of hospital and healthcare efficiency proves that a parallel exists between healthcare efficiency today and the state of efficiency in manufacturing during the late 70's and early 80's. In the 70's and 80's, MRP technology came into vogue as a means for attacking complicated problems with expensive, complicated, technology-based solutions. Today, many hospitals hope to solve their efficiency and human error problems by implementing computer based delivery, order-filling, and data systems. Better manufacturers made a move away from complicated solutions, toward lean practices focused on instead simplifying the problems; healthcare should then do the same.

A generic lean methodology geared toward the differing nuances of healthcare is developed. Lean is offered as a solution to both efficiency and medical error (on the basis that visual systems reduce error and that lean reduces stress, a major contributor to human error). A connection between stress and lean has been found by prior research, and is taken a step further and connected with human error. This is based on

research showing that stress causes the potential for human error in skilled workers to increase by 2-5 times.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Chapter 1

Introduction and Analysis of Healthcare Efficiency Issues

The foundation of all enterprise is the system. When a group of entities functions well one with another, the participants can meet a goal and the system they comprise is considered a good system. Adequate systems may also meet their goals, but are marked by a constant struggle among entities to interact, wasted resources, and confusion. An adequate system remains in a state of transience, forever poised on the line of distinction between viability and weakness. When an adequate system is overcome by its components' inability to interact, it no longer meets its goals. A system that does not meet its goals is a poor system. Poor systems generally result in the death of the enterprise.

In the United States, manufacturing enterprises began to come into existence and thrive in the early 1900s. Like all enterprises, each manufacturing firm developed for itself a set of systems allowing for the daily production that equated to survival. The best of these was developed by the Ford Motor Company, and with its utilization of assembly line techniques beginning in 1913 the enterprise grew by 1926 to claim an enormous 50% share of the automotive market. Ford Motors exceeded its goals. It had a good system.

By 1935, Ford had an adequate system, and General Motors was now in control of the market. What change had occurred in the Ford Company to allow such a serious compromise of the company's position? The answer is that there had in fact been no change. Ford lost market share to a competitor with more evolved systems; specifically, GM had developed the capacity Ford lacked to create flexible products. Ford was either not aware of or unwilling to address the fact that their world, as defined by the wants of their customers, had changed. Lack of response cost them considerably.

In the ensuing years, Ford and many other manufacturing organizations have begun to appreciate the need for system evolution in order to maintain viability in the face of changing demands. To this end, a group of techniques and tools falling under the banner of Lean Manufacturing has been developed and employed with varying degrees of success. In the best case scenarios (e.g., Toyota, Alcoa, etc.), lean strategies have resulted in significant system enhancement. Many manufacturers today perform at a level of flexibility, speed, and efficiency undreamt of a century ago. These manufacturing enterprises remain viable, and because of this both a national economy remains strong and the entities directly affected in the system—the employees—retain their incomes. Few will argue the importance of livelihood, and therefore the ultimate benefit of lean principles' incorporation into manufacturing is plain to see.

Given then that employment is important, how much more necessary is it for a system to run well if its products include not only livelihood but also quality of life, and perhaps life itself? The question is key when considering the fact that although lean principles are proven to be successful in manufacturing systems, their use is to date extremely limited in other enterprises in general and in healthcare enterprises in particular. The need to become more efficient, better in control, less expensive, and more flexible is being felt strongly in healthcare today. Patients, the public, and the government expect hospitals to do more, better, and with fewer resources. In order to make these evolutionary jumps, healthcare enterprises need their own version of the lean principles that have allowed manufacturing to thrive.

The purpose of the research presented here is twofold:

- Presentation of the case for lean programs in healthcare
- Proposal of a model targeted on hospital pharmacy

The case for lean in healthcare may be found in Chapter 1. Chapter 2 examines the current state of healthcare from the perspective of efficiency and delivery, and the improvement efforts that are presently under way. A review of relevant existing literature is included. Chapter 3 frames a methodology for implementing lean concepts in healthcare. Chapter 4 offers a case study of the methodology's use at the pharmacy in Baptist Medical Center in Memphis, TN. Chapter 5 contains concluding remarks and suggestions on future study in this field.

Increasing Costs in Healthcare

Many healthcare facilities are today where Henry Ford's company was in 1935. Having been premier suppliers of medical services, they developed a mindset that suggested that everything they did was done well because there was no clear historical alternative. While geography and insurance policy stipulations limit the impact of competition among hospitals, other factors continue to result in diminishing profits. The cost of doing business has been dramatically increasing over the last decade, while revenue per patient has seen a steady decline. This trend effectively places many healthcare institutions in a serious monetary bind.

The increasing costs associated with healthcare may be traced to three primary roots. These are:

- Insurance
- Labor
- Administration

Insurance

Malpractice insurance has risen steadily due to a number of factors. In the wake of the September 11, 2001 bombing of the World Trade Center, many financially stressed insurers have either raised premiums or dropped more risk-prone lines of coverage such as malpractice insurance (Cary, 2002). Jury awards in malpractice lawsuits have seen a precipitous increase since the mid 1990s, affecting profitability of insurers (see Figure 1.1), and therefore rates (Albert, 2003). Poor stock market performance is also cited as a contributing factor in rate increases (Lake, 2002).

Labor

The Health Resources and Services Administration is the primary Federal agency responsible for providing information and analysis relating to the supply and demand for health professionals. According to a July 2002 report by the HRSA, 30 states were estimated to have shortages of registered nurses (RNs) in the year

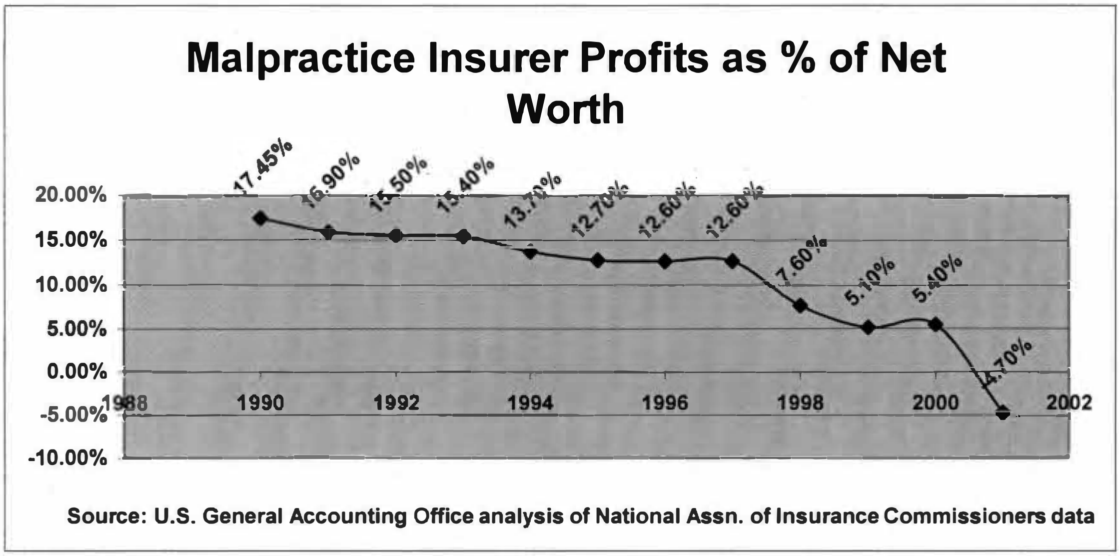


Figure 1.1: Malpractice Insurer Profits

2000 (US Deptartment of Health and Human Services, 2002). States with shortages are shown in Figure 1.2. This shortage falls 6% short of demand, and extrapolation based on existing trends suggest that by the year 2020 the shortage is expected to grow to 29% of demand. The number of nursing graduates has been declining steadily in recent years, with a 26% drop from the years 1995 to 2000 (Figure 1.3) for diploma, bachelors, and associate degrees. The Health Affairs journal predicts similar trends for physicians, though the shortage is not expected to be as significant as that for nursing employees. Extrapolation from the Cooper, et al., trend model suggests shortages of 5% and 7% for years 2010 and 2020 respectively (Cooper et al, 2002). As salaries are a clear function of supply and demand, the cost of labor in healthcare is poised to climb substantially within the near future.

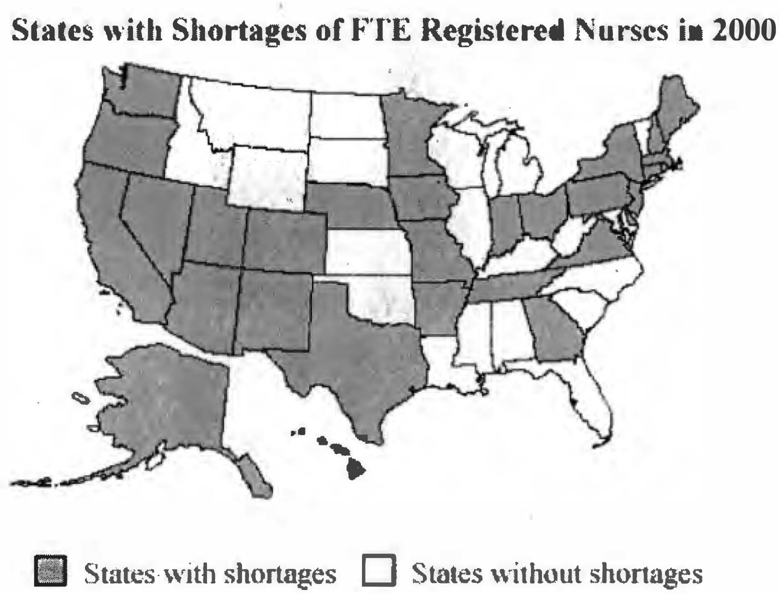


Figure 1.2: Nursing Shortage by State

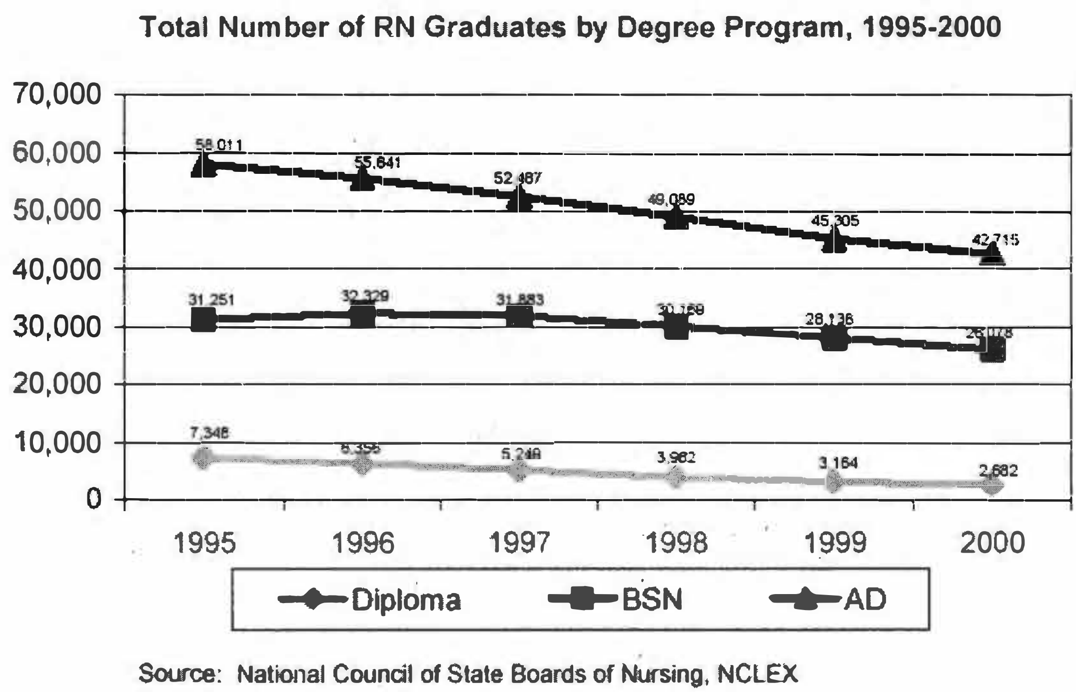


Figure 1.3: Decline in Available Registered Nurses

Administration

According to a nationwide study by the New England Journal of Medicine, hospital administration accounted for an average of 24.8 percent of each hospital's spending in fiscal 1990 (Woolhandler et al, 1993). Average hospital administrative costs ranged from 20.5 percent in Minnesota to 30.6 percent in Hawaii. Administrative salaries accounted for 22.4 percent of the average hospital's salary costs. Healthcare is a regulated enterprise, far more so than the majority of manufacturing, and as such is subject to a greater degree of government oversight. With regulation increasing periodically, administration costs must follow suit.

Decreasing Revenues in Healthcare

Increasing costs, while having tremendous impact, account for only part of the overall diminishing profitability in healthcare. Whereas in a natural market a supplier of goods or services sets its prices based on customer demand and desired margin, hospitals in the United States are bound by price intervention from the government in the form of Medicare and Medicaid. Physicians have faced decreasing Medicare payments since Congress passed the 1997 balanced budget law (Pub. L. 105-33) which mandated a reduction in payments to physicians, hospitals, nursing homes and other health care providers. As a result, physicians took a 5.4 percent cut in payments in 2002, and could expect additional cuts of 12 percent over the subsequent three years. This includes a possible decrease of about 4.4 percent in 2003 (Babula, 1991). With Medicare or Medicaid accounting for an increasing percentage (having gone from 50% to 77% since the plan's inception) of each patient's total remuneration, healthcare providers have little latitude in price structure. This means, in essence, that income from the government is slowly eroding.

Decrease in Patient Satisfaction

In order to counter these trends, hospitals nationwide have adopted a strategy whereby the bottom line is held steady by accepting larger numbers of patients at reduced margins per each individual. The focus now is on efficiency; however, it is not in most cases an efficiency born of restructuring but rather a result of arbitrary cuts in manpower and a concerted effort to speed up the less than optimal existing systems. Without modifying the existing logistical structure, many facilities have created additional problems in terms patient satisfaction and medical error.

It may help to consider this notion in terms of equation. Patient satisfaction is the ultimate goal of the healthcare institution and as such, is a function of service. Healthcare service is in turn a function of inputs and outputs: specifically, revenues and costs. Therefore, Satisfaction = f(Service) = f(Revenue – Cost). More simply, patients actually receive less care per dollar.

Data suggests that medical error is also becoming increasingly prolific, and this may stem from the reduction in resources. Two studies of large samples of hospital admissions are particularly noteworthy. The first of these was performed in 1991 based on data from a New York hospital in 1984 and showed that 1.68% of all admissions would experience an adverse event (defined as injuries caused by medical management) as a result of preventable error(Brennan et al, 1991). A similar study in 1999 based on 1992 data from hospitals located in Utah and Colorado showed that almost 2% of all admissions would result in avoidable injury due to medical error (Thomas et al, 1999). Extrapolation of this data to the over 33.6 million admissions to US hospitals in the year 1997 suggests that a minimum of 44,000 Americans die annually as a result of medical error (American Hospital Association, 1999). On the high end of the estimate, it is believed that as many as 98,000 deaths may occur annually through preventable medical error.

Lean Strategy as a Means to Achieve Improvements

At the most general level, the need for improvement in healthcare may be distilled to the two inter-related aspects of efficiency and quality. Efficiency may be measured as a function of throughput time, cost, and value-added/non-value-added time. Quality is based on accuracy and capability and may be defined as internal (referring to in-process issues) or external (problems reaching the patient or customer). There is empirical evidence supporting the fact that Lean Strategies have a significant effect on these factors within manufacturing (White et al, 1999). Table 1.1 and Table 1.2 summarize survey data collected from a sampling consisting of 454 members of the Association for Manufacturing Excellence (AME). AME represents a broad cross-section of manufacturers from different regions throughout the United States. Note that better throughput time is listed as the primary improvement in both small and large companies, with quality trailing by a very few percentage points.

Table 1.1: Frequencies of Changes in Performance Attributed to JIT Implementation (Improved Metrics)

Performance Measures	Mfgr Size	Manufacturers Indicating Not Better	Manufacturers Indicating Better	Percent Better
Throughput Time	sm*	30	144	82.80%
Throughput Time	lg**	31	249	88.90%
Internal Quality Level	sm	35	139	79.90%
Internal Quality Level	lg	43	237	84.60%
External Quality Level	sm	62	112	64.40%
External Quality Level	lg	83	197	70.40%
Labor Productivity	sm	42	132	75.90%
Labor Productivity	lg	77	203	72.50%
Employee Behavior	sm	85	89	51.10%
Employee Behavior	lg	141	139	49.60%

*sm = Small Manufacturers (N = 174)
** lg = Large Manufacturers (N = 280)

Table 1.2: Frequencies of Changes in Performance Attributed to JIT Implementation (Reduced Metrics)

Performance Measures	Mfgr Size	Manufacturers Indicating not Lower	Manufacturers Indicating Lower	Percent Lower
Inventory Levels	sm	34	140	80.50%
Inventory Levels	lg	48	232	82.90%
Unit Cost	sm	66	108	62.10%
Unit Cost	lg	99	181	64.60%
Cost of Equipment	sm	152	22	12.60%
Cost of Equipment	lg	237	43	15.40%
Cost of Employee Training	sm	169	5	2.90%
Cost of Employee Training	lg	268	12	4.30%
Administrative Costs	sm	101	73	42.00%
Administrative Costs	lg	170	110	39.30%

The Argument that Manufacturing Principles do not Apply to Healthcare

Given that Lean Strategies are proven to enhance efficiency and accuracy within manufacturing environments, and that these are precisely the same areas at issue in healthcare, why have hospitals largely ignored the potential benefits of such applications? Culture is a significant matter, and as is the case in many manufacturing facilities, the notion among employees that their system is singularly unique will have often reached dogmatic status. Many manufacturers erroneously identify this "uniqueness" as the reason why a Lean Implementation will not work in their facility. In healthcare, not only do providers perceive themselves to be different from one another; they also consider their industry to be far removed from others in general and manufacturing in particular. The fact that all enterprise is fundamentally similar is overlooked in the face of superficial differences.

All enterprises, hospitals included, serve to render a product in some form. Healthcare is not commonly thought of as a product in the physical sense, owing perhaps to the notion that it is inhumane or distasteful to consider human beings in the same terms manufacturers employ to describe a palette of mufflers. The introduction of scientific metrics regarding the product may be perceived as dehumanizing a process based strongly on the interaction between the nurses and physicians who supply services and the patients who consume them. Hospitals choose not to the think in such terms. The fact remains, however, that the discharge of a healthy and therefore value-added patient is the primary goal of such a facility. If a product can be identified, the differences between the medicine and manufacturing are nuance.

First and perhaps most readily apparent among these nuances is the physical nature of the environment. Hospitals do not look like production plants. The manufacturing facility in the infant stages of lean strategy may be expected to be unorganized, polluted, and altogether hostile in terms of ergonomic considerations. By way of contrast, every hospital is required by law to maintain certain standards of internal cleanliness and, in the case of areas such as operating rooms, pharmacies, and those areas designated for cleaning reusable operating tools, sterility. The noise pollution generated by heavy industrial equipment is not present. The surroundings are well lit. The manner of dress is formalized for both management and direct-care personnel. Signs and visual indicators are often in place.

One of the basic tenants of Lean Manufacturing involves removing low-level decision-making (for example, where to place tools) from the production process through use of a well-defined system. Herein lies another reason for the opposition to Lean in hospitals. Healthcare employees are doctors, nurses, pharmacists, technicians, and administrators—all well educated. Whereas the lesser-educated employee working in manufacturing is employed on the basis of some repeated physical activity he or she is expected to perform (i.e., load a machine, assemble a product), educated people are employed for two reasons:

- An educated worker has derived some set of special skills from his or her education.
- An educated worker has the ability to make sound decisions on a regular basis.

It is the second criterion that serves as the basis for the argument that Lean strategies will not work in healthcare. Given that decision-making is an integral element of the employee's job and that many unique decision-making situations occur, it is then presumed that all decisions must be made on a dynamic basis and that a structured set of pre-made decisions will not work in a dynamic environment.

The error in this reasoning is that all decisions, both high and low level, are being grouped together. This need not be the case, especially for those decisions that have to do with procedural sequence, approach, and timing. It is not necessary to decide the order of tasks within a given activity each time it is undertaken. While prioritization under crisis conditions of activities directly affecting patient health must clearly be judged on a case-by-case basis, there must be one best method for performing a status quo activity. Once that best method has been determined, it may become the standard.

Many hospitals share a common reluctance to accept the idea of standard operations. The basis for this reluctance is that hospitals are by necessity forced to deal with unpredictable emergency conditions and that the frequency of such occurrences precludes the possibility of developing a routine. The potential for interruption in a medical setting is considerable, but such potential exists to some degree in all systems. The possibility of equipment malfunction does not preclude order in a manufacturing system. To suggest that potential interruption does so in medicine is a specious argument

While differences do exist between manufacturing and healthcare, the similarities are such that, with the enhancements subsequently outlined in this thesis, Lean implementation will result in significant improvement to service level.

Chapter 2

Efficacy of Modern Healthcare Improvement Concepts, Including a Survey of Relevant Literature

Before the details of a Lean Pharmacy Methodology can be developed, certain questions must first be answered regarding the choice of Lean Philosophy as a vehicle for improvement. Chapter 1 establishes both the need for improvement and the viability of Lean as a means of achieving that improvement. At issue then is, given that Lean is viable, is it a better approach than other potential alternatives? Secondly, does a Lean Pharmacy methodology already exist, and if so, is it adequate in terms of results and universal applicability?

A survey of healthcare improvement efforts as they exist today, with special emphasis on pharmacy, becomes necessary in answering these questions. This chapter encompasses this survey, including excerpted material from the most relevant sources. Discussion begins with general healthcare and moves toward pharmacy specific improvement efforts.

Comparing Improvement Approaches

In evaluating the performance of alternative courses of action, two criteria must be considered:

- Does the course of action in question allow the goal to be realized?

- How does the ratio of resources input to results achieved compare to the same ratio for other alternatives?

Lean Philosophy is by definition centered on the concept of simplification. As an extension of that principle, the expenses associated with its execution are relatively minimal. Lean implementation requires time and effort, but offers significant advantage in that it does not require the acquisition of additional capitol materials.

In contrast, research demonstrates that the current paradigm in healthcare is centered on implementation of computer-based delivery, order-filling, and data systems. While such approaches do in the best case scenarios suggest limited success with regard to enhanced efficiency and human error reduction, the improvements come at substantial cost. Technology-based solutions are by their nature high-dollar solutions. Further, technology-based solutions may potentially create more human error problems than they solve as they are frequently characterized by the interaction between technology and workers unfamiliar with its nature. Further still, information technology is complex. Complicated solutions are themselves known to engender new, more complicated problems requiring still more complicated solutions, and thus an ever-escalating and very expensive cycle ensues.

Roughly 80 percent of technology purchases in the healthcare industry today revolve around administration purposes rather than care-giving (Gale 2003). Healthcare administration includes internal communications between and with doctors and nurses, as well as patient monitoring, patient scheduling, admitting and discharging, and patient records management. This also includes communications with insurance vendors, HMOs, PPOs, laboratory and diagnostic services, billing/mediation vendors, and other external parties within the healthcare industry.

Huerta's paper (1995) on the Role of Technology in Rising Healthcare costs establishes that new technologies are enthusiastically embraced in American healthcare but that the unwise use of technology is prevalent and represents a considerable factor in escalating costs. Technology applications, with computed tomography (CT) cited as just one example (Office of Technology Assessment, 1978), are known to be widely diffused before evidence of efficacy or cost-effectiveness has been repudiated. Further, new technologies often do not replace existing technologies. Angioplasty, for example, was introduced in 1986 as an alternative to surgical coronary bypass but did not in six years' time result in a reduction in the total number of bypasses performed (Greene, 1992).

While CT Scanning and Angioplasty technologies are clearly more internal to the patient care process than the largely external information relay aspects concerning this thesis, Huerta's assertions regarding healthcare's use of technology still hold true at a broad level. The main difference between these internal and external uses of technology is that unnecessary internal tech use may in fact be desirable to the healthcare provider as it increases profitability. (Independent studies by McCormick (1991), Swedlow (1992), Mitchell (1992), Hillman (1992), and Hemenway (1990) show that the utilization of technology increases significantly when physicians own the ancillary services to which they refer patients.) External use of unnecessary tech, by contrast, benefits neither the patient nor the healthcare provider.

In this regard, a parallel exists between healthcare efficiency efforts today and the state of efficiency efforts in manufacturing during the late 1970s and early 1980s. During this period, Materials Resource Planning, or MRP, technology gained favor as the preferred means for schedule development. Environments functioning with an MRP have been proven to be significantly impacted by uncertainty(Koh 2003). Master production scheduling (MPS) was a large component of this. MPS was attractive, complex, expensive, and in terms of efficiency enhancement, detrimental(Woodhead 2003). In order to redress its problems, MRP evolved into MRP II. While MRP II added new levels of functionality, it also added new levels of complexity while never addressing the underlying problems. These steps toward efficiency proved to be "bumps in the road" for manufacturing, and it is the contention of this thesis that healthcare can learn from and avoid the pitfalls to which its forbearer was subject.

Technology Based Efficiency Efforts in Healthcare

Butler's work, published in *Production and Inventory Management Journal*, suggests the use of local area networking for inventory control and product delivery scheduling in hospital pharmacies. Here he states that hospitals are prime candidates for creative efficiency techniques due to escalating costs, reduced revenues, and high inventory investment. In this he is correct, as the same argument is established in Chapter 1 of this thesis. The article, however, goes on to outline the suggested approach as follows:

LAN-enabled workstations are to be located at satellite stations that receive materials from the pharmacy, or source satellite. A spreadsheet is to be devised in order to track usage at each of the satellite stations and obtain information on expected usage rates and the variation thereof. This information is used to set safety levels, and data on current holdings, usage, and planned orders are used within the spreadsheet to generate a schedule forecasting use, delivery, and replenishment (Figure 2.1) at each station. These spreadsheets link to a master spreadsheet which functions in much the same manner. This creates a schedule that then drives deliveries from the pharmacy to the satellite stations and sets dates for the pharmacy itself to reorder.

Summary of Planned Storeroom to Satellite Deliveries

	Past Due	*1*	*2*	*3*	*4*	*5*
A			700		700	
B		150			150	
C				500		500
D				300		300
E		500		500		500
F		300			300	
Total	0	950	700	1300	1150	1300

Pharmacy Storeroom
Summary of Planned Deliveries
Heparin

Figure 2.1: Demand and Delivery Spreadsheet

Though the nomenclature is never used within the article, Butler is clearly describing a classic MRP system and suggesting its use in enhancing efficiency. Though the article was published some two decades after the advent of MRP in manufacturing, the connection is not made within the text and the problems with the use of such a system in a hospital environment are not explored.

Paramount among the qualities making MRP unsuitable as a scheduling device for healthcare is its aforementioned inability to account for considerable system variation. The usage of medication is prone to considerable variation—particularly in smaller hospitals where the number of unique ailments may approach the number of individuals within the patient population. The lack of a good usage predictor necessitates another approach to variation. That is, flexibility, an attribute missing from MRP yet fundamental to Lean Principle.

Butler does mention the nominal expense associated with such a system, though he only considers LAN-card installation into existing equipment. If computers dedicated to inventory management and scheduling must be purchased, and if a healthcare facility has no programmer on-hand (which is likely), then the cost will clearly be more substantial. Training employees to use such a system must also be factored into the price both in terms of the time spent learning and the time spent correcting mistakes made by those unfamiliar with the interface.

Also at issue in such a system is the fact that information, signals, and potential failsafes exist only in a virtual rather than visual state. There is no tangible link between information and physical items, and this implies three things. First, the accuracy of information becomes questionable as situations such as conflicting inputs from multiple users emerge. Confidence in the system's accuracy would then result from detailed and time-consuming accounting, verification, and audit procedures. Failure on the part of any one user to properly interact with the system on its own terms would result in difficulties for many other affected users. Secondly, when there are no visual indicators of inventory, hording and theft involve less effort and may become more prevalent. Finally, users must seek information rather than having it presented to them in a simple format, and seeking is not a value-added activity.

Prior efforts also indicate limited effectiveness of information systems in reducing workload. Aydin and Ischar performed a study in 1989 wherein they examined the interface between nursing and pharmacy departments at Cedars-Sinai Medical Center in Los Angeles, CA. At the heart of this research was the notion that the frequency of verbal interface between the two departments had a considerable impact on overall patient care. This impact was viewed as having dual facets, both positive and negative. As for positive effects, the authors site a high frequency of communication as resulting in better working relationships. Conversely, frequent interfaces are also noted to be distracting to pharmacists attempting to perform their duties, limiting their overall productivity. The authors employed a survey in order to ascertain the effect of a computerized order entry system, HART MEDS, on interface frequency.

Based on answers from 191 respondents out of a total 463 RNs and LPNs queried, the results shown in Figure 2.2 were obtained. Answers are based on a 7-point Likert Scale with higher score indicating stronger agreement. The authors' hypothesis, stating that nursing personnel would speak less frequently with pharmacy

Variable	Mean	S.D.
1. In general, the HART MEDS System has improved communication between pharmacy and nursing.	5.49	1.68
2. Before HART MEDS, I usually spoke with someone from pharmacy several times a day.	4.54	1.98
3. Since HART MEDS, I usually speak with someone from pharmacy several times a day.	4.00	2.00
4. Before HART MEDS, I knew the people who worked in pharmacy very well.	4.22	2.21
5. Since HART MEDS, I know the people who work in pharmacy very well.	5.38	1.85

Figure 2.2: Response to HART MEDS system

personnel after the implementation of the HART MEDS computer system, was rejected on the basis that the decrease in spoken contact shown in the data was not statistically significant. (Rejection was based on a paired t-test wherein $t(67) = 1.71$, $p<.10$) This is an important point as it provides evidence that computer order input systems do not necessarily reduce the number of interruptions to work flow in the pharmacy.

Statistics-based Improvement Efforts in Healthcare

The available literature regarding statistics-based improvement efforts in healthcare focuses largely on the potential of Six Sigma, though the lack of significant depth suggests that Six Sigma carries more weight as a neologism than as a practical concept. Speaking of the Sigma metric, Stacker contends that "It is currently misunderstood, not used, underused, and misused in health care." Current efforts encounter problems and resistance due to the fact that educational efforts focus largely on the mechanics of Six Sigma and not on the underlying principles or the principles of improvement associated with Lean.

Six Sigma is, in truth, only one potential piece of what must be a larger improvement initiative. In The Art and Science of Winning Physician Support for Six Sigma Change, Ettinger and Kooy describe the effects of unsuccessfully implementing Six Sigma exclusively. Skepticism runs rampant and employees are left feeling that significant change is unlikely.

Improvement Approaches Specific to Pharmacy

Literature pertaining to the reorganization of existing pharmacy procedures falls largely into two areas. The first of these relates to the use of computer-based systems designed to take the human out of the scenario to the greatest extent possible. Creators of such systems are numerous (Table 2.1), and while each system has its advantages they also have drawbacks in terms of cost and complexity issues. It therefore becomes apparent that pharmacy, like healthcare in general and manufacturing before it, is tending toward increasingly complex answers to its problems. Most of the literature in this area focuses on the introduction or availability of such tools and is not scientific in nature.

The second area in which pharmacy improvement is sought relates to reorganization of the processes themselves. Literature of this nature is limited but does include aspects of Lean Principle. The Minneapolis-St. Paul Business Journal

Table 2.1: Pharmacy Software Providers

Company	Pharmacy Software Description
Allwin Data	Point-of-sale DME claims processing with full research and recovery reconciliation support.
Athens Software, Inc.	Pharmacy management systems for small to medium-sized hospitals with programming adapted to specific needs.
Delphi Associates	Pharmacy management and dispensing software application.
Etreby Computer Company	Pharmacy management systems and drug database service.
First DataBank	A provider of electronic drug information, delivering knowledge bases for various healthcare applications.
Hann's On Software	Hospital pharmacy and medication management system, interfaces with CPOE systems such as VisualMED (Pyxis) and autodispensing systems; ADT/billing/lab interface; electronic and printed MARs.
Interactive Business Systems	Hospital pharmacy drug distribution and control software.
Interactive Systems & Management Corp. (ISM)	Integration with MIS and other special services, IT systems and high-volume OPD clinic pharmacies.
Lexi-Comp	Lexi-Comp Online integrates databases and enhanced searching technology of time-sensitive clinical information at the point of care.
McKesson APS	Integrated and scalable pharmacy automation and services to increase pharmacy efficiency, enhance patient safety, and improve patient care.
Medi-Span	Line of drug databases, including clinical decision support and disease suite modules, application programming interfaces, and stand-alone PC products.
QS/1 Data Systems	Provider of outpatient pharmacy management and durable medical equipment sales and rental systems. Can run single or multiple pharmacy locations for compounding, durable medical equipment, long-term-care, and employee prescription needs.

Table 2.1: Continued

Company	Pharmacy Software Description
ScriptPro	Fully integrated pharmacy management/workflow systems and robotics. Resources to promote patient persistence and compliance, as well as cross-selling of OTCs and other products.
SXC Health Solutions, Inc.	Point-of-care technology solutions for automating pharmacy service management.
TeleManager Technologies, Inc.	Providing interactive voice response (IVR) solutions.
Telepharmacy Solutions, Inc.	Remote pharmacy-controlled outpatient point-of-care dispensing technology.
Thomson MICROMEDEX	Evidence-based clinical information for healthcare professionals. Content and software tools are available for desktop computers, PDAs, and for integration within clinical information systems.
Zebra INC	Barcoding solutions for pharmacy.

carried an article in 2004 on the use of Lean Principles in reducing the costs of healthcare (Smith, 2004). Here he alludes to a project that improved the flow of drugs to patients at a Methodist Hospital in St. Louis Park. Time for prescription-filling was reduced by 44 percent by eliminating events deemed disruptive to pharmacists. Specifics on the approach were not disclosed.

In 2003 a project was undertaken at Cancer Treatment Centers of America at Midwestern Regional Medical Center (CTCA at MRMC) to decrease turnaround time by 20 percent utilizing lean concepts (Lepper, 2003). An invasive process, the changes listed include:

- Redesigned and physically renovated the pharmacy department
- Implemented Lean Thinking methodology and tools
- Eliminated steps in the process that were non-value-added to the customer
- Developed new standard operating procedures (SOPs) for order entry, chemotherapy preparation, pharmacist oversight, and product delivery
- Developed and implemented new chemotherapy safety log
- Improved and standardized chemotherapy order entry process
- Implemented the 5S and visual workplace principles
- Developed and implemented a Daily Lean Management System that includes a Production/Safety Board
- Implemented a new Inventory Management System for IV supplies which is based on the Just-In-Time concept
- Changed staffing patterns to meet high chemotherapy demand times

While CTCA's level of commitment was considerable, what they lacked was a general guideline that could be passed along to other pharmacies. They focused largely on elimination of steps. Further, CTCA's analysis of change lacked statistical proof of true differentiation and did not incorporate test-scenarios through modeling. A general guideline developed at Malcolm Baldritch attempts to remedy this, but does so only on a general level.

The work in this thesis goes several steps further than a local-level project such as that at CTCA in addressing each of the deficiencies mentioned. Chapter 3 presents a global approach for this largely initiatory area of Lean application.

Chapter 3

Methodology for Implementing Lean Principles into a Hospital Pharmacy

The differences between a pharmacy environment and a manufacturing environment are, as stated in prior chapters, a matter of form rather than function. Given this notion, it then follows that the approach to Lean implementation within a pharmacy must make certain allowances for such a form while maintaining the same underlying principles as those found in existing Lean methodologies geared toward mass-production. This chapter provides such a methodology, places it into stepwise fashion, and considers the reasoning behind each phase. Figure 3.1 presents a summary of the approach that may be used as guide or worksheet. This methodology is broken into seven distinct phases:

1. Amelioration of Pharmacy Cultural Issues
2. Assessment of the Current State
3. Workplace Organization: Incorporation of 5S Principles
4. Proper Definition and Standardization of Pharmacy Work Tasks and Systems
5. Creation of Enhanced Flow Patterns, including the Single-Stimulus Job Center
6. Pattern Inspection through Simulation
7. Sustaining Improvements

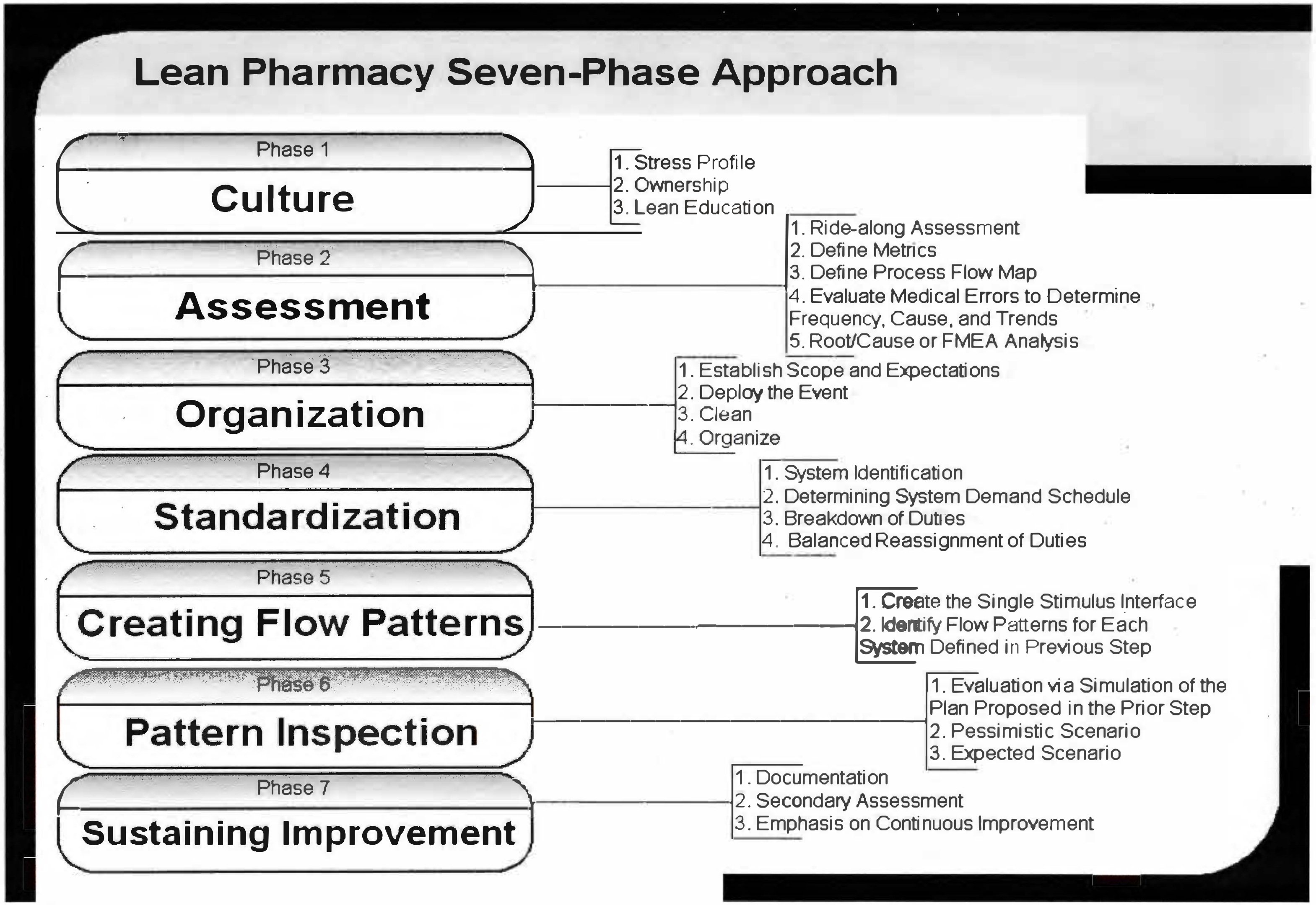


Figure 3.1: Lean Pharmacy Seven-Phase Approach

Lean Pharmacy Phase 1: Amelioration of Pharmacy Cultural Issues

Culture refers in the most basic sense to the willingness of employees in general (and for purposes of this research, pharmacy employees in particular) to accept the types of changes incumbent to a Lean implementation. The question that is then implied is, under what conditions does acceptance become more probable? As Lean Philosophy carries with it a large component of information transfer and systemization, it is reasonable to consider existing research performed on the acceptance of technology-based information systems in healthcare facilities as representative of the criteria necessary to ensure acceptance of a comprehensive lean implementation.

Peredina and Allen propose that in order for the implementation of new techniques to be successful, the adopting organization must address not only the technological aspects but also managerial challenges such as the acceptance of the technology among users(Allen, 1995).

Chau and Hu performed a study published in 2002 wherein they examined physicians' acceptance of telemedicine technology(Chau and Hu, 2002). This study investigated user technology acceptance in healthcare organizations already providing or planning to provide telemedicine-enabled patient care and services. In the paper, the word "telemedicine" refers to "the use of IT [Information Technology] to support healthcare services and activities via electronic transmission of information or expertise among geographically dispersed parties, including physicians and patients, in order to improve service effectiveness and resource allocation/utilization efficiency". The authors used a model integrating aspects of the technology acceptance model (TAM) and the theory of planned behavior (TPB) in order to determine those causal factors with the strongest relationship to behavioral intention. Behavioral intention has been shown to predict or explain an individual's performing a conscious act, such as making a decision to accept or reject a technology, program, or approach. The integrated model is shown in Figure 3.2. Table 3.1 shows question items used in the study as measures to operationalize attitude, subjective norms, perceived behavioral control, perceived usefulness, perceived ease of use, and behavioral intention. A total of 408 effective responses were received with results based on a 7-point Likert Scale summarized in Table 3.2. Figure 3.3 shows resulting relative coefficients for the integrated model.

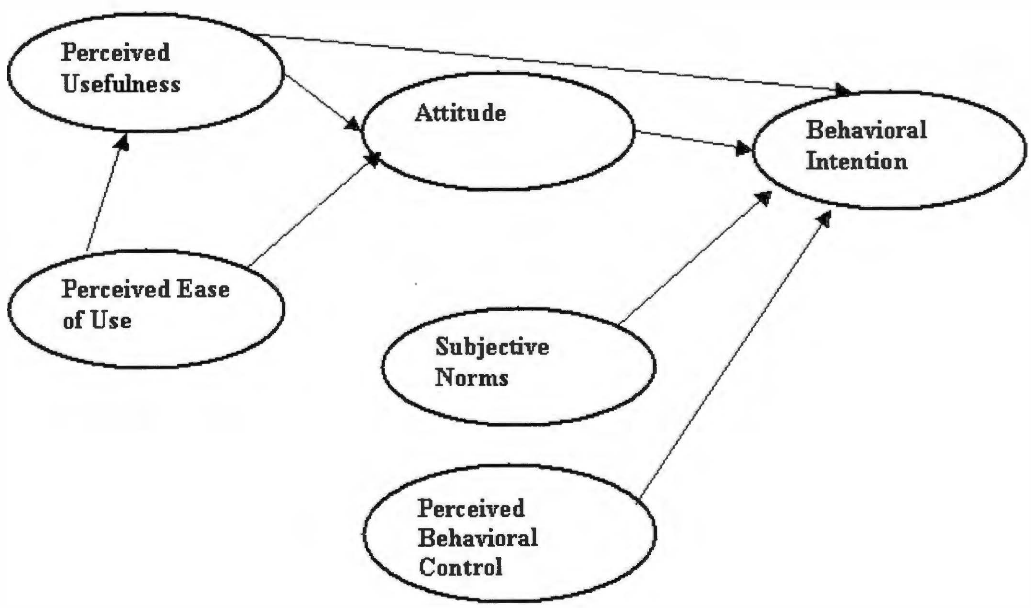


Figure 3.2: Integrated Behavioral Prediction Model

Table 3.1: Telemedicine Technology Survey Fields

Construct	Item	Measure
Attitude (ATT)	ATT1	Using Telemedicine technology in patient care and management is a good idea.
	ATT2	Using telemedicine technology in patient care and management is unpleasant.
	ATT3	Using telemedicine technology is beneficial to my patient care and management.
Subjective Norms (SN)	SN1	People who influence my clinical behavior think that I should use telemedicine technology.
	SN2	People who are important to my health care services think that I should not use TT.
	SN3	People who are important in assessing my patient care and management think that I should not use TT.
Perceived Behavioral Control (PBC)	PBC1	I would have the ability to use telemedicine technology in my patient care ad management.
	PBC2	Using telemedicine technology would be entirely within my control.
	PBC3	I would not have the knowledge to make use of telemedicine technology in my patient care and management.
	PBC4	I would have the resources (including training) to make use of telemedicine technology in my patient care and management.
Perceived Usefulness (PU)	PU1	Using telemedicine technology cannot improve my patient care and management.
	PU2	Using telemedicine technology cannot enhance my effectiveness in patient care and management.
	PU3	Using telemedicine technology can make my patient care and management easier.
	PU4	I would not find telemedicine technology useful for my patient care and management.

Table 3.1: Continued

Construct	Item	Measure
Perceived Ease of Use (PEOU)	PEOU1	Learning to operate telemedicine technology would not be easy for me.
	PEOU2	I would find it easy to get telemedicine technology to do what I need it to do in my patient care and management.
	PEOU3	It is not easy for me to become skillful in using telemedicine technology.
	PEOU4	I find telemedicine technology easy to use.
Behavioral Intention (BI)	BI1	I intend to use telemedicine technology
	BI2	Whenever possible, I intend not to use telemedicine technology for patient care.
		To the extent possible, I would use telemedicine technology in my patient care frequently.

Table 3.2: Telemedicine Technology Survey Results

Construct		Mean	S.D.	Reliability
Attitude (ATT)	ATT1	2.83	1.03	0.69
	ATT2	2.96	1.16	
	ATT3	2.59	1.15	
Subjective Norms (SN)	SN1	3.66	1.07	0.75
	SN2	3.3	1.03	
	SN3	3.36	1.07	
Perceived Behavioral Control	PBC1	2.85	1.08	0.55
	PBC2	3.94	1.34	
	PBC3	2.88	1.39	
	PBC4	3.85	1.31	
Perceived Usefulness (PU)	PU1	2.8	1.17	0.86
	PU2	3.04	1.2	
	PU3	3.3	1.22	
	PU4	2.93	1.16	
Perceived Ease of Use (PEOU)	PEOU1	3.02	1.3	0.77
	PEOU2	3.46	1.16	
	PEOU3	3.11	1.6	
	PEOU4	3.21	1.18	
Behavioral Intention (BI)	BI1	3.47	1.28	0.86
	BI2	2.98	1.26	
	BI3	3.23	1.26	

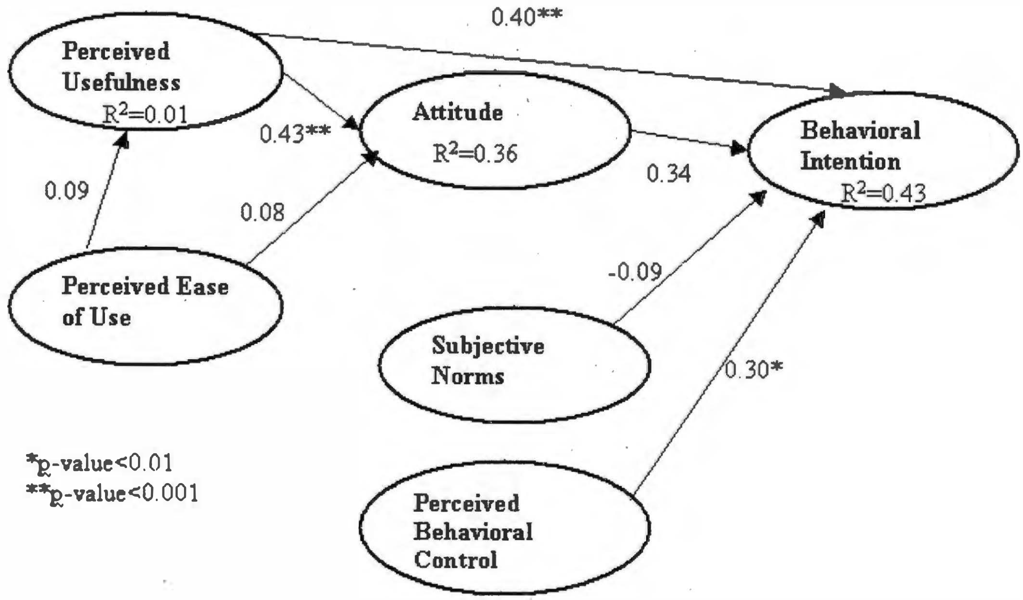


Figure 3.3: Results of Integrated Model

Perceived usefulness was clearly the most significant factor affecting physician's acceptance of new approaches, with path coefficients from perceived usefulness to both attitude and behavioral intention consistently the highest for the models examined. This then suggests that a perception that an approach or technology will prove useful must be created by any pharmacy hoping to implement new procedure. Additionally, perceived usefulness appears to be a critical determinant of attitude formation.

If usefulness is not perceived, then acceptance does not occur. If acceptance does not occur, a Lean initiative fails before it begins. It is for this reason that education is suggested as the cornerstone of the Lean Pharmacy Methodology. The workforce will need to be educated on the principles of lean and further told how impending changes will benefit them on a personal level. The efficiency aspects of Lean such as reduced stress and chaos are compelling ideas; the potential reduction of serious human errors and subsequent fallout is still more so. One or more short sessions both delineating these benefits and describing Lean fundamentals will have an effect lasting throughout the life of the project. A robust training program such as that used by The Center for Productivity Innovation at The University of Tennessee (Figure 3.4) would ensure that not only do participants buy in but that they also have a proper toolset with which they may continue the effort.

It will also be important to seek input from employees at every stage and particularly at the outset. Allowing employees to participate in the generation of objectives imbues a sense of ownership and creates a sense of direction. Participants should articulate objectives including:

- Clean Environment
- Safe Environment
- Ordered Environment
- Interruption Free Environment
- Pride in Workplace
- Efficient Access to Information
- Efficient Access to Tools
- Efficient Access to People
- Sharing of Information

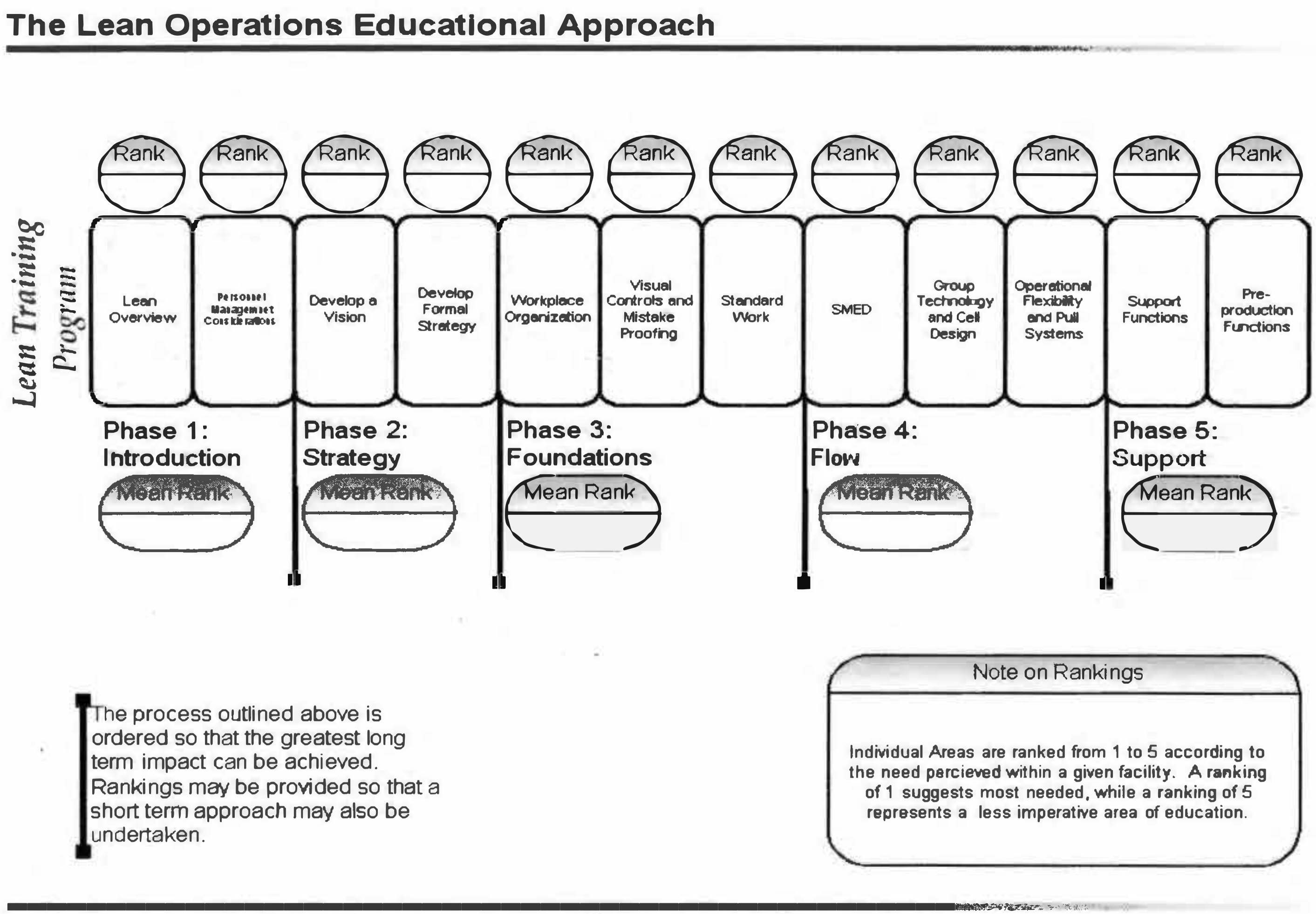


Figure 3.4: Lean Operations Educational Approach

During this initial phase, it is also incumbent upon the facilitators to assess the extent to which stress impacts the worker. The survey currently under development in Naim Hossain's thesis may be employed here to not only accumulate data for evaluative purposes but also to enhance the employee's perception of managerial concern (Hossain 2004). The Impacts of stress are further discussed in the section on Phase 4.

Phase one may therefore be said to comprise three action items:

- Stress Profile
- Engendering Acceptance through Ownership
- Lean Education

Lean Pharmacy Phase 2: Assessing the Existing State

The purpose of this analysis phase is to find specific information within the pharmacy with which a Lean Implementation is immediately concerned. Such information will include a listing of failure states, the summation of frequency data regarding these failures, a root-cause analysis, and a priority-based ranking of events. While this analysis should echo both problem scenarios and causes generalized in the literature as established throughout this thesis (i.e., human error and the conditions that contribute to it, as described in Phase 5), the assessment remains meaningful for three reasons. First, there is an ever-present potential that some truly unique or as yet unconsidered factor is at play and that special corrective actions would have to be considered. Second, the summarization of data into a concise format enhances the ability of participants to appreciate the extent to which failure conditions occur. This in turn improves the potential for acceptance by increasing perceived usefulness as outlined in the preceding section. Third, while standard problems are likely to be uncovered, they will have a configuration and distribution unique to the given situation.

In order for a complete assessment to be made, Phase 2 requires five distinct steps. These are:

- Ride-Along Assessment
- Metrics Definition
- Process Flow Map
- Medical Error Frequency, Trend, and Causal Analysis
- Root Cause or FMEA Analysis

Ride-Along Assessment

The Ride-Along is the portion of the assessment wherein an outside observer (ideally, one who has a solid grounding in basic Lean principles) accompanies each pharmacy worker throughout the course of the day. The objective is to create an unbiased set of observations of potential problems, and in order to do this the observer doing the Ride-Along must have no pre-conceived notions.

The results from the Ride-Along will be in the form of a simple list. The purpose of this listing is to create a beginning point for ideas both big and small. In the early stages, improvements may be ranked according to ease of implementation. While undertaking some of these small tasks may not affect overall system performance, early victories tend to improve acceptance of more appreciable changes to come.

Metrics Definition

The metrics used to judge performance in healthcare also parallel those of many manufacturers in that they either do not exist or are classically inappropriate. For example, "efficiency" is a metric commonly used in manufacturing but frequently misunderstood. Companies such as Sanford USA, Donaldson, etc., evaluate worker "efficiency" on the basis of how much product can be produced in a time period, irrespective of whether that product is needed or not, and the desire to score well on this measure results in excessive inventory. The definition of efficiency used in such cases does not in fact identify efficiency at all but rather speed relative to a more or less arbitrary standard. While speed is often a function of efficiency, the two terms are not synonymous. *The American Heritage® Dictionary of the English Language, Fourth Edition 2000,* defines efficiency as the ratio of the effective or useful output to the total input in any system. Speed is defined as a rate or a measure of the rate of motion.

Commonly used healthcare metrics are also problematic in that they include utilization and average delivery times as measures of performance. It is assumed that high utilization of equipment, personnel, or beds is desirable on the basis that such utilization justifies pre-existing expenditures. It is an accepted axiom in Lean principle, however, that high absorption merely constitutes evidence of system congestion. The average time to make a delivery is likewise a poor metric in that, by definition, half of all delivery times used to calculate the average must exceed that average. A system whose average time to meet a demand equals the target time to meet a demand will therefore fail fifty percent of the time while still being deemed successful.

Proper metrics must therefore be identified for use. Delivery lead-time is a logical metric if it is fully understood in terms of its distribution and variation. System efficiency must be established as a ratio of value-added time to total delivery time. Error frequency may be employed, as may cost per prescription filled.

Whatever metrics are selected at this stage, it is important that they are relevant to the manner in which the system functions and that their true mathematical meanings are understood by all involved. Those employees who have been through the Lean Training outlined in Phase 1 should have a grasp on this concept and may be charged with relaying the concept to others.

Process Flow Map

To this point, the activities occurring within the pharmacy have likely been defined in only the loosest of terms. Change can only begin to take place once a synergistic team is formed, and the key to synergy is communication. For this to occur, the team needs both a common language with which to describe processes and a beginning point of reference to build upon. The Value Stream Map is the tool of choice for manufacturing as it shows the linkage between information flow and material flow and makes wastes more visible. While these functions of a Value Stream Map are ideal for a pharmacy, the extent of variation in pharmacy activities at this stage limits the usefulness of most time-based data collected for a VSM. More suitable, then, is a basic Process Flow Map which may be modified into a VSM subsequent to the standardization in Phase 4.

Medical Error Frequency, Trend, and Causal Analysis

The objective of this step is a detailed accounting and ranking of error conditions. The outputs of this step should be:

- Listing of potential medical errors
- Frequency chart depicting the relative probability of occurrence for each potential medical error
- Frequency chart depicting the relative probability that any error originates during a given activity
- Series of moving average charts for each potential error, plotted over time (6 months up to a year)

For basic summation and charting, a spreadsheet application such as Microsoft Excel is an invaluable tool. Such an application not only allows the user to view graphs depicting frequency of occurrence for error conditions but also to incorporate lines depicting moving average values over time. The value here is that the moving average offers insight into an error condition's trend, answering the question of whether frequency should be expected to increase or decrease given existing conditions.

Root/Cause Analysis

For root-cause analysis, the Ishikawa Diagram is a standard tool that has been consistently proven both effective and readily understood. This tool follows a basic pattern that presents a problem condition, asks the question of why it occurred, subsequently asks why the cause occurred, and so forth until all underlying root-causes have been exposed. While there is some redundancy between steps 4 and 5, the root/cause analysis attempts to take much of the information gleaned from the data analysis and place it into a framework. What the root/cause analysis should reveal is that many medical errors will have similar causes, many of which will be sited as "human error".

Lean Pharmacy Phase 3: Workplace Organization

Workplace organization is essentially the elimination of chaos producing conditions. 5S Principles typically employed for Lean Implementation (Sort, Set in order, Shine, Standardize, and Sustain) provide the basic approach. In order to ensure success, however, a degree of planning is called for throughout the event. This thesis recommends expansion of the standard 5S as follows:

Ensure the success of the event by defining the scope of the event within the focused area

- Establish the expectations associated with the designated metrics
- Commitment from management
- Allocate resources

- Define a champion
- Establish plans and event logistics

Event deployment

- Clear – remove everything not required
- Tag questionable items
- Create a list of questionable items
- Set target date for disposition of tagged items
- Convey list and date to all relevant persons
- Get consensus that items should be removed
- Remove unnecessary items

Clean – all items allowed to remain

- Prioritize cleaning
- Sort remaining materials
- Initiate the 5S procedure

Organize

- Color/activity coordination
- Labelling

Lean Pharmacy Phase 4: Standardization

In order to assemble myriad functions together into a singular processing unit, it is first necessary to define those functions. Standardization allows this while at the same time enhancing supervisors' ability to properly schedule, making procedures that may lead to errors more distinct and addressable, and enabling new employees to more quickly grasp procedures. There are three steps in pharmacy standardization:

- System Identification
- Determining System Demand Schedule
- Breakdown and Balanced Reassignment of Duties

System Identification

One of the more notable contrasts between pharmacy and manufacturing is in the way that tasks are systematized. In manufacturing, a common tendency to arrange equipment into distinct departments results in what is known as a process oriented layout. Such a layout isolates subsequent aspects of a job's completion and inhibits the smooth flow of the work. In a pharmacy, however, systemization tends toward the opposite extreme. The work required for multiple, disparate objectives is frequently mingled due to limited manpower, constant prioritization of tasks, and poor planning. Essentially, several unique systems overlap, losing their distinctiveness and consistency. The results of this are marked confusion, a feeling of inundation, and the incessant interruption/resumption of tasks.

Before pharmacy flow may be made efficient, the web of systems must be untangled and ordered. This may be done by once again returning to the definition of "system": a group of entities working together to achieve a similar purpose. Purpose is the key. Every purpose (filling a cart, rectification of records, etc.) and its associated tasks represent one system. Once systems are identified, they may be both properly aligned and prioritized at the macro level and better enhanced at the sub-system or task levels.

Determining System Demand Schedule

Having identified the distinct subsystems within the pharmacy, it is important to note that each subsystem will have differing levels of demand placed upon it throughout the course of the day. Resources will have to be rededicated periodically as needed.

Breakdown and Reassignment of Duties

As part of his study on the effect of varying levels of illumination on pharmacists' prescription-filling accuracy, Buchanan ascertained the effect of prescription workload on dispensing error rate(Buchanan, 1989). The study incorporated direct, undisguised observation and retrospective prescription review over a period of twenty-one consecutive working days in an Army outpatient pharmacy. Ten pharmacists dispensed 12,492 prescriptions. Of these, a total of 422 (3.38%) were found to have errors either in drug content or labeling. The effect of the total number of prescriptions dispensed by a study pharmacist on the number of incorrect prescriptions dispensed by that same pharmacist was investigated. Regression analysis was performed on the individual workloads and errors and showed that the relationship between them is in fact linear. These findings correspond to those of an earlier 1983 study wherein the relationship between workload and the rate of "serious" errors in outpatient prescription dispensation was found to be linear(Guernsey et al, 1983).

While the literature establishes the fact that increasing workload results in increasing dispensation errors in pharmacy, the relationship is generally accepted at this surface level and decomposed no further. This thesis proposes that the relationship has multiple inter-related facets as follows:

- A perceived heavy workload may result in a tendency for the pharmacist to divide his attention among many simultaneously performed tasks, with an end effect being that no one task ever receives his complete attention. Unplanned or improperly planned "multi-tasking" then fosters a state of perpetual distraction.
- A perceived heavy workload results in a tendency to prioritize. Constant prioritization serves to further distract the pharmacist.
- Prioritization may result in a tendency to leave tasks semi-completed as higher priority tasks present themselves. Upon the pharmacist's return to the semi-completed task, the potential for error increases.
- The need to complete a heavy workload within a limited amount of time creates stress. Miller and Swains 1986 *Handbook of Human Factors/Ergonomics* provides evidence that the probability of human error for a skilled worker under moderate stress is double that of the same

operator under normal stress conditions. Very high stress levels are cited as resulting in a human error rate increase factor of five.

The best means of addressing the error-inducing effects of heavy workload is the reduction of the workload into a series of shorter, discrete tasks. Such a division reduces the stress for the employee who feels inundated by the daily requirements. Further, when tasks are properly systematized, the need for prioritization is diminished. This in turn allows tasks to run from beginning to completion without interruption. An added benefit is that scheduling becomes easier and more judicious. All of this then implies that work must be standardized.

While standardization of work within the pharmacy environment is a necessary step, it is also one of the Lean initiatives likely to engender heavier resistance. Work standardization carries with it a certain set of connotations derived from its general use in manufacturing. In manufacturing, standards typically refer to a sequence of pre-defined tasks and corresponding times prescribed for the shop floor to produce a unit of output within a static environment. A pharmacy is arguably more dynamic: a semi-static environment where the workload has both predictable componets and variable components. For this reason, standardization within the pharmacy must be approached with an appropriate seven step procedure.

Step 1: Document all activities performed in the pharmacy.

The first step in pharmacy standardization involves capturing all aspects of the existing state in concise form and in one place on paper. This will include a list of all tasks performed, by whom each task is performed, associated times and frequencies. This documentation will allow the outsider a better understanding of work he may not be familiar with while at the same time allowing the insider a more objective view of work with which he may have become too comfortable.

Step 2: Benchmark the relative performance of the pharmacy.

Comparison of activities documented in Step 1 to either industry standards or available information from neighboring pharmacies may help in identification of potential improvement areas.

Step 3: Break all pharmacy activities down into the smallest logical task.

Many activities are unnecessarily performed in batches, increasing the per-unit and average completion time. (Proper sequencing of activities will be more fully discussed in Phase 5 on Flow.)

Step 4: Distinguish between short tasks and long tasks.

Tasks such as inventory reconcilliation or on-site clinical responsibilities may not be divisible. The difference in time requirements for tasks may be substantial, and therefore particular scheduling considerations must be made so that longer tasks have minimal interruption.

Step 5: Ensure that every task is assigned to an appropriate employee.

There are some tasks in a pharmacy that are required by law to be performed by pharmacists. Many are not. As a pharmacist is a more expensive resource than a technician, and a substantially more expensive resource than a data-entry clerk, an effort should be made to ensure that a pharmacist's time is properly utilized . Identify current pharmacist activities that may be reassigned.

Step 6: Establish a standard routine.

A set routine reduces confusion. Short tasks such as order-filling will likely occur throughout the day but may require more workers during high-demand hours. Long tasks may be performed during lower-demand periods of the day as worker capacity becomes available. Less frequent tasks must also be scheduled over the course of the month or year.

Step 7: Document each task and the new standard routine.

Posting and this documentation eases the training of new employees and makes it easier to percieve required updates.

Lean Pharmacy Phase 5: Creating Flow Patterns

This phase of Lean Pharmacy implementation focuses on creating an environment wherein the pharmacy meets the demands of its customers without allowing the delivery of those demands to overwhelm or deter the quality of the work being performed. There are two aspects to flow, the Single-Stimulus interface and the Cyclic Flow Pattern.

The Interface with the Pharmacy

In addition to workload and stress, environmental variables also come into play in the causation of prescription-filling errors. Allan (1994) cites the following likely sources of error as noise, sound, conversation, interruption, and distraction. Figure 3.5 shows Allan's proposed model of the relationship among key variables.

Noise

Noise is defined by Burrows (1960) as an "auditory stimulus or stimuli bearing no informational relationship to the presence or completion of the immediate task". A 1969 study found that excessive energy is required to adapt to unpredictable noises and that there was a significant increase in the number of proofreading errors found for groups exposed to changing noise conditions (Glass et al, 1969).

Sound

Sound is defined as a change in loudness bearing some informational relationship to the presence or completion of the worker's immediate task at hand.

Conversation

Jones and Broadbent (1991) state that intelligible and irrelevant speech disrupts performance. Unintelligible speech falls under the "noise" classification. Conversation is not related to the task at hand.

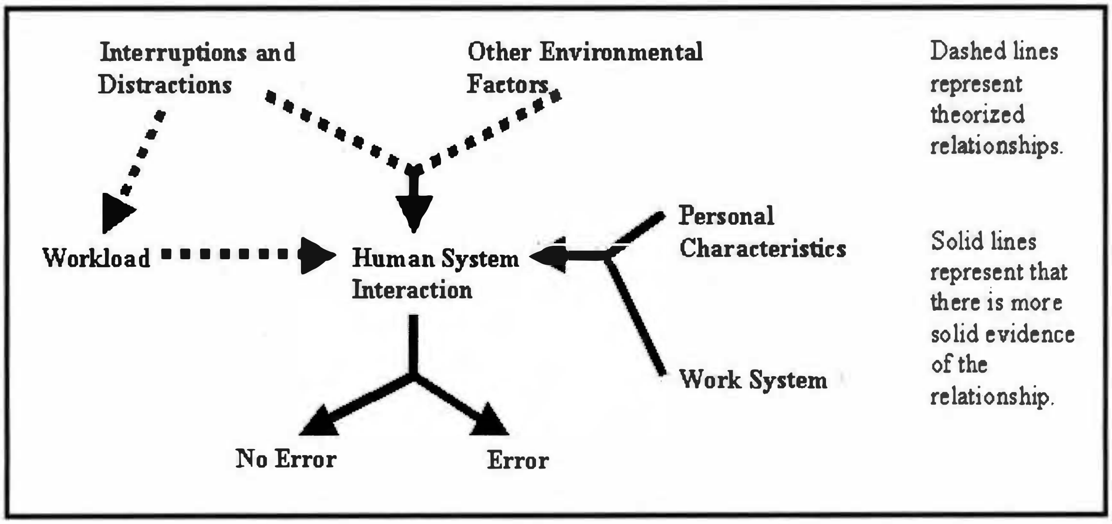


Figure 3.5: Relationship Between Environmental Factors and Human/System Interaction

Interruptions

An interruption is defined as "the cessation of productive activity prior to completion of the current task element for any externally-imposed, observable or audible reason." Mandler (1964) states that workers have a tendency to want to complete an interrupted task and that this creates a state of tension in the worker that remains until he or she is able to do so. He further states that interruption leads to repetition of work and this clearly decreases efficiency.

Several studies support the theory that interruption is a contributor to decreased pharmacy performance. A 1988 study found that interruptions due to telephone calls or people were perceived as the most stressful job situation among pharmacists surveyed (Wolfgang et al, 1988). A 1989 case study found that twelve of sixteen pharmacists felt that their performance was adversely affected by interruptions (Allan, 1989). A 1991 survey of pharmacists from several diverse pharmacy settings found that being interrupted while performing job duties was the most stressful job situation (Ortmeir and Wolfgang, 1991).

Distractions

A distraction is a stimulus from a source external to the worker that is not followed by the cessation of activity. The worker continues productive efforts while responding in a manner that is visibly or audibly observable. Distraction has been shown in certain cases to result in a worker's tending to rush tasks, presumably in an effort to escape the distraction (Wright, 1988).

Creating the Single-Stimulus Interface

As Lantos (1958) suggests, "work areas for preparing medications should be well-lighted, quiet, and relatively free of traffic". Telephone calls, requisitions made in person by other hospital staff, standard orders input by fax, form, or computer—each of these represents a competing external stimulus that disallows smooth first-in-first-out flow and increases the potential for human error. These stimuli must be eliminated, modified, or controlled. Given this information, the Lean-based principles of visual information relay may be used to great effect not only for their known contribution to efficiency but also in order to remedy environmental concerns. Creating a new Lean Pharmacy Interface is a three-step process.

Eliminate Unnecessary External Stimuli

Prior to elimination, it is necessary to understand the nature, frequency, and effect of all stimuli affecting the pharmacy area. To this end, it is advisable to undergo a study period wherein pharmacists may be asked to fill out forms such as the one pictured in Figure 3.6. The form in Figure 3.6 was developed specifically for the hospital observed in this thesis' case study as a means for determining which stimuli were most frequently associated with interruption of other activities.

Relative levels of sound, noise, conversation, and distraction may be less easily identified by workers and should be observed by an outsider or filmed. This information will be useful at each step of Interface redesign.

Interruption Log

Initials	Date /

Time	What Was Interrupted?	Source	Nature of Interrupt	Remedy	Time To Remedy
	O Putting Orders into Computer	O Window	O NEW Stat Order	O Correct MAR	O 1 Min
______	O Physically Filling Cart	O Phone	O Floor Stock Exhausted	O Explain discrepancy	O 5 Min
	O Charging	O FAX	O Procedural Question from within Pharmacy	O Explain procedure	O 10 Min
	O Putting together IV's	O		O Assemble new or replacement order	O 15 Min
	O Inventory Activities				O 20 Min
	O Assembling Order due ASAP		***MAR Does Not Match Drawer Contents***	O	O 30 Min
	O				O 45 Min
			O Too Many Doses in Drawer		O 1 hour
			O Too Few Doses in Drawer		O
			O Incorrect Med		
			O Dose does not match		
			O Frequency does not match		
			O Wrong Patient		
			O		

Figure 3.6: Interruption Log Form

It should be noted that one frequent source of interruption, the asking of questions regarding perceived mistakes originating from the pharmacy, may be cyclic and self-propagating. That is, an interruption regarding a mistake may in fact cause the pharmacist to make a second mistake as he leaves the task at hand to correct the prior error. In this case, breaking the cycle will likely implicitly reduce the frequency of occurrence of the stimulus even if it is not explicitly eliminated.

Explicit elimination of stimuli may incorporate:

- Movement of the pharmacy itself to a lower traffic area.
- Soundproofing the pharmacy against outside noise.
- Re-location of workers within the pharmacy.

Translate All External Stimuli into a Single Form

Given that a pharmacy is a system that must produce on-demand in order to meet the needs of the hospital it serves, it is clear that most stimuli cannot be eliminated in the first step. These necessary stimuli are now considered. Although questions, orders, and requests may not be eliminated, they may be modified into a form in which necessary information is conveyed visually and silently. This purpose may be served by the introduction of several printed forms incorporating concepts of kanban. Appropriate task-specific forms may then be used to drive all on-demand activities within the pharmacy.

Phone queries should be completely discontinued, as the nature of the telephone serves largely to distract or interrupt. Only outgoing phone calls should be the norm. Any query or request previously made by phone should now come in on a proper form through a dedicated fax machine.

Walk-up requests may also be handled through the use of a similar form with explicit checkboxes explaining the nature of the query or request. It may also be advisable that existing windows be replaced with access slots only. Visitors should not be allowed to interrupt pharmacy procedures.

Prioritization Method for all External Work Requests

In order for the pharmacy to function well internally, external inputs will require regulation. The objective here is to create one visual interface containing all the information the pharmacy needs for prioritization—this will be a Job Request Center. The Job Request Center may incorporate multiple slots for holding job request forms and multiple fax machines for incoming orders. The Center may be color coordinated for prioritization, with each type of form having its own pre-assigned priority level/color.

Development of Internal and External Flow Patterns

Specific flow patterns will depend upon the nature of the particular pharmacy undergoing the lean implementation, but certain axioms can be put forth. Flow must be cyclic with each task path terminating at the origin point for the succeeding task. The most important of these nodes is the Job Request Center described in the previous section. Multiple concurrent task paths (and corresponding begin/end cycle nodes) may be necessary due to workload and the number of available individuals qualified to perform given activities. Task paths and worker allocation will likely have to change throughout the course of the day, falling into appropriate pre-established patterns that mirror demand changes occurring over the course of a day. High priority jobs may be done early in the day, with lesser priority activities occurring as resources become available.

The key to proper flow is ensuring that only one task is undertaken at a given time and that a given task always runs to completion prior to the beginning of another. In the case of order filling, this equivocates to a One-Patient Flow wherein all the medications prescribed for a patient are collected and made ready for administration prior to the beginning of filling for the next patient. This concept is similar to the One-Piece Flow commonly referred to in the literature on manufacturing and invites all the benefits seen in that industry. These established benefits include an increased flexibility, decreased inventory of work-in-process materials, and improved level of control. Of more particular interest to pharmacy, the reduction of task interruption lessens the potential for medical error.

Lean Pharmacy Phase 6: Inspection of Proposed Flow Patterns

Before a full implementation of new flow patterns is undertaken, it is logical to first test the proposed improvements in a virtual environment. Simulation is an ideal method for establishing the proofs for several reasons. Modern technology makes simulation both relatively inexpensive and time-effective. Since changes may be made in a virtual environment, multiple trial scenarios may be evaluated with no detrimental effect on the actual system. Further, simulation offers the advantage of time compression and allows the collection in minutes of data that an actual system would take years to generate.

The simulation process entails first the generation of a model representing the current state of the system in question. This model must be verified by expert opinion or via a statistical comparison between historical values and model-generated values for given parameters. Since error creation is of primary concern in this model, and a history of error creation was collected in Phase 2, it is logical to use this parameter as the comparison basis. If the computer model can generate the same average output as the historical average output, then the computer model may be said to be verified. Comparison occurs with a T-test, Wilcoxon Signed Rank test, or sign test, depending on the nature and quantity of available data. Specifics on testing are covered in Chapter 4 of this thesis.

Having a verified baseline model allows the user to experiment with differing configurations of the proposed flow patterns and the impacts of reduced stress. Pessimistic and expected-case scenarios may then be generated in order to convey to management the probable nature of impacts to the system.

Lean Pharmacy Phase 7: Sustaining Improvements

Perhaps the most challenging aspect of change is in the resistance of falling back into old habits. For this reason, a periodic evaluation by both an insider and an outsider from some hospital area other than the pharmacy is recommended. An insider knows how well established parameters are being met. An outsider may offer new insight useful in further improvement. Tracking these evaluations along with metrics such as delivery time and error frequency data will over time create a picture of how far the pharmacy has come. This then allows the participants to view progress in very certain terms, enhancing overall pride and satisfaction.

Chapter 4

Case Study: Baptist Memorial Hospital-Collierville, TN

Baptist Memorial Hospital-Collierville opened May 1, 1999. Medical services at the hospital include a sleep disorders center, a birthing center and Level II nursery, outpatient rehabilitation, inpatient and outpatient surgery, critical care unit, full-service emergency room, inpatient and outpatient diagnostics, five surgery suites, 48 acute care beds, six critical care beds and six LDRP (labor, delivery, recovery, and postpartum) beds. The facility is currently in an expansion phase, endeavoring in 2004 to open a Physician's office building, new diagnostic center, a new 24-bed unit served by its own nursing station, and an expanded Sleep Disorders Center.

In May 2003, Baptist was compelled by partner/stockholder General Electric to begin investigating approaches for improving overall efficiency and reducing the frequency of medical error. Baptist contacted The Center for Industrial Services (CIS) at the University of Tennessee. CIS in turn contacted Dr. Rupy Sawhney, Associate Professor at the University, who would oversee the project.

It was decided that the project would focus on the hospital's pharmacy. Work took place on the project from May to November of 2003. Information on the pharmacy's inner workings was collected during this period. In November of 2003, a number of factors including internal politics, a restructuring in administration, and a continuing concern over short-term profitability led to the premature termination of the project.

This chapter interprets the events at Baptist and incorporates the methodology developed in Chapter 3 with the data collected by the project. In doing so, an assessment is made of the points at which Baptist deviated from Lean Pharmacy Methodology and a corrected approach is offered. This corrected approach comprises a specific plan of action derived from the more generalized Lean Pharmacy Methodology. The simulation model developed in Phase 6 serves to demonstrate the viability of both the concepts and specific approach.

Lean Pharmacy Phase 1: Amelioration of Pharmacy Cultural Issues

Stress Profile

The three pharmacists and two technicians working within the pharmacy were asked to complete a survey assessing the stress profile of the department. The survey itself is based on Hossine's modification of Rice's work (Hossine, 2004). Complete results may be viewed in Table 4.1. Of particular note are fields 51 through 57, giving a strong indication of dissatisfaction with the workplace.

Engendering Acceptance through Ownership

Throughout the course of the project it became clear that ownership of activities within the pharmacy rested and would continue to rest with the pharmacy supervisor. The pharmacy supervisor had been a key participant in developing the current-state systems and therefore possessed a strong sense of proprietorship. Critiques of the existing system were taken personally; suggestions and questions were generally met with passive-aggressive resistance.

Table 4.1: Results of Stress Profile Survey

#	Stress Profile Field	Respondents Answering 0% Of Time	Respondents Answering 25% Of Time	Respondents Answering 50% Of Time	Respondents Answering 75% Of Time	Respondents Answering 100% Of Time
1	Support personnel are incompetent or inefficient	0%	20%	40%	40%	0%
2	My job is not very well defined	40%	40%	20%	0%	0%
3	I am not sure of what is expected from me	40%	60%	0%	0%	0%
4	I am not sure of what will be expected of me in the future	0%	40%	20%	0%	40%
5	I cannot seem to satisfy my superiors	40%	40%	20%	0%	0%
6	I seem to be able to talk to with my superiors	0%	20%	0%	20%	60%
7	My superiors strike me as incompetent, yet I have to take orders from them	60%	40%	0%	0%	0%
8	My superiors seem to care about me as person	0%	20%	0%	0%	80%
9	There are feelings of trust, respect and friendliness between me and my superiors	0%	20%	0%	20%	60%
10	There seems to be tension between me and my superiors	40%	40%	20%	0%	0%
11	I have autonomy in carrying out my job duties	0%	0%	40%	20%	40%
12	I feel as though I can shape my own destiny in this job	20%	60%	0%	0%	20%
13	There are too many bosses in my area	40%	40%	20%	0%	0%
14	It appears that my boss has "retired on the job"	60%	40%	0%	0%	0%
15	My superiors give me adequate feedback about my job performance	0%	0%	40%	20%	40%
16	My abilities are not appreciated by my superiors	20%	40%	20%	20%	0%
17	There is little prospect for personal or professional growth in this job	20%	0%	0%	20%	60%
18	The level of participation in planning and decision making at my place of work is satisfactory	0%	20%	20%	40%	20%
19	I feel I am overeducated for this job	20%	0%	40%	40%	0%
20	I feel that my education background is just right for this job	0%	20%	40%	20%	20%
21	I fear that I will be laid off or fired	0%	40%	20%	20%	20%
22	In-service training is inadequate for my job	20%	40%	20%	0%	20%
23	Most of my colleagues are unfriendly or seem uninterested in me as a person	40%	20%	20%	20%	0%
24	I feel uneasy about going to work	40%	40%	20%	0%	0%
25	There is no release time for personal affairs or business	20%	80%	0%	0%	0%
26	There is obvious sex/race/age discrimination in this job	60%	20%	20%	0%	0%
27	The physical work environment is crowded, noisy, or dirty	20%	40%	40%	0%	0%
28	Physical demands of the job are unreasonable	60%	20%	20%	0%	0%
29	My work load is never ending	20%	20%	20%	40%	0%
30	My pace of work is too fast	0%	20%	80%	0%	0%

Table 4.1: Continued

#	Stress Profile Field	Respondents Answering 0% Of Time	Respondents Answering 25% Of Time	Respondents Answering 50% Of Time	Respondents Answering 75% Of Time	Respondents Answering 100% Of Time
31	My job seems to consist of responding to emergences	20%	0%	80%	0%	0%
32	There is no time for relaxation, coffee breaks, or lunch breaks on the job	20%	20%	20%	40%	0%
33	Job deadlines are constant and unreasonable	20%	40%	40%	0%	0%
34	Job requirements are beyond the range of my ability	60%	40%	0%	0%	0%
35	At the end of the day I am physically exhausted from work	20%	20%	60%	0%	0%
36	I cant even enjoy my leisure because of the toll my job takes on my energy	20%	60%	20%	0%	0%
37	I have to take work home to keep up	80%	20%	0%	0%	0%
38	I have responsibility for too many people	40%	60%	0%	0%	0%
39	Support personnel are too few	0%	40%	0%	40%	20%
40	Support personnel are incompetent or inefficient	0%	40%	40%	20%	0%
41	I am sure of what is expected of me	0%	20%	0%	40%	40%
42	I am not sure of what will be expected of me in the future	0%	20%	40%	0%	40%
43	I leave work feeling burned out	20%	0%	40%	40%	0%
44	There is little prospect for personal or professional growth in this job	0%	40%	0%	0%	60%
45	In service training is inadequate for my job	0%	80%	0%	20%	0%
46	There is little contact with colleagues on the job	20%	60%	20%	0%	0%
47	Most of my colleagues are unfriendly or seem uninterested in me as a person	20%	20%	40%	0%	20%
48	I feel uneasy about going to work	20%	40%	40%	0%	0%
49	The complexity of my job is enough to keep me interested	0%	20%	40%	40%	0%
50	My job is very exciting	20%	20%	20%	40%	0%
51	My job is varied enough to prevent boredom	0%	20%	40%	40%	0%
52	I seem to have lost interest in my work	0%	40%	40%	20%	0%
53	I feel as though I can shape my own destiny in this job	40%	20%	20%	20%	0%
54	I leave work feeling burned out	0%	40%	60%	0%	0%
55	I would continue to work at my job even if I did not need the money	80%	20%	0%	0%	0%
56	I am trapped in this job	60%	0%	20%	0%	20%
57	If had it to do all over again I would still choose this job	20%	0%	60%	20%	0%

Compounding this problem was the fact no other pharmacy employees felt a strong degree of interest in acquiring ownership. Input-gathering sessions were largely met with indifference. This was not unexpected given the results of the stress profile.

Lean Education

A deficiency in Lean Education almost certainly had some bearing on the level of resistance with which the project was met. Baptist management hoped to take advantage of the benefits of a Lean Implementation but on the basis of short-term costs and employee availability chose to forego training of pharmacy employees. This omission exacerbated the existing situation and forestalled the integration of perceived usefulness among pharmacy workers.

Lean Pharmacy Phase 2: Assessing the Existing State

Ride-Along Assessment

On August 16, 2003, this Ride-Along Assessment was performed. This took place over a six-hour period deemed by the pharmacy staff as typical and exemplary. The assessment is broken down according to functional area or activity. The listing shows multiple areas of potential improvement and may serve as the basis for a Kaizen-style event.

Area 1: Cart Delivery

Cart Delivery is performed as one daily milk-run wherein a loaded pharmacy cart is trucked from hospital location to subsequent location. This task is performed by one pharmaceutical technician and takes approximately one hour. The cart itself is made up of numbered cartridges ostensibly corresponding to the numbers of patients' rooms. A set of cartridges is delivered in each of six different hospital areas. Notes collected during this activity included:

- The cartridges for each station are all beige. They are not color-coded, and this misses an opportunity for mistake-proofing.
- Medicines and keys ride unsecured on top of cart.
- Key-code must be entered for access to the hospital birthing center. This differs from all other areas, and no reason can be given as to why.
- Not all medicines are stored in similar locations in all areas. ICU medicines are stored in overhead cabinets with top drawers being difficult for technicians to see into. Some medicines are stored in hospital corridors, others in isolated rooms.
- Medicines were observed to be located outside of the ICU cabinet and were not ordered or labeled. No system is in place to account for non-narcotic drugs once they have left the pharmacy.
- The locations dedicated to drug storage may be arbitrarily changed by hospital employees in their respective areas. It was observed that the technician had to ask where medicines should be placed in Outpatient Surgery. There is no standard or visual indicator.

- The technician's keys are labeled but not color-coded. The technician must take time to read the label on each key when delivering meds from the cart. Technician was observed to try two keys at birthing center prior to finding the correct one.
- Keys are single-sided. Double-sided keys may eliminate time lost seeking proper orientation when unlocking doors.
- Boxes on the floor in various locations including the pharmacy impede the movement of cart.
- A PRN medication which should have been left on the floor was taken by accident and had to be sent via air tube back up to the nurses' station. There was no visual indication that the drug needed to be left where it was.
- Bags removed from drawers are placed atop the cart rather than being fed directly into the shredder.

Area 2: Pick Station

The pick station is an area where the more commonly used drugs are localized for prescription-filling. This displays a logical application of ABC theory, though the method used to select the most commonly used drugs does not rely on current data nor is it updated on a regular basis.

- While drugs are alphabetized at the pick station, labels are not uniform and must be scrutinized carefully so that a mistake is not made.
- Containers are not color-coded.

- Containers have open tops and may be filled to brimming. There is a potential that drugss may find their way into incorrect containers.
- All meds removed from the cart are placed into a single bin, from which they are later sorted and returned to inventory. This adds an additional step which may take in excess of an hour.
- Location of certain meds within pick station may require significant reaching.

Area 3: Inventory

- Different areas are assigned to individuals, and an inventory is expected once per month. There is no formal schedule.
- Out of Stock meds are listed in a "want-book", which a pharmacist uses to order replacement meds. This task does not require a pharmacist, but a pharmacist performs the activity.

Area 4: Scheduling

- Weekend work typically is held over until Monday morning.

Area 5:Narcotics

- Narcotics sheets hold upwards of 40 patients and become increasingly difficult to read as they are filled.
- Narcotics requisitions may come to the pharmacy via the air tube, adding one more means by which input reaches the pharmacy.

- The mix of narcotics kept on the floor is variable and depends on nurses' decisions on which meds they want on the floor.
- Meds are typically dispensed by the box for ease of inventory determination.
- Narcotics sign-out book is subject to monthly accounting.
- Narcotics sheets are audited by state government.
- A signature was found to be missing from one narcotics sheet during the visit. Procedure for getting delinquent signatures involves sending e-mail and holding sheet at pharmacy. Time to correct ranges from 20 minutes to 4 months. This occurs frequently.

Area 6:Pharmacy Layout

- Both full and empty cardboard boxes may be found on the floor.
- One full cardboard box was observed being used as a doorstop .
- Shelf labels are small and difficult to read. General areas containing similar products are not delineated. Color-coding is not used.
- There are no signs designating areas such as Pick Station, IV room, storage, etc.
- Pharmacy is located on first floor while most delivery stations (excluding ICU) are located on the second floor.

Metrics Definition

Metrics defined for this project included, in order of relevance:

- Frequency of Error Commission

- The time required to perform tasks
- Employee Satisfaction with the new system

Process Flow Map and Process Interaction Maps

The Pharmacy Process Flow Map depicted in Figure 4.1 outlines the current state of the pharmacy's functionality. An amalgamation within the process of activities that cannot be separated into discrete sequences reveals a system in need of proper definition.

The Process Interaction Map in Figure 4.2 illustrates the interface between the pharmacy and those areas it serves. Note here that information and requests enter the pharmacy via as many as five direct and indirect media, and that this results in confusion, distraction, and stress elevation.

Medical Error Frequency, Trend, and Causal Analysis

Figure 4.3 includes a listing of all known potential error conditions and their historic relative frequencies of occurrence over a six-month period. Of all errors recorded, 42% were related to dosage (and consistently cited as "human error").

Figure 4.4 displays relative frequency for any error condition to have a given point of origin. Again, the largest percentage of errors occur in the dispensation phase with "human error" cited as the primary causal factor by those interviewed.

Trend analysis for each error condition appears in Figure 4.5. For each error type, the trend line (formulated from a moving average calculation) indicates whether

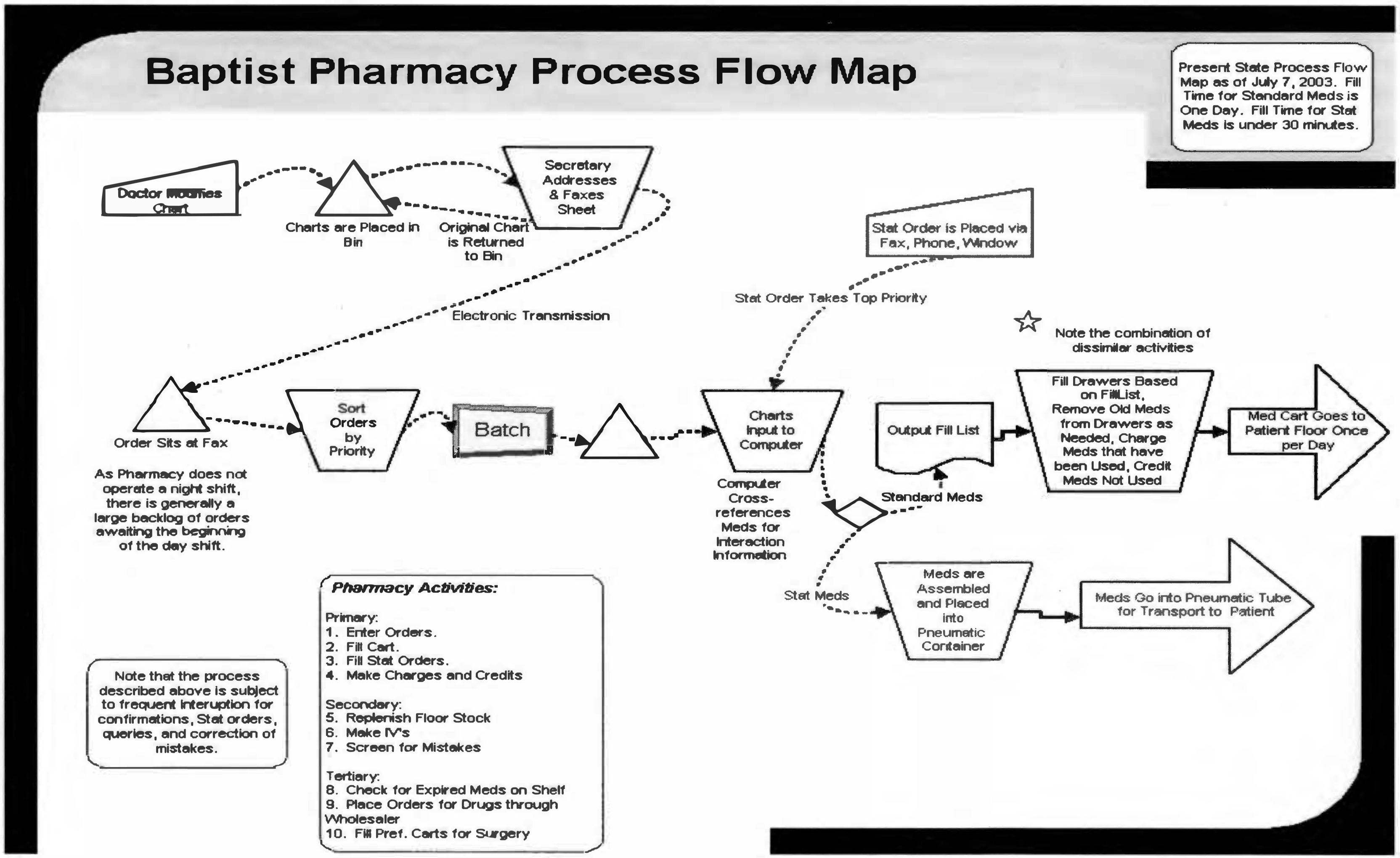


Figure 4.1: Process Flow Map

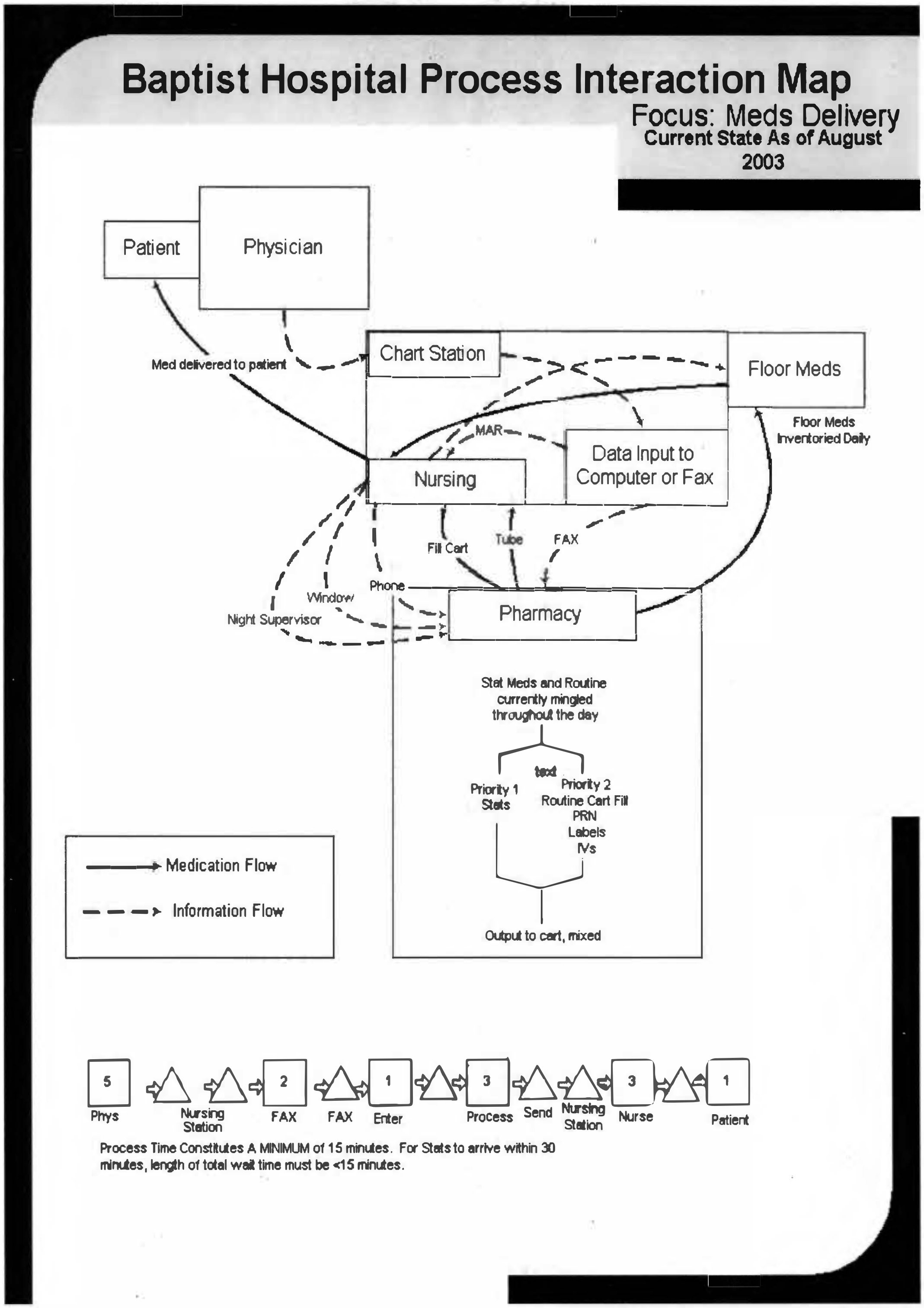


Figure 4.2: Process Interaction Map

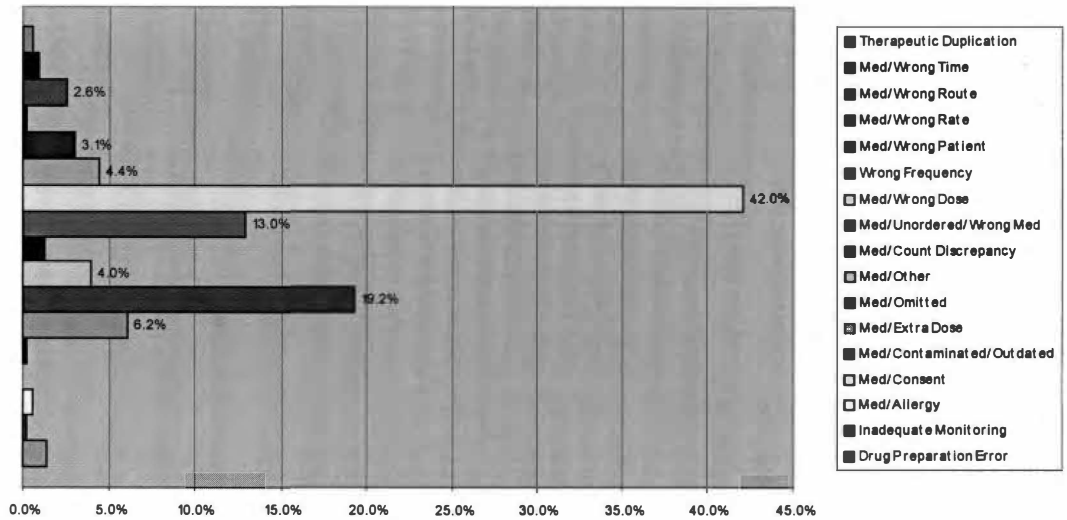


Figure 4.3: Relative Error Frequencies

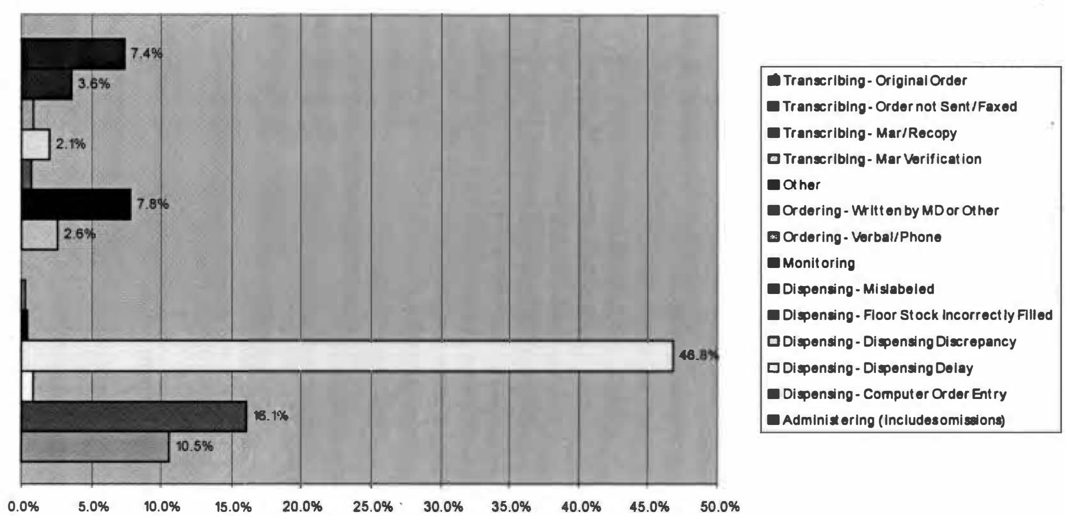
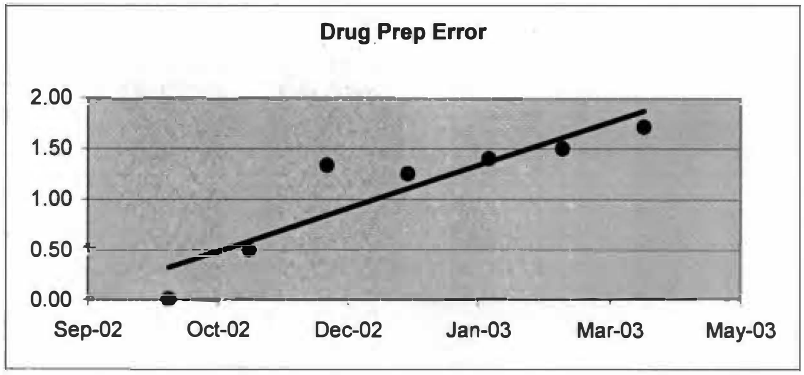
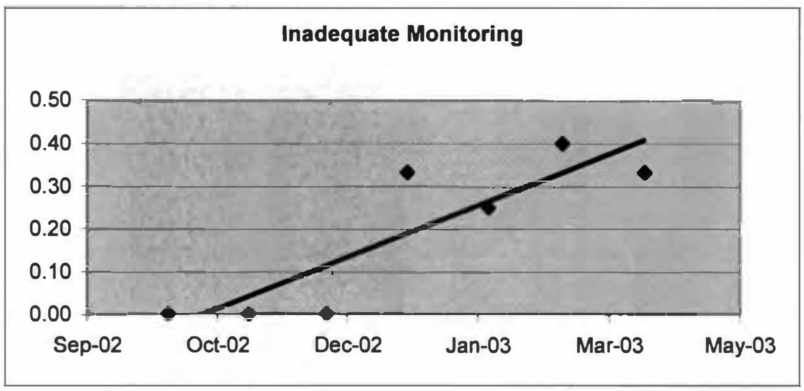


Figure 4.4: Relative Error Origin-Point Frequencies

(A)



(B)



(C)

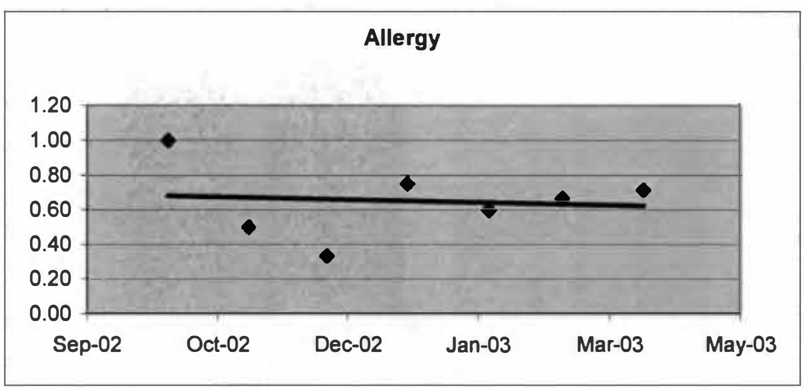
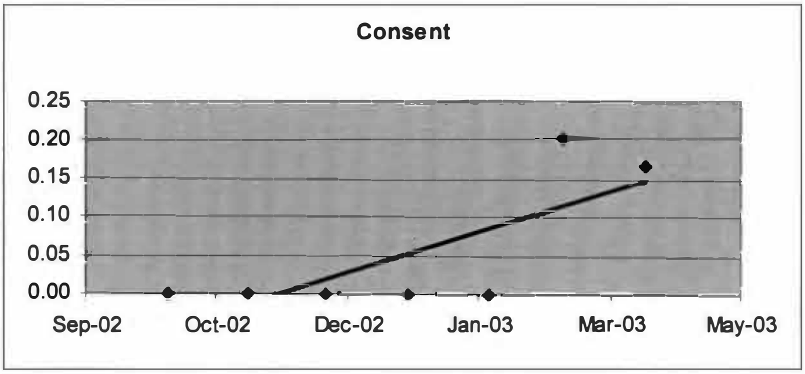
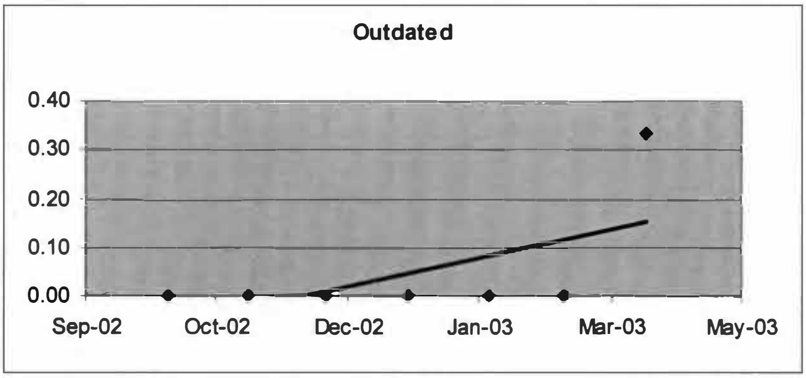


Figure 4.5: Trend Analysis for Pharmacy Error Conditions

(D)



(E)



(F)

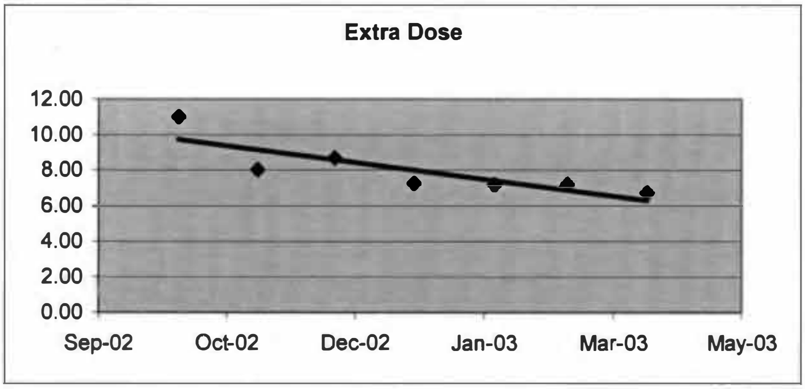
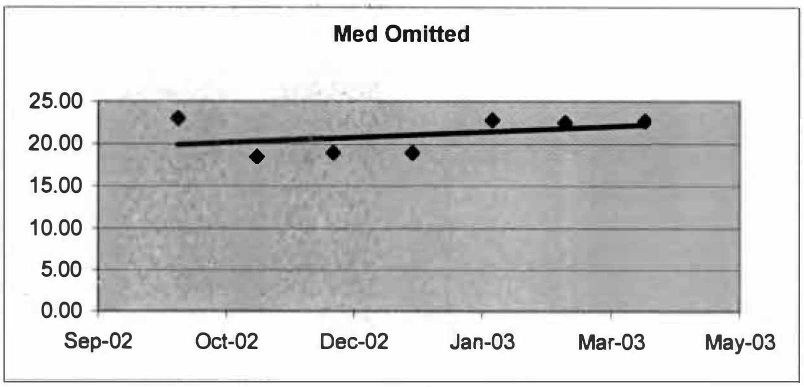
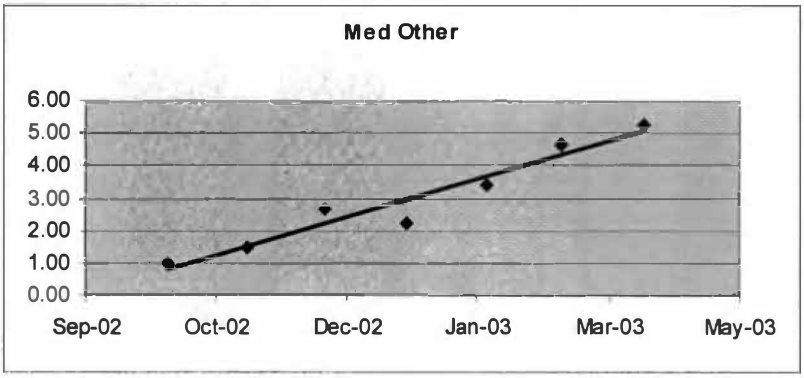


Figure 4.5: Continued

(G)



(H)



(I)

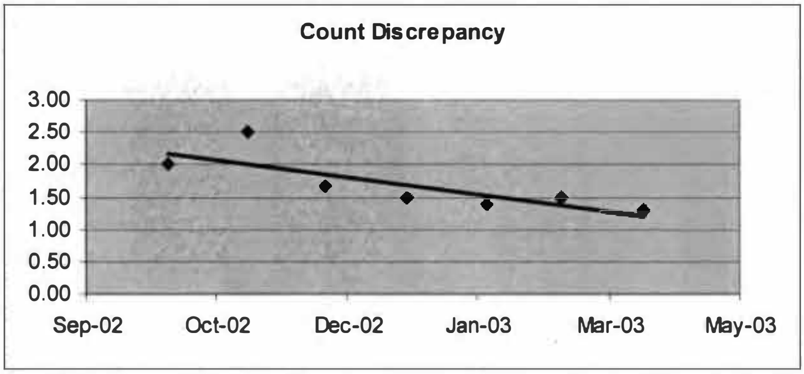
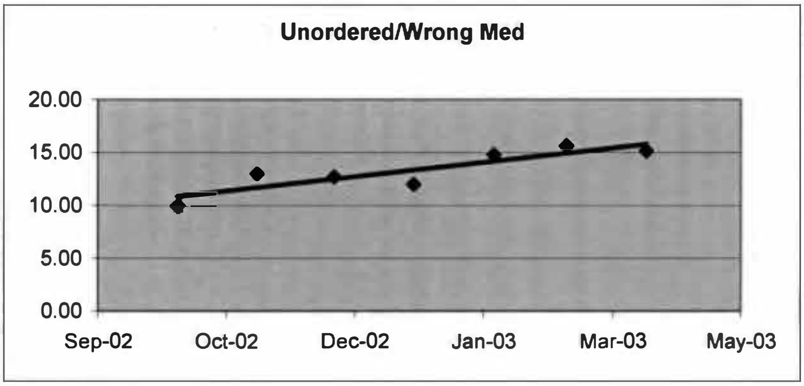
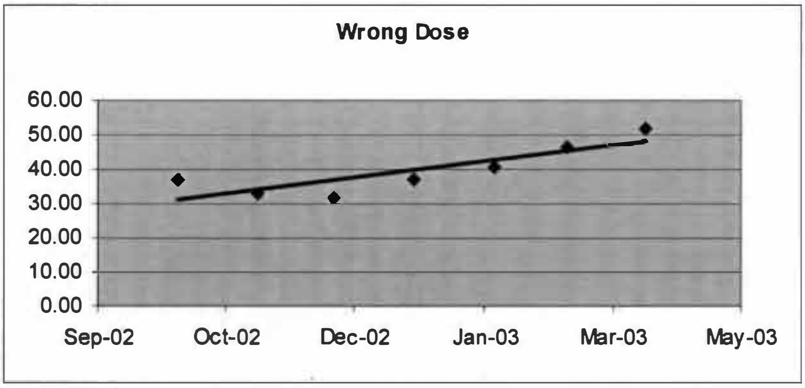


Figure 4.5: Continued

(J)



(K)



(L)

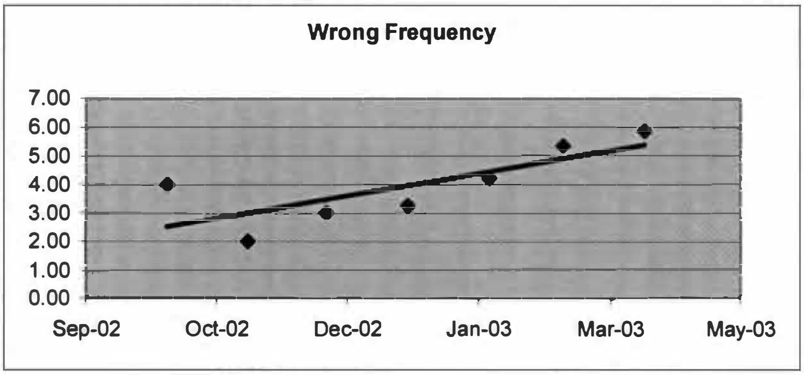
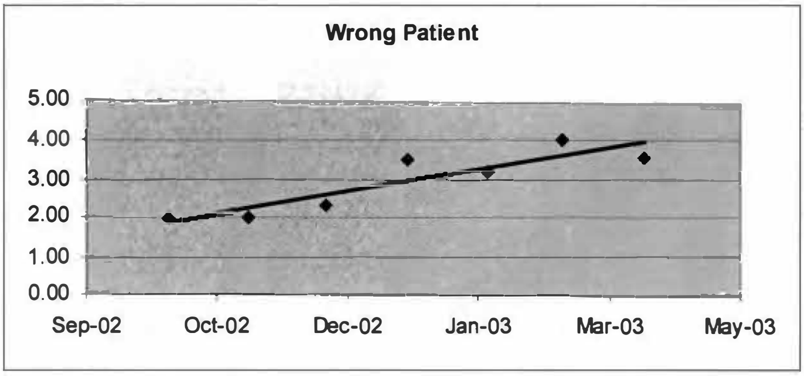
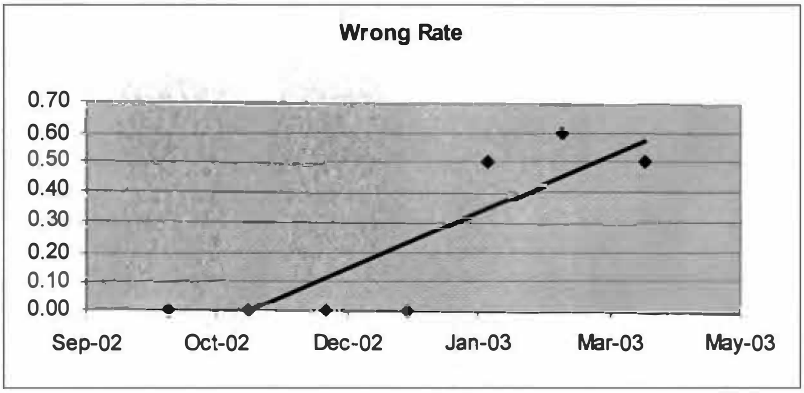


Figure 4.5: Continued

(M)



(N)



(O)

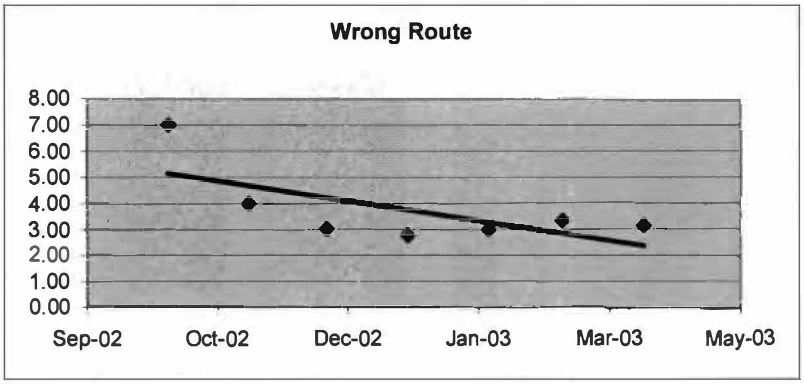
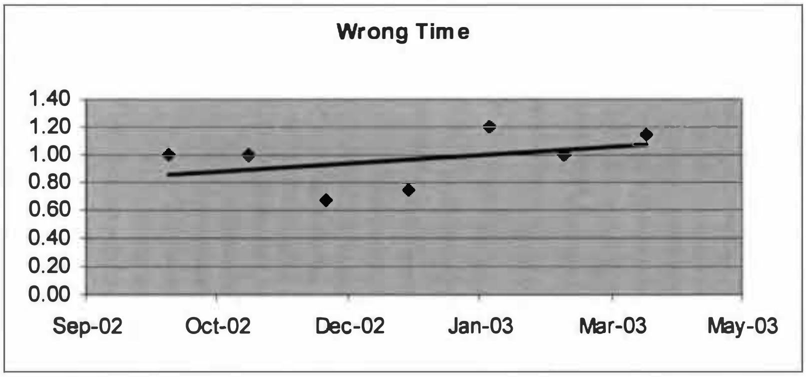


Figure 4.5: Continued

(P)



(Q)

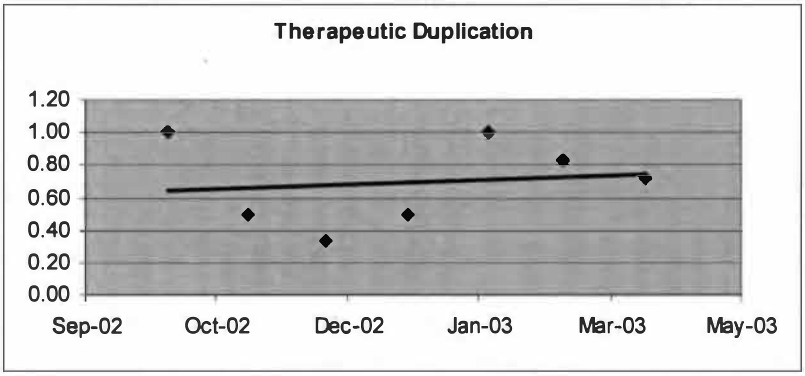


Figure 4.5: Continued

the frequency of that error is currently increasing or decreasing. This analysis shows that most errors are becoming increasingly common within Baptist-Collierville. Without intervention, frequency is likely to increase.

Root/Cause Analysis

Root cause analysis performed with the pharmacy staff quickly became enlightening as the ultimate root cause defined for all problems taken under consideration was "human error". This again was a clear indication of a system in need of both mistake-proofing measures and elimination of environmental factors known to increase the likelihood of human error.

Lean Pharmacy Phase 3: Workplace Organization

Space would serve to constrain the extent to which more radical reorganization could occur within the Baptist pharmacy, but this point became moot as a potential relocation to the Hospital's new addition further quelled the workers' already limited interest. Areas noted during the Ride-Along Assessment would have proven particularly beneficial in this phase, especially those related to color-coding and standard information relay.

Lean Pharmacy Phase 4: Standardization

Work performed within the pharmacy is presently systemized in only the most general and informal manner—many activities occur differently from one day to the next, responsibility for each activity shifts randomly from one individual to another throughout the course of the day, and the schedule is very loosely defined.

System Identification

By determining who the pharmacy's customers are, it becomes more apparent what systems must be in place to meet those customers' needs. Referring back to Figure 4.2, one notes that systems include:

- The Cart Fill and Delivery Scenario
- Random Individual Request Filling Scenario
- Floor Stock Replenishment and Inventorying

Determining System Demand Schedule

Baptist's current scheduling of capacity appears in Table 4.2. Workers are scheduled on the basis of a simple schedule rotation, with no consideration given to capacity requirements. This consistently results in an unbalanced workload wherein those employees working over the weekend are completely inundated with tasks that must be prioritized. On Monday mornings a period of very high activity dissipates work left over from the weekend. In order to create a foundation for Lean, these workloads must be balanced.

As the demands placed on the pharmacy vary significantly throughout the course of the day, it is logical to have capacity flex into three different pre-defined arrangements. The key is standardization. The nature of the system during the morning and through the middle part of the day will follow a pattern designed to fill

Table 4.2: Current State Schedule Rotation

Day	Pharmacists	Technicians	Employees Total
Saturday	1	2	3
Sunday	1	2	3
Monday	3	2	5
Tuesday	2	2	4
Wednesday	3	2	5
Thursday	2	2	4
Friday	3	2	5

the cart as quickly as possible. At a certain point, orders that had backed up will become depleted, and manpower may be reallocated to other tasks necessary to keep the pharmacy running. It will be at this point that systems for refilling floor meds and PRNs will be activated. Finally, remaining duties such as inventory control or IV preparation may be scheduled during the remaining hours.

Breakdown and Reassignment of Duties

Pharmacy Activities are broken down in Table 4.3.

Staff interviews revealed that one pharmacist functions as a technician at most times throughout the week. Further, many functions of both pharmacists and technicians are clerical in nature and require no advanced degree or governmental regulation. When asked why employees of a high pay grade were tasked to the point of overtime with duties which could readily be reassigned to employees of a

Table 4.3: Daily Pharmacy Activities Breakdown

Activity	Approximate Time	Performed By
Order Entry	8 Hours	Pharmacist 1
Order Entry	As Available	Pharmacist 2
Order Entry	As Available	Pharmacist 3
Narcotics Reconciliation	2-5 Hours	Pharmacist 2
Trays	2 Hours	Pharmacist 2
Monitor Phone	Varies	All Pharmacists
Check Cart	Varies	All Pharmacists
Clinical Duty	6-7 Hours	Pharmacist 3
Cart Delivery	1-1.5 Hours	Technician 1
Charges and Credits	2-3 Hours	Technician 1
Fill Cart	2-3 Hours	Technician 1
Make IV	2 Hours	Technician 2
Inventory IV	2 Hours	Technician 2
Floor Stock	4-5 Hours	Technician 2

significantly lower pay grade, the response was that budget allowances were made by the hospital on the basis of number of individual workers. That is, the pharmacy supervisor was given a permission to employ a certain number of employees. Pay grade was not a factor, and it was therefore desirable to have employees of the higher pay grade as they could process a wider range of functions.

Narcotics reconciliation, drug ordering, and charge/credit processing are all tasks that, combined, constitute up to eight hours of employee working time per day that could be reassigned to clerical staff. While this would entail a slight alteration in budgeting, the potential savings more than justifies the change.

Lean Pharmacy Phase 5: Creating Flow Patterns

Creating the Single-Stimulus Interface

In order for the pharmacy to function well internally, external inputs require regulation. Once protocol is established, the level of chaos within the pharmacy becomes more readily controlled. The objective here is to create one visual interface containing all the information the pharmacy needs for prioritization—this will be a job request center. Creation of the job request center entails the use of separate fax machines for stat (urgently needed) and regular meds. Having orders arrive via separate faxes ensures that orders arrive but remain separated based on priority level. Last-in-first-out should be the procedure for meds within a given priority level.

Questions or med requests coming through a pharmacy window should be done through use of a simple form the visitor may fill out and slide into a job request queue. When the next available worker sees a window form in the queue, it will be given priority over Regular meds, but not Stat meds. Visitors are no longer allowed to interrupt pharmacy procedures. It is further advisable that the existing window be replaced with a slot. This eliminates the potential for individuals at the window to try to persuade pharmacy workers to change the order of tasks.

Phone queries should be completely discontinued, as the nature of the telephone serves to distract. Only outgoing phone calls should be the norm. Any query or request previously made by phone should now come in through another dedicated fax machine, where it will enter a queue receiving the same priority as window queries. A standard form with explicit checkboxes explaining the nature of the query or request should be used.

Eliminate Unnecessary External Stimuli

Explicit elimination of stimuli may incorporate:

- Movement of the pharmacy itself to a lower traffic area.
- Soundproofing the pharmacy against outside noise.
- Re-location of workers within the pharmacy.

Development of Internal and External Flow Patterns

The plan developed for Baptist is broken down into flow pattern scenarios that will differ throughout the course of the day.

Cart-Fill Scenario (Morning)

One of the keys to reducing error is eliminating the need for employees' attention to be divided. To this end, it is recommended that the goal for each worker become single-patient flow. Single-patient flow essentially means that one or more employees process the work associated with one patient, and only one patient, from beginning through completion. The worker does not accept additional requests in any form until his task is completed.

Figure 4.6 illustrates the assignment of two functional areas. Area 1 represents the input and data processing side of the operation. An employee functioning in this area follows a loop. When he finishes inputting one patient's data, the employee then walks back to the job request area and selects one new job form. Selection is based on priority, and priority is established based on the job request's location in one of

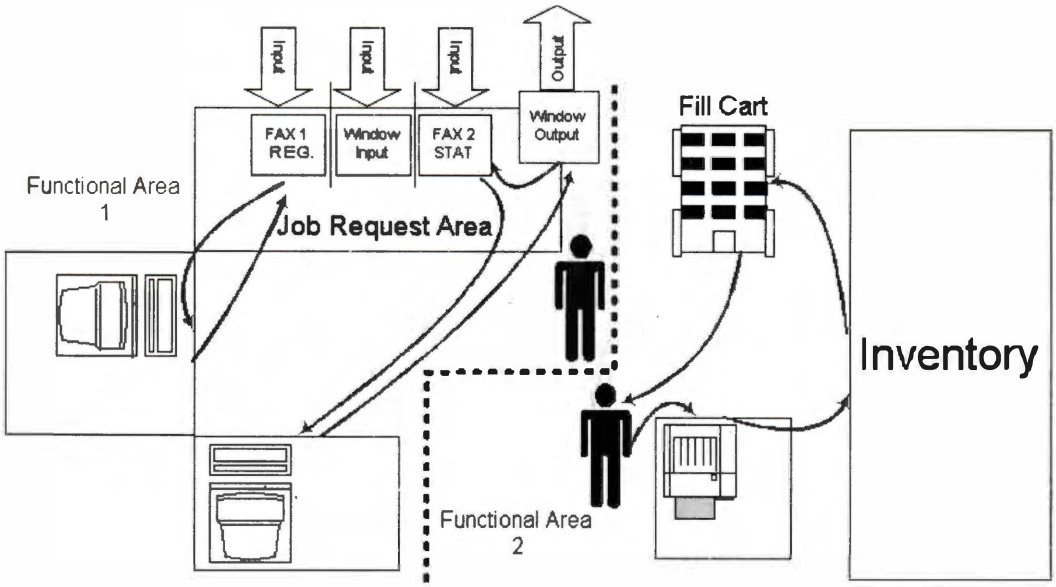


Figure 4.6: Work Flow Pattern (Internal)

three queues. This worker then returns to his computer for inputting. In the case of a query having been submitted at the window input queue, the pharmacy employee returns the answer to the window output queue, picks up his next job request, and proceeds in the same pattern.

Functional area 2 incorporates the tasks associated with filling the cart, also performed on a one-patient-at-a-time basis. An employee in this area picks up one fill request from the printer, proceeds to fill that order, places it into the cart (or tube), and returns to the printer. A fill list is no longer employed, as it represents batching within the operation and increases the potential for errors to arise. Multiple employees working in this functional area may be set into what is known as a rabbitchase pattern, wherein a few minutes is allowed between the beginning times for each worker so that cross traffic is minimized.

The amount of time it then takes to begin processing a stat order will be the amount of time taken to process an order in the slowest functional area divided by the number of employees in that area. Stat orders must be designated as such. They may be printed on a secondary printer by functional area 1 and placed into a box near functional area 2's printer/work request area.

Floor Meds And PRN Discretionary Medications (Mid-day)

All medications given on a discretionary basis should be accounted for in the same way. The current system wherein some of these meds are charged prior to use and some are charged subsequent to use is needlessly confusing, and may be eliminated by choosing to charge only meds that are used from a PRN storage cabinet located in the patient care area. This storage cabinet may have compartments for each room/patient, and a set supply of discretionary medication (likely, two days worth, so that the pharmacy need only make one trip to the Nurse station per day) will be allocated. When a worker from functional area 1 encounters a job request for a new patient and that patient has as-needed meds, he will process the order and the nurse on the floor upon receiving the order will place the meds in the proper drawer, removing any existing as-needed meds to a secondary storage unit. It is also the function of the nurse on the floor upon administering the med from this storage area to initial a replenishment card (with med/patient ID/Room Number) and place it into a slot on a board. The pharmacy will fill the as-needed meds cart in the same manner outlined above, one at a time, drawing from a queue of replenishment cards. The pharmacy employee will on a daily basis bring meds up to the floor based on cards collected the previous day, distribute the meds, collect new cards and discontinued PRNs, and return to the pharmacy. Observe Figure 4.7.

Tertiary Activities (Late Day or Weekly)

Crediting unused meds and returning them to stock will become a late day activity and may be carried out in the same manner in which the cart was originally filled. Activities such as placing orders, inventories, etc., will need to be listed and decisions will need to be made on their frequency of occurrence.

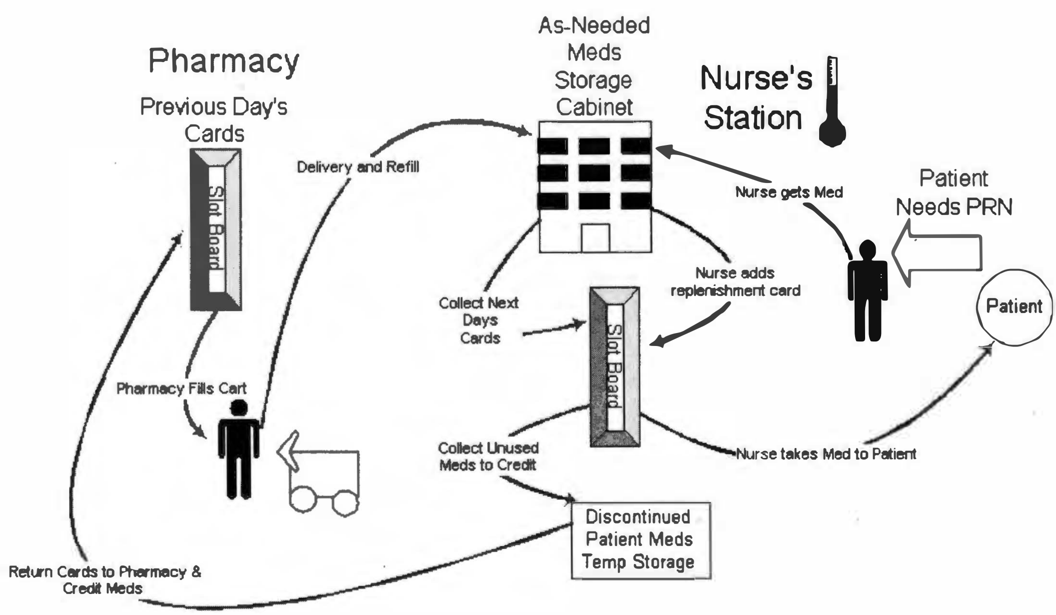


Figure 4.7: Work Flow Pattern for Floor Medications

Lean Pharmacy Phase 6: Inspection of Proposed Flow Patterns

This phase builds upon the work already presented by describing the impacts of the proposed approach in quantified terms. A series of three computer simulations and accompanying statistical analyses serve as a proof that the changes proposed for the Baptist Pharmacy would result in significant improvement.

Simulations were created using Rockwell Arena 5.0 software. Best-fit information and plotting of distributions associated with sample data were created using an Input Analyzer program packaged with the Arena software. Statistics and Wilcoxon tests were calculated with Microsoft Excel, part of the Microsoft Office 2000 desktop software package. T-tests were performed with the JMP Statistical Software.

Simulation Run 1: Baseline

In order to make a meaningful comparison between successive simulation runs it is first necessary to create a baseline model representing the existing state at Baptist. This model was generated based on historical time data collected from the facility and the facility's flow charts. This module may be viewed in Plate 1 as "Baptist_Simulation_Month.doe". This simulation is based on the following assumptions:

- A sample size, or replication, consists of data collected over a simulated 30-day period. This is in keeping with the format of Baptist's historical data, which is summarized by month.

- For purposes of this study, the variation in times required to perform activities will be fully described as random. No special factors will affect successive daily or monthly outcomes.
- Each day, a set number of tasks must be performed. These fourteen tasks and the times associated with them are outlined in the table below.
- Based on survey results, the base model is assumed to represent a high-stress environment. Likelihood of error commission associated with each employee takes this into consideration.
- Interruptions occur at random intervals according to the distributions in the table.
- An interruption affects a given worker by increasing his potential for error commission for a random period of time based on the distribution in the table.
- Error commission results in a delay (value in table) for the worker to correct the error.
- Likelihood of error commission or interruption for each employee depends on relative complexity of tasks performed.
- Pharmacist 2 and 3 will assist Pharmacist 1 given that there is time available after completion of other tasks.
- Base time unit is one minute.
- The time to perform all tasks (excluding the primary order entry task for Pharmacist 1) is exponentially distributed. The primary order entry task for

Pharmacist 1 takes up a full workday and is therefore allowed to function as a constant. Table 4.4 exhibits input data.

The total number of errors occurring over the course of the month was selected as the primary response variable. Total time dedicated to performing all monthly tasks was selected as the secondary response variable.

In order to prove that the baseline model accurately represents the physical Baptist Pharmacy, the historical data for the primary response variable was compared to the output from the simulation model. Given that only seven months of data were available, sufficient proof does not exist that the data follow a normal distribution pattern. This then created the possibility that the data violated the assumption of normality inherent in the use of a t-test for assessing the sameness of the sample means. The Wilcoxon Signed-Rank Test was therefore employed as an alternative.

The Wilcoxon Signed-Rank Test differs from the t-test in that it assesses whether there is a difference in means without making any assumptions as to the distribution of the data. For small sample sizes with unknown distributions, this test is more sensitive than the t-test, and therefore more suitable in this case. The test does assume that samples are independent and that the distributions of the two sets of sample statistics are symmetrical, with matching distributions preferred. Independence of samples is programmed into the simulation. Figures 4.8 and 4.9 show the outcome of analysis for the historical data and the simulated samples, respectively. These analyses include best-fit data and show that the assumptions of symmetry and identical distribution hold.

Table 4.4: Baseline Model Input Parameters

Type	Parameter	Input
Task	Order Entry Task	480
Task	Narcotics Task	expo(225)
Task	Tray Fill Task	expo(60)
Task	Check Cart Task	expo(30)
Task	Cart Delivery Task	expo(45)
Task	Cart Disassembly	expo(20)
Task	Charges/ Credits	expo(120)
Task	Fill Cart Task	expo(180)
Task	Make IVs Task	expo(120)
Task	Inventory IVs	expo(60)
Task	Refill Floor Stock	expo(300)
Task	Clinical Task	expo(360)
Error Rate	Pharmacist 1	0.00131
Error Rate	Pharmacist 2	0.0026
Error Rate	Pharmacist 3	0.00185
Error Rate	Tech 1	0.0026
Error Rate	Tech 2	0.00313
Interruption Interval	Pharmacist 1	Norm(60, 6)
Interruption Interval	Pharmacist 2	Norm(33,3.3)
Interruption Interval	Pharmacist 3	Norm(33,3.3)
Interruption Interval	Tech 1	Norm(33,3.3)
Interruption Interval	Tech 2	Norm(33,3.3)
Universal	Error Rate Increase After Interruption	0.0045
Universal	Duration of Interruption Affect	expo(2)
Universal	Time to Fix an Error	expo(20)

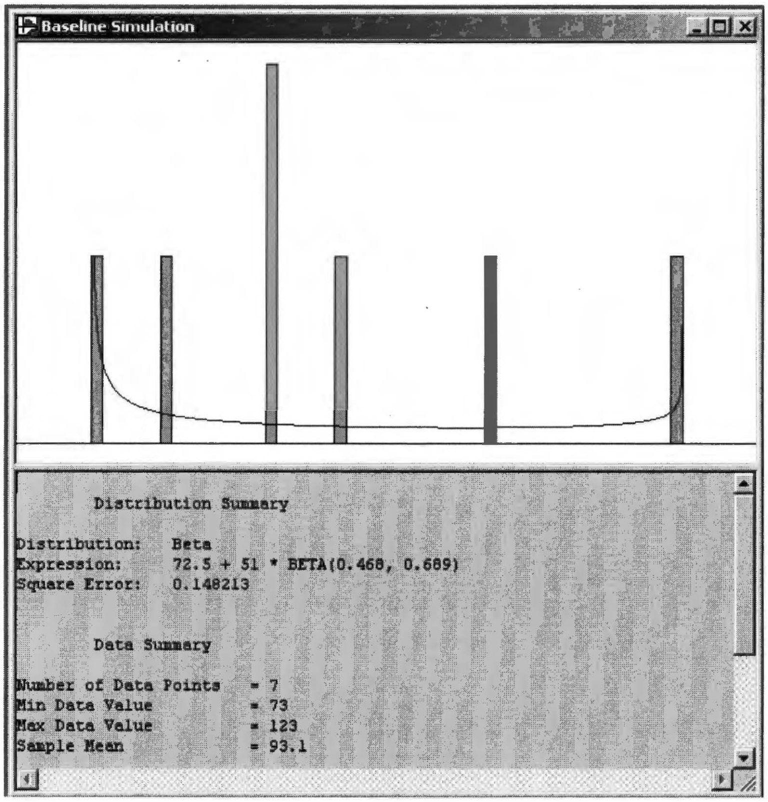


Figure 4.8: Distribution of Baseline Model, Small Sample Size

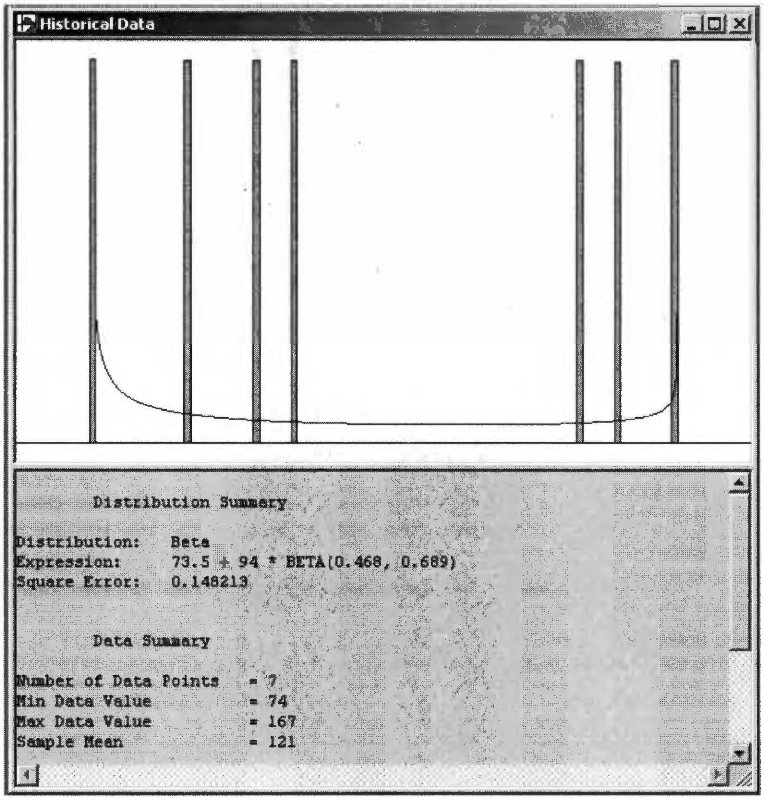


Figure 4.9: Distribution of Historical Data

Figure 4.10 illustrates the Wilcoxon procedure as it was formulated into a spreadsheet calculator, using macro features for ranking. The two sample sets are shown, with the test statistic calculated as 2. The hypothesis test is defined as H_0: $\mu_1 = \mu_2$ and H_a: $\mu_1 \neq \mu_2$.

For a sample size of 7 and a significance p=0.05, the test statistic does not fall into the critical region. The null hypothesis is not rejected, and this therefore allows the conclusion that the simulation represents the actual system.

Simulation Run 2: Direct Effect of Interruption Removed

This run assumes that the Lean Pharmacy strategy has been implemented and that all stimuli reaching the pharmacy system do so in one form through the job

			Rank!		reset		
Samples							
History	Simul	di=xi-yi	Abs value	Rank	Signed Rank	W+	W-
100	88	12	12	1	1	1	0
74	88	-14	14	2	-2	2	-2
89	79	10	10	3	3	3	0
106	73	33	33	4	4	4	0
158	123	35	35	5	5	5	0
167	94	73	73	6	6	6	0
152	107	45	45	7	7	7	0
						28	2
120.8571	93.14286						
						Statistic	2

Figure 4.10: Wilcoxon Calculator

request center. This scenario may be considered the “minimal impact” or “pessimistic improvement” scenario due to the fact that it assumes that only those effects directly linked to interruptions have been minimized. That is, since there are minimal interruptions, those periods of time immediately following an interruption wherein the propensity for error commission increases cease to be a factor. This scenario leaves all else constant, most notably the impact of stress.

The input parameters for Simulation Run 2 vary from those in Run 1 according in that the interval between interruptions for all employees is Norm(240,24). This change suggests that there will be about two interruptions per day per employee.

Each of the two runs was repeated in 70 month-long replications. The sample size of 70 was chosen as it is the largest value of n for which the reporting functions in Arena remain stable. A large sample size was desirable so that the likelihood of normality would be enhanced.

The output data for the total number of error commissions for both Run 1 (The Base Model, Figure 4.11) and Run 2 (No Direct Interruption Effect, Figure 4.12) normalize for large sample sizes. This normalization allows comparison of the means via a paired t-test. This testing shows that the average value for errors in Run 2 is reduced from that obtained from Run 1 and that there is a 95% chance that that reduction falls within the range from 5.5948 to 9.7195 errors (Figure 4.13). Run 2 therefore shows improvement over Run 1.

In terms of the total amount of time necessary to complete all tasks, outputs for Runs 1 and 2 may both be classified as normal (Figure 4.14 and Figure 4.15). A

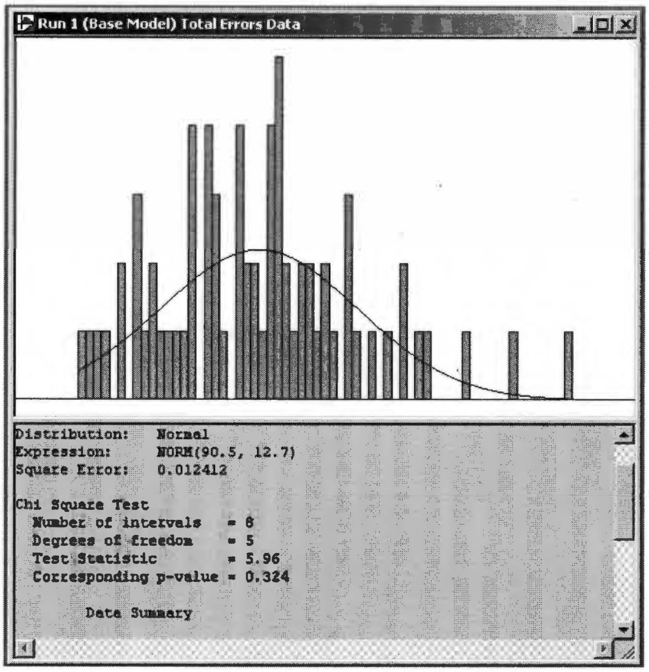


Figure 4.11: Distribution of Baseline Model, Large Sample Size

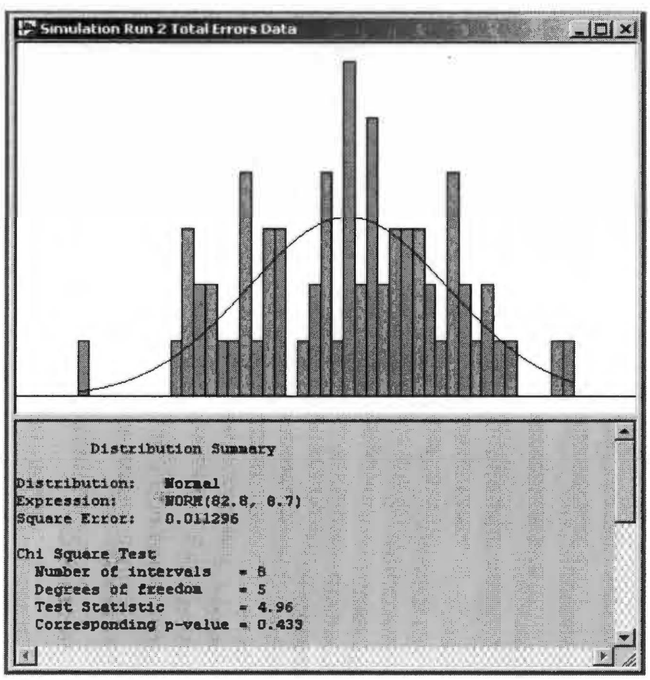


Figure 4.12: Distribution of Run 2 Output

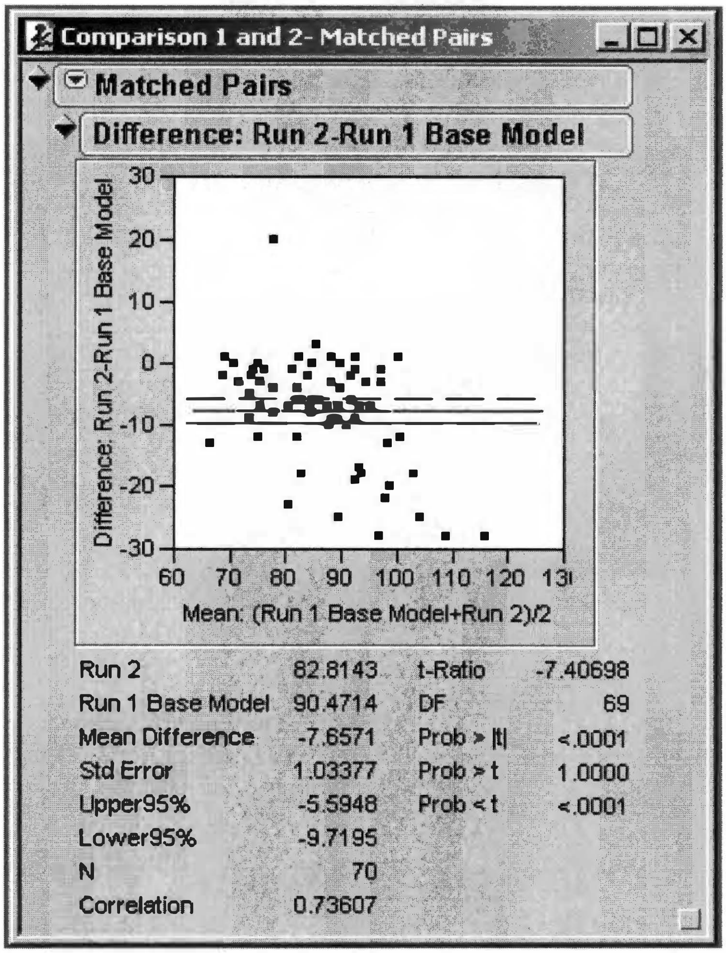


Figure 4.13: T-test, Run 1 Errors Compared to Run 2

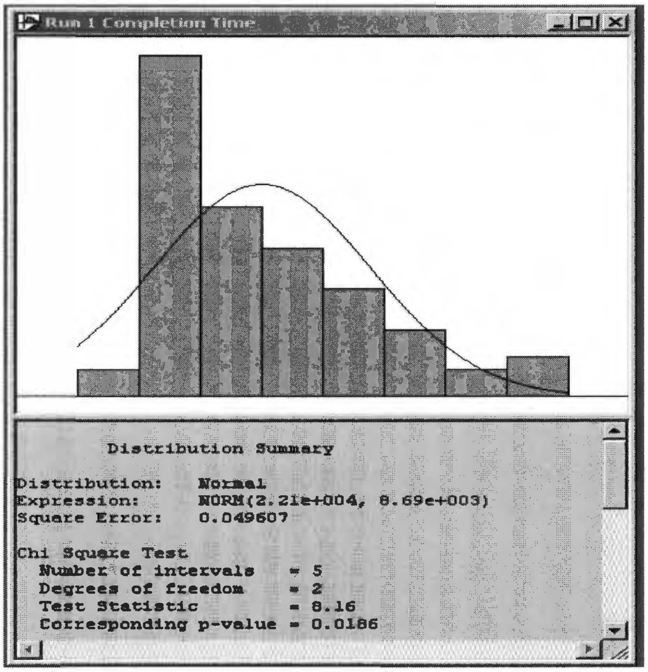


Figure 4.14: Run 1 Completion Time Distribution

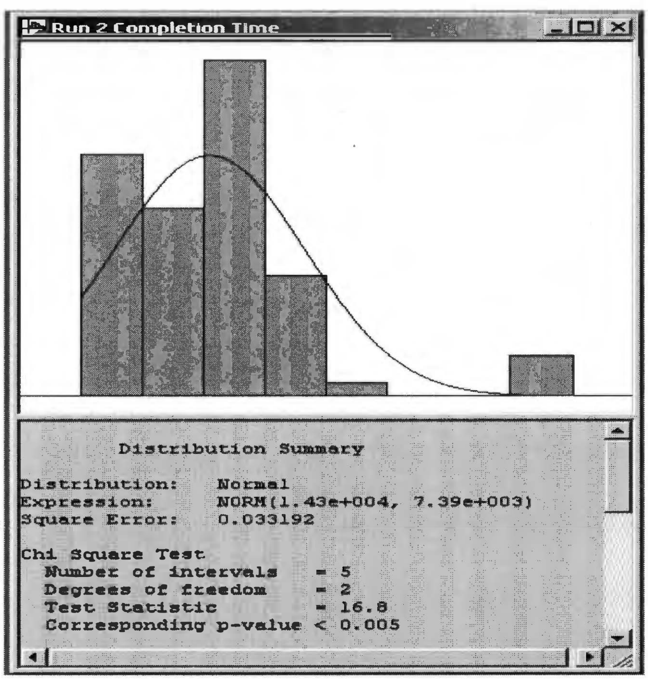


Figure 4.15: Run 2 Completion Time Distribution

comparison of Run 1 and Run 2 Time to Completion data (Figure 4.16) suggests that the 95% confidence interval for the difference between the means contains a zero value. A significant difference may not be inferred; given that case 2 represents the most pessimistic outcome, this result is not unexpected.

Simulation Run 3: Stress Effect of Interruption and Effects of Variability Reduced

Run 3 builds upon Run 2 and may be considered the "Expected Results" Scenario. Whereas Run 2 assumed that only the frequency of interruption was minimized, Run 3 further assumes that the associated stress and distraction factors must also decrease as a result of the minimization of interruption. Run 3 conservatively assumes a decrease in stress level from high to moderate (although the level is more likely to approach low levels given time), and therefore incorporates a reduction in the potential for error of 3/5 according to the Miller and Swain model (1986). Run 3 inputs are listed in Table 4.5.

The distribution table (Figure 4.17) for Run 3 Total Errors output data shows that the output is clearly normal and therefore meets the criteria for a paired t-test with Run 2 outputs. The t-test analysis (Figure 4.18) shows a definite statistical difference, with the mean of Run 3 error outputs being lower than those of Run 2 by between 47.797 and 51.146 at a 95% confidence level. Run 3 shows a marked improvement over both Runs 1 and 2.

Run 3 compares more favorably than Run 2 to Run 1 in terms of Completion Time. Run 3 completion time data are shown to be approximately normal (Figure 4.19). The paired t-test in Figure 4.20 shows that there is proof that the difference in

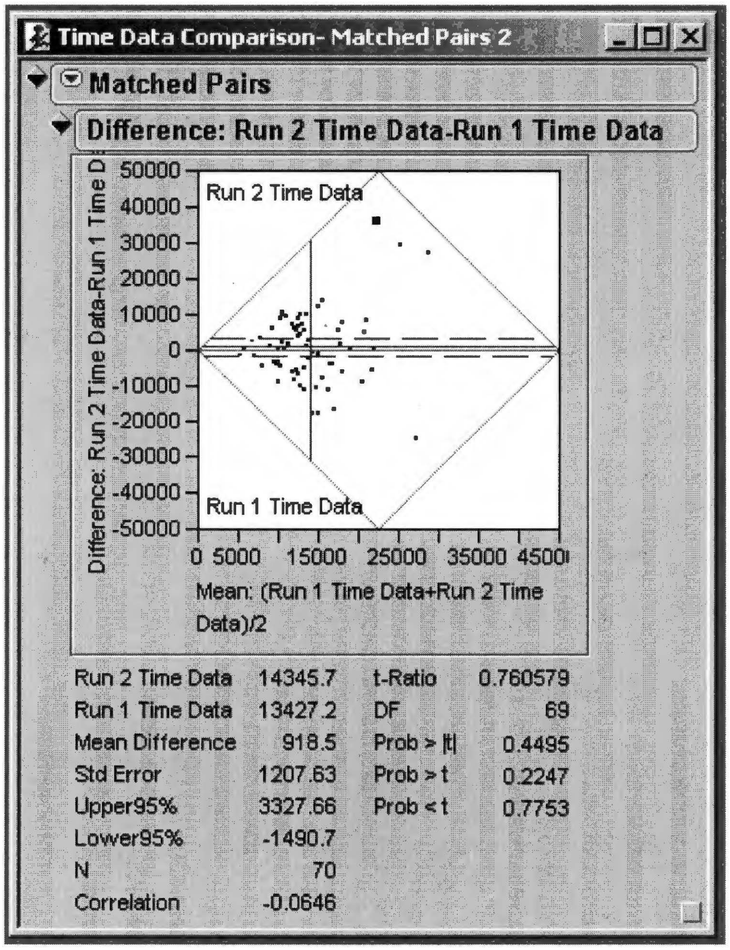


Figure 4.16: T-test, Run 1 Completion Time Compared to Run 2

Table 4.5: Error Potential Inputs

Parameter	Input
Pharmacist 1	0.000524
Pharmacist 2	0.00104
Pharmacist 3	0.00074
Tech 1	0.00104
Tech 2	0.001252

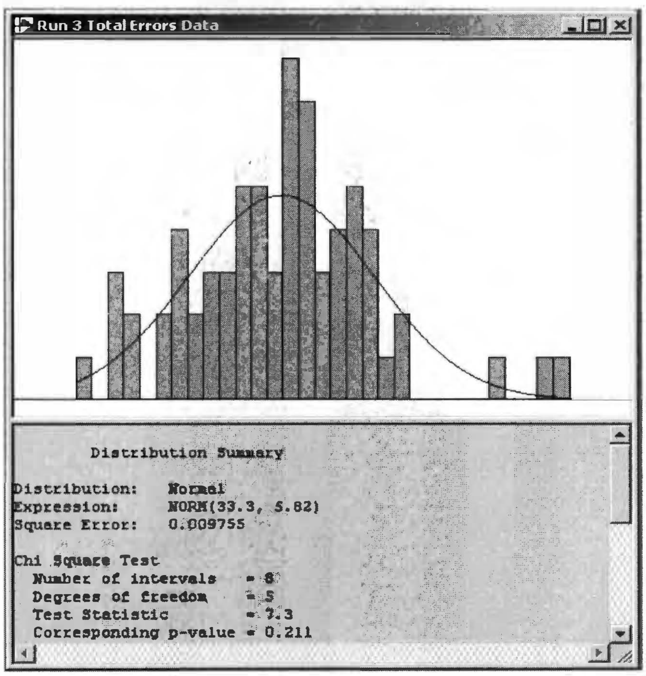


Figure 4.17: Run 3 Errors Distribution

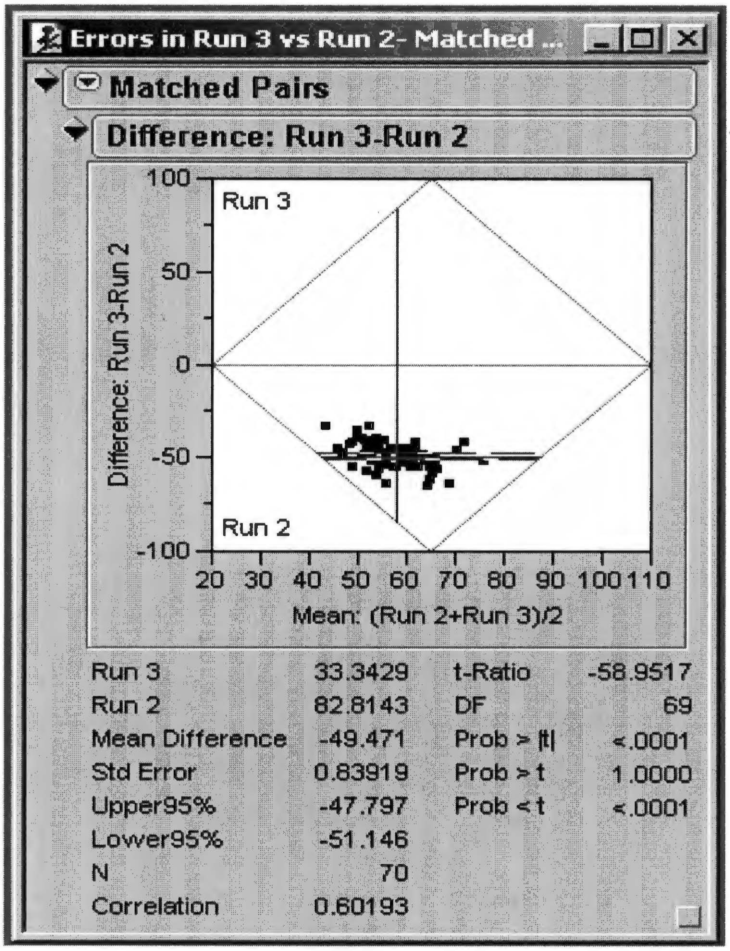


Figure 4.18: T-test, Run 2 Errors Compared to Run 3

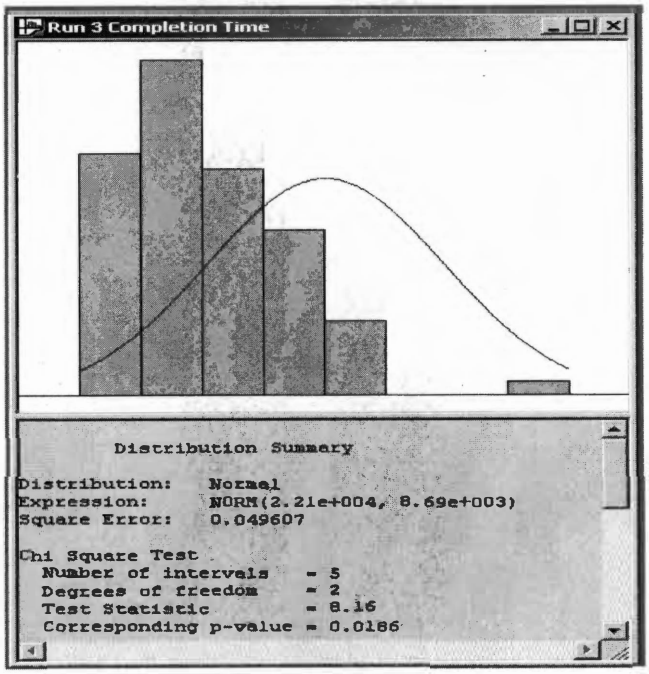


Figure 4.19: Run 3 Completion Time Distribution

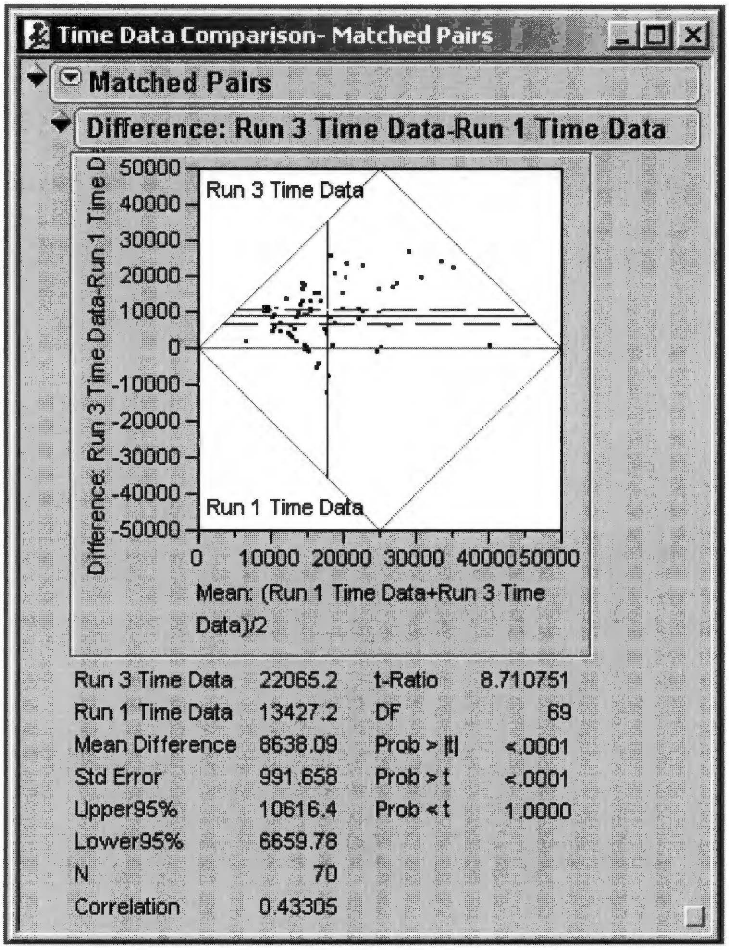


Figure 4.20: T-test, Run 1 Completion Time Compared to Run 3

means is significant, and that the difference lies with 95% probability in the range from 10616.4 to 6659.78 seconds needed for total tasks completed during the month.

Lean Pharmacy Phase 7: Sustaining Improvements

The plan developed here entails, inarguably, a significant upset in the way activities are currently undertaken at Baptist, a dramatic change in work culture, and a not-inconsiderable dedication of resources to implement. Given that these changes could be made, sustaining an improved state becomes the challenge. A series of periodic audits is called for, conducted both by pharmacy insiders and overseen by outsiders. A series of incentives is also logical, though in the case at Baptist it may be necessary to have both positive and negative responses in place. Given the extreme initial resistance to the program, fear of reprisal may have to be exploited during the early stages of the sustenance phase.

Chapter 5

Concluding Remarks and Areas of Future Research

The Baptist Case Study modeled in Chapter 4 allows several conclusions to be drawn. First, the response of the system in Runs 2 and 3 to the implementation of Lean Principals according to the outline shows positive results. The number of errors committed within the Lean system is substantially diminished from that exhibited by the Original system. Further, the amount of time necessary to complete a predetermined number of tasks is also reduced in the Lean system as compared to the Original system. Thus, it is concluded that the implementation of Lean Principles serves to meet the goals outlined in Chapter 1 of this thesis.

Further, the successful specific application to the Baptist Pharmacy of the generalized pharmacy plan suggests that the generalized pharmacy plan is viable in other pharmacies. While the Baptist-specific plan is by its nature limited in scope to the Baptist Pharmacy, the methodology is viable for more widespread use.

Additionally, the approach used in proving the viability of the model in an academic environment may also find application in proving to system participants the anticipated usefulness of the system, therefore enhancing the probability that they accept the changes prescribed. This follows from the discussion in Chapter 3 on perceived usefulness.

While the value of Lean Principles in a Pharmacy environment is the particular focus of this thesis, potential future work may be done to expand the use of the concepts to other areas of healthcare. For example, the time-reducing impacts of

Lean may be of particular merit in intensive care facilities and emergency rooms. Much potential exists here in creating models incorporating disaster scenarios, where for short periods of time demand greatly exceeds capacity. Home-based healthcare provides further opportunity in that movement from the home of one patient to the next must be not only made lean but also made optimal. Assessment procedures may be further refined into a singular, standard tool that incorporates a computer data-basing approach. Another area of opportunity exists in inventory forecasting.

As the population of the world continues to increase, so does the strain placed on the capacity available to meet its needs. Needs—healthcare, food, housing, etc.—are met as a result of various processes. A basic tenant of Lean thinking is that reduction of waste enhances available capacity. The singular application here of Lean to pharmacy should be considered a first step to the expansion of the principles to many non-traditional areas.

LIST OF REFERENCES

Albert, Tanya. "Liability Insurance Forecast Sees Double-digit Hikes Ahead." American Medical News 25 August 2003.

Allan, E.L. "An Evaluation of Environmental Conditions in a Hospital Pharmacy Department and their Potential Relationship to Performance." 46th ASHP Annual Meeting. Nashville, TN (1989).

Allan, Elizabeth Lynn, Ph.D. Relationships Among Facility Design Variables and Medication Errors in a Pharmacy Dissertation, Auburn University (1994).

American Hospital Association. Hospital Statistics Chicago: Health Forum, LLC, 1999.

Aydin, C., Ischar, R. "The Effects of Computerized Order Entry on Communication Between Pharmacy and Nursing." Proceedings: The Thirteenth Annual Symposium on Computer Applications in Medical Care 13 (1989): 796-800.

Babula, Joelle. "Medicare Payments: LV Doctors Predict Woes If Bill Dies." Las Vegas Review-Journal 15 November 2002.

Brennan, Troyen A., Leape, Lucian, Laird, Nan M., et al. "Incidence Of Adverse Effects And Negligence In Hospitalized Patients: Results Of The Harvard Medical Practice Study I." New England Journal of Medicine 324 (1991): 370-376.

Buchanan, Terry Lee. On The Effect Of Varying Levels Of Illumination On The Prescription Dispensing Error Rate In An Army High Volume Outpatient Pharmacy Service Thesis, Auburn University (1989).

Burrows, A. "Acoustical Noise, an Informational Definition." Human Factors (1960): 163-168.

Butler, Timothy W. "Utilizing Local Area Networks (LAN) for Multiechelon Inventory Systems: A Hospital Pharmacy Example." Production and Inventory Management Journal 34.2 (1993): 23-27.

Cary, Annette. "KGH Hopes to Heal Hurt Profits." Tri-City Herald [Kenniwick, WA] 10 April 2002.

Chau, P.Y.K., Hu, P.J.H. "Investigating Healthcare Professionals' Decisions To Accept Telemedicine Technology: An Empirical Test Of Competing Theories." Information & Management 39 (2002): 297–311.

Cooper , Richard, et al. "Economic And Demographic Trends Signal An Impending Physician Shortage." Health Affairs 21.1 (2002): 56-66.

Ettinger, W., Van Kooy, M. "The Art and Science of Winning Physician Support for Six Sigma Change." The Physician Executive September-October 2003, 34-38.

Gale Group. "Reducing Error, Improving Communications and Efficiency: A New Era in Healthcare Administration." Business Wire 6 October 2003.

Glass, D.C., Singer, J.E., Friedman, L.N. "Psychic Cost of Adaptation to an Environmental Stressor". Journal of Personality and Social Psychology 12 (1969) 200-210.

Greene, S.B. "North Carolina Health Trends" Blue Cross and Blue Shield of North Carolina Report 1992.

Guernsey, B.G., Ingrim N.B., Hokanson J.A., et al. "Pharmacist's Dispensing Accuracy in a High-Volume Outpatient Pharmacy Service: Focus on Risk Management." Drug Intelligence & Clinical Pharmacy 17 (1983): 742-746.

Hemenway, D. et al. "Physician's Responses To Financial Incentives: Evidence From A For Profit Ambulatory Care Center." New England Journal of Medicine 322 (1990): 1059-1063.

Hillman, B.J. et al. "Physician's Utillization And Charges For Outpatient Diagnostic Imaging In A Medicare Population." Journal of the American Medical Association 268 (1992): 2050-2054.

Hossain, Naim Nezhad. Utilizing Employee Stress to Establish Guidelines for Managing Personnel During Lean Transition Unpublished Thesis, University of Tennessee (2004).

Huerta, Julio A. "The Role of Technology in Rising Healthcare Costs." Journal of Clinical Engineering 20.1 (1995): 48-56.

Jones, D.M., Broadbent, D.E. "Human Performance and Noise." In C.M. Harris (Ed.), Handbook of Acoustica Measurements and Noise Control 3rd Edition New York: McGraw-Hill (1991).

Koh S.C.L., Saad S.M. "MRP-Controlled Manufacturing Environment Disturbed By Uncertainty." Robotics And Computer Integrated Manufacturing 19.1 (2003): 157-171.

Lake, Richard. "Malpractice Insurance Rates Rising for Lawyers." Las Vegas Review-Journal July 25 2002.

Lantos, R. "Report of the Committee on Safety Practices and Procedures." American Journal of Hospital Pharmacy 15 (1958) 710-712.

Lepper, Carol. Improvement Report: Lean Thinking Applied to Pharmacy Processes IHI National Forum (2003).

Mandler, G. "The Interruption of Behavior." In D. Levine (Ed.), Nebraska Symposium on Motivation: 1964 Lincoln, Nebraska: University of Nebraska Press.

McCormick, B. "Florida Considering Banning Self-Referrals; Bill Eyed As Model For Other States." American Medical News 34.3 (1999): 6-7.

Miller, D., Swain, A. "Human Error and Human Reliability", in G. Salvendy (Ed.), Handbook of Human Factors/Ergonomics New York: John Wiley (1986).

Mitchell, J.M., Scott, E. "Physician Ownership Of Physical Therapy Services. Effects On Charges, Utilization, Profits, And Service Characteristics." Journal of the American Medical Association (1992): 2055-2059.

Office of Technology Assessment. Policy Implications of the Computed Tomography (CT) Scanner Washington: National Academy Press, 1978.

Ortmeir, B.G., Wolfgang, A.P. "Job-related Stress: Perceptions of Employee Pharmacists." American Pharmacy NS31 (1991) 635-639.

Perednia, D.A., Allen, A., "Telemedicine Technology And Clinical Applications." Journal of the American Medical Association 273 (1995): 483–488.

Smith, Scott D. "Hospitals Think Lean to Fight Rising Costs." The Minneapolis-St. Paul Business Journal April 9, 2004.

Staker, Larry V. "Teaching Performance Improvement: An Opportunity for Continuing Medical Education." The Journal of Continuing Education in the Health Professions 23 (2003): 34-52.

Swedlow, A. et al. "Increased Costs And Rates Of Use In The California's Worker's Compensation System As A Result Of Self-Referral By Physicians." New England Journal of Medicine 327 (1992): 1502-1506.

The American Heritage Dictionary of the English Language, Fourth Edition. Boston: Houghton Mifflin Company (2000).

Thomas, Eric J., Studdert, David M., Newhouse, Joseph P., et al. "Costs of Medical Injuries in Utah and Colorado." Inquiry 36 (1999): 255-264.

US Dept. of Health and Human Services. Projected Supply, Demand, and Shortages of Registered Nurses: 2000-2020 Washington: GPO, 2002.

White, Richard E., Pearson, John N., Wilson, Jeffrey R. "JIT Manufacturing: A Survey of Implementations in Small and Large U.S. Manufacturers." Management Science 45.1 (1999): 1-15.

Wolfgang, A.P., Perri III, M., Wolfgang, C.F. "Job-related Stress Experienced by Hospital Pharmacists and Nurses." American Journal of Hospital Pharmacy 45 (1988) 1342-1345.

Woodhead, Ralph. "Going Lean? Start with MRP." Metalworking Production 147.2 (2003): 20.

Woolhandler, Steffie, Himmelstein, David U., and Lewontin, James P. "Administrative Costs in U.S. Hospitals." New England Journal of Medicine 329 (1993): 400-403.

Wright, P. "The Harassed Decision Maker: Time Pressures, Distractions, and the use of Evidence." Journal of Applied Psychology 59 (1988) 555-561.

VITA

Jason North was born in Harlan, KY on February 9, 1978. He went to elementary school at Wallins Elementary and Junior High School in Wallins Creek, KY. He attended high school at Powell Valley High School in Tennessee and completed work on his B.S. at the University of Tennessee, Knoxville.

Jason is currently pursuing his post graduate work at the University of Tennessee.