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UTILIZATION OF HEALTH INFORMATION TECHNOLOGY SYSTEMS IN QUALITY IMPROVEMENT METHODOLOGIES AT HEALTHCARE ORGANIZATIONS IN THE UNITED STATES: A RETROSPECTIVE STUDY

by

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ABSTRACT

Quality improvement in healthcare has been one of the key challenges in the United States for decades now. To overcome those challenge, healthcare organizations have employed many of the common Quality Improvement Methodologies (QIMs). Those methodologies and others have been some of the most effective tools for quality improvement in many other industries, including manufacturing and supply chain. However, it is unclear as to how QIMs are utilized in healthcare settings and if the QIM implementations can benefit from the commonly implemented Health Information Technologies (HITs). This study evaluates the hypothesis of whether or not QIMs are implemented using HIT systems in hospitals and practices in the United States. This involves evaluating the types of implemented QIMs as well as investigating the outcomes of the employed methodologies in terms of efficiency, throughput and financial impact. Moreover, the study forms an understanding on how the different HITs that exist in many healthcare settings are used as part of QIMs. The study also assesses the obstacles that prevent hospitals and practices from utilizing HITs in QIMs. To conduct the study, two datasets have been obtained, which are the Dorenfest Institute dataset and the Healthcare Information and Management Systems Society (HIMSS) Analytics data source. In addition, a survey has been conducted to collect data about how healthcare settings in the United States have been utilizing QIMs in the last ten years. Finally, the allocated and collected data have been analyzed and the results have been presented and discussed.

Keywords: quality improvement; quality control; healthcare challenges; clinical and business intelligence; data analytics

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LIST OF ABBREVIATIONS

BPR	Business Process Reengineering
CBI	Clinical and Business Intelligence
CDC	Centers for Disease Control and Prevention
CDS	Clinical Decision Support
CEHRT	Certified Electronic Health Record Technology
CMS	Centers for Medicare & Medicaid Services
CPOE	Computerized Physicians Order Entry
CQI	Continuous Quality Improvement
CQM	Clinical Quality Measure
CTC	Critical To Cost
CTQ	Critical To Quality
CTS	Critical To Schedule
DAMIC	Define, Analyze, Measure, Improve and Control
DICOM	Digital Imaging and Communications in Medicine
DPO	Defect per Opportunity
DPMO	Defect per Million Opportunity
ECG	Electrocardiogram
EH	Eligible Hospital
EHR	Electronic Health Record
EMR	Electronic Medical Record
EP	Eligible Professional
ER	Emergency Room
ETL	Extraction, Transformation and Loading
GE	General Electric

HCAI	Health Care-Associated Infection
HHS	Department of Health and Human Services
HIE	Health Information Exchange
HIMSS	Healthcare Information and Management Systems Society
HIPAA	Health Insurance Portability and Accountability Act of 1996
HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health
HL7	Health Level Seven
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
ICD-10-CM	International Classification of Diseases, 10th Revision, Clinical Modification
ICD-10-PCS	International Classification of Diseases, 10th Revision, Procedure Coding System
IOM	Institute of Medicine
IT	Information Technology
LIS	Laboratory Information System
LOINC	Logical Observation Identifiers Names and Codes
LSL	Lower Specification Limit
LSS	Lean Six Sigma
LWL	Lower Warning Limit
MRSA	Methicillin-Resistant Staphylococcus Aureus
MU	Meaningful Use
ONC	Office of the National Coordinator for Health Information Technology
OR	Operating Rooms
ORU	Unsolicited Observational Reporting

PACS	Picture Archiving and Communication System
PIO	Problem or Improvement Opportunity
PIS	Pharmacy Information System
QIM	Quality Improvement Methodology
QRE	Quality-Related Event
RIS	Radiology Information System
SBP	Systolic Blood Pressure
SIPOC	Suppliers, Inputs, Processing, Output, and Customers
SOAP	Subjective, Objective, Assessment and Plan
STD	Standard Deviation
ToC	Theory of Constraint
TPS	Toyota Production System
TQM	Total Quality Management
USL	Upper Specification Limit
UWL	Upper Warning Limit
WHO	World Health Organization
XML	Extensible Markup Language

CHAPTER I: INTRODUCTION

1.1 Statement of the Problem

Quality improvement is one of the key challenges for healthcare organizations, health government agencies, and patient safety advocates[1,2]. This issue has been highlighted in many reports published by highly respected institutions. For instance, the Institute of Medicine (IOM) has reported that, in the United States, between 44,000 to 98,000 patients die due to preventable mistakes[3]. The IOM also estimated that around 1.5 million preventable medication errors occur each year in the United States[4]. From the cost point of view, it has been reported that the healthcare waste value in the United States has reached $750 Billion in 2009[5]. In Europe, the World Health Organization (WHO) has reported that one of the healthcare quality issues, Health Care-Associated Infections (HCAIs), causes 16 million extra-days of hospital stay annually and causing financial losses of approximately € 7 billion every year, including direct costs only[6]. Such serious alarms and others highlight the importance of implementing solutions that assist in overcoming the quality improvement challenges.

To tackle a range of quality issues in many industries, especially in manufacturing and supply chain, multiple Quality Improvement Methodologies (QIMs) have been developed and employed. Many healthcare organizations have already been utilizing a variety of those methodologies. A study that was conducted in the Netherlands has shown that 91% of surveyed hospitals have implemented at least one of the common methodologies[7]. The study also pointed that 39% of the hospitals have used five or more

QIMs. Table 1 details the frequency of utilization of each methodology as well as the instances of implementing combined methodologies in the same healthcare organization.

Approaches	Total (%)	*CP**	*BM**	*BPR**	*LM**	*TOC**	*CI**	*TQM**	*OR**	*FF**	*LSS**	*SS**
*Clinical pathways (CP)***	91		32	20	20	18	15	10	12	10	8	6
*Benchmarking (BM)***	78	32		20	18	18	13	11	11	7	6	4
*Business Process reengineering (BPR)***	48	20	20		14	10	6	6	10	6	5	4
*Lean management (LM)***	48	20	18	14		13	7	4	8	7	2	5
*Theory of constraints (ToC)***	43	18	18	10	13		8	6	7	6	2	4
*Continuous improvement (CI)***	33	15	13	6	7	8		4	1	5	2	1
*Total Quality Management (TQM)***	28	10	11	6	4	6	4		5	2	2	1
*Operations research (OR) **	28	12	11	10	8	7	1	5		4	3	3
*Focused factories (FF)***	22	10	7	6	7	6	5	2	4		1	1
*Lean six sigma (LSS)***	17	8	6	5	2	2	2	2	3	1		3
*Six sigma (SS)***	13	6	4	4	5	4	1	1	3	1	3	

* = Other approaches used by hospitals that used the approach indicated in the left-hand column. Result in column CP till SS in numbers.
** = approach used.

Table 1: QIMs Utilized in the Netherlands Healthcare Organizations[7]

1.1.1 Lean Six Sigma

Lean Six Sigma (LSS) has been one of the key methodologies for quality improvement in many industries for decades now[8,9]. A well-known case-study has taken place at Motorola, which reported savings of in excess of US $9 billion from Six Sigma projects[10]. General Electronic (GE) has also obtained major benefits through LSS, as the operating income increased initially by $300 million and then doubled in the next year to over $600[11]. The aforementioned cases are only examples of the effectiveness of LSS and how this methodology has been adopted by a number of major organizations around the world.

LSS consists of two main parts: Lean and Six Sigma. Lean, which was developed by Toyota Motor Corporation[12], is designed around the customer requirements to ensure the delivery of products or services in the most effective, timely and safe manner possible[13]. The customer term refers to the main beneficiary of the business process. Any other

processes that do not meet the customer requirements are considered wastes, or non-value-added activities, and should be either reduced or eliminated. Customer requirements are usually obtained through qualitative methods, such as customer interviews, focus groups, and surveys. Many tools have been developed to breakdown business processes based on the Lean definition, including the Toyota Production System (TPS), Suppliers, Inputs, Processing, Output, and Customers (SIPOC), and 5S's.

SIPOC

Muda City Medical Center Case Study updated 1-29-12

Suppliers	Inputs	Process	Outputs	Customers
1a1.Community 1a2. Advertizing 1a3. Medical schools 1a4. Insurance companies	1b1. Sick patient & Patient Information 1b2. Medical Equip. ER 1b3. Medical Personnel ER 1b4. Insurance Companies coverage	1c1. Admission/ER	1d1. Patient Information 1d2. Order to admit 1d3. Diagnosis 1d4. Lab results 1d5. Treatment plan 1d6. Processed/admitted patient	1e1.Patient 1e2. Staff (Doctors, Nurses) of Telemetry Unit 1e3. Lab
2a1. Telemetry and medical Equip companies 2a2. Medical schools 2a3. Insurance Companies 2a4. Community	2b1. Patient Information from ER 2b2. Order to admit 2b3. Diagnosis 2b4. Lab results 2b5. Treatment plan 2b6. Processed/admitted patient	2c1.Telemetry	2d1. Patient with developed complications 2d2. Patient Chart 2d3. Telemetry Documents 2d4. Patient Information 2d5. Order to admit to ICU 2d6. Diagnosis 2d7. Lab results 2d8. Treatment plan	2e1. Patient 2e2. Staff (Doctors, Nurses) of ICU 2e3. Lab
3a1. ICU and medical Equip companies 3a2. Medical schools 3a3. Insurance Companies 3a4. Community	3b1. Patient with developed complications 3b2. Patient Chart 3b3. Telemetry Documents 3b4. Patient Information 3b5. Order to admit to ICU 3b6. Diagnosis 3b7. Lab results 3b8. Treatment plan	3c1.ICU	3d1. Stabilized patient 3d2. Patient Chart 3d3.ICU Documents 3d4. Patient Information 3d5. Order to transfer to Telemetry 3d6. Diagnosis 3d7. Lab results 3d8. Treatment plan	3e1. Patient 3e2. Staff (Doctors, Nurses) of Telemetry 3e3. Lab

Table 2: An example of the SIPOC tool

The Six Sigma part is a process improvement methodology that has been created by Motorola[14]. Sigma (σ) is a Greek letter that represents the standard deviation of a dataset[15]. A selected Sigma Level indicates a business process variation based on the customer requirements. The requirements determine what is called the Lower Specification Limit (LSL) and the Upper Specification Limit (USL), which both represent the selected Sigma Level[16]. Any value that fall outside the LSL and the USL are considered defect[17] or error, and therefore, should be eliminated. Technically, any error rate in a business

processes can be converted to a sigma level. The organization then can use this level as a base and start the Six Sigma process from this point.

However, a shift of ±1.5σ has been considered by the developer of the Six Sigma methodology, Motorola, in order to accommodate the long-term change on the process performance. Figure 1 illustrates the ±1.5σ shift that occur on the long-term and should be accounted for in the Six Sigma process.

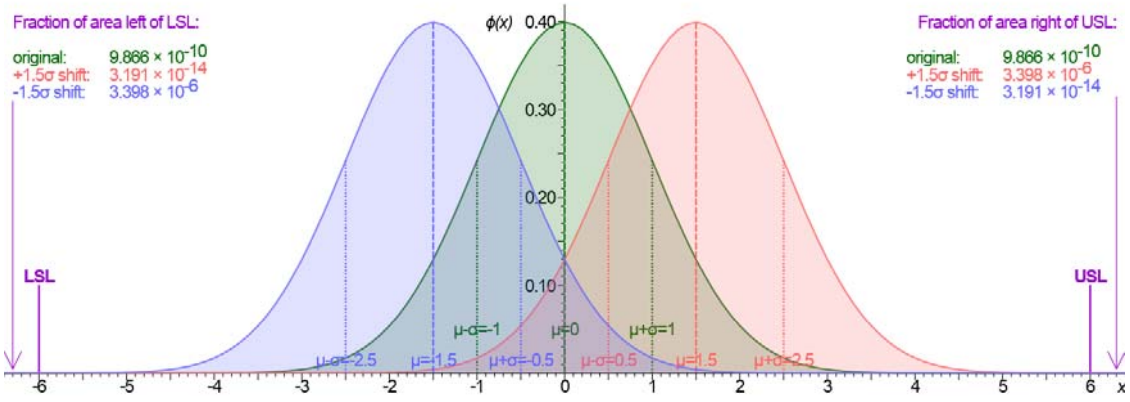


Figure 1: The ±1.5σ shift in the Sigma level

Table 3 lists the Six Sigma levels along with other important parameters after applying the necessary 1.5σ shift[18].

Sigma level	Sigma (with 1.5σ shift)	DPMO (with 1.5σ shift)	Percent defective (with 1.5σ shift)	Percentage yield (with 1.5σ shift)
1	-0.5	691,462	69%	31%
2	0.5	308,538	31%	69%
3	1.5	66,807	6.7%	93.3%
4	2.5	6,210	0.62%	99.38%
5	3.5	233	0.023%	99.977%
6	4.5	3.4	0.00034%	99.99966%
7	5.5	0.019	0.0000019%	99.9999981%

Table 3: Levels of Six Sigma

To determine the status of a business process against the selected Six Sigma level, a parameter called the Defect per Million Opportunity (DPMO) has to be identified. This parameter is derived from another parameter called the Defect per Opportunity (DPO), which can be calculated using the following equation:

$$DPO = \frac{Number\ of\ Defects}{Number\ of\ Units\ \times Opportunity\ for\ a\ Defect\ per\ Unit}$$

Then, the DPMO can be calculated as follows:

$$DPMO = DPO\ \times\ 10^6$$

To implement both, Lean and Six Sigma, the Define, Measure, Analyze, Improve and Control (DMAIC) methodology is commonly used[19]. It involves phases that implement the ultimate goals of Lean and Six Sigma, which both target wastes and defects in business processes.

Phase Zero initiates the whole LSS process in a specific area in the healthcare organization. It focuses on identifying a potential Problem or Improvement Opportunities (PIO) in a business process. The process starts when a person, internal or external to the work area, identifies a PIO. The potential problem can be hidden and waiting to be highlighted and then handled by the LSS process. However, the problem can also be known to the management and/or a number of workers in the area, but has to be clarified.

Phase One, the Define phase, clearly specifies the PIO that was identified in Phase Zero. It also defines the project and the team that is going to work on the PIO. This is done using three steps, or tollgates: 1) developing the Team Charter, 2) develop high-level process maps and customer requirements, and 3) prepare a project plan.

Phase Two, Measure, focuses on quantifying the PIO that was identified in the Define phase. To perform so, two main tollgates are involved: 1) creating a data-collection plan, and 2) implementing the data-collection plan.

Phase Three, the Analyze phase, is the process of converting the collected data, from the Measure phase, to information. The difference between data and information is mainly related to facilitating decisions. Data is a collection of numbers and labels. However, informed decisions cannot be made on those numbers and labels unless they are framed in contexts, and in this case, they become information.

Phase Four, Improve, starts after the information has been obtained from the Analyze phase. The information is used to make informed decisions on how process improvements or problem solutions can be achieved. This is done by the LSS team and complied in a list of improvements or solution actions. The Improve phase involves materializing those actions. The phase has two tollgates: 1) generate solutions, and 2) implement and test the solutions.

Phase Five, the Control phase, is the final stage of the DMAIC process. This phase handles how the implemented process improvement or problem solutions can be sustained. Otherwise, the achievements that have been reached in the previous phases can be no more than instant or short-term positive effects, with the high potential of disappearing soon after the QIM process is over. Two tollgates are involved in the Control phase: 1) determining methods for control, and 2) implementing the control methods.

1.1.2 Continuous Quality Improvement

Continuous Quality Improvement (CQI) is a QIM that introduces small and incremental improvements to the environment. Dramatic improvement results appear slowly and over an extended period. This approach is entirely different from innovations, which bring large and quick changes to workflows, yet, comes with high risk and significantly greater rate of issues[20]. On the other hand, the CQI's approach of gradual improvement produces smaller and less issues, which allow them to be handled more effectively.

CQI relies mainly on a framework called Plan-Do-Study-Act (PDSA), which is also known as the Deming Wheel or Deming Cycle[21], referencing to the quality improvement legend William Edwards Deming.

The framework continuously repeats four phases: Plan, Do, Study and Act. The ultimate aim of this framework is that with each round, a small improvement is made. Figure 2 shows the four phases with brief description of the tasks that they involve.

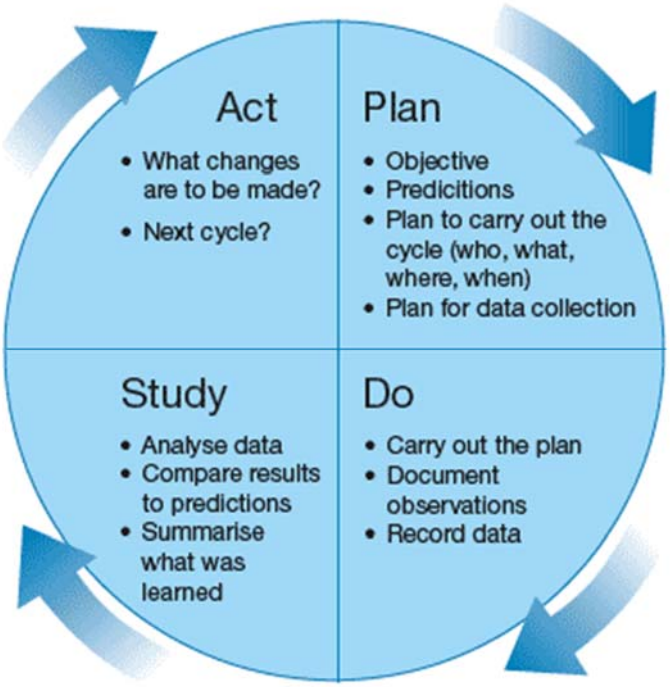


Figure 2: An illustration[22] of how CQI handles improvement in a continuous manner

The Plan phase establishes a goal for improvement. There are many tools that are used to identify opportunities for improvement, including the methods that are discussed in the LSS methodology. The Plan phase also involves setting measurements and predictions for the handled improvement process. A plan for how the process will be executed and how the performance data will be collected is also part of this phase. The Do phase executes the components of the Plan phase, including the implementation of the improvement and the collection of the data that were generated after the improvement has been made. In the Study phase, the observations and collected data are analyzed to build an understanding around the executed improvement in the Do phase. The collected data are transformed to information in order to be ready for making informed decisions in the next phase. The final phase, Act, involves decisions on the findings of the Study phase, including whether or not the cycle has accomplished the targeted improvements

sufficiently. This decision determines if another cycle is necessary to achieve the goals or fulfilling the remaining unmet requirements.

It is important to highlight that similar to DMAIC, PDSA does not define specific tools for executing the phases. Instead, they provide general guidelines that assist in achieving the intended objects.

1.1.3 Total quality management

Total Quality Management (TQM) is a set of philosophies, guiding principles, management techniques, and quality improvement tools that represent the foundation of a continuously improving organization[23]. Nonetheless, there is no consensus in the quality improvement community on what TQM preciously involves in terms of procedures and tools[24-26]. However, a number of TQM experts have developed their own methods and tools for achieving the overall goal of TQM. The methods and tools included common best practices in organizational behaviors such as change and conflict management as well as staff motivation and team development.

Creech[24] bases TQM on what he names as "Five Pillars"; Product, Process, Organization, Leadership, and Commitment. Creech[24] argues that the product of any organization is the essence of its objectives. However, the quality of products cannot be achieved without quality in the process. In the same manner, the quality in the process is impossible without the right organization, which is meaningless without the proper leadership. Overall, solid commitment from the decision makers in the organization supports all other pillars. In healthcare, the same "Five Pillars" are still applicable. Products can be any diagnostic or therapeutic procedures that patients receive. Physician exams or

consults are also products that healthcare organizations and practices provide. Those products cannot be of high quality unless their processes, or how they are provided, are at high quality levels. For example, a therapeutic procedure such as appendectomy cannot achieve a high quality level if the median Length of Stay (LOS) of this procedure in a hospital is above the regional or national LOS for similar procedures. In this case, the cause should be pointed to one or more issues in the way the product, appendectomy is provided to patients. When traced further, the issue might be complications that are caused by poor surgical practices or by frequent sepses initiated by improper sterilization or surgical equipment and instruments. Nonetheless, the right organization allows rectifying such issues and maintaining the positive change using organizational tools, which include policies, procedures and staff trainings. However, the right organization fail in many instances to implement quality improvement actions due to various factors, including change resistance and negative bureaucracies. This is the reason why leadership, supported by the organization's commitment for quality improvement, are crucial to achieve the overall goal of TQM.

Another approach for implementing TQM is promoted by Anschutz[27], which defines four components as the main parts that form this QIM; Empowerment, Process Management, Customer Obsession and Strategic Planning. The Empowerment component deals with how staff members can be made partners in the work-environment, instead of subordinates with the sole duty of executing management orders. This approach is vastly different from the traditional authoritarian methods that were commonly used up until few decades ago[27]. The Process Management component relates to a shared area with other QIMs, such as LSS and Business Process Reengineering. In fact, TQM uses most of the

common process management tools that are considered part of the other QIMs. The Customer Obsession component ensures that customers' requirements are seriously considered in the quality improvement process. In this regard, the customer satisfaction is used as a measurement to the level of fulfilling the requirements. The final component, the Strategic Planning, is about widely sharing and utterly implementing the strategies that are set to lead the organization to the defined vision. This level of planning targets both, the long-term (three to five years) and short-term (one-year) periods. Nonetheless, TQM experts are more concerned about the long-term strategic planning because of tendency to focus on the short-term for easier and quicker gains.

It is worth noting that the previously mentioned four components overlap to a very large degree with Creech[24] definition of TQM that relies on the "Five Pillars". In essence, the disagreement of experts is on strategy of executing TQM and not on the overall objectives of the methodology.

1.1.4 Theory of Constraints

Introduced by Eliyahu M. Goldratt in his book titled "The Goal: A Process of Ongoing Improvement"[28], the Theory of Constraints (ToC) is a unique approach for quality improvement that focuses on obstacles or constraints, instead of errors or wastes. Constraints are simply anything that prevent the work environment from achieving its objectives. ToC considers constraints as weak points that limit the overall system capability. In fact, ToC adopts the common idiom "A chain is no stronger than its weakest link"[29] to explain how even a single constraint can fail the whole system despite its strength in the other areas.

To handle constraints, ToC utilizes a method called the Five Focusing Steps, which consists of: identifying the constraint, exploiting the constraint, subordinating and synchronizing to the constraint, elevating the performance of the constraint, and finally, reinitiating the method again. Figure 3 demonstrations how the five steps repeat indefinitely to achieve the ToC goals of identifying and then reducing constraints.

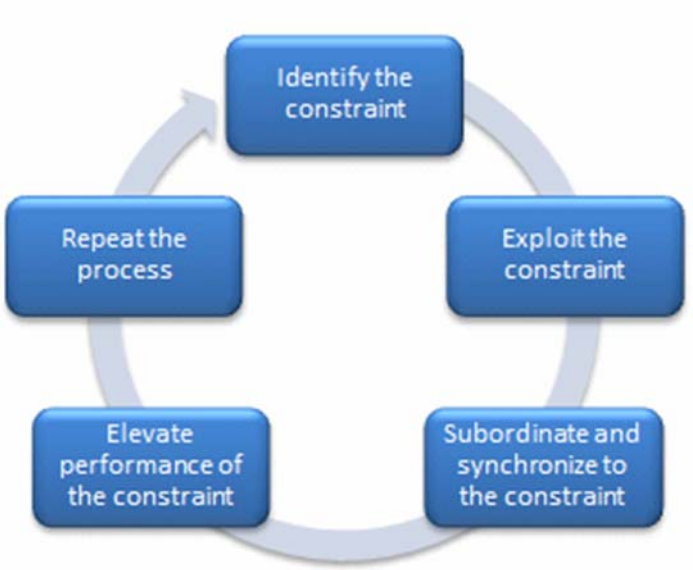


Figure 3: An illustration[30] on how ToC uses the Five Focusing Steps to identify and reduce constraints

The first focusing step is related to identifying the constraint. This can be done using a method such as Process Mapping where processes in the work environment are traced and broken down into steps with time stamps and task descriptions. This allows the analysts to identify constraints that are the root causes of wastes and errors. However, the Process Mapping method alone might not be sufficient to identify certain types of constraints such as the organization behavioral, managerial, and logistical. These types of constraints require further investigation that involve focus groups, interviews, surveys as well as reviewing the organization's policies and procedures.

Once the constraint is known, the second step is to maximize the positive side of the constraint and work on reducing the negative side. For example, if the constraint that causes a delay in the workflow is a required clinical documentation, a computerized dictation system can be used to fulfill the requirement while reducing the delay. Common quality improvement methods such as the 5S's and Kaizen can be used to achieve this goal.

The third step aligns the whole system to support the constraint and reduce its negative effect. In the previous clinical documentation example, aligning the system could implicate changing the policies and procedures in order to allow assistant consultants to document the initial clinical reports, which will significantly assist consultants to finalize those reports in shorter times.

It might be also necessary to increase the capacity of the constraint, and this is the fourth component of the Five Focusing Steps. If more resources is allocated to handle the constraint, the negative implications can be reduced. In the clinical documentation example, the constraint has caused a delay in the workflow. However, if more physicians are sourced to conduct the documentation process, the requirement will be fulfilled while the delay is condensed.

The fifth and final step restarts the cycle. Similar to a number of other quality improvement methods, the Five Focusing Steps is a continuous process and should not stop as long as the organization is operational.

1.1.5 Business Process Reengineering

Business Process Reengineering (BPR) is a set of management policies, project management procedures, as well as modeling, analysis, design and testing techniques for

analyzing existing business processes and if necessary, redesigning them[31]. Unlike CQI, which relies on small and incremental improvements, the BPR methodology introduces radical changes[32] to the work environment aiming to achieve major positive improvements and in relatively short period[33]. Another unique feature of BPR is the focus on the business process with all the small components that it involves, instead of concentrating on specific issues, such as in the CQI or TQM methodologies, or in methodologies that focus on constraints, which is the case in the ToC methodology.

BRP methodology became very popular in the mid-nineties to the point that about 60% of the Fortune 500 companies at that time claimed that they either have implemented BPR or planning to do so[34]. It is anticipated that this popularity was due to the significant increase in IT adoption[35]. Many organizations have shifted their business processes from traditional manual and paper-based platforms to electronic-based technologies. This included Enterprise Resource Planning (ERP) Systems, emails, databases, business intelligence systems, automatic tracking and identification, and other tools that forced organizations to comprehensively rethink their processes.

One of the methods that are used to implement BRP is a life cycle that consists of four steps: 1) identifying an eligible process, 2) reviewing and analyzing as-is, 3) design to-be, and 4) test and implement to-be. Figure 4 illustrates the cycle in a graphical representation.

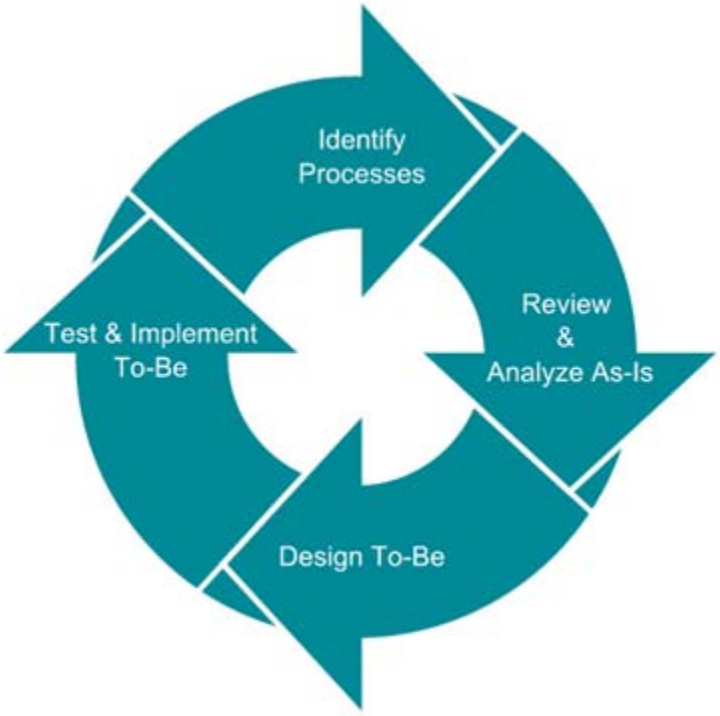


Figure 4: The BPR life cycle

BPR life cycle starts by identifying a process that has significant issues, and therefore, requires redesign. There are a number of methods that are used to conduct this step; many of them rely on the customer requirements as criteria for the processes that need to be rectified. There are also other factors that may make some processes eligible, including core processes that have high impact on the organization and also front-line and customer serving processes[36].

While the first step was about selecting an eligible business process for reengineering, the second step analyzes the candidate process. The analysis involves scrutinizing the related policies, business rules, costs, values added, revenues, workflows, conceptual business process models, business functions, organizational structures, organizational unit mission, job definitions and information technologies that are related

to the process[37]. The result of the analysis are information pieces that will be used in the next step, design, to make informed decisions. In fact, the success of the rest of the steps depends mostly on the comprehensiveness of this step and how accurate the analysis was conducted.

The design step that follows the review and analysis is actually the reengineering point in the cycle. The step incorporates the information that were gathered and generated in the previous step into a new improved process.

The final step in the cycle consists of two sub-steps, testing and implementation. Before the new process is implemented, it gets exposed to thorough testing to uncover issues in the new process that might require addressing before the implementation. If the issues are minors, the modification can occur at this stage. However, if major issues are discovered, the whole cycle should be halted and repeated for the same business process. This is because it is a clear indication that the previous stages, mainly the review and analysis, have not been conducted properly. Nonetheless, if the testing step involved no issues or minor issues were identified and rectified, the new business process can be implemented.

1.1.6 Benchmarking

Benchmarking is a method that involves comparing processes with equivalent internal or external processes in order to follow best practices and achieve higher process quality. Benchmarking has been used for more than 40 years and there are many reasons why many believe that it will continue being an important QIM in the future[38]. It will

always be beneficial to learn from the success of other organizations regardless if competitiveness exists or not.

Generally, benchmarking is divided into four types: internal, competitive, functional, and generic[39]. The internal benchmarking type compares similar processes within the same organization. For example, a Complete Blood Count (CBC) process in an inpatient lab can be compared with CBC process conducted by another inpatient lab in the same hospital; provided that the reference process has a high quality level. It is worth mentioning that even in a hospital network, comparing processes among the different network's hospitals is still an internal benchmarking type, although the management of each hospital could be completely autonomous.

The competitive benchmarking type is related to selecting one or more processes and comparing their performances with equivalent processes conducted by competitors. Usually, competitors who are performing better than the organization are taken into consideration. However, competitors who are threatening the position of the organization in the market should also be considered, even if they have lower market-shares or their overall performances are lower than the organization.

The functional type of benchmarking is a comparison of processes with organizations that are outside the industry. For example, a hospital process such as x-ray equipment maintenance can be relatively compared with the x-ray equipment maintenance in airports, using similar measurements that include downtime, breakdown rate, and annual maintenance costs. This is especially beneficial if an organization has reached the highest performance in the field and would like to make further improvements.

The generic benchmarking type evaluates the organization's processes against best practices that have been set by well-respected institutes in the field. Clinical guidelines produced by medical associations represent one of the sources for best practices in the healthcare field. Guidelines set many benchmarking parameters for healthcare providers. For example, the door-to-balloon time is one of the benchmarking parameters that has been set by the American College of Cardiology (ACC) and the American Heart Association (AHA). It is critical to effective treatment to control the time it takes to handle a Myocardial Infarction (MI) patient starting from the patient's entrance through the door of the emergency room and until the blocked artery is open. Therefore, the ACC and AHA associations have set a 60-minute median door-to-balloon time as the benchmark for top-performing institutions[40]. Hospitals that have this process can use the 60-minute parameter as a generic benchmark for best practice.

To start the benchmarking process, the organization has to select a benchmark entity, which could be a product, service or process. The organization then has to set key performance metrics that are related to the selected benchmark entity. The metrics have to be comprehensive in order to cover as many aspects of the benchmark entity as possible, yet, the metrics should not exceed what is available as information about the metrics from the reference organizations or best practices. The next step is to choose an organization or best practice to benchmark against. Data is then collected about the reference process and compared against the organization's parameters to identify opportunities for improvement[41]. Similar to other QIMs, this process should be repeated periodically on the same process to update the benchmarking status and utilize the new practices.

Benchmarking should also be continuous and considers the key processes in the organization based on priorities.

1.1.7 Clinical Pathways

Clinical pathways is a quality control and improvement methodology that assists different healthcare providers to follow evidence-based practices for patients with predictable clinical courses. The methodology of clinical pathways is popular in many clinical specialties. In critical care, for example, clinical pathways have become an industry standard for quality improvement for many of the Diagnosis Related Groups (DRG) in acute care[42]. A number of studies have shown that the implementation of clinical pathways can improve healthcare outcomes in a multiple areas[43-46]. A systematic review/meta-analysis study that covered twenty-seven studies, involving 11,398 participants, concluded that clinical pathways is associated with reduction in in-hospital complications and improved documentation[47].

A complete implementation of the clinical pathway methodology includes a decision tree, Clinical Decision Support (CDS), an educational program, and a quality improvement system[48]. The decision tree, or pathway map, is a flow-chart that illustrates how the process is supposed to work from the beginning to the end. The process also includes logics that handles slight differences that patients usually have. The decision tree is implemented in many formats ranging from interactive and web-based applications to traditional flow-charts that are printed on papers. Figure 5 demonstrates an example of an interactive decision tree for depression in adults care pathway.

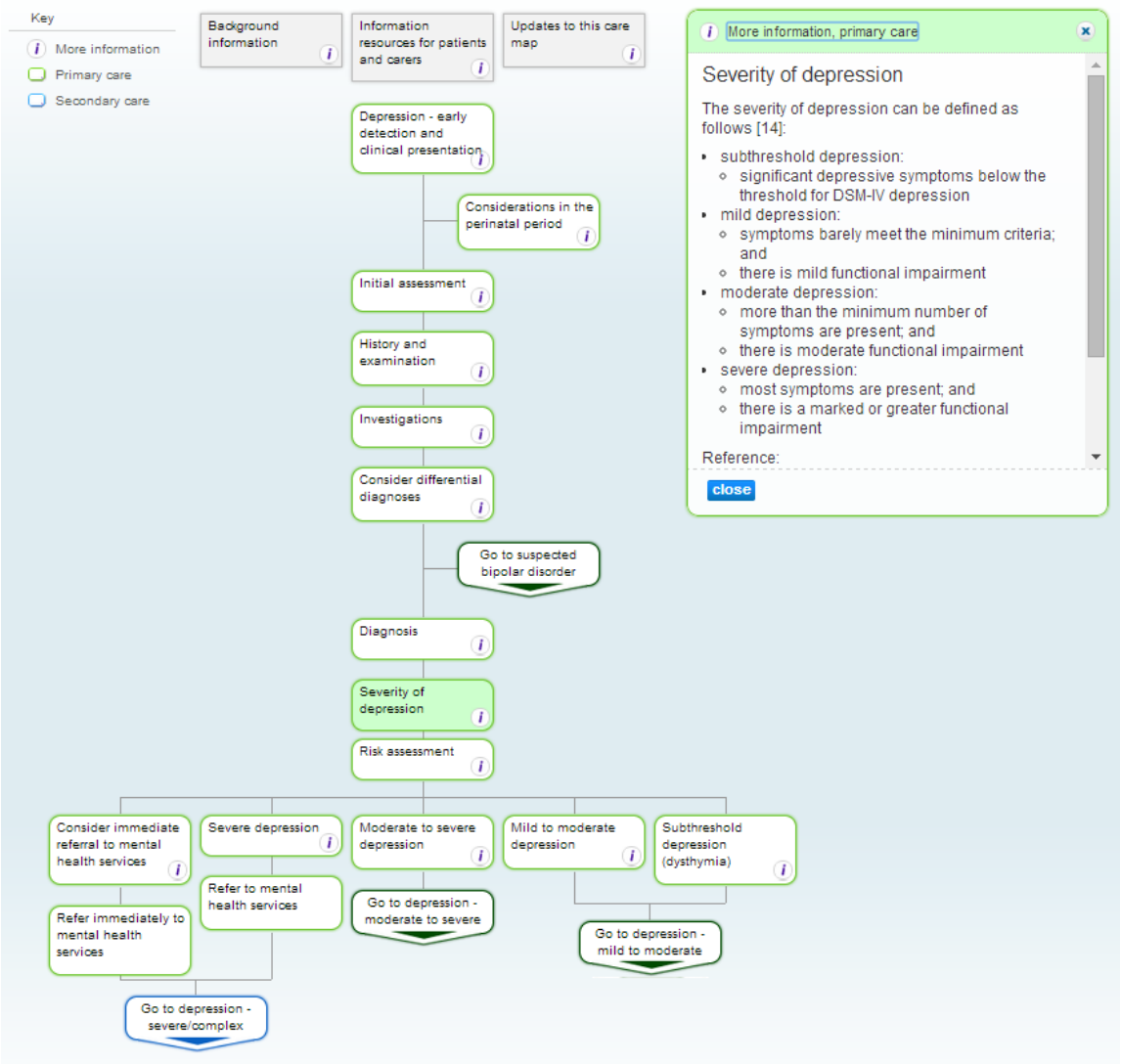


Figure 5: An example of a clinical decision tree for depression in adults care[49]

Interactive decision trees add a number of features to the traditional flow-charts, which just show the track of the process. Apart from being available online and can be access from anyplace that provide access to the Internet, interactive decision trees offer extensive help materials for every step of the process. Many steps can be vague or misunderstood, or in the worst-case scenario, completely unknown to the healthcare provider. An interactive decision tree allows the provider to display a summary about the step as well as references that can be referred to if more information is needed. In addition,

an interactive decision tree can be linked to another decision if the clinical pathway refers the healthcare provider to another pathway at the end of the process.

The second component of a clinical pathway is CDS, which is usually a software module that is integrated to a HIT system. CDS has the ability to capture, process, and provide healthcare providers with suggested decisions. In the case of clinical pathways, CDS assists healthcare providers to comply with the best practices outlined by medical experts.

Given the potential benefits of CDS, the United States Office of the National Coordinator for Health Information Technology (ONC) has spearheaded a number of activities in order to encourage the use of CDS. Such activities have included the development of a roadmap to promote the widespread utilization of CDS in the United States; creating CDS recommendations across five American Health Information Community (AHIC) workgroups; and the establishment of the Advancing CDS Project, focused on addressing major barriers to achieving widespread CDS usage[50].

CDS systems predominantly rely on Information Technology (IT) and HIT infrastructures to capture, process, and present required information to end-users. Healthcare organizations must not only have those infrastructures in place, but should also have them fully integrated with the clinical workflows in order to effectively run CDS. In some healthcare organizations, clinical workflows operate on hybrid systems that are an amalgamation of HIT and paper-based processes. In such setups, CDS systems cannot function properly because all parameters that are necessary to run CDS algorithms and logics are not captured by the system. On the system backend side, essential HIT systems

in the healthcare organization have to be integrated, as not doing so creates major issues for the CDS operation. For instance, not integrating the Laboratory Information System (LIS) with the Electronic Health Record (EHR) could result in skipping critical notifications such as a bleeding alert when a physician orders acetylsalicylic acid medication for a patient who has a recent laboratory test of high Prothrombin Ratio (PR) and International Normalized Ratio (INR).

The development and operation of CDS involve multiple parties including medical societies, healthcare organizations, HIT software development companies, and governmental agencies. This situation requires that the CDS algorithms, workflows, guidelines, and data formats be standardized in order to facilitate the sharing of CDS components across the organizations. In response to this necessity, multiple standards have been developed, including HL7 Arden Syntax and GELLO languages, which standardize the CDS rules, query, and expressions, as well as Asbru, EON, and GLIF to standardize the clinical guidelines. Moreover, a number of existing standards such as the HL7 messaging, HL7 CDA, SNOMED CT and LOINC have been utilized to standardize the data query, format, coding and vocabulary.

The main method that is used by CDS to help healthcare providers complying with clinical pathways is through alerts. Alerts are divided into those that are clinically important enough to make them interruptive, and those that are non-interruptive or informational. The non-interruptive alerts are messages that show up on the background or on the side of the screen and do not prevent the end-user from proceeding with the current process[51]. An example of a non-interruptive CDS alert is shown in Figure 6. In the example, a provider is following a clinical pathway for patients with Non-ST Elevation

Myocardial Infarction (NSTEMI) and the CDS module is assisting the provider by recommending aspirin medication, to comply with the clinical pathway.

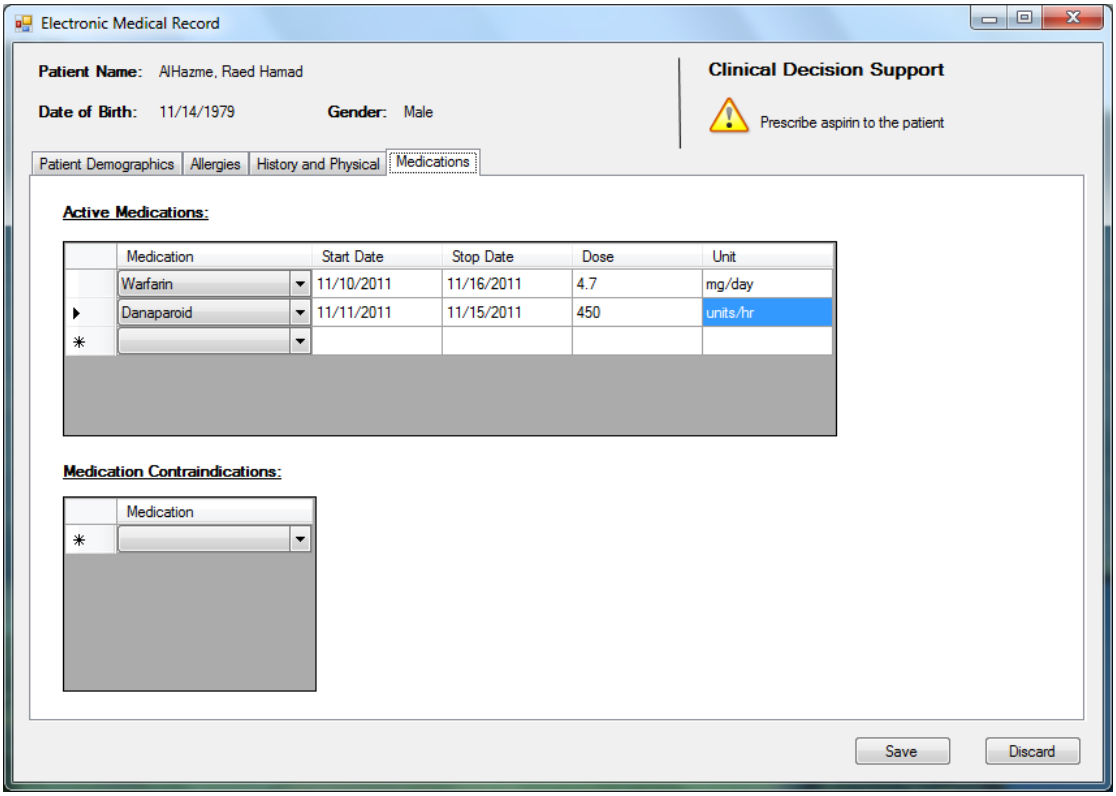


Figure 6: An example of a non-interruptive CDS alert

On the other hand, "interruptive alerts" are pop-up messages that stop the healthcare providers from moving any further until the condition of the alert is satisfied. This type of alerts represents a very powerful method for enforcing the compliance with clinical pathways. However, if interruptive alerts are not designed carefully to consider every possible clinical scenario, they can cause major issues in clinical workflows.

The other component of clinical pathways that completes the implementation process is educating the healthcare providers on how to best follow the pathways. This is a continuous process, which involves multiple types of clinical pathways users. New

healthcare providers need to be provided with an initial training on how to follow the relevant clinical pathways for their specialties. Afterward, they should get refresher trainings to maintain the information they gained previously and also to close the gaps in their knowledge. For healthcare providers who have issues in certain areas or specific clinical pathways, targeted training can be used to overcome the issues in their knowledge and prepare them to handle the areas in question in a better manner.

Despite the importance of the other components, clinical pathways cannot produce tangible positive outcomes without a system that monitors the quality of clinical pathways and implements improvements on them, when needed. To monitor the performance of a clinical pathway, a set of compliance and outcome measures have to be developed and implemented. After enough data are collected, analysis should be conducted on the data to identify if the compliance level is satisfactory and if all targeted outcomes have been met. The last step in the quality improvement system is to form an improvement plan on the clinical pathways and then implement it.

1.2 Background of the Problem

Despite their proven effectiveness[8,9,52,53], most of the common QIMs have been developed originally for work environments that are vastly different from healthcare. For example, the Lean methodology was developed by Toyota[12] and the Six Sigma methodology was created by Motorola[14]. Both of these work environments are mostly manufacturing-based. Even after a traditional QIM is extended to other industries, there are significant challenges in meeting the environment and requirements of healthcare settings. For example, the first phase of many of the QIMs is about selecting a business process to identify a PIO. While business processes can be limited in industries where

traditional QIMs are popular, there are usually hundreds or even thousands of business processes in some areas in healthcare organizations, such as the ER. Considering that the ICD-9 controlled vocabulary system is being used to code the admission diagnosis of each encounter, which represents business processes. With this large number of business processes, the selection of a business process that has a PIO using the traditional QIMs would be completely impractical. Among many, this is only one example of issues that exist when traditional QIMs are implemented in healthcare organizations. The significance of such issues is very high, and in fact, the reported high implementation failure rate of some of the traditional QIMs in healthcare[54] is mostly the results of such issues.

The other issue that results from implementing traditional QIMs in healthcare settings is the low reliability and validity. Reliability in data collection is obtaining the same result every time data are gathered, while validity is obtaining the correct piece of data. Figure 7 illustrates reliability and validity in a graphical representation.

Figure 7: Data reliability and validity

In traditional QIMs, data is collected manually from paper-based or electronic clinical documentation. Reliability in this method of data collection is affected mainly by the fact that typically there are many data sources within the healthcare organization that retains the same pieces of information. For example, the admission date and time can be

logged on a multiple documents in an Emergency Room (ER) setting, and this includes the admission form, the history and physical form, and the discharge form. When data is collected using manual methods, the person who collects the data might select a data source that is different from the other person in team who is also assisting in the data collection. Although the documents in healthcare environments should all be consistent, unfortunately, this is not the case in reality, as many pieces of data are written manually in a multiple documents. For example, the admission date and time on the admission form is always the correct source and this date and time should never be obtained from the other documents mentioned previously. It is important to highlight that there is always one source that is known to be the "master source" and manual data collectors are not always aware of the master source of every piece of information. Although the quality improvement team might be successful in selecting the master source in the initial execution of the project, the second round of the improvement process can use another source, which could be less accurate and, therefore, not applicable for comparison with the previous results.

Collecting data manually also affects validity, as it is prone to errors. During the manual data collection process, the same data piece gets copied manually one or more times until it reaches the analysis stage. This manual copying action introduces errors, unlike when the data is retrieved automatically by computers, saved in the data warehouse and then passed through analysis software algorithms.

1.2.1 Health Information Technologies

Although the healthcare industry has been moving naturally toward the implementation and vast reliance on Health Information Technology (HIT) solutions,

many governmental incentive programs have already been established to expedite and better steer the adoption process. One of the largest governmental HIT incentive programs in the world is the United States EHR Meaningful Use, which provides financial incentives to eligible healthcare providers that successfully achieve the meaningful use of EHR. The program has three main components: 1) The use of a certified EHR in a meaningful manner, such as e-prescribing, 2) The use of certified EHR technology for electronic exchange of health information to improve quality of health care, and 3) The use of certified EHR technology to submit clinical quality and other measures[55]. Eligible healthcare professionals and hospitals are highly encouraged, and also offered financial incentives, to implement these components.

1.2.1.1 Requirements and Implications of the Meaningful Use Program

The meaningful use program is equipped with a number of requirements that indicate the compliance of healthcare providers. The requirements are linked to the definition of "meaningful use" of a "certified" EHR; a definition that was established by CMS on December 30, 2009. The Meaningful Use requirements are encapsulated into three stages, one progressively building upon the other[56].

Figure 8: Overall stages of the Meaningful Use program[57]

Stage 1 had been in effect between 2011 and 2012. The stage consists of requirements for two groups of healthcare providers: healthcare professionals, and hospitals. The stage highlights a total of 25 meaningful use objectives for eligible professionals, 15 of them are required, and 10 are elective. For eligible professionals to qualify for the incentive payments, 20 out of the 25 objectives have to be followed. Eligible hospitals have 24 meaningful use objectives, in which 14 of them are mandatory, and 10 are elective. For an eligible hospital to qualify for the incentive payment, 19 objectives have to be fulfilled. For eligible professionals and hospitals to demonstrate their compliance with the meaningful use objectives, a set of Clinical Quality Measures (CQMs) are required to be reported. Eligible professionals have 44 CQMs, which consist of core, alternative core, and additional CQMs. Six of the measures have to be reported in order to demonstrate the meaningful use and qualify for the incentives. Eligible hospitals are required to report 15 CQMs in order to become qualified for the incentives.

Stage 2 of the Meaningful Use was planned to be launched in 2013. However, the HIT Policy Committee, a group of specialized stakeholders who provide recommendations to the federal government, voted on the 8th of June 2011 in favor of delaying the start date to 2014[58]. Although, the requirements of this stage is still under development[59], this stage is expected to emphasis on disease management, clinical decision support, and medical management through use of data[60].

Stage 3 is scheduled to start in 2016. However, with considering the expected postponement on stage 2, this stage might also be delayed. Stage 3 is anticipated to focus on promoting quality improvement, meeting safety and health outcomes, using data to support decision-making for priority conditions, providing patient access to self-

management tools, implementing HIT information exchange, and improving population health[60].

1.2.1.2 Challenges

Although meaningful use is expected to resolve many of the healthcare issues, there are a number of challenges that have to be overcame in order to fully obtain the benefits. Patient information security, fulfilling clinical specialty needs, risk of implementation failure, and the ongoing operation cost are some of the challenges.

Patient information security is one of the main issues of the meaningful use program, as there are many concerns about healthcare organizations' preparedness to implement EHR systems while maintaining the security of patient information. As mentioned by Miliard[61], "Obviously you cannot give too high a grade when you have that many breaches [in healthcare systems]". CMS has to implement components in the meaningful use program that ensure the protection of patient information. In addition, CMS has to elevate the healthcare providers' awareness about this critical issue, besides encouraging the implementation of EHR.

Encouraging healthcare providers to implement EHR systems causes, in some cases, issues in clinical processes, as many EHR systems are not developed to fulfill the detailed requirements of the different specialties and sub-specialties. Kadry, Sanderson, and Macario[62] stated that, "Database architectures are often designed to support single clinical application and are not easily modified to meet the enterprise-wide needs desired by all end-users". Healthcare providers have to weigh the clinical requirements, and identify the core and optional functionalities that have to exist in the EHR system, prior to

the acquisition. This will ensure that the EHR implementation will not neglect key functionalities that might affect critical clinical needs.

The risk of implementation failure is also one of the challenges that face healthcare providers. Failing to implement an EHR has a significant cost, and this risk turns many healthcare providers to be more reluctant to conduct the implementation until the technology becomes much more mature, and consequently, the risk becomes much lower. However, the risk can be managed by learning from successful implementations, and also by acquiring competent resources to assist in the implementation process.

Although the meaningful use program provides financial incentives to eligible healthcare providers that implemented EHR systems, the incentive fund offsets only part of the acquisition cost, but does not cover the ongoing operation expenses. Such systems typically require significant operation cost that is needed for maintenance, administration, and customization. Many physician practices and hospitals do not have the ability to allocate such fund. However, one of the solutions for this issue is to implement an EHR in a successful manner that enhances the healthcare processes in the practice or hospital, and in turn, generates saving that offsets, or maybe exceeds, the cost required for the system operation.

1.2.1.3 Rewards for Implementers

After an eligible healthcare provider implements an EHR system, in compliance with the meaningful use program, they have to demonstrate, or attest, the compliance. Healthcare providers have to file the attestation in a CMS web-based system called the Medicare & Medicaid EHR Incentive Program Registration and Attestation System. In this

system, providers need to fill in numerators and denominators for the meaningful use objectives and clinical quality measures, and formally prove that they have successfully demonstrated meaningful use of EHR. The system also allows filling requests for exclusions to specific meaningful use program objectives.

Once the attestation is accepted, incentive payments will be made in approximately four to eight weeks. CMS started the payments for the program in May 2011, and will continue through 2015, 2016, or 2021, depending on the service type of the healthcare provider[55].

For eligible healthcare professionals, the payment and the schedule depend on the nature of service, Medicare or Medicaid. Medicare eligible professionals must successfully demonstrate meaningful use for each year of participation in the program. For calendar years 2011–2016, eligible Medicare professionals who demonstrate meaningful use of certified EHR technology can receive up to $44,000 over 5 years. Medicaid eligible professionals also have to successfully demonstrate meaningful use for each year of participation in the program. For calendar years 2011–2021, Medicaid participants can receive up to $63,750 over 6 years. It is important to highlight that both, Medicare and Medicaid professionals, who participate lately in the program will receive lower incentive payments.

Eligible hospitals that adopt and successfully demonstrate meaningful use of certified EHR technology can begin receiving incentive payments for any year starting from 2011 through 2015 for Medicare services, and until 2016 for Medicaid services. The

incentive payment is based on a number of factors, and it begins with a $2 million base payment.

1.2.2 Interoperability in Health Information Technologies

Interoperability, or sharing information across systems, is one of the capabilities that can significantly affect the utilization of HIT systems in the implementation of QIMs. In healthcare organizations, the information produced by different clinical activities are archived for many purposes. One of those purposes is having the information available for future reference, which involves the normal practice of viewing the clinical history of patients. Besides reviewing the history, the information might also be passed to another area in the hospital for reporting. The information is also needed in many hospitals for billing purposes. In addition, the information is extremely vital if a legal medical case is brought.

Typically, the documentation and storage format in hospitals is paper-based, but recently, many healthcare organizations have moved to store clinical information in an electronic-based format, thus replacing the traditional documentation system with a number of HITs. The need for multiple HITs, not one that could serve all, is because documentations in the various hospital clinical services differ significantly, and therefore, it has been impossible for HIT companies to devise a solution that would fulfill all needs.

Storing information in HITs has many advantages for healthcare organizations. Information can be accessed from any terminal connected to the hospital network. In fact, many hospitals provide physicians with the capability of accessing the information even from home to provide clinical services, such as a second opinion. With HITs, information is more secure, unlike paper where it could be lost easily. Another significant benefit of

employing HITs is cost, as the manpower to manage paper-based charts could be reduced significantly, and also the space needed to store those files could be vastly reduced. This is due to the fact that huge amount of data could be stored in HITs with a relativity small footprint.

Although this kind of technology employment is very beneficial, clinical information remains within a specific system and cannot be passed to others where it might be needed. The solution to overcome this limitation is to have the organization's systems interoperable with each other, and this would allow clinical information to be exchangeable within the organization, and also from one healthcare organization to another. The interoperability is defined by the Healthcare Information and Management Systems Society (HIMSS)[64] as "the ability of health information systems to work together within and across organizational boundaries in order to advance the effective delivery of healthcare for individuals and communities".

1.2.2.1 Integration Standards

In order to make system integration easy to implement and maintain, many communication and medical terminology standards have been developed. System integration may include the utilization of one or more standards, depending on the nature of systems that are exchanging information.

For sharing textual information, and to some extent, graphs and images, a standard called Health Level 7 (HL7) has been developed. As defined by Henderson[65] "HL7 is a standard series of predefined logical formats for packaging healthcare data in the form of

messages to be transmitted among computer systems". Currently, HL7 is the main standard for exchanging textual information among HITs.

Digital Imaging and Communication in Medicine (DICOM) is a standard used for medical image interoperability. With the introduction of computed tomography (CT) followed by other digital diagnostic imaging modalities in the 1970's, and the increasing use of computers in clinical applications, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) recognized the emerging need for a standard method for transferring images and their associated information between devices manufactured by various vendors. Therefore, ACR and NEMA have developed the DICOM communication standard as a solution to this issue. DICOM is currently the dominant standard for transferring images across medical equipment and HIT systems.

For interoperability among applications residing on the same workstation, Clinical Context Object Workgroup (CCOW) has been created. CCOW is an interoperability specification for visual integration of applications, which allows users to work with an integrated computer-user session on workstation platforms. With CCOW, applications from different vendors could be integrated together to show information about a selected patient. A highly practical solution that could significantly save time for the end-users, instead of manually configuring each clinical application to display the patient's information.

Most of the previously mentioned standards are encapsulated in a framework called Integrating the Healthcare Enterprise (IHE). IHE is an initiative by a number of healthcare professionals and industry entities that aim to improve the way computer systems in

healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively.

In addition to standardizing the communication channels for carrying information and images, many coding systems have been developed to standardize the information stored in different HITs. Current Procedural Terminology (CPT), International Classification of Diseases (ICD), and Systematized Nomenclature of Medicine (SNOMED) are some of the standard coding systems that are currently available. The main benefit of following a standard coding system is avoiding different phrasings of the same term which affects other areas such as accounting, data processing, statistics, and decision support.

In many system integration implementations, a combination of the above standards and coding systems is used. For example, Picture Archiving and Communication Systems (PACS) and Radiology Information Systems (RIS) could involve using HL7 standard for carrying patient demographics, orders and results; DICOM for transferring images from the modality to the PACS system; CCOW for sharing the context among the PACS, RIS and EHR; IHE for defining the workflow; and SNOMED coding system for controlling the medical vocabulary. Figure 9 shows an example of a healthcare environment that implemented a combination of the previously mentioned standards.

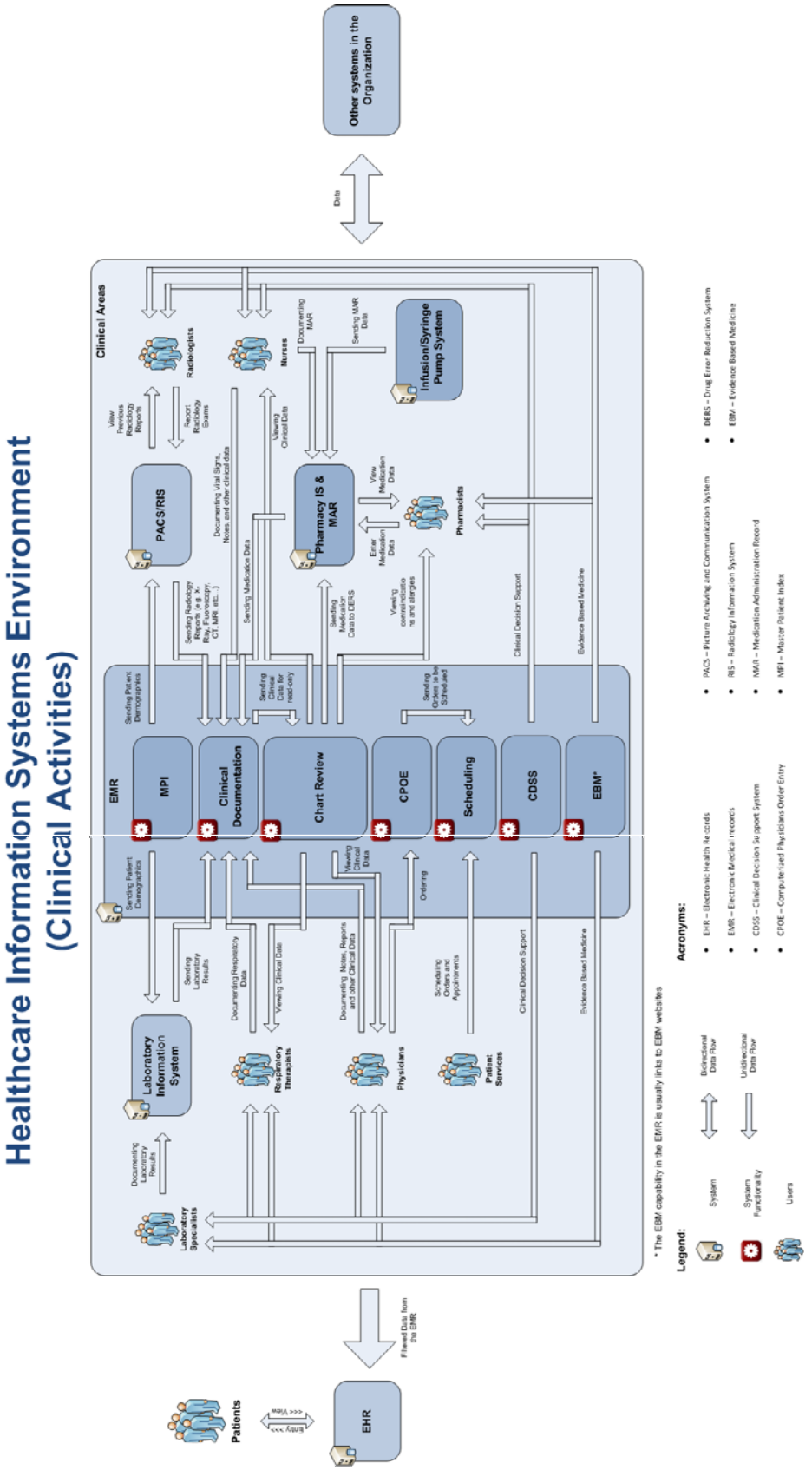


Figure 9: An example of interoperability in a healthcare environment

1.2.2.2 Benefits of System Integration

System Integration offers many advantages to all parties involved in the healthcare process. For patients, it provides safer and quicker service, especially for the risky and lengthy clinical procedures, as it eliminates procedure repetitions that are caused by the inability of having information passed from one heath care provider to the other. For governments, the costs of healthcare services could be reduced by avoiding repetitive procedures, which involves unnecessary spending. For healthcare service providers, repeating procedures translates to a higher probability of not having the medical bills reimbursable by insurance companies. According to a white paper published by the Public Health Data Standards Consortium[66], "lack of integration and interoperability across public health systems leads to the duplication of efforts and frustration among providers and consumers asked to provide the same information on multiple forms of varying formats to various programs. None of these activities are reimbursed by health insurance".

System Integration at the level of EHR could also empower medical research and the collection of much-needed evidence concerning the efficacy of various treatment alternatives. The term of art for decision-making rooted in scientific knowledge is "evidence-based medicine," a concept that is now frequently discussed in academic and scientific circles[67]. By integrating systems, data is stored in a format that is easily accessible to research. However, without system integration, data is scattered in a multiple systems and extremely cumbersome for mining.

1.2.2.3 Challenges of System Integration

However, the benefits that QIMs can gain from HIT interoperability are faced with a number of challenges. Those challenges are of different kinds, relating to implementation, maintenance, standard and information privacy.

1.2.2.3.1 Integration Implementation

A number of challenges face organizations during the implementation of system integration. Many existing systems and equipment are not capable of exchanging data with each other. This is not specific for legacy systems, but also for new systems and equipment. Conformance with communication standards is still an issue due to the fact that the standard bodies do not have standard enforcement tools to oblige companies to comply. Nonetheless, spreading awareness about considering communication standard conformance, as one of the key selection factors, might be a long-term solution for this issue. For healthcare providers, one of the available solutions is to replace the systems and equipment that cannot be integrated or adding the missing connectivity capabilities. However, this option involves significant costs, and therefore, might not be acceptable by the organization's decision makers without strong Return of Investment (ROI) justifications.

Implementing integration across systems involves adding, depending on the number and the nature of the interfaces, potentially expensive hardware and software. In addition, high-end interface management and monitoring systems, called Interface Engines, might be needed and are usually expensive. Moreover, additional manpower is needed to conduct all processes related to ensuring that the interfaces are up-and-running. All of those components add significantly to the cost of implementing integration, and they

make the process more difficult to be accepted by the decision makers in the organizations. However, an ROI study could assist in justifying the costly investment and provide a complete picture about the benefits that the organization will gain from integrating the systems.

1.2.2.3.2 Integration Maintenance

Once the integration components are in place, a number of periodic tasks have to be conducted, in order to ensure that the integration is running at an acceptable level. One of the tasks is managing changes in the integrated systems to maintain the links, as not doing so could cause numerous issues. Some of those issues could be trivial, such as having the transmitted data by the sending system not accepted by the receiving system. However, some issues could be as significant as having the communication link between systems completely failed. An example for a major communication issue can involve two PACS systems, Radiology and Cardiology, integrated to each other for exchanging DICOM medical images. If the transfer syntax in the Radiology PACS has been changed from "1.2.840.10008.1.2-Implicit VR, Little Endian" to "1.2.840.10008.1.2.1-Explicit VR, Little Endian" without applying the same changes or making sure that it is supported by the Cardiac PACS, the integration could break down, as the two systems will be communicating with different image formats.

1.2.2.3.3 Changes of Standards

Although integration communication standards have been developed to simplify implementations and avoid operational issues, this is not the case with many of the current interoperability standards. For instance, the HL7 standard is designed to have backward compatibility in order to maintain interfaces even after upgrades. However, this is not

applicable if a system, which is running a new revision of the standard, is sending data to a system running an older revision of the standard. In this case, data will be ignored or rejected. This can be demonstrated in a scenario that involves an EHR, running an HL7 v2.4 interface, and a clinical information system, running an HL7 v2.3.1 interface. In this case, the mismatch on the revision of the standard would cause a number of issues. One of the issues is related to the order flow from the EHR to the clinical information system, as HL7 v2.4 carries the order information in messages called "OMG", while version v2.3.1 of the standard supports "ORM" messages, for orders, and does not recognize the "OMG" messages. In this situation, all orders submitted from the EHR will not be accepted by the clinical information system.

Furthermore, some standards, like HL7, are currently developed in multiple versions that are completely incompatible with each other. For example, HL7 has two versions of the communication standard being developed concurrently, HL7 v3.x and HL7 v2.x. HL7 v2.x is built based on flat file format, while HL7 v3.x is built based on the Extensible Markup Language (XML) format.

To overcome the aforementioned issues, interoperability implementers should ensure revision compatibility among systems that are involved in the integration. In addition, a middleware layer, such as an integration engine, should be utilized to solve issues with incompliant systems.

1.2.2.3.4 Limitations of Interoperability Standards

The technical features in interoperability standards are, alone, not enough to ensure smooth implementations. The limitations of interoperability standards arise from the fact

that standards tend to serve as facilitators of communication more than specifiers of metadata (Henderson, Dayhoff, Titton and Casertano, 2006, p. 48). This is one of the challenges that makes integration not fully automated, even if the systems that are involved in the integration process are fully compliant with a communication standard. System integration cannot be implemented without conducting a lengthy process of translating the different vocabularies used by different systems. For example, significant interoperability issues will result between two systems that are fully compliant with the HL7 communication standard, but system A is based on ICD-9-CM and system B is based on SNOMED-CT coding system. When system A is sending an Admission Message (ADT-A01) to system B with the diagnosis code 410, in the field DG1-3, system B will not be able to match it with the "Acute Myocardial Infarction" diagnosis definition in SNOMED-CT that has the code of "57054005". It is important to highlight that the definition of diagnosis is a retired field in HL7 as of version 2.3, and the code is the only available field for identifying diagnosis. In this example, system integration will not work without an extensive translation process because of this vocabulary mismatching issue. The key to resolving such issues is for healthcare organizations to ensure that all acquired HIT systems follow the same coding system.

Defining what information should be passed from one system to another is a process left, for the most part, to implementers. This process could be particularly challenging, especially with systems that gather huge amounts of data, such as the Electronic Charting Systems (ECS). This HIT system gathers extensive clinical information from the Intensive Care Units (ICUs) and Operating Rooms (ORs). Deciding what ECS information should be passed to, for example, the EHR is a vital decision. Selecting brief information might

not accomplish the goal of replacing the patient's paper-based record with the EHR, as the missing information would be printed and included in the paper-based record. At the same time, sending excess information, might affect the use of the EHR, as locating information would be more difficult when the system is padded with unnecessary information. In addition, the system's performance might negatively be affected because of the large amount of information being transmitted at a very high frequency. In order to pass this challenge, the data set that is being be considered in the system integration has to be studied clinically to only include the amount of information needed by the receiving system.

1.2.2.3.5 Privacy, Confidentiality and Medico-Legal Issues

Interoperable HIT systems pass clinical information, such diagnoses and procedures, not only from one system to another, but also among organizations. Health information privacy and confidentiality regulations limit such widespread dissemination of information, causing a conflict with the system integration approach. Health Insurance Portability and Accountability Act (HIPAA), which was passed by the United States Congress in 1996, is one of the main guidelines for regulating the exchange of health information. Despite its protections for personal health information, privacy experts warn that HIPAA does not fully anticipate the government's model of unrestricted sharing of information among a wide network of unrelated healthcare providers[68].

The interoperability issue also imposes medico-legal issues, including liabilities if a wrong diagnosis was given by a healthcare organization and, based on that diagnosis, a clinical procedure was performed at another organization and caused harm to the patient. Moreover, most of the integration standards do not require documenting information about the healthcare workers involved in the clinical procedure. For instance, the HL7

Unsolicited Observation Reporting (ORU) message, has all fields related to the healthcare worker involved in the result optional. Therefore, a site could send a result about a procedure with no information that would trace to the workers who performed the procedure, yet, would be still fully compliant with the integration standard for textural information, HL7.

1.3 Research Hypothesis

This research study will evaluate whether or not QIMs are implemented using HIT systems in healthcare organizations in the United States.

1.4 Objectives of the Research

The aim of this study is to answer the following research questions:

1. What is the adoption level of QIMs in healthcare organizations?
2. Is the utilization of QIMs at healthcare organizations in the United States increasing or decreasing over the last ten years?
3. Are HIT systems utilized in QIM implementations at healthcare organizations in the United States?
4. What are the main obstacles that prevent the utilization of HIT systems in QIMs?
5. Is there any correlation between the manual data collection method and efficiency outcomes in QIM implementations?
6. Does the manual data collection method have correlation with throughput outcomes in QIM implementations?

7. Is there any correlation between the manual data collection method and financial outcomes in QIM implementations?
8. Does the healthcare organization's type have a statistical significant association with the utilization of HIT in QIMs?
9. Is the healthcare organization's size one of the factors that influences the utilization of HIT systems in QIMs?
10. Is there any correlation between the geographical location of the healthcare organization and the utilization of HIT systems in QIM implementations?

CHAPTER II: LITERATURE REVIEW

2.1 Healthcare Quality Issue

Many literatures have indicated the dire need for quality improvement in the United States healthcare sector. The IOM reported that between 44,000 to 98,000 patients die annually in the United States due to preventable mistakes[3]. In addition, around 1.5 million preventable medication errors occur each year[4]. Besides the direct harm on patients, this low quality level causes waste of resources that should completely be allocated to effective patient healthcare. The IOM estimated the healthcare waste value in the United States in 2009 at $750 Billion[5].

Healthcare quality issues could in fact amplify the wastes in the healthcare system. Every year, 1.7 Million HCAIs occur in the United States costing around $45 billion[71]. HCAI causes around 98,987 deaths annually in the United States[72] - causing more deaths than HIV, breast cancer, and auto accidents combined[73]. In Europe, Gram-negative infections are estimated to account for two-thirds of the 25,000 deaths annually, where

hospital surveys had been conducted[74]. These are only examples of how lack of healthcare quality can cause major health issues that require vast amount of resources. In fact, the WHO has identified 89 studies that reported data on the burden of HCAI in terms of mortality, costs and increased length of stay in health-care settings[6].

The understanding of the importance of quality improvement seem to be at an acceptable level among healthcare providers. A study published in 2014 by Kirchhoff et al. [75] evaluated the opinion of primary care physicians about quality improvement. The study included n = 691 physicians providing services in urban areas, and n = 127 physicians working in rural areas. The study concludes that "primary care physicians from rural and urban areas share similar attitudes regarding the importance of participating in quality improvement and fulfilling professional responsibilities". Despite the fact that the study was limited to specific quality improvement responsibilities that mainly relate to physicians, it reflects the positive view and even the readiness to participate in implementing quality improvement actions.

2.2 Success of LSS in Improving Healthcare Quality

There is no shortage of studies that indicate the success of LSS in improving healthcare processes. A study by van de Heuvel et al.[76] involved conducting 21 quality improvement projects at a 384-bed hospital using LSS. The total cost saving for the hospital was $1.4 million with an average of around $67,000 per project. The improvement projects had been implemented on clinical processes with different natures, including Operating Room (OR) admissions, medication administrations and delivery room operations.

A more recent study, published by Deckard et al.[77], targeted a primary care setting and also indicated positive outcomes resulted from the implementation of LSS. The project covered two specialties of the setting, genitourinary and gynecology. Table 4 lists the project metrics and their pre- and post- mean and Standard Deviation (STD) figures.

Metric	Baseline, d (Pre--12/2007)	Actual, d (Post--8/2008)
Genitourinary		
Total process	60.5 (27)	37.5 (12)
Consult request to appointment made	21 (17)	9.2 (4.6)
Appointment made to day of appointment	36 (22.7)	27.9 (10.1)
Gynecology		
Total process	135.8 (67.2)	34.9 (9.3)
Consult request to appointment made	102 (62.9)	9.9 (3.5)
Appointment made to day of appointment	33.1 (14.9)	26.4 (4.7)

Table 4: Positive LSS outcomes reported in the Deckard et al.[77] study

In Table 4, the performance of each specialty has been tracked by three measurements: 1) total process, which is the number of days from the initiation of the referral and until the date of the appointment, 2) consult request to appointment made, which consists of the number of days between initiation of the referral and the date the appointment is made, and 3) appointment made to day of appointment. The figures in the table indicate significant decreases in the number of days the patients had to wait. For instance, the gynecology process had a 74% reduction in the average total process time, and it was mainly due to the major improvement in the consult request to appointment made metrics, which had a 90% decrease in the average time.

LSS has also been proven effective in the infection control area of healthcare. A study by Carboneau et al.[78] has been conducted at the Presbyterian Healthcare Services in

Albuquerque, New Mexico, which evaluated the effectiveness of LSS in improving the hand hygiene compliance rate. The DMAIC stages of the LSS methodology lasted for 12 months and focused on the hand hygiene infection control process. The LSS Improve stage consisted of educational, cultural, and environmental actions that are expected to have significant improvements on many infection issue. Nonetheless, the study assessed the outcome of the quality improvement project on MRSA infections, and revealed an infection reduction of 51%, which saved the hospital around US$276,500.

2.3 Critical to Quality Requirements

Some literatures has discussed the sources of Critical To Quality (CTQ) requirements that properly fit healthcare. Gamm et al.[79] highlighted the IOM's Six Aims for Improvement[80] as a requirement source for different improvement methodologies. As mentioned by Gamm et al.[79], "The committee concluded that solutions to the challenges faced in improving the quality of patient care and safety are inherently multifaceted and multi-organizational and require attention to 6 factors: (1) safety; (2) effectiveness; (3) patient-centeredness; (4) timeliness; (5) efficiency; and (6) equity". The six aims highlight the healthcare areas that need to be addressed in order to achieve overall quality improvement. In fact, the aims could be considered as a comprehensive source for CTQ requirements and should be considered in healthcare-implemented QIM projects.

Shown in Table 5, Gamm et al.[79] have listed the six aims along with the different technologies that can be used to accomplish them. They also explained how many of those technologies can be part of improvement methodologies, such as LSS. For example, the Timeliness aim require techniques that handle a set of measures, such as waiting time, consult to appointment time, and appointment scheduling to appointment date time. The

authors suggest LSS as one of the methodologies that are already equipped with such techniques.

	Organizational technologies			
IOM aims	**Clinical**	**Social**	**Information**	**Administrative**
Safety: "Patients should not be harmed by the care that is intended to help them, nor should harm come to those who work in health-care."(IOM, 2001)	• Number of accidental injuries • Diagnosis accuracy • Treatment safety • *Infection rates* • *Monitoring results*	• Treatment plans followed as intended • Informed patients • Patients' perception of treatment plan success • *Staff attention to safety opportunities*	• Knowledge about patients • Prescription errors • Drug interactions • *CPOE* • *Reduction in data entry*	• Communication efforts to promote transparency • *Self-correction processes* • *Staff training* • *Number of employee injuries*
Effectiveness: "Effectiveness refers to care that is based on the use of systematically acquired evidence to determine whether an intervention produces better outcomes. . .." (IOM, 2001)	• Use of evidence-based diagnostic tests, treatment, and therapy • *Chronic care measures* • *Prevention actions*	• Patient satisfaction • Patient needs are met • *Patient knowledge level* • *Support from informal caregivers and paraprofession-als*	• Access to relevant science base and research •*Overuse and misuse of care* • *Interfaces across clinical and administrative information systems*	• Monitor results of care • Study patterns of care and outcomes • *Identification of opportunities for improvements*
Patient-centeredness: "A system that works or fails to work to meet individual patients' needs . . . encompasses qualities of compassion, empathy, responsiveness to needs, values and preferences." (IOM, 2001)	• Patient experience • Physical comfort • *Patient engagement and empowerment* • *Shared decision making*	• Respect patient needs/values • Information, communication, and education for patients • Coordination of care • Emotional support • Involvement of family and friends • *Overall patient satisfaction* • *Level of communication*	• Integration of care •*Use of PHR* •*Use of EMR* •*Provision of timely and re-enforcing information*	• Use of patient satisfaction results and other data to improve systems and processes • Satisfaction with appointment • Scheduling

(*continues*)

	Organizational technologies			
IOM aims	**Clinical**	**Social**	**Information**	**Administrative**
Timeliness: "Timeliness is an important characteristic of any service and is a legitimate and valued focus of improvement in healthcare . . . emotional distress and physical harm may result from delays. . .." (IOM, 2001)	• Waiting time • Early diagnosis and prevention rates • *Reducing barriers to access* • *Prevention, screening, early intervention*	• Waiting time for therapy and other professional services • *Timeliness in communication with patient*	• Waiting time for diagnostic test results • *Access to patient health record* • *Time lag to update PHR* • *Synchronous entry and review of patient information*	• Diagnostic tests scheduling • *Waiting time at registration* • *Waiting times on the phone (billing, scheduling, clinic)* • *Monitor and value patients' time*
Efficiency: "In an efficient healthcare system, resources are used to get the best value for the money spent . . . the opposite of efficiency is waste. . .." (IOM, 2001)	• Clinical information entry and access • Number of entries reduced to minimum • Maximize level of secure access to clinical information • Recycle appropriate resources • Wise substitution of resources	• *Integrated team approach to care* • *Employ information and communication models of coordination*	• *Effective use of CPOE* • *Information availability* • *Number of access points to CPOE, EMR, and PHR information* • *Accurate charting and coding*	• Reduce layers of control • Reduce administrative costs • Minimize sign-off and approval requirements for process improvement initiatives • Simplify staff classifications • *Appropriate level of care* • *Reduce duplication*
Equity: "The aim of equity is to secure these benefits (reducing the burden of illness, injury, and disability, and improving the health and functioning of people) for all the people of the United States." (IOM, 2001)	• Access to care regardless of income and insurance • *Emphasize population health* • *Recognize personal and societal burden of untreated illness or delayed treatment*	• *Ethnically and culturally appropriate health delivery, patient education, and follow-up* • *Draw upon cultural connections, CHWs, family, and peers to reach out to underserved* • *Deploy social linkages to retain underserved in treatment*	• *Tracking of health outcomes and quality of care by population groups of interest* • *Employ information systems to enroll the uninsured in a medical home* • *Employ PHRs to track care for those without a single medical home*	• *Culture of racial and ethnic tolerance is communicated and implemented* • *Culture of fairness and equity is communicated and practiced* • *Fair treatment of physicians and employees regardless of rank, race, age, and other factors*

Table 5: IOM Suggested Strategy for Healthcare Quality Improvement[79]

In fact, Gamm et al.[79] have assisted in listing several measures that are derived from the IOM's Six Aims for Improvement. Those measures can be used as indicators for the CTQ requirements as part of LSS. For example, to evaluate the improvement on the Safety Aim, the diagnosis accuracy measure can be used. This can be calculated through a number of methods, including the fundamental differences among the admission, primary, and discharge diagnoses. Low diagnosis accuracy translates to delays in handling the patient's actual needs and probably exposes the patient to risks; all negatively affecting the patient's safety.

2.4 Limitations of Traditional LSS in Healthcare

Despite the proven effectiveness of the traditional LSS, many studies have highlighted a number of issues that prevented obtaining the utmost benefits of such methodology in the healthcare environment. A recent literature published by Aleem[81] explains a set of challenges that resulted from the implementation of LSS at Hertel Elmwood Internal Medicine Center, an ambulatory healthcare organization based in Buffalo, NY and is affiliated with the University of Buffalo. After completing the application of LSS, the involved team in the quality improvement process has learned a number of lessons, including challenges associated with the traditional LSS methodology.

The first lesson was related to the importance of collecting valid and real time data for performance evaluation and faster integration of LSS in the healthcare environment. The team realized that HIT systems have the capabilities of providing valid and real time data, especially with the increase use of technology in health care. In fact, the team understood that the decisions on what improvement project to start with should be based on the reliability and accuracy of data. This lead the team to value the importance of

automating most healthcare processes in order to easily detect and quantify process issues, as well as eliminate human variability in data. Automation also has the potential of assisting the LSS team to overcome the issues of obtaining value measurements that allow performing different financial analyses, including the cost-benefit analysis. This would be possible by linking the coded diagnosis and procedures with dictionaries that include standard costs of services, such as DRG.

Another study published by Chand[82] has shared some of the challenges stated by Aleem[81]. The study was part of a LSS quality improvement project aimed primarily to eliminate wastes and variations identified in resident rounds. A secondary goal was to improve the efficiency of the rounding process. The project was successful, as the median rounding time per patient went down by around 50% and the median nonvalue-add time per patient was reduced by approximately 64%. However, the LSS team faced a number of challenges that prevented further immediate improvement as well as risking the maintenance of improvement on the long-term. Firstly, the LSS team realized that the collection of observational data is both labor-intensive and time-consuming. Secondly, the team learned that one of the limitations is the low number of observations and survey responses that they received when they were studying the processes. The team also learned that one of the core approaches of LSS is to make small changes, measure again, and then continually improve the process. Nonetheless, the team had major issues with manual data collection as there were fewer survey responses after the intervention. Finally, the team anticipated issues when this improvement project is replicated to other departments or even institutions, as many of the data-driven solutions addressed in the project would need to be individually customized to fulfill the needs of the other areas.

Unlike the previous studies, where data collection was conducted manually, the study by Cima[83] et al. described a LSS quality improvement project that utilized the HIT infrastructure for data collection. Figure 10 shows an OR clinical process linked to HIT to gather LSS data.

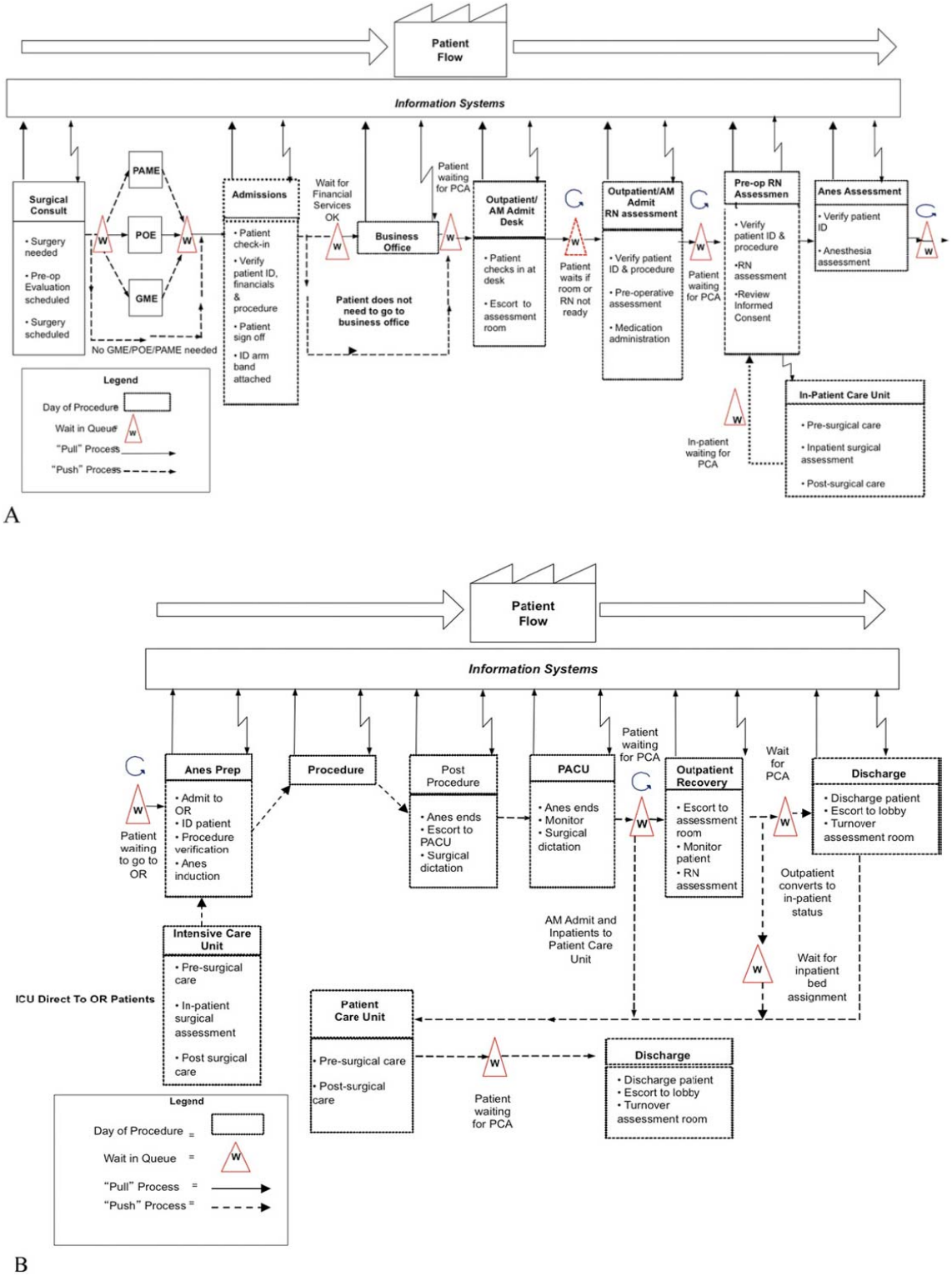


Figure 10: A clinical process linked to a HIT for data collection[83]

The study demonstrates that many of the data points that are necessary for the LSS process can be obtained from common HIT systems. However, the integration of LSS into HITs was limited to part of the Measure stage, data collection, and did not include the process necessary for the other stages, analyze, improve, and control.

Another issue was highlighted by a recent study authored by Lin et al.[84], in which a LSS implementation at a large tertiary otolaryngology clinic was illustrated. The outcomes of the study were significantly positive, as the patient lead the time from clinic arrival to exam start time decreased by 12.2% on average ($P = 5.042$), on-time starts for patient exams improved by 34% ($P < 0.001$), and the excess patient motion was reduced by 34% reduction in motion per visit. Nonetheless, the authors point to a limitation in the LSS process caused by the potential implications of observer or Hawthorne effect, in which there may be changes in a person's behavior due to the presence of an observer. In a traditional LSS implementation, this issue cannot be eliminated, as many of the processes are performed manually, which require the obvious activities of the LSS team.

The ad hoc data collection that occur during the traditional LSS project causes issues after the project is completed, as up-to-date data is needed to maintain improvement and monitor performance on the long-run. The ad hoc data collection issue was stated in a study conducted by Parks et al.[85]. The authors stated that, at the time of writing the literature, they did not have follow-up data to show the impact of the implemented changes. This is due to the reason that an ad hoc data collection has to be conducted every time a snapshot of the performance needs to be evaluated. Nevertheless, the authors speculated the results after forming an analogy with a similar study conducted by van de Heuvel et al.[76].

2.5 Benchmarking Outcomes

A number of scientific literatures have shown the benchmarking methodology effectiveness in improving healthcare quality. In a 12-month study, Hermans et al.[86] evaluated the quality of primary care for patients with type 2 diabetes by using HbA1c, LDL cholesterol, and Systolic Blood Pressure (SBP) cardiovascular risk factors as quality indicators. The study covered primary care practices that treat patients with type 2 diabetes in six European countries. In each practice, patients were divided into two groups, control and benchmarked. The control group received standard treatment without comparison against the other practices. On the other hand, the indicator results of the benchmarked group were constantly compared against other practices. The outcomes of the study have shown that the HbA1c target was achieved in the benchmarking group by 58.9 vs. 62.1% in the control group; 40.0 vs. 30.1% patients met the SBP target; 54.3 vs. 49.7% met the LDL cholesterol target. Overall, the percentage of patients achieving all three targets during the study was significantly larger in the benchmarking group than in the control group (12.5 vs. 8.1%; $P < 0.001$).

On a national level, a scientific literature by Tworek et al.[87] highlighted an anatomic pathology benchmarking program that was established by the American College of Pathology to facilitate peer-comparison of hospital laboratories based on specific quality metrics. Laboratories from the United States, Canada, and 16 other counties have participated in the benchmarking program. The program established national benchmarks in anatomic pathology, addressing factors in the disciplines of cytopathology, surgical pathology, and autopsy pathology. Studies have shown that national benchmarking programs are associated with improvement in quality of care[88,89].

2.6 Challenges of CQI

Multiple studies have shown positive outcomes that were part of the results of CQI implementations[90-93]. However, some literatures have pointed to challenges associated with traditional CQI implementations. For example, a study was conducted in 2012 with the objective of identifying the initial challenges of implementing a standardized CQI program in a number of community pharmacies. Through a qualitative data collection method, interviews, the study that covered community pharmacies in Nova Scotia, Canada, was performed to identify such challenges. Interviews were conducted with 10 involved staff members, such as staff pharmacists and technicians. The study unveiled six key CQI challenges, which are: finding time to report, having all pharmacy staff involved in quality-related event (QRE) reporting, reporting apprehensiveness, changing staff relationships, meeting to discuss QREs, and accepting the online technology[94]. The first challenge, finding time to report, indicates that the manual data collection in traditional CQI implementations is not practical in many instances. Requesting healthcare staff members to report extensive data distracts them from their highest priority task, which is providing safe and effective care for patients. The second challenge, having all pharmacy staff involved in QRE, also points the practicality issue in the traditional CQI. This issue creates resistance against participation in quality-related activities. The third challenge, reporting apprehensiveness, refers to a typical organizational behavior that involves avoiding actions that can create conflicts in the workplace, even if the conflicts are constructive, resulted from objective reports about the processes in the workplace.

CHAPTER III: MATERIALS AND METHODS

This study relies on three data sources to facilitate the analysis. The database provided by the Dorenfest Institute for Health Information is used to obtain demographical information about healthcare organizations. This includes the organization size, type, location, HIT status, and the contact information of the organization's representatives. The Electronic Medical Record Adoption Model (EMRAD) of HIMSS is used as one of the data sources in order to attain information about whether or not the healthcare organization has reached a closed-loop HIT implementation. The third data source is a survey that evaluated the experiences of hospitals and practices and completed the missing variables that are not provided by the Dorenfest Health Information database or the HIMSS EMRAD.

The complete list of the study measures, which have been derived from the three data sources, is presented in Appendix A. The Hospital_Bedsize_A measure was derived from the Hospital_Bed_No_A. The values were categorized based on the Healthcare Cost and Utilization Project (HCUP) bed size categorization method[95], illustrated in Table 6. The method takes into consideration the hospital location from the metropolitan status and geographical region point of view.

BEDSIZE CATEGORIES (Beginning in 1998)			
Location and Teaching Status	Hospital Bedsize		
	Small	Medium	Large
NORTHEAST REGION			
Rural	1-49	50-99	100+
Urban, nonteaching	1-124	125-199	200+
Urban, teaching	1-249	250-424	425+
MIDWEST REGION			
Rural	1-29	30-49	50+
Urban, nonteaching	1-74	75-174	175+
Urban, teaching	1-249	250-374	375+
SOUTHERN REGION			
Rural	1-39	40-74	75+
Urban, nonteaching	1-99	100-199	200+
Urban, teaching	1-249	250-449	450+
WESTERN REGION			
Rural	1-24	25-44	45+
Urban, nonteaching	1-99	100-174	175+
Urban, teaching	1-199	200-324	325+

Table 6: The HCUP hospital bed size categorization method

To determine the metropolitan status of hospitals, the 2010 United States Census Bureau classification for urban and rural areas was used. The United States Census Bureau's urban-rural classification defines geographical areas, identifying both individual urban areas and the rural areas of the United States. The Bureau's urban areas represent densely developed territory, and encompass residential, commercial, and other non-residential urban land uses. Rural areas encompass all population, housing, and territory not included within an urban area[96].

The US_Region_A measure was derived from the United States Census Bureau regional divisions[97], which are:

- Region 1: Northeast
    - Division 1: New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)
    - Division 2: Mid-Atlantic (New Jersey, New York, and Pennsylvania)

- Region 2: Midwest (Prior to June 1984, the Midwest Region was designated as the North Central Region.)
    - Division 3: East North Central (Illinois, Indiana, Michigan, Ohio, and Wisconsin)
    - Division 4: West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota)
- Region 3: South
    - Division 5: South Atlantic (Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, Washington D.C., and West Virginia)
    - Division 6: East South Central (Alabama, Kentucky, Mississippi, and Tennessee)
    - Division 7: West South Central (Arkansas, Louisiana, Oklahoma, and Texas)
- Region 4: West
    - Division 8: Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming)
    - Division 9: Pacific (Alaska, California, Hawaii, Oregon, and Washington)

The Basic_HIT_Installed measure is obtained from the Dorenfest database, by searching the table HAEntityApplication of the database using the hospital ID to identify if the three applications have been installed. The three application benchmark have been set based on HIMSS EMRAD, which specifies that the basic installation of HIT consists of those three applications, as mentioned in stage 1 of the model.

However, in the case of physician practices, the only application that was checked is the "Ambulatory EMR" and the "Practice Management" systems in the Dorenfest database, which both represent Stage 1 of HIMSS Ambulatory Electronic Medical Record Adoption Model[98]. Practice Management is a system that provides schedule management, patient demographics, medical billing management, claims scrubbing, and reporting capabilities[99].

SPSS version 22.0.0.0 software was used to conduct the statistical analyses, which included descriptive statistics, frequencies, Analysis of Variance (ANOVA), Chi-Square (Pearson, Phi, Cramer's V), Correlation (Gamma, Spearman and Pearson's R) and Logistic Regression.

CHAPTER IV: RESULTS

The submitted survey invitations have yielded 144 responses from 134 hospitals and 10 physician practices, representing 2.3% of the 5,723 hospitals that exist in the United States[100]. The types/locations of the participating hospitals are classified as 50% urban non-teaching, 38.1% rural and 11.9% urban teaching.

The geographical locations of the responding healthcare organizations included the four main regions of the United States, as defined by the US Census Bureau[101]. The participation shares of the Northeast, Midwest, South, and West regions were 24.3%, 33.3%, 27.8% and 14.6%, respectively. Figure 11 illustrates the geographical locations of the healthcare organizations that participated in the survey.

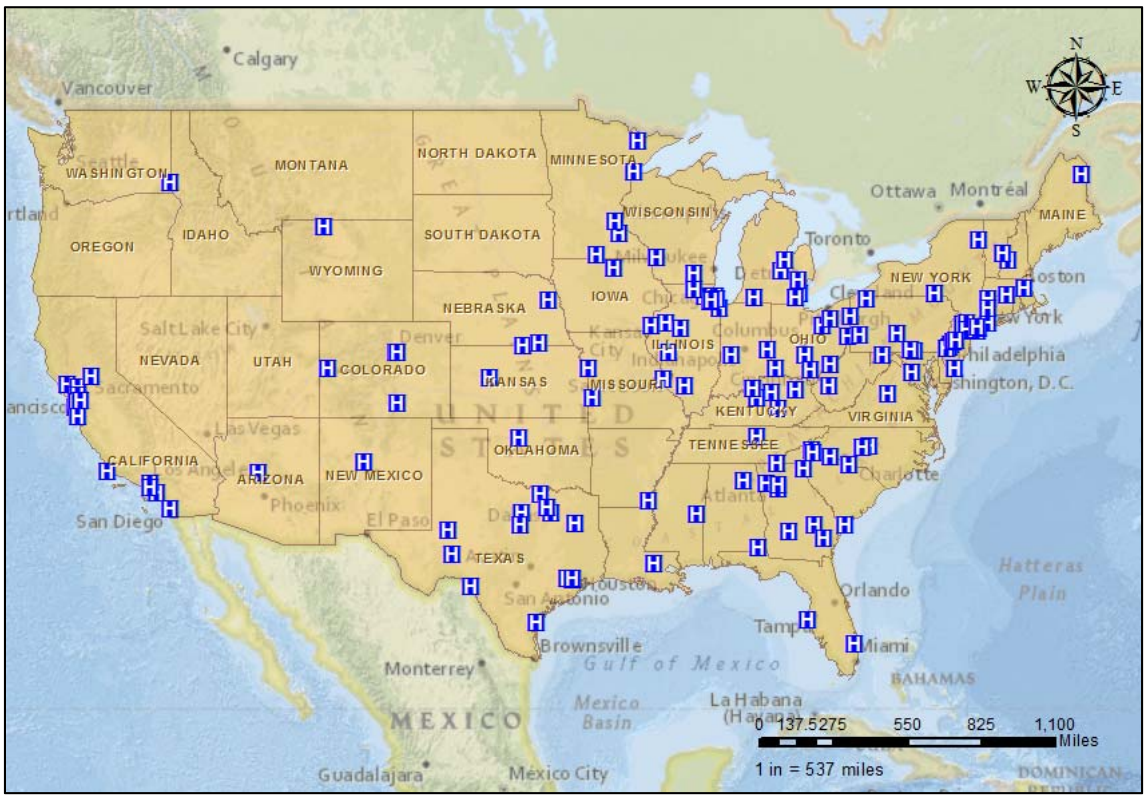


Figure 11: Responses from hospitals and physician practices have covered the four main regions of the United States

Table 7 shows the results of the frequency analysis that has been conducted on a multiple key stratifiers in the dataset in order to explore the distribution of the data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hospital	134	93.1	93.1	93.1
	Ambulatory	10	6.9	6.9	100.0
	Total	144	100.0	100.0	

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Rural	51	35.4	38.1	38.1
	Urban, nonteaching	67	46.5	50.0	88.1
	Urban, teaching	16	11.1	11.9	100.0
	Total	134	93.1	100.0	
Missing		10	6.9		
Total		144	100.0		

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Northeast	35	24.3	24.3	24.3
	South	48	33.3	33.3	57.6
	Midwest	40	27.8	27.8	85.4
	West	21	14.6	14.6	100.0
	Total	144	100.0	100.0	

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Hospital	45	31.3	33.6	33.6
	Medium Hospital	20	13.9	14.9	48.5
	Large Hospital	69	47.9	51.5	100.0
	Total	134	93.1	100.0	
Missing		10	6.9		
Total		144	100.0		

Table 7: Frequency analysis of the healthcare organizations' characteristics

In relation to the QIM utilization, it was found that 99.3% of the healthcare organizations have implemented at least one of the common QIMs, which were mentioned in the survey. Benchmarking was found to be the top utilized QIM with 83.3% of the healthcare organizations reporting the implementation of this QIM in the last ten years. CQI and CP were second and third in the top QIM utilization list, with 71.5% and 67.4% utilization, respectively. TQM and LSS also have shown a significant utilization with around half of the surveyed hospitals and practices reporting to have utilized those QIMs. However, the least utilized methodologies that were reported in the survey are SS and BPR. Table 8 shows a frequency analysis of the common QIMs that have been included in the survey.

Frequencies

	N	Checked			Unchecked		
		Frequency	Percent	Valid Percent	Frequency	Percent	Valid Percent
LSS	141	67	46.5	47.5	74	51.4	52.5
CP	141	97	67.4	68.8	44	30.6	31.2
Benchmarking	141	120	83.3	85.1	21	14.6	14.9
SS	141	29	20.1	20.6	112	77.8	79.4
BPR	141	21	14.6	14.9	120	83.3	85.1
LM	141	56	38.9	39.7	85	59.0	60.3
ToC	141	1	.7%	.7	140	97.2	99.3
CQI	141	103	71.5	73.0	38	26.4	27.0
TQM	141	78	54.2	55.3	63	43.8	44.7
Others	141	14	9.7	9.9	127	88.2	90.1

Table 8: Frequency analysis of the utilized QIMs

Although the utilization of some of the QIMs appeared to be low, their timeline variables indicated very high increases over time, as shown in Figure 12. For example, LSS, which is the identified fifth common methodology as indicated in Table 8, has an

average utilization increase of 36%, which can place it in the near future in the second position, after Benchmarking, surpassing CQI and CP, which both have no major increases in use over the last ten years. On the other hand, some QIMs have shown an over time stagnation, such as in the case of CQI, or even utilization decline, as in the case of TQM.

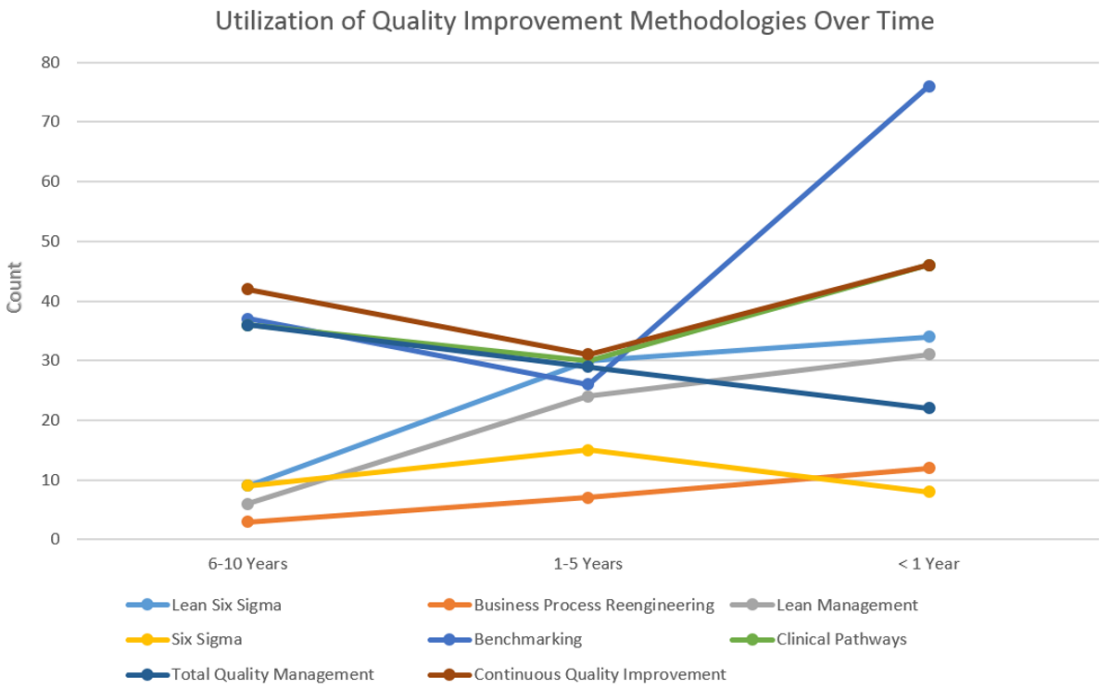


Figure 12: The utilization of QIMs over the last ten years

The survey also analyzed the data sources that have been used during the implementation of each QIM, as revealed in Figure 13. Despite the fact that many types of HIT systems have been used as data sources, manual data collection was the most common method during the implementation of most QIMs, with an average utilization of 70%. It was also noticed that 59.1% of the healthcare organizations have reported the utilization of EHRs in QIM implementations, at a higher level than the utilization of LIS, PIS, CPOE

and RIS, in which they had utilization averages of 34.46%, 29.35%, 29.25% and 26.89%, respectively.

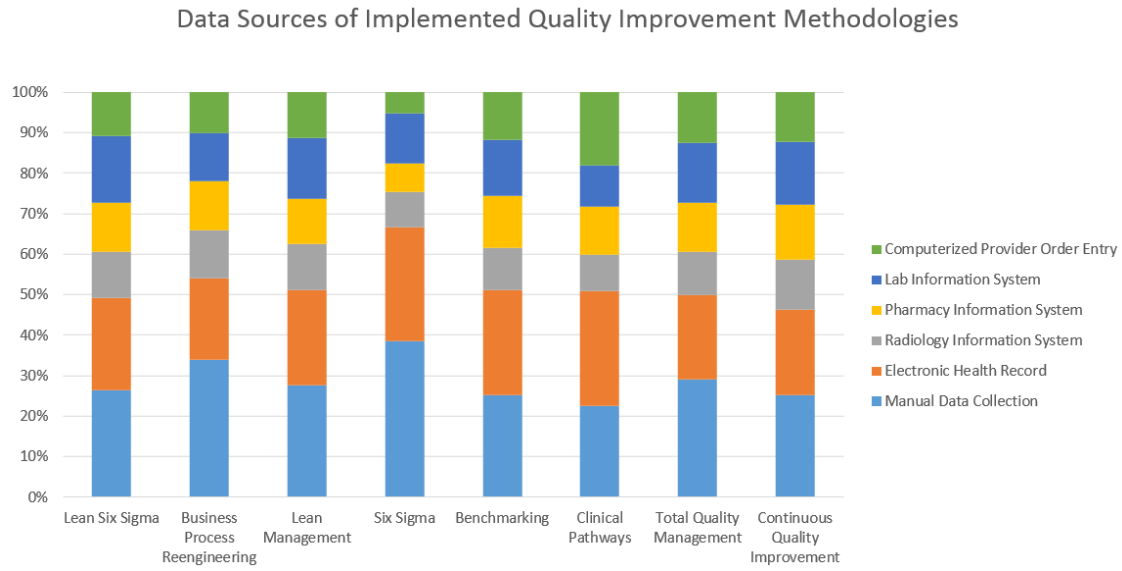


Figure 13: The data sources of the implemented QIMs

Besides the previously mentioned QIMs, data about the utilized quality improvement tools have been collected from the participating healthcare organizations. The results have shown that the mostly utilized tool has been Cause-and-Effect Diagram (Fishbone or Ishikawa), by 63.2% of the healthcare organizations. In the second and third places of the highly utilized quality improvement tool list, Failure Mode and Effects Analysis (FMEA) and Strength, Weaknesses, Opportunities and Threats (SWOT) Analysis came with 56.9% and 56.3% utilization, respectively. On the contrary, the least utilized quality improvement tools were Reasonable, Understandable, Measurable, Believable, Achievable (RUMBA), Specific, Measurable, Achievable, Relevant, Time-Oriented and Important (SMARTI) and Substitute, Combine, Adapt, Modify, Put to Another Use, Eliminate and Reverse (SCAMPER) Analysis, with 2.1%, 2.1% and 1.4% utilization,

correspondingly. Table 9 presents the frequencies of the utilized quality improvement tools along with their relevant percentages.

Frequencies

	N	Checked			Unchecked		
		Frequency	Percent	Valid Percent	Frequency	Percent	Valid Percent
Process Capability Analysis	110	11	7.6	10.0	99	68.8	90.0
Statistical Process Control	110	48	33.3	43.6	62	43.1	56.4
Failure Mode and Effects Analysis (FMEA)	110	82	56.9	74.5	28	19.4	25.5
Cause-and-Effect Diagram (Fishbone or Ishikawa)	110	91	63.2	82.7	19	13.2	17.3
Supplier, Input, Process, Output, and Customer (SIPOC or COPIS)	110	27	18.8	24.5	83	57.6	75.5
System of Work (SOW)	110	24	16.7	21.8	86	59.7	78.2
RUMBA	110	3	2.1	2.7	107	74.3	97.3
SMARTI	110	3	2.1	2.7	107	74.3	97.3
X - Y Matrix	110	18	12.5	16.4	92	63.9	83.6
Process Failpoint Analysis Matrix	110	7	4.9	6.4	103	71.5	93.6
Waste Analysis Matrix	110	25	17.4	22.7	85	59.0	77.3
Five Whys	110	53	36.8	48.2	57	39.6	51.8
Process Mapping	110	71	49.3	64.5	39	27.1	35.5
SWOT Analysis	110	81	56.3	73.6	29	20.1	26.4
SCAMPER Analysis	110	2	1.4	1.8	108	75.0	98.2
others	110	5	3.5	4.5	105	72.9	95.5

Table 9: Frequency analysis of the employed QIM tools

Although those quality improvement tools are used by many of the QIMs, it is highly challenging to establish a correlation between the utilization of QIMs and quality improvement tools. This is because many of the quality improvement tools are generic and shared among a number of the QIMs. In fact, most of the tools are independent to a very large degree and can be implemented separately from any other quality improvement tool or methodology.

4.1 Influence on Outcomes

The reported overall outcomes of all main QIMs fell around the middle level on all of the three outcome areas; efficiency, throughput and financial improvement. The reported outcomes indicate relatively similar results, despite the vast variances in utilization, which was discussed previously. The STD values were generally below one, which shows that the variations in the outcome data was very low, and that most of the reported outcome values were generally at the moderate level. Table 10 displays the overall outcomes of each of the common QIMs that were included in the study.

	Efficiency of Workflow $\bar{x}$(STD)	Throughput of Workflow $\bar{x}$(STD)	Financial Improvement $\bar{x}$(STD)
Lean Six Sigma (LSS)	*3.72*(0.86)	*3.7*(0.86)	*3.45*(1.1)
Six Sigma (SS)	*3.88*(0.83)	*3.68*(0.98)	*3.62*(1.05)
Clinical Pathways (CP)	*3.8*(0.82)	*3.74*(0.84)	*3.25*(1.06)
Business Process Reengineering (BPR)	*3.45*(0.82)	*3.42*(0.9)	*3.17*(0.94)
Lean Management (LM)	*3.3*(0.96)	*3.25*(0.96)	*3.36*(1.0)
Continuous Improvement (CI)	*3.54*(0.93)	*3.51*(0.84)	*3.23*(1.02)
Total Quality Management (TQM)	*3.33*(1.03)	*3.28*(0.97)	*3.0*(1.02)
Benchmarking	*3.54*(0.9)	*3.57*(0.91)	*3.28*(1.0)
Average	*3.57*(0.89)	*3.52*(0.91)	*3.3*(1.02)

* The used measurement scale is from 0 to 6, which was averaged in the table

Table 10: Overall outcomes of QIMs implementations

In order to explore the influence of HIT utilization on QIMs, the dataset has been filtered to eliminate the observations that do not have a complete reliance on the HIT data sources. The results have shown a noticeable differences in the outcomes between the two groups. Table 11, shows the averages and STDs of the outcomes for QIM implementations that were based solely on HIT data sources.

	Efficiency of Workflow $\bar{x}$(STD)	Throughput of Workflow $\bar{x}$(STD)	Financial Improvement $\bar{x}$(STD)
Lean Six Sigma (LSS)	*4.2*(0.84)	*4.2*(0.84)	*3.6*(1.14)
Six Sigma (SS)	*4.0*(0.00)	*3.33*(0.58)	*3.67*(0.58)
Clinical Pathways (CP)	*4.13*(0.64)	*4.0*(0.54)	*3.63*(1.19)
Business Process Reengineering (BPR)	N/A	N/A	N/A
Lean Management (LM)	*3.86*(1.07)	*3.71*(0.95)	*2.86*(1.22)
Continuous Improvement (CI)	*4.0*(0.63)	*4.33*(0.54)	*3.33*(1.21)
Total Quality Management (TQM)	*3.83*(0.75)	*3.67*(0.52)	*3.17*(0.98)
Benchmarking	*3.67*(0.5)	*3.6*(0.53)	*3.89*(0.6)
Average	*3.96*(0.74)	*3.83*(0.64)	*3.45*(0.99)

* The used measurement scale is from 0 to 6, which was averaged in the table

Table 11: Outcomes of HIT-based QIM implementations

To compare the means between the two groups, with and without utilizing HIT systems in QIMs, one-way ANOVA test has been performed on the independent variable "Only_Manual_Data_Collection_Was_Used" and the dependent variables of average outcomes: "Avg_Efficiency_Outcome_A", "Avg_Throughput_Outcome_A" and "Ave_Financial_Outcome_A". The descriptive statistics of the analysis is presented in Table 12.

Descriptive Statistics

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower Bound	Upper Bound		
The average efficiency outcome across all quality improvement methodologies	No	107	3.48	.667	.064	3.35	3.61	2	5
	Yes	8	3.10	.456	.161	2.72	3.49	2	4
	Total	115	3.46	.660	.062	3.33	3.58	2	5
The average throughput outcome across all quality improvement methodologies	No	106	3.48	.617	.060	3.36	3.60	2	5
	Yes	8	2.95	.406	.143	2.61	3.29	2	4
	Total	114	3.44	.619	.058	3.33	3.56	2	5
The average financial outcome across all quality improvement methodologies	No	106	3.25	.808	.079	3.09	3.40	1	5
	Yes	8	3.03	.467	.165	2.64	3.42	3	4
	Total	114	3.23	.790	.074	3.08	3.38	1	5

Table 12: Descriptive statistics of the QIM outcomes with/without utilizing HIT-systems

The results of the descriptive statistics, revealed in Table 12, has shown that mean efficiency, throughput and financial impact are all lower when healthcare organizations rely exclusively on the manual data collection method, 3.10, 2.95 and 3.03, when compared to QIM implementations that included the use HIT systems, 3.48, 3.48 and 3.25. It was also important to highlight that there was a very high consistency in the reported outcomes, as the STDs were lower than one on all outcomes.

ANOVA F-test analysis has yielded the results shown in Table 13, which shows that overall throughput outcomes had a p-value of 0.018. Based on 95% confidence limit, we notice that there is a statistically significant difference between the throughput outcome

means with and without the utilization of HIT systems in QIM implementations. Nevertheless, the overall efficiency and financial improvement mean values did not show statistically significant differences, p-values of 0.119 and 0.461 for the efficiency and financial improvement outcomes, respectively.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
The average efficiency outcome across all quality improvement methodologies	Between Groups	1.060	1	1.060	2.464	.119
	Within Groups	48.637	113	.430		
	Total	49.698	114			
The average throughput outcome across all quality improvement methodologies	Between Groups	2.108	1	2.108	5.736	.018
	Within Groups	41.153	112	.367		
	Total	43.260	113			
The average financial outcome across all quality improvement methodologies	Between Groups	.343	1	.343	.548	.461
	Within Groups	70.121	112	.626		
	Total	70.464	113			

Table 13: ANOVA results for the QIM outcomes with/without the utilization HIT systems

The results of Robust Tests of Equality of Means also supports the findings of the F-test, mentioned previously. The Welch and Brown-Forsythe significance values of the overall throughput outcomes were both 0.018, which indicates a statistically significant difference between the two groups of means, with and without utilizing HIT systems in QIM implementations. The significance values of the overall efficiency and financial

improvement, 0.056 and 0.266, correspondingly, also confirms the previous finding that suggests statistically insignificant differences in mean values of the groups. Table 14 presents the results of the Robust Tests of Equality of Means.

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
The average efficiency outcome across all quality improvement methodologies	Welch	4.727	1	9.405	.056
	Brown-Forsythe	4.727	1	9.405	.056
The average throughput outcome across all quality improvement methodologies	Welch	11.726	1	9.640	.007
	Brown-Forsythe	11.726	1	9.640	.007
The average financial outcome across all quality improvement methodologies	Welch	1.379	1	10.486	.266
	Brown-Forsythe	1.379	1	10.486	.266

a. Asymptotically F distributed.

Table 14: Robust tests of equality of means for the QIM outcomes with/without the utilization HIT systems

4.1.1 Throughput Outcomes

To further evaluate the impact of the manual data collection practice on throughput outcomes, correlation analysis was performed on the variable "Only_Manual_Data_Collection_Was_Used", which flags the observation when QIM is implemented without relying on HIT data sources, and the variable that shows the QIM implementation throughput outcomes, "Avg_Throughput_Outcome_A".

The case processing summary illustrates that out of the 124 that met the requirements of one of the two variables, there were 116 observations, which did not involve the use of manual data collection in QIMs, and 8 observations, which involved the

use of the sole manual data collection in QIMs. The 114 observations that met the requirements of both variables included 8 observations that involved the exclusive use of the manual data collection method in the QIM implementation, while 106 observations comprised the utilization of HIT systems as data sources. Only 10 observations had "The average throughput outcome across all quality improvement methodologies" variable missing values. All of the 10 observations showed that the manual data collection method has not been used exclusively in the QIM implementations. Table 15 presents the results of the case processing summary.

Case Processing Summary

	Indicates if the only data source was the manual data method	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
The average throughput outcome across all quality improvement methodologies	No	106	91.4%	10	8.6%	116	100.0%
	Yes	8	100.0%	0	0.0%	8	100.0%

Table 15: Case processing summary for the impact of manual data collection on throughput outcomes of QIMs

The results of the basic statistics for the two groups, the group that relied completely on manual data collection in QIM implementations and the group that did not, has revealed a number of findings. Table 16 displays the results of the basic statistics. Both, the throughput outcome mean and median, were lower for the group that exclusively utilized the manual data collection method in QIM, 2.95 and 3.00, in compared to 3.48 and 3.41 for the group that utilized HIT data sources.

Despite slight variations, the STD was found to be below 1 in both groups. Along with considering the relatively close mean and median values, this shows that the data within the groups are relatively normally distributed.

Descriptives

	Indicates if the only data source was the manual data method			Statistic	Std. Error
The average throughput outcome across all quality improvement methodologies	No	Mean		3.48	.060
		95% Confidence Interval for Mean	Lower Bound	3.36	
			Upper Bound	3.60	
		5% Trimmed Mean		3.48	
		Median		3.41	
		Variance		.381	
		Std. Deviation		.617	
		Minimum		2	
		Maximum		5	
		Range		3	
		Interquartile Range		1	
		Skewness		.074	.235
		Kurtosis		.349	.465
	Yes	Mean		2.95	.143
		95% Confidence Interval for Mean	Lower Bound	2.61	
			Upper Bound	3.29	
		5% Trimmed Mean		2.96	
		Median		3.00	
		Variance		.165	
		Std. Deviation		.406	
		Minimum		2	
		Maximum		4	
		Range		1	
		Interquartile Range		1	
		Skewness		-.581	.752
		Kurtosis		.070	1.481

Table 16: Descriptive statistics for the impact of manual data collection on throughput outcomes of QIMs

The previously mentioned normal distribution finding is also supported by the throughput outcome Test of Normality results that showed a significance value of 0.003, as shown in Table 17.

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
The average throughput outcome across all quality improvement methodologies	.105	114	.003

a. Lilliefors Significance Correction

Table 17: Test of Normality for throughput outcomes of QIMs

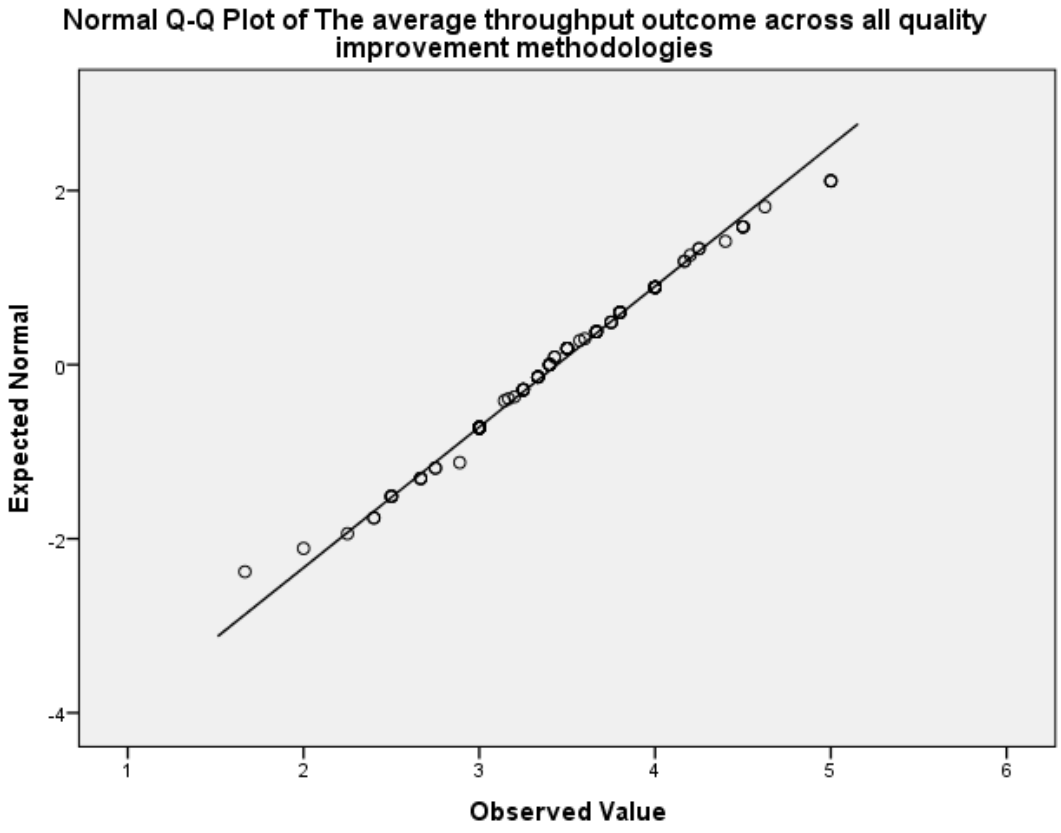


Figure 14: Normal Q-Q plot of the impact of manual data collection on throughput outcomes of QIMs

The Box-Whisker plot, presented in Figure 15, also confirms the findings that were revealed through the descriptive statistics. Although the group that did not rely exclusively on the manual data collection method had a wider value range than the group that did, its median, 1st quantile and 3rd quantile were higher.

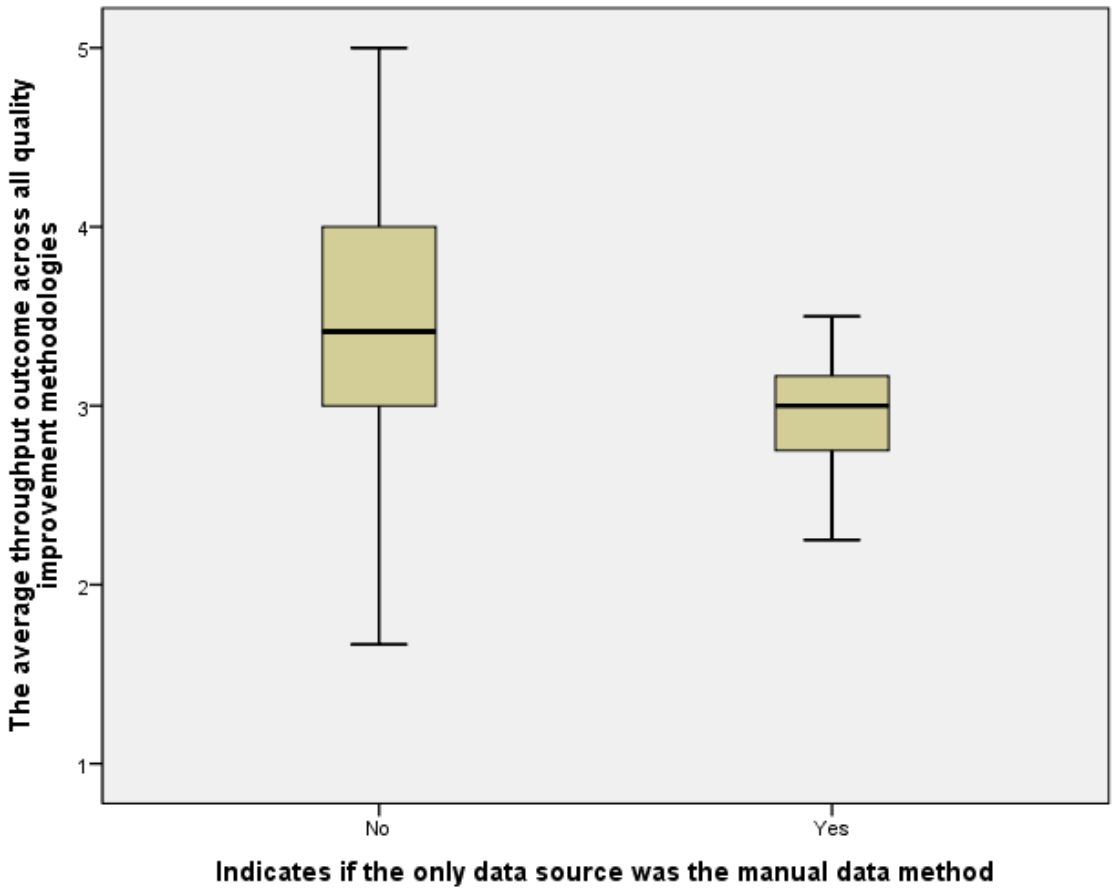


Figure 15: Box-Whisker plot for the impact of manual data collection on throughput outcomes of QIMs

The correlation result of Gamma test has shown a statistically significant association between the two variables, p-values=0.012 (95% Confidence Limit), as shown in Table 18. Based on the significance test result, the null hypothesis (H_0) was rejected and

the alternative hypothesis (H_1) was accepted. The direction of the correlation analysis has demonstrated an inverse, or negative, correlation between the manual data collection and throughput outcomes, Gamma=-0.593, which also indicated a strong degree of inverse correlation. This reveals that when manual data collection is used, throughput outcomes of QIMs decreases and vice versa.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.593	.141	-2.518	.012
Interval by Interval	Pearson's R	-.221	.069	-2.395	.018[c]
N of Valid Cases		114			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 18: Correlation test for the impact of manual data collection on throughput outcomes of QIMs

To identify what are the QIMs that yielded throughput improvements when HIT systems are used, correlation tests have been performed on all of the selected common QIMs. However, the only QIMs that had a statistically significant correlation with the utilization of HIT systems were LSS and CP.

For LSS, the case processing summary, Table 19, has shown that the number of valid observations in this analysis were 55, while the observations that had missing values in one or both of the variables were 89, representing 61.8% of the total number of observations in the analysis.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Manual Data Collection: Lean Six Sigma (LSS): For each of the quality improvement methodologies selected previously, from where the data came? * Throughput of Workflow: Lean Six Sigma (LSS):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors	55	38.2%	89	61.8%	144	100.0%

Table 19: Case processing summary for the impact of manual data collection on throughput outcomes of LSS

The frequency analysis of the manual data collection and LSS utilization throughput outcomes is shown in Table 20. The table rows presents the observations based whether or not the manual data collection was utilized in the LSS implementation, while the columns show the LSS implementation outcomes. By studying the throughput outcome values of LSS implementations and how they are related to the utilization of the manual data collection method, it is clear that the outcome frequencies increase when the manual data collection method variable is unchecked: 0, 3, 5 and 5, on the scale from 1 to 5,

respectively. On the other hand, the outcome frequencies are lower when the manual data collection method is checked: 4, 16, 16 and 6, on the same scale, respectively.

Crosstab

		Throughput of Workflow:Lean Six Sigma (LSS):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors				
		2	3	4	5	Total
Manual Data Collection: Lean Six Sigma (LSS):For each of the quality improvement methodologies selected previously, from where the data came?	Unchecked	0	3	5	5	13
	Checked	4	16	16	6	42
Total		4	19	21	11	55

Table 20: Crosstab result of the impact of manual data collection on throughput outcomes of LSS

As shown in Table 21, the Gamma correlation test between the manual data collection and LSS throughput outcomes has yielded a p-value of 0.032, which suggests rejecting the null hypothesis *(H_0)* and accepting the alternative hypothesis *(H_1)*, based on 95% confidence limit. This points to the statistically significant correlation between the manual data collection and throughput outcomes of LSS implementations. The direction and strength of the correlation is indicated by the Gamma value, -0.505, which points to a strong negative correlation. This suggests that there is a statistically significant evidence that throughput outcomes go down when the manual data collection method is used solely in the implementation of LSS and vice versa. This conclusion also can be inversely

reflected on the utilization of HIT systems in LSS implementations, as not using the manual data collection solely would mean that one or more HIT systems were used as data sources.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.505	.200	-2.143	.032
	Spearman Correlation	-.279	.123	-2.117	.039[c]
Interval by Interval	Pearson's R	-.285	.118	-2.168	.035[c]
N of Valid Cases		55			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 21: Correlation test for the impact of manual data collection on throughput outcomes of LSS

The case processing summary for the manual data collection and CP throughput outcome variables, Table 22, has shown that the number of valid observations in the analysis were 80, or 55.6% of the total number of the observations, 144. The summary also showed that the observations that had missing values in one or both of the variables were 64, representing 44.4% of the total number of observations in the analysis. This indicates that majority of the available observations were qualified to be included in the correlation analysis between the manual data collection and CP throughput outcome variables.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Manual Data Collection: Clinical Pathways (CP): For each of the quality improvement methodologies selected previously, from where the data came? * Throughput of Workflow: linical Pathways (CP):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors	80	55.6%	64	44.4%	144	100.0%

Table 22: Case processing summary test for the impact of manual data collection on throughput outcomes of CP

The frequency analysis of the manual data collection and CP utilization throughput outcomes is shown in Table 23. The table rows presents the observations based on whether or not the manual data collection method has been utilized in the CP implementation, while the columns show the CP implementation outcomes. By reviewing the throughput outcome values of CP implementations and how they are related to the utilization of the manual data collection method, it is noticed that the outcome frequencies increase when the manual data collection method variable is unchecked: 0, 1, 8, 17 and 4, on the scale from 1 to 5, respectively. On the other hand, the outcome frequencies decline when the manual data collection method is checked: 2, 4, 22, 19 and 3, on the same scale, respectively.

Crosstab

		Throughput of Workflow:Clinical Pathways (CP):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors					
		1	2	3	4	5	Total
Manual Data Collection:Clinical Pathways (CP):For each of the quality improvement methodologies selected previously, from where the data came?	Unchecked	0	1	8	17	4	30
	Checked	2	4	22	19	3	50
Total		2	5	30	36	7	80

Table 23: Crosstab result of the impact of manual data collection on throughput outcomes of CP

The correlation test of CP throughput outcomes and the utilization of HIT systems have resulted in significance value of 0.01, suggesting the rejection of the null hypothesis *(H_0)* and the acceptance of the alternative hypothesis *(H_1)*, based on 95% confidence limit, Table 24. This infers to the statistically significant correlation between the manual data collection and throughput outcomes of CP implementations. The direction and strength of the correlation is specified by the Gamma value, -0.45, which points to a strong negative correlation. This proposes that there is a statistically significant evidence that throughput outcomes decrease when the manual data collection method is used solely in the implementation of CP and vice versa. This assumption also applicable, but inversely, on the utilization of HIT systems in CP implementations, as not using the manual data

collection solely would mean that one or more HIT systems have been used as data sources in the QIM implementation.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.450	.162	-2.561	.010
	Spearman Correlation	-.268	.103	-2.455	.016[c]
Interval by Interval	Pearson's R	-.266	.095	-2.439	.017[c]
N of Valid Cases		80			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 24: Correlation test for the impact of manual data collection on throughput outcomes of CP

4.1.2 Efficiency Outcomes

In relation to average efficiency outcomes and the utilization of the manual data collection method, the case processing summary illustrates that there were 124 observations that met the requirements of one of the two variables. Among them, there were 116 observations that did not involve the use of manual data collection in QIMs, and 8 observations that involved the use of the sole manual data collection in QIMs. The 115 observations that met the requirements of both variables included 8 observations that involved the exclusive use of the manual data collection method in the QIM implementation, while 107 observations comprised the utilization of HIT systems as data sources. Only 9 observations had the "The average efficiency outcome across all quality improvement methodologies" variable missing. All of the 9 observations showed that the

manual data collection method has not been used in the QIM implementations. Table 25 presents the results of the case processing summary.

Case Processing Summary

	Indicates if the only data source was the manual data method	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
The average efficiency outcome across all quality improvement methodologies	No	107	92.2%	9	7.8%	116	100.0%
	Yes	8	100.0%	0	0.0%	8	100.0%

Table 25: Case processing summary for the impact of manual data collection on efficiency outcomes of QIMs

The basic statistics test that has been conducted for the two groups, the group that relied completely on manual data collection in QIM implementations and the group that did not, has revealed a number of findings, shown in Table 26. In the results, it is obvious that both, the efficiency outcome mean and median, were lower for the group that exclusively utilized the manual data collection method in QIM, 3.10 and 3.17, in compared to 3.48 and 3.50 for the group that utilized HIT data sources.

The data variation in both groups was very minimal, as the STD values was found to be below 1 in both groups. Besides the close mean and median values, this finding indicates that the data within the groups are relatively normally distributed. This is also supported by the efficiency outcome Test of Normality results that showed a significance value of 0.004, as shown in Table 27.

Descriptives

	Indicates if the only data source was the manual data method			Statistic	Std. Error
The average efficiency outcome across all quality improvement methodologies	No	Mean		3.48	.064
		95% Confidence Interval for Mean	Lower Bound	3.35	
			Upper Bound	3.61	
		5% Trimmed Mean		3.49	
		Median		3.50	
		Variance		.445	
		Std. Deviation		.667	
		Minimum		2	
		Maximum		5	
		Range		3	
		Interquartile Range		1	
		Skewness		-.124	.234
		Kurtosis		.136	.463
	Yes	Mean		3.10	.161
		95% Confidence Interval for Mean	Lower Bound	2.72	
			Upper Bound	3.49	
		5% Trimmed Mean		3.12	
		Median		3.17	
		Variance		.208	
		Std. Deviation		.456	
		Minimum		2	
		Maximum		4	
		Range		1	
		Interquartile Range		1	
		Skewness		-.816	.752
		Kurtosis		.485	1.481

Table 26: Descriptive statistics for the impact of manual data collection on efficiency outcomes of QIMs

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
The average efficiency outcome across all quality improvement methodologies	.105	114	.004

a. Lilliefors Significance Correction

Table 27: Test of Normality for efficiency outcomes of QIMs

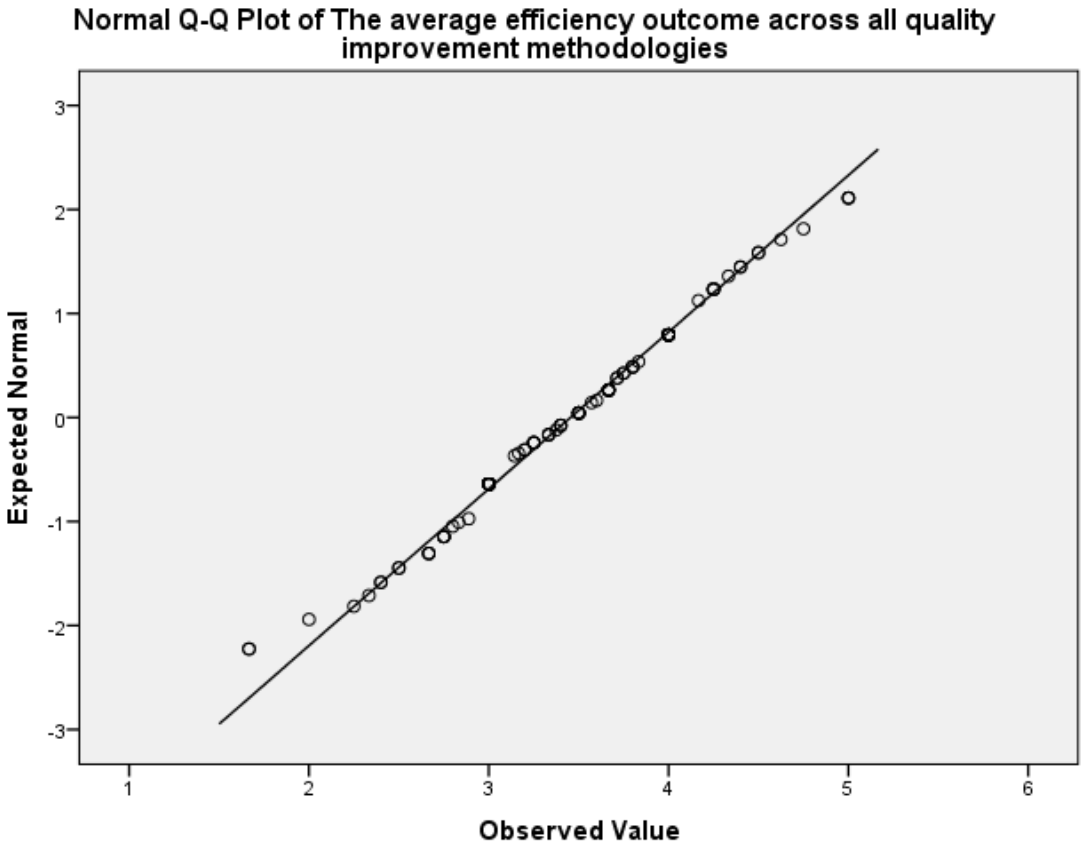


Figure 16: Normal Q-Q plot of the average efficiency outcome across all quality improvement methodologies

Figure 17 illustrates a Box-Whisker plot that demonstrates the impact of manual data collection on efficiency outcomes of QIMs. The plot also confirms the findings that were revealed through the descriptive statistics, presented in Table 26. Although the group that did not rely exclusively on the manual data collection method had a wider value range than the group that did, its median, 1st quantile and 3rd quantile were higher. This finding is also indicted in the descriptive statistics.

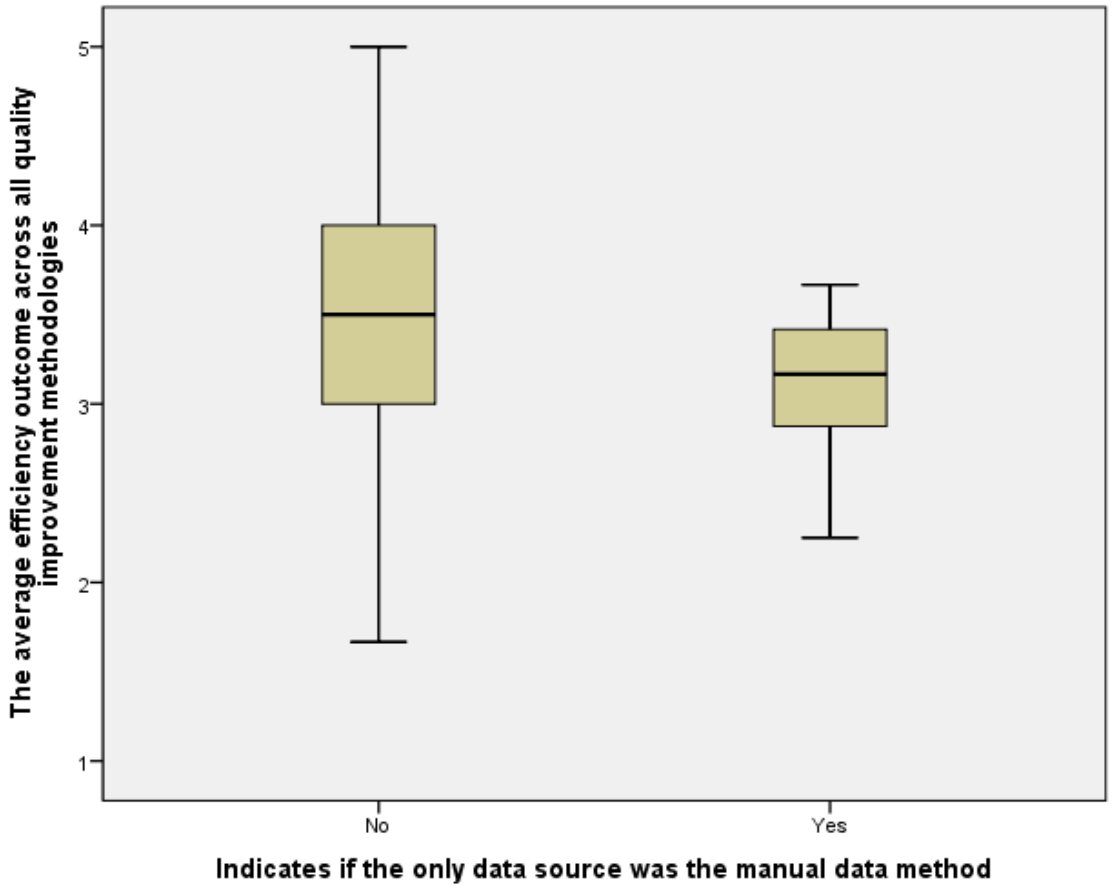


Figure 17: Box-Whisker plot for the impact of manual data collection on efficiency outcomes of QIMs

The efficiency outcomes variable also has shown a statistically significant association with the manual data collection method. The p-value was 0.047, lower than 0.05 based on 95% confidence limit. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. The correlation was found to be inverse with moderate strength, Gamma=-0.388, suggesting that the overall efficiency outcomes decrease when the manual data collection method is utilized in QIMs. The correlation results are presented in Table 28.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.388	.152	-1.986	.047
Interval by Interval	Pearson's R	-.146	.067	-1.570	.119[c]
N of Valid Cases		115			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 28: Correlation analysis for the efficiency outcomes and manual data collection

However, when each QIM efficiency outcome variable was tested individually against the variable of the manual data collection method, the only QIMs that showed statistically significant correlations were LSS and CP.

The correlation between LSS implementation efficiency outcomes and the utilization of the manual data collection method has been tested and the results of the case processing summary is illustrated in Table 29. In total, there were 144 observations that have been considered in the analysis. Among them, 38.2%, or 55 observations, met the

requirements of both variables, while 61.8%, or 89 observations, did not meet one of the requirements.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Efficiency of Workflow: Lean Six Sigma (LSS):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors * Manual Data Collection: Lean Six Sigma (LSS):For each of the quality improvement methodologies selected previously, from where the data came?	55	38.2%	89	61.8%	144	100.0%

Table 29: Case processing summary for LSS efficiency outcomes and manual data collection

Also as part of the correlation analysis, the frequency test of the manual data collection and LSS efficiency outcomes has been conducted. The results are shown in Table 30. The table rows display the observations based on whether or not the manual data collection method was utilized in the LSS implementation, while the columns show the LSS implementation efficiency outcomes. By analyzing the efficiency outcome values of LSS implementations and how they are related to the utilization of the manual data collection method, it is clear that the outcome frequencies surge when the manual data

collection method variable is unchecked: 0, 3, 5 and 5, on the scale from 1 to 5, respectively. On the other hand, the outcome frequencies decline when the manual data collection method is checked: 3, 18, 14, and 7, on the same scale, respectively.

Crosstab

		Efficiency of Workflow: Lean Six Sigma (LSS):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors				
		2	3	4	5	Total
Manual Data Collection: Lean Six Sigma (LSS):For each of the quality improvement methodologies selected previously, from where the data came?	Unchecked	0	3	5	5	13
	Checked	3	18	14	7	42
Total		3	21	19	12	55

Table 30: Crosstab result of LSS efficiency outcomes and manual data collection

The correlation between the manual data collection method and LSS efficiency outcomes has been found to be statistically significant. With p-value=0.035, lower than 0.05 based on 95% confidence limit, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. The results of the correlation analysis are shown in Table 31.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.494	.198	-2.105	.035
	Spearman Correlation	-.272	.123	-2.062	.044[c]
Interval by Interval	Pearson's R	-.275	.121	-2.084	.042[c]
N of Valid Cases		55			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 31: Correlation analysis for LSS efficiency outcomes and manual data collection

The correlation was found to be strong with an inverse direction, Gamma=-0.494, suggesting that the LSS efficiency outcomes decrease when the manual data collection method is utilized. This assumption also applicable, but inversely, on the utilization of HIT systems in LSS implementations, as not using the manual data collection exclusively would imply the utilization of one or more HIT systems as data sources in the LSS implementation. Consequently, the finding here suggests that the utilization of HIT systems would have a positive impact on LSS efficiency outcomes.

For CP efficiency outcomes and the utilization of the manual data collection method, the case processing summary illustrates that out of the 144 observations, 56.3%, or 81 observations, involve the use of manual data collection in the QIM. However, 43.8%, or 63 observations, had the "var8O34QN10147" variable with null values. Table 32 presents the results of the case processing summary.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Efficiency of Workflow: Clinical Pathways (CP):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors * Manual Data Collection: Clinical Pathways (CP):For each of the quality improvement methodologies selected previously, from where the data came?	81	56.3%	63	43.8%	144	100.0%

Table 32: Case processing summary for CP efficiency outcomes and manual data collection

The frequency analysis of the manual data collection and CP utilization efficiency outcomes is shown in Table 33. The table rows display the observations based on whether or not the manual data collection method has been utilized in the CP implementation, while the columns show the CP implementation efficiency outcomes. The results show how efficiency outcomes of CP implementations are influenced by the utilization of the manual data collection method, as the outcome frequencies tend to slightly shift to the higher end when the manual data collection method variable is unchecked: 1, 1, 7, 13 and 8, on the scale from 1 to 5, respectively. In contrast, the outcome frequencies incline to stay at the middle level when the manual data collection method is checked: 1, 6, 22, 18 and 4, on the same scale, respectively.

Crosstab

		Efficiency of Workflow: Clinical Pathways (CP):Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors					
		1	2	3	4	5	Total
Manual Data Collection: Clinical Pathways (CP):For each of the quality improvement methodologies selected previously, from where the data came?	Unchecked	1	1	7	13	8	30
	Checked	1	6	22	18	4	51
Total		2	7	29	31	12	81

Table 33: Crosstab result of CP efficiency outcomes and manual data collection

The significance test of the CP efficiency outcomes and manual data collection has suggested that there is a correlation between the two variables. The p-value was found to be 0.007, lower than 0.05 based on 95% confidence limit. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. Gamma value has shown a strong negative correlation, Gamma=-0.456, suggesting that the CP efficiency outcomes decrease when the manual data collection method is utilized in QIMs. The correlation test results are presented in Table 34.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.456	.157	-2.714	.007
	Spearman Correlation	-.291	.106	-2.701	.008[c]
Interval by Interval	Pearson's R	-.267	.110	-2.459	.016[c]
N of Valid Cases		81			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 34: Correlation analysis for CP efficiency outcomes and manual data collection

4.1.3 Financial Outcomes

The association between the average financial outcomes and the manual data collection method has been tested using correlation analysis. The case processing summary shows that out of the 124 that met the requirements of one of the two variables, there were 116 observations, which did not involve the use of manual data collection in QIMs, and 8 observations, which involved the use of the sole manual data collection in QIMs. The 114 observations that met the requirements of both variables included 7.01%, or 8 observations, that involved the exclusive use of the manual data collection method in the QIM implementation, while 92.9%, or 106 observations, comprised the utilization of one or more HIT systems as data sources. Only 8.6%, or 10 observations, had "The average financial outcome across all quality improvement methodologies" variable unfilled. All of the 10 observations showed that the manual data collection method has not been used in the QIM implementations. Table 35 presents the results of the case processing summary.

Case Processing Summary

	Indicates if the only data source was the manual data method	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
The average financial outcome across all quality improvement methodologies	No	106	91.4%	10	8.6%	116	100.0%
	Yes	8	100.0%	0	0.0%	8	100.0%

Table 35: Case processing summary for the impact of manual data collection on financial outcomes of QIMs

By applying the basic statistics test for the two groups, the group that relied completely on manual data collection in QIM implementations and the group that did not, a number of findings have been identified, shown in Table 36. The results have shown that both, the financial outcome mean and median, were lower for the group that exclusively utilized the manual data collection method in QIM, 3.03 and 3.00, in compared to 3.25 and 3.25 for the group that utilized HIT data sources.

Moreover, the data variation in both groups was very minimal, as the STD values were found to be below 1 in both groups. Besides the close mean and median values, this finding indicates that the data within the groups are relatively normally distributed.

Descriptives

	Indicates if the only data source was the manual data method		Statistic	Std. Error
The average financial outcome across all quality improvement methodologies	No	Mean	3.25	.079
		95% Confidence Interval for Mean — Lower Bound	3.09	
		95% Confidence Interval for Mean — Upper Bound	3.40	
		5% Trimmed Mean	3.25	
		Median	3.25	
		Variance	.653	
		Std. Deviation	.808	
		Minimum	1	
		Maximum	5	
		Range	4	
		Interquartile Range	1	
		Skewness	-.264	.235
		Kurtosis	.004	.465
	Yes	Mean	3.03	.165
		95% Confidence Interval for Mean — Lower Bound	2.64	
		95% Confidence Interval for Mean — Upper Bound	3.42	
		5% Trimmed Mean	3.01	
		Median	3.00	
		Variance	.218	
		Std. Deviation	.467	
		Minimum	3	
		Maximum	4	
		Range	2	
		Interquartile Range	1	
		Skewness	1.339	.752
		Kurtosis	2.253	1.481

Table 36: Descriptive statistics for the impact of manual data collection on financial outcomes of QIMs

The previously mentioned normal distribution finding is also supported by the financial outcome Test of Normality results that showed a significance value of 0.004, shown in Table 37.

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
The average financial outcome across all quality improvement methodologies	.104	114	.004

a. Lilliefors Significance Correction

Table 37: Test of Normality of financial outcomes of QIMs

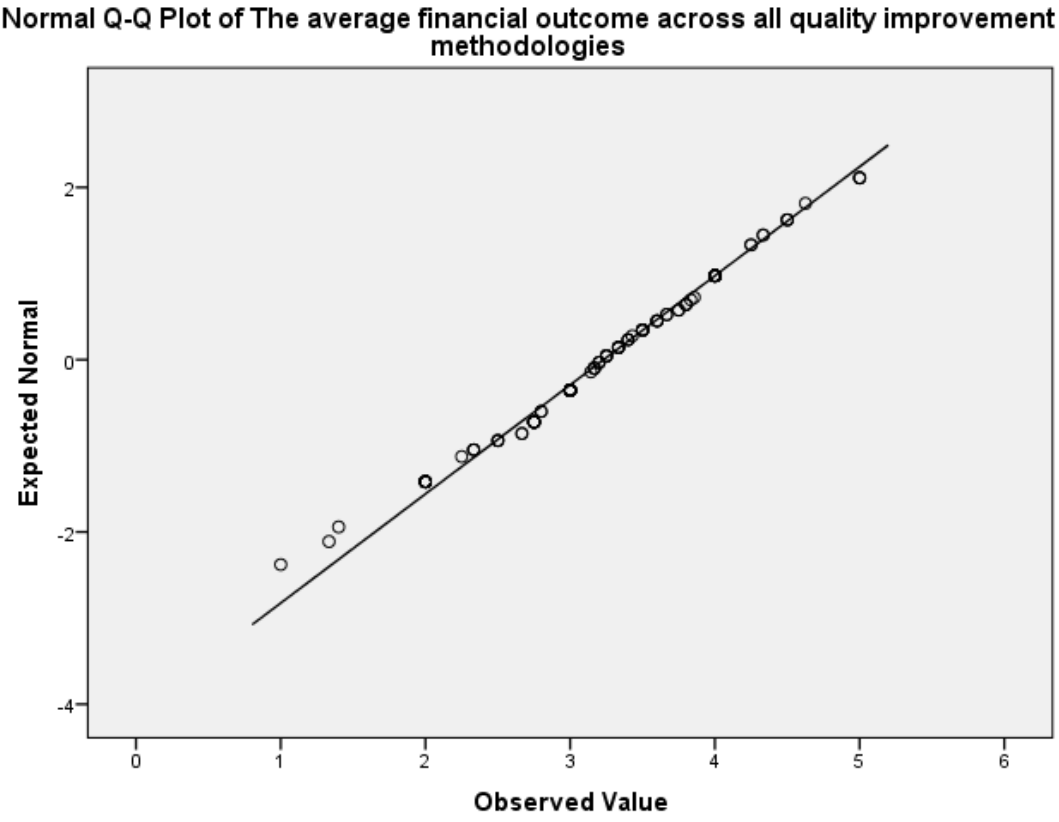


Figure 18: Normal Q-Q plot of the average financial outcome across all quality improvement methodologies

Figure 19 illustrates a Box-Whisker plot that shows the impact of manual data collection on financial outcomes of QIMs. The plot also confirms the findings that were revealed through the descriptive statistics, presented in Table 36. Although the group that did not rely exclusively on the manual data collection method had a wider value range than the group that did, its median, 1st quantile and 3rd quantile were higher. This finding is also indicted in the descriptive statistics.

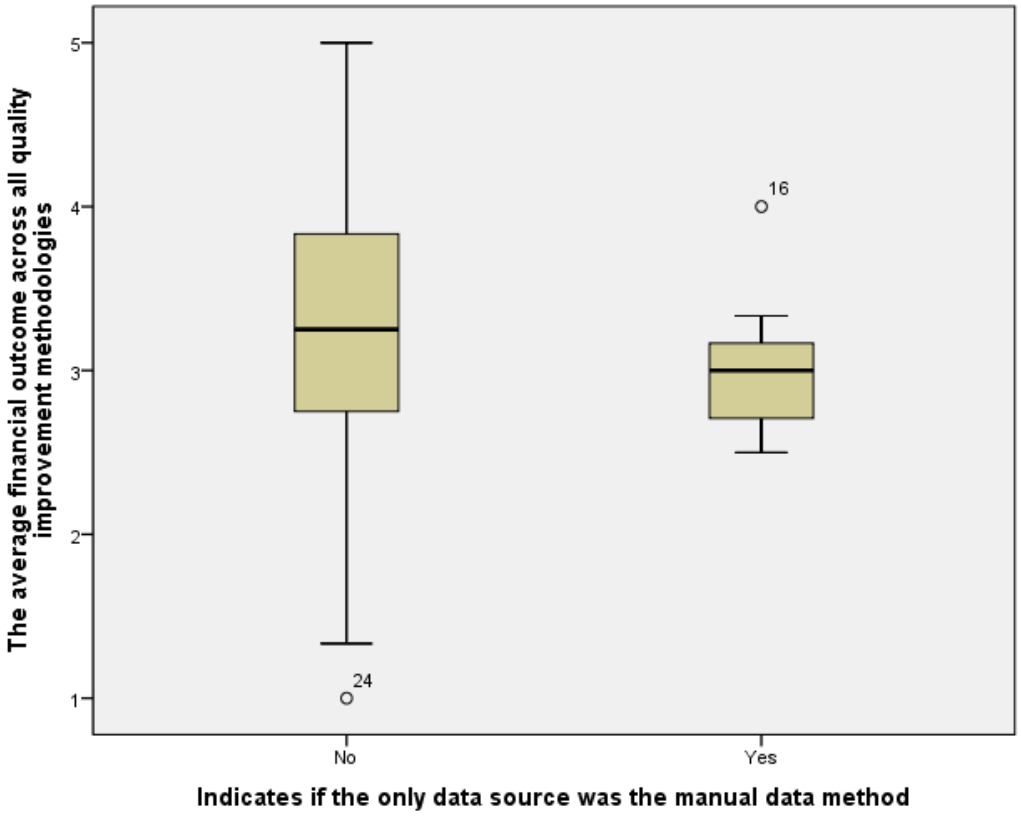


Figure 19: Box-Whisker plot for the impact of manual data collection on financial outcomes of QIMs

However, the overall financial outcome variable had a statistically insignificant association with the manual data collection. The p-value was 0.159, which suggests accepting the H_0, based on 95% confidence limit, as shown in Table 38.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.273	.172	-1.408	.159
Interval by Interval	Pearson's R	-.070	.058	-.740	.461[c]
N of Valid Cases		114			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 38: Correlation analysis for the financial outcomes and the manual data collection

CP is the only QIM that was found to individually have a statistically significant correlation with the financial outcomes when HIT systems are used as data sources.

The case processing summary of CP financial outcomes and the manual data collection illustrates that there were 144 observations that were considered in the analysis, out of which, 56.3%, or 81 observations, met the requirements of the two variables. Those 81 observations involved the exclusive use of the manual data collection method in CP implementation. Nonetheless, 43.8% of the considered observations, or 63 observations, had the "var8O36QN10147" variable null. Table 39 presents the results of the case processing summary.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Financial Improvement: Clinical Pathways (CP): Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors * Manual Data Collection: Clinical Pathways (CP): For each of the quality improvement methodologies selected previously, from where the data came?	81	56.3%	63	43.8%	144	100.0%

Table 39: Case processing summary for CP financial outcomes and the manual data collection

The frequency analysis of the manual data collection and CP utilization financial outcomes is shown in Table 40. The table rows present the observations based on whether or not the manual data collection method was utilized in the CP implementation, while the columns show the CP implementation financial outcomes. A high-level analysis of the financial improvement values of CP implementations and how they are swayed by the utilization of the manual data collection method reveals that the financial outcome frequencies have increased when the manual data collection method variable is unchecked: 1, 4, 7, 13 and 5, on the scale from 1 to 5, respectively. However, the financial outcome

frequencies were generally at the middle level when the manual data collection method is checked: 2, 13, 21, 11 and 4, on the same scale, respectively.

Crosstab

		Financial Improvement: Clinical Pathways (CP): Have the goals of the implemented quality improvement methodology(s) been achieved? Based on the efficiency, throughput, and financial factors					
		1	2	3	4	5	Total
Manual Data Collection: Clinical Pathways (CP): For each of the quality improvement methodologies selected previously, from where the data came?	Unchecked	1	4	7	13	5	30
	Checked	2	13	21	11	4	51
Total		3	17	28	24	9	81

Table 40: Crosstab result of CP financial outcomes and the manual data collection

The Gamma correlation test has shown that the financial outcome variable has a statistically significant association with the manual data collection method. The p-value was 0.015, lower than 0.05 based on 95% confidence limit. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. The correlation is also inverse with strong level, Gamma=-0.4, suggesting that the overall efficiency outcomes decrease when the manual data collection method is utilized in QIMs. The correlation test results are presented in Table 41.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.400	.156	-2.442	.015
	Spearman Correlation	-.265	.108	-2.446	.017[c]
Interval by Interval	Pearson's R	-.249	.109	-2.288	.025[c]
N of Valid Cases		81			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 41: Correlation analysis for CP financial outcomes and the manual data collection

4.2 Effects of Healthcare Organization's Characteristics

Statistically, the utilization of HIT systems in QIMs has been found to have a significant association with the healthcare organization's type only in Benchmarking and BPR. Table 42 demonstrates the results of the Chi-Square test that evaluated the association between the utilization of HIT systems in Benchmarking and the healthcare organization's type variables.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.984[a]	2	.018
Likelihood Ratio	9.957	2	.007
Linear-by-Linear Association	4.090	1	.043
N of Valid Cases	135		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.16.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.243	.018
	Cramer's V	.243	.018
N of Valid Cases		135	

Table 42: The association between the utilization of HIT systems in Benchmarking and the healthcare organization's type

The results suggest a statistically significant association between the utilization of HIT systems in Benchmarking and the healthcare organization's type, p-value=0.018, based on 95% confidence limit. The strength of the association has been tested using Phi and Cramer's V, which yielded the value of 0.243, pointing to a moderate level of association.

In the same manner, Chi-Square test has been performed to evaluate the association between the utilization of HIT systems in BPR and the healthcare organization's type variables. Table 43 lists the results of the Chi-Square test.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.412[a]	2	.000
Likelihood Ratio	10.554	2	.005
Linear-by-Linear Association	5.270	1	.022
N of Valid Cases	135		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.19.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.338	.000
	Cramer's V	.338	.000
N of Valid Cases		135	

Table 43: The association between HIT utilization in BPR and the healthcare organization's type

Similar to Benchmarking, the results shown in Table 43 indicate a statistically significant association between the utilization of HIT in BPR and the healthcare organization's type, p-value=0.001, based on 95% confidence limit. The strength of the association has been tested using Phi and Cramer's V, which yielded the value of 0.338, suggesting that the association strength is moderate.

To evaluate if the healthcare organization's size has an influences on the utilization of HIT systems in QIMs, the "Only_Manual_Data_Collection_Was_Used" was used against the variable "Hospital_Bed_No_A". The "Only_Manual_Data_Collection_Was_Used" variable indicates if QIMs have been implemented without the reliance on any HIT system data sources. This unveils if the

healthcare organization's size has any correlation and effect on the utilization of HIT systems in QIMs. The correlation test result is shown in Table 44 and 45. The significance of the correlation has a p-value of 0.01, which shows a statistically significant correlation. The Gamma value is -0.744, which points to a strong inverse correlation between the healthcare organization's size and the use of manual data collection in QIM implementation. The conclusion shows that large healthcare organizations rely more on HIT systems during the implementation of QIMs, and vice versa.

Crosstab

		Labels hospitals with one of three main size identifications: Small, Medium or Large			
		Small	Medium	Large	Total
Indicates if the only data source was the manual data method	No	35	14	58	107
	Yes	5	2	0	7
Total		40	16	58	114

Table 44: Crosstab results of the HIT utilization in QIMs and the healthcare organization's size

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.744	.149	-2.592	.010
	Spearman Correlation	-.249	.062	-2.716	.008[c]
Interval by Interval	Pearson's R	-.244	.065	-2.665	.009[c]
N of Valid Cases		114			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table 45: The correlation between HIT utilization in QIMs and the healthcare organization's size

To predict the utilization of HIT systems in QIMs based on the healthcare organization's size, the linear regression test has been used. The result showed a test significance of 0.031 and Odds Ratio (OR) of 0.265, confirming the results of the previously mentioned correlation test and predicting that larger healthcare organizations are approximately 73% more likely to use HIT system in QIMs than smaller healthcare organizations. Table 46 shows the results of the logistic regression test.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Hospital_Bed size_A	-1.328	.614	4.671	1	.031	.265	.080	.884

a. Variable(s) entered on step 1: Hospital_Bedsize_A.

Table 46: Logistic regression for HIT utilization in QIMs and the healthcare organization's size

The study also evaluated the association between the geographical location of the healthcare organization and the utilization of HIT systems in QIM implementations. Chi-Square test has been used to assess the association between the two variables. The result of the analysis is presented in Tables 47 and 48.

Crosstab

		Identifies the region where the healthcare organization is located, i.e. Northeast, Midwest, South, or West				
		Northeast	South	Midwest	West	Total
Indicates if HIT systems have been used in QIM implementations	0	8	11	5	6	30
	1	27	37	35	15	114
Total		35	48	40	21	144

Table 47: Crosstab results of the HIT utilization in QIMs and the healthcare organization's geographical location variables

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.660[a]	3	.447
Likelihood Ratio	2.810	3	.422
Linear-by-Linear Association	.026	1	.871
N of Valid Cases	144		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 4.38.

Table 48: The association between HIT utilization in QIMs and the healthcare organization's geographical location

From the result of the analysis, Table 47 and 48, it is obvious that there is no statistically significant association between HIT utilization in QIMs and the healthcare organization's geographical location, as the p-value of Pearson Chi-Square test was 0.447, based on 95% confidence limit. Consequently, the null hypothesis (H_0), which suggests that there is not statistically significant association between the two variables, was accepted and the alternative hypothesis (H_1) was rejected.

4.3 Reasons for Using Manual Data Collection in QIMs

To further analyze the manual data collection method, the survey gathered the reasons that forced healthcare organizations to lean to this traditional approach solely or along with collecting the data using HIT system data sources. Six main reasons have been evaluated along with the ability for the surveyee to add other reasons. The results are illustrated in Table 49.

Frequencies

	N	Checked			Unchecked		
		Frequency	Percent	Valid Percent	Frequency	Percent	Valid Percent
Clinical systems did not have the needed data elements	111	74	51.4	66.7	37	25.7	33.3
Did not have access to the databases of the clinical systems	111	18	12.5	16.2	93	64.6	83.8
It was easier to collect the data manually	111	18	12.5	16.2	93	64.6	83.8
There were technical challenges in retrieving the data from systems	111	66	45.8	59.5	45	31.3	40.5
Quality improvement methodologies require manual data collection	111	14	9.7	12.6	97	67.4	87.4
We do not have clinical systems implemented at the site	111	14	9.7	12.6	97	67.4	87.4
Others	111	10	6.9	9.0	101	70.1	91.0

Table 49: Frequency analysis for the reported reasons for using manual data collection in QIMs

From Table 49, the reason that indicates that “Clinical systems did not have the needed data elements” scored the highest among the reasons, as it was reported by 51.4% of the respondents. The reason that stated that “There were technical challenges in retrieving the data from systems” was the second highest reason and was reported by 45.8% of the respondents.

CHAPTER V: DISCUSSION AND STUDY LIMITATION

The throughput and financial outcomes did not show statistically significant relation with the manual data collection, H_0 was accepted based on 95% confidence limit. It is recommended that a further study would involve collecting a sample size that is suitable for analyzing the impact of the manual data collection method on the aforementioned outcomes.

It is also recommended to evaluate the outcomes of QIMs that fully utilize HIT systems. This can be conducted by developing a Clinical and Business Intelligence (CBI) prototype that is HIT-integrated and provide the data and analyses of QIMs. The result of the study will indicate if the HIT-integrated QIM module can be successfully developed and implemented. In addition, the study will explore the outcomes of the implementation.

5.1 Prototype of a HIT-Integrated QIM Module

LSS can be used as the QIM that will be implemented in the prototype. The commonly utilized HIT systems in healthcare organizations can be the data sources for LSS. Nowadays, many healthcare organizations in the United States are capable of capturing the necessary LSS parameters through HIT systems. According to HIMSS, 52.9% of the surveyed 5,458 hospitals in the United States are now using HIT to electronically document patients' workflows from admission to discharge, including the different orders and results that get placed and documented during the encounter[101]. This current high level of HIT adoption makes the HIT-integrated LSS module relevant to majority of the healthcare organizations. In fact, the average adoption rates of basic EHRs in the last four years[102] indicates that the adoption percentage will reach 90% in the next few years.

The HIT-integrated LSS module can be developed based on a CBI framework. While HIT systems will deliver the clinical data, CBI will automate the implementation of the various LSS tools. This will be facilitated through the different CBI components, including the data transformation, analysis and presentation functionalities. Figure 20 illustrates a schematic diagram of a HIT-integrated LSS module and how it operates with other HIT modules.

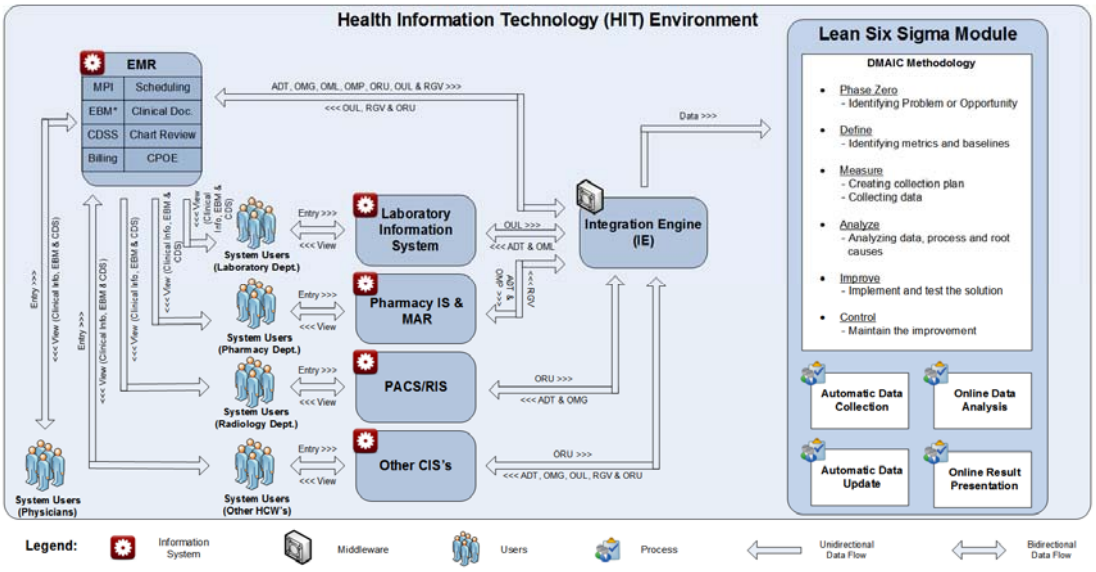


Figure 20: A suggested topology of the HIT-integrated LSS Module

5.1.1 CBI Framework Preparation

The framework of the CBI has to be available in order to host the LSS module. The first step to build the framework is to allocate the necessary hardware and software needed to operate the CBI. Then, all hardware and software have to be installed and configured. It is important to mention that some healthcare organizations already have CBI frameworks available for other applications. In such cases, resources from the existing CBI could be allocated to the LSS module.

After the CBI is implemented or allocated to the LSS module, a number of analytical tools will be available to the LSS to be used not only for this study, but also for other LSS studies or projects. Although the kinds of tools that come with every CBI brand vary, an average CBI solution should offer the set of tools that are listed in Table 50.

Tool	Description	Targeted Users
Dashboards	Show indicators	- Administrators - Quality Mgrs. - Planners
Analytical Reports	Run pre-developed analytical reports	- Administrators - Quality Mgrs. - Planners
Cube Analyzers	Allows slicing and dicing data cubes	- Quality Mgrs. - Planners - Statisticians
Report Builders	Allows building analytical reports and sharing them	- Quality Mgrs. - Planners - IT Personnel

Table 50: Common CBI tools that can be used in the DMAIC stages of the LSS process

5.1.2 Data Preparation

Retrieving data using CBI is far practical and faster than the manual data collection process. The CBI software component that handles data, the Extraction, Transformation and Loading (ETL) tool, is usually configured to get the up-to-date data from the different clinical reporting systems every 24 hours. On the other hand, manual data gathering takes weeks or even months to obtain the raw data, cleanse it, filter it, and then reformat it. The difference in data availability lag, 24 hours to weeks or months, can have a significant impact on the decisions made by organizations, which rely for the most part on data.

As part of the ETL functionality, the data from the different clinical reporting systems get extracted, transformed and loaded into a data warehouse. Figure 21 presents a screenshot of a high-end ETL system that has been configured to perform these processes.

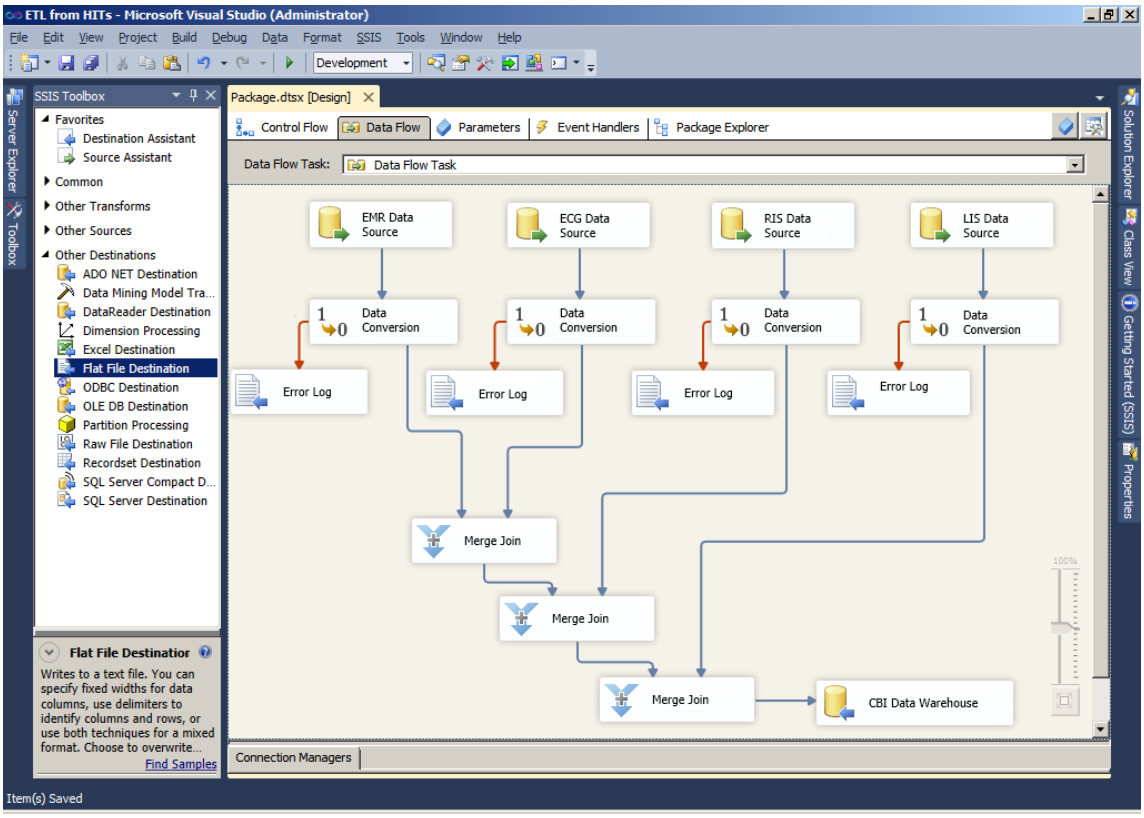


Figure 21: Automatic data retrieval performed by an ETL tool

The tasks that are involved in the ETL process are shown in Figure 21 at a very high-level, which hides many of the technical details of how the underlying processes are functioning. However, this is a standard ETL process and understanding the concept that is relevant to the LSS process does not require the lengthy coverage of the technical details.

The process starts from the data sources that are shown in the Figure 21, the EMR, ECG, RIS, and LIS. All tables that contain workflow data are queried to obtain their data in a raw format. At this point, the configuration is conducted to fulfill as many future LSS processes as possible and not only the data relevant to the process on hand. This is because

the ETL configuration process is extremely time consuming and performing such a process every time a new LSS process is introduced is impractical.

The next step in the ETL process performs the data cleansing and standardization tasks in order to make the data ready for merging without discrepancy issues. To do so, the raw data from each data source is passed through a data conversion task that deals with data issues such as having the encounter number entered with dashes between numbers in one system and not documented in this format in another. Another common data consistency issue is the way gender is saved as some systems code the data as M and F or 0 and 1, while other systems captures the full word as Male and Female. The data conversion task rectifies those differences and others in preparation for the next task.

The merge tasks, which follow the data conversion, link data records that come from different systems. This step is critical to the LSS process because it is actually what turns fragmented data, which are gathered from different systems, into logically connected data pieces.

The final step in this ETL task is loading the processed data into a dedicated database called the data warehouse. It is important to highlight that usually many tasks are used to build a complete data warehouse and each task deals with a specific dimension of the overall LSS project objectives.

5.1.3 Executing DMAIC Stages Using the LSS Module

After preparing the CBI framework and the data that are collected from the different clinical reporting system, this part will discuss how each stage of the DMAIC methodology can be conducted using the LSS module.

5.1.4 Phase Zero: Problem or Improvement Opportunity Identification

This stage initiates the whole LSS process in a specific area in the healthcare organization. It focuses on identifying a potential Problem or Improvement Opportunity (PIO) in a business process of the healthcare setting. Figure 22 shows a flowchart of the process that takes place in this phase of LSS.

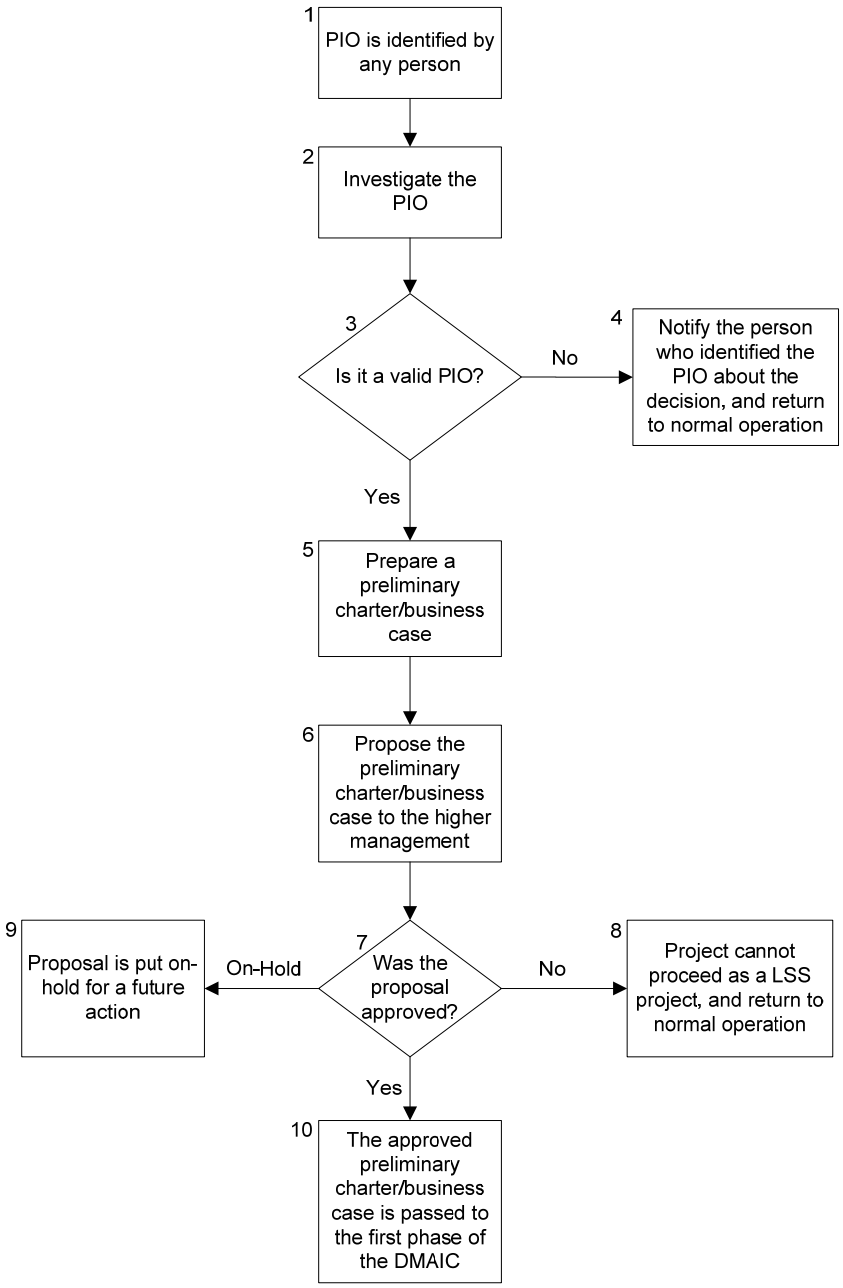


Figure 22: Flowchart of the PIO identification process

In the traditional LSS, the process starts when a person, internal or external to the work area, identifies a PIO. The potential problem can be hidden and waiting to be highlighted and then handled by the LSS process. However, the problem can also be known to the management and/or a number of workers in the area, but needs to be clarified. An example of this problem is having a high utilization rate of ER beds. The problem in this case is known but has to be defined, and in subsequent stages of the LSS process, dissected and resolved.

In other cases, there are no known issues but there might be "opportunities" to either streamline processes, or "leaning" them, as well as "opportunities" to improve the processes by reducing the errors, using Six Sigma. An example for this case is having an ER with no known major problems, but opportunities can be found to make the workflow more efficient in the area.

The LSS module can handle both of the previously mentioned cases; identifying problems or finding opportunities. By dissecting the different workflows in, for example, the ER, it might be noticed that certain steps take longer than what they should be, or some of the steps are unnecessary. Such problems or opportunities are usually not noticeable when the workflow is described or imagined, but when the workflow is formed in a proper representation, PIOs become very obvious.

Prior to discussing how CBI can be utilized in Phase Zero, it is important to mention that there are a number of data points from where the process type can be harvested. In a typical ER setup, there are four labels that specify the nature of the encounter, and those labels are: the Chief Complaint (CC), the admission diagnosis, the primary diagnosis, the discharge diagnosis, and the primary procedure. The CC is what the physician has

understood in terms of why the patient is seeking healthcare assistance. In reality, the patient is the one who is making the diagnosis and the physician is simply rewording it into medical terms as accurate as possible. Because CC is determined very early in the patient encounter's episode, there is a high probability that it will be changed to either a more specific description of the patient's health issue or gets replaced completely with a different health problem. The admission diagnosis gets assigned after the attending physician completes the Subjective, Objective, Assessment and Plan (SOAP) process and just before the patient is determined to be admitted. The primary diagnosis gets determined and also modified, if necessary, during the patient stay in the hospital. Both, the admission diagnosis and the primary diagnosis are not the most ideal choices because they usually change during the patient stay if the attending physician realizes that the diagnosis was not accurate, probably after reviewing new test results or exam reports. Nonetheless, the discharge diagnosis is the most suitable data element that can be used as the process type. One of the important reasons is the fact that the most accurate diagnosis is logged in this data field. All the other diagnosis data element can, and in many cases do, change during the course of the patient stay. However, the discharge diagnosis is the final verdict on the patient's health condition. The other advantage that comes with selecting the discharge diagnosis data field is the ability to benchmark with the reported and recommended figures in the medical guidelines and literatures. The primary procedure is the medication intervention that has been performed on the patient. This is usually the only definite field for this data element and it shares the advantage of the discharge diagnosis in terms of the accuracy and the ability to benchmark with references. For example, it has been reported in a number of scientific literatures that the normal LOS for Laparoscopic Appendectomy

(ICD-9 procedure code 47.01) is around three days. This figure sets the benchmark when the LOS is queried for the Laparoscopic Appendectomy in the hospital. The benchmark is then translated to a Lower specification Limit (LSL) and an Upper Specification Limit (USL). A high variation that exceeds those limits would mean an opportunity for process enhancement.

The LSS module will have a number of solutions for identifying the most common process types in the clinical area. One of the most powerful solutions is analyzing the data in its native format using a standard database language called the Structured Query Language (SQL). This language is used to communicate with databases regardless of the brand. Among its many important functions, SQL provides the ability to retrieve the data, transform it, and then represent it in the format needed. Analysis fine tuning, which are always needed during the PIO identification process, can be done easily and on-the-fly by an SQL programmer when needed by the LSS team. Figure 23 shows a screenshot of an SQL query that analyzes the top 10 process types of an ER clinical setting, searching for PIOs.

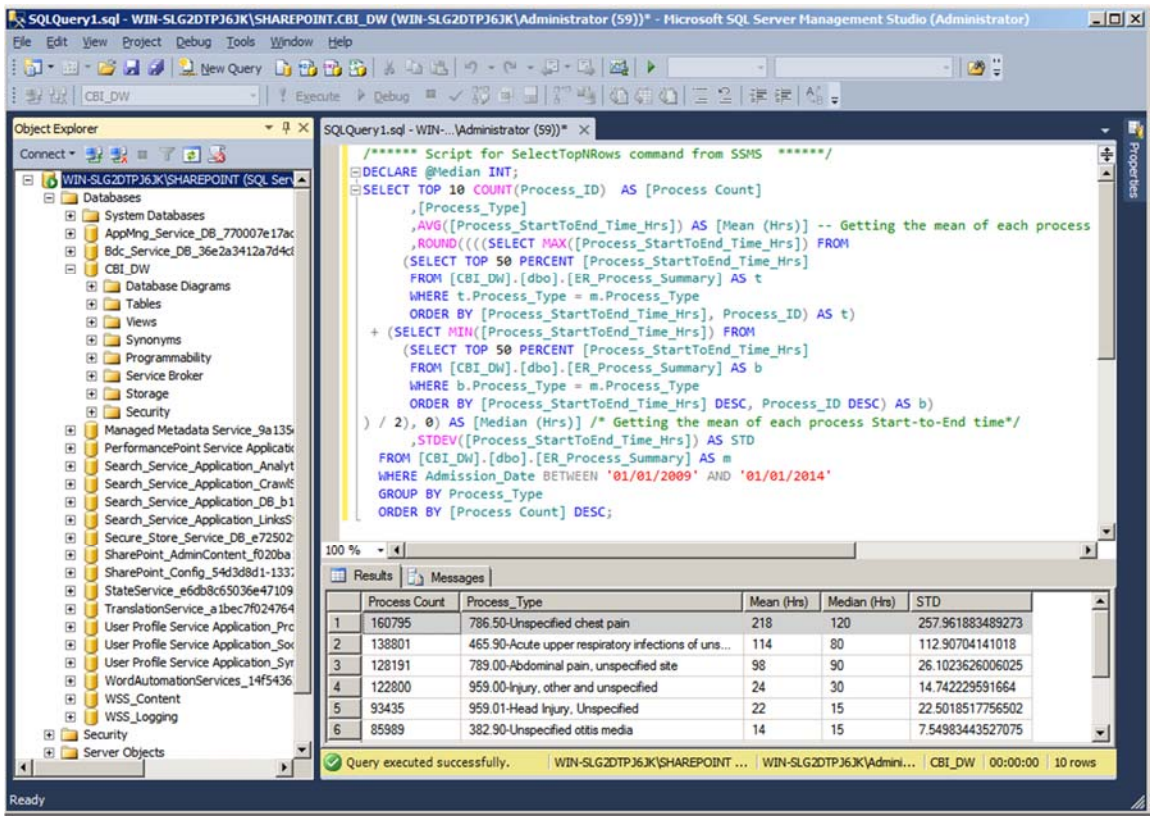


Figure 23: An SQL report showing the top 10 process types of an ER clinical setting

It is worth noting that the query only included the last 5 years of encounters. Taking the right time period is important so it will cover the routine change cycle that occur in typical work settings. At the same time, the time period should not go very far in the past, so it would not be affected by old policies and procedures or clinical guidelines and pathways that have no relevance in the current time.

A number of findings can be obtained from the result of the SQL query that is shown in Figure 23. Firstly, the result identified the top 10 process types in the work area. The criticality of this result stems from the importance of resolving issues that will have the most significant effect on the work area. Solving problems and/or improving those process types will have the highest positive impact on the whole clinical area.

The second finding is related to the mean, median and Standard Deviation (STD) values of the LOS. These parameters are critically important for identifying the variation in the process type. A high STD means that the process type is not handled in the same manner every time it gets executed and this generates a large amount of process wastes that have to be tackled.

The third finding is related to identifying the process types that consume the most resources of the work area. In a work area, the higher the LOS in a process type, the more resources are consumed, and larger positive outcomes are yielded when such processes are improved or their errors are minimized. The median LOS is selected as opposed to the mean because the median value eliminates outliers in the data, unlike the mean value. This is highly important in healthcare because of the extreme outliers that occur in almost every process type. For example, while the typical LOS of a congestive heart failure patient is around 7 days, a few patients might develop complications that could extend their hospital stay to months. The mean value would consider those few patients in the calculation and show a value that is skewed because of the exceptional cases. On the other hand, the median value eliminates exceptional cases and only considers the common ones in calculating the middle value.

However and despite the usefulness of the SQL tool, it is obvious from Figure 19 that a person with special knowledge and skills is required, in which many LSS certified personnel are lacking. Therefore, the LSS module should offer other solutions that assist in overcoming this issue and provide a comparable functionality, including tools that connect to the data cubes of the CBI data warehouse and provide analysis capabilities. Figure 24 presents a screenshot of a tool called Microsoft PowerPivot, which allows a

person without deep technical knowledge to slice and dice the data with simple clicks. Keeping in mind that other comparable tools are also available in the analytics market.

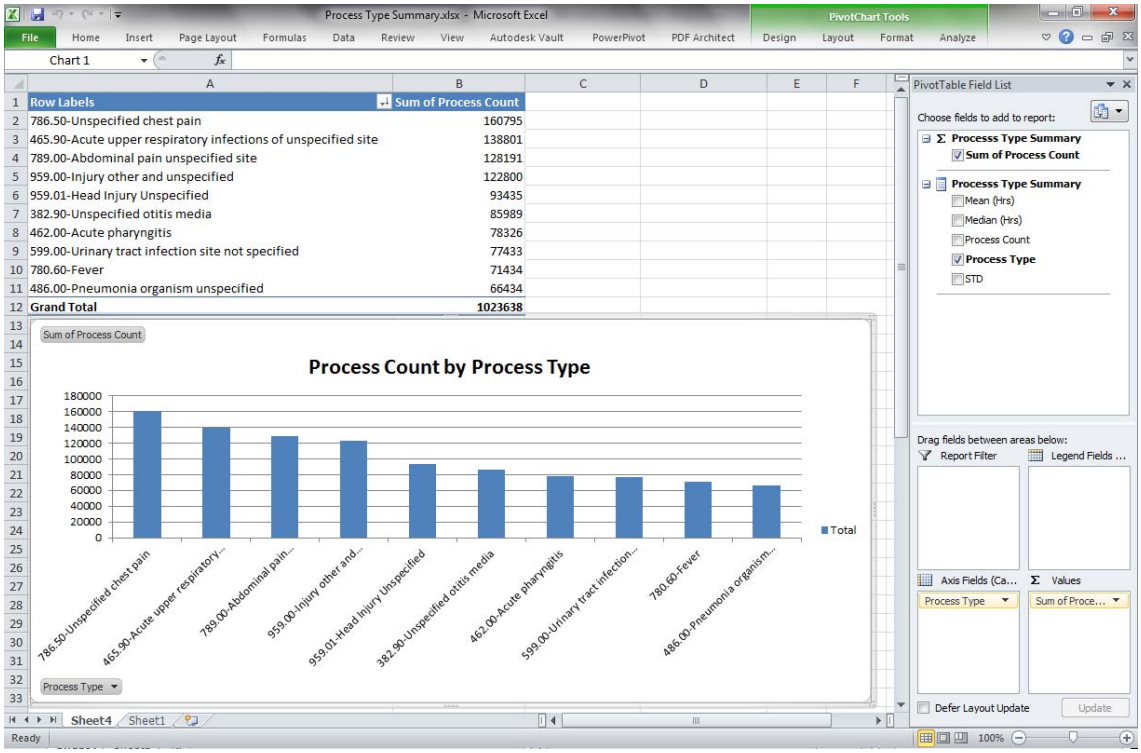


Figure 24: Analyzing data using CBI client tools

Data cubes, which are queried by the tool in Figure 24, are blocks of data that consist of two main components, facts and dimensions. Facts are quantitative or aggregatable data pieces while dimensions are qualitative or categorical data pieces. The client tools read the content of the cube and list the available facts and dimensions to the end-user, as shown on the right side of the screenshot. The end-user can easily add a dimension or a fact by checking the box on the right side of the relevant cube component. For example, the report shown in the figure did not take more than two minutes to generate. When the box next to the "Process Type" was checked, the client tool listed the process types that are available in the cube. Afterward, the fact "Process Count" was checked to show the total number of processes by process type. Graphical representation of the data

was also done by a few additional clicks through the top menu of the tool. It is important to state that despite the intuitiveness of such tools, initial data preparation by an SQL expert is always needed to be conducted, but with much less demand and frequency in compared to using SQL directly.

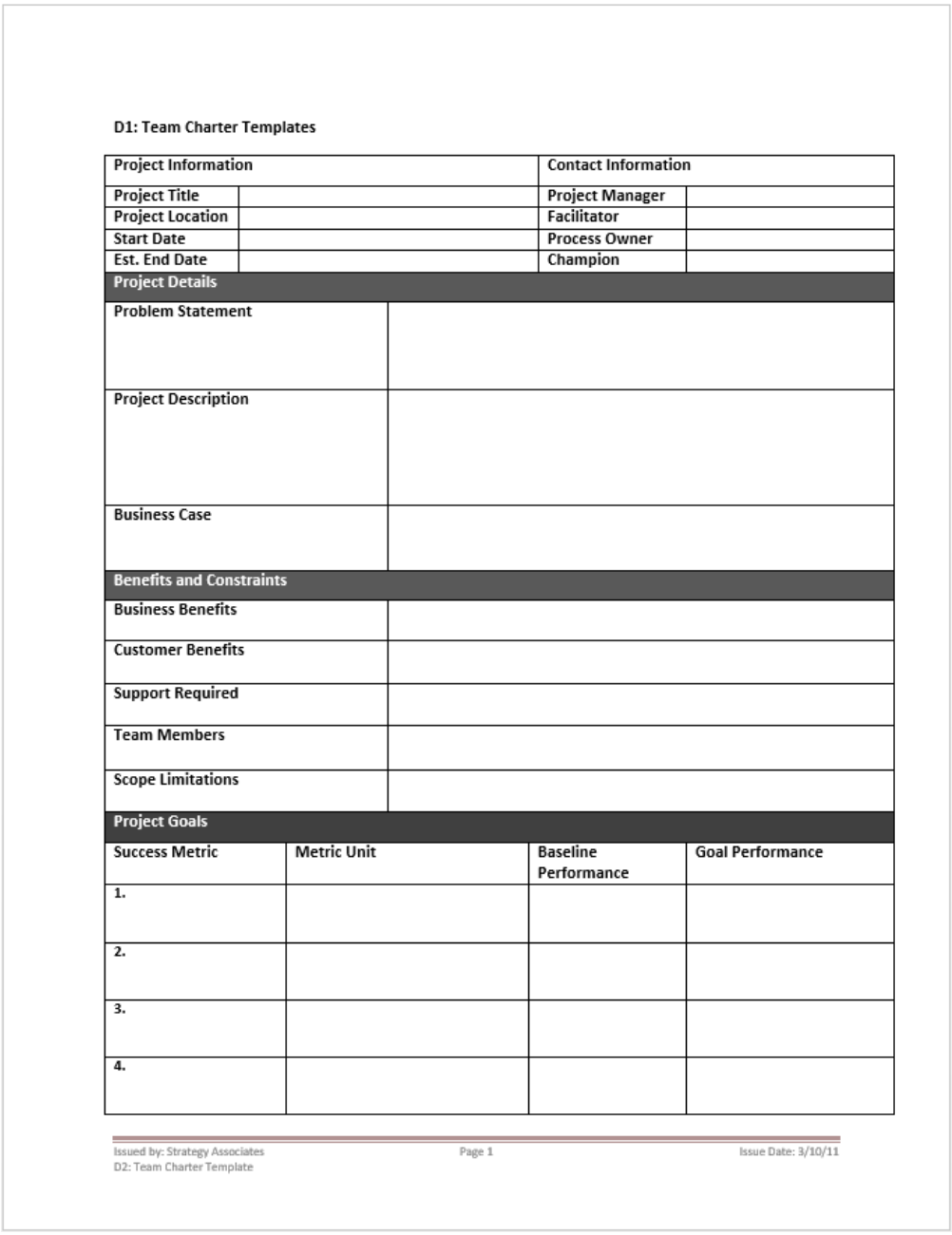
While the discharge diagnosis and the LOS time can assist in identifying potential "Lean" opportunities, comparing the admission, primary and discharge diagnoses to each other can unveil potential "Six Sigma" issues. The discrepancy among the admission, primary and discharge diagnoses is an indication of errors in the clinical setting's work processes. The same CBI tools mentioned above and others can assist in indicating such problems.

However, it is critical to consider that it is a normal tendency in the medical treatment to start from a general diagnosis and then determine specific diagnoses along the process. Therefore, identifying errors in the process should be limited to the change from one diagnosis to a completely different one. The standard diagnosis coding system in the United States, ICD, has the ability to identify the root of each diagnosis. Using this feature, the normal tendency to go from a general to a specific diagnosis can be eliminated in the query that searches for errors in the diagnosis. The result of the query will only show diagnoses that have been changed completely.

5.1.5 The Define Phase

The Define phase provides ample specifics to the PIO that was identified in Phase Zero, Problem/Opportunity Identification. This is conducted using three Tollgates: 1) Developing the Team Charter, 2) Develop high-level process maps and customer requirements, and 3) Prepare a project plan.

The Team Charter tollgate consists mainly of a document that indicates the title of the project and the team that will execute it. Figure 25 shows an example of a Team Charter document.



D1: Team Charter Templates

Project Information		Contact Information	
Project Title		Project Manager	
Project Location		Facilitator	
Start Date		Process Owner	
Est. End Date		Champion	

Project Details	
Problem Statement	
Project Description	
Business Case	
Benefits and Constraints	
Business Benefits	
Customer Benefits	
Support Required	
Team Members	
Scope Limitations	

Project Goals			
Success Metric	Metric Unit	Baseline Performance	Goal Performance
1.			
2.			
3.			
4.			

Issued by: Strategy Associates Page 1 Issue Date: 3/10/11
D2: Team Charter Template

Figure 25: A template of a team charter document - ©Strategy Associates

The Team Charter document also explains the PIO that is being handled and how to measure the effectiveness of the project in tackling the PIO. The effectiveness is

measured using a set of metrics that have a complete section in the document. The metrics should be derived from the components of the PIO. For example, high ICU bed utilization can be monitored using three metrics: average LOS, order cancellation rate, and complication rate. The baseline for those metrics can be obtained using the previously discussed analysis tools of the LSS module. The goal performance can be set based on the hospital guidelines, scientific literatures, or by benchmarking against local, regional or national hospitals.

The second tollgate, developing a high-level process maps and customer requirements, can be executed using the Swimlane Process Mapping and SIPOC tools. The steps and timestamps of the process map can be identified from the admission, transfer, orders, results, and medication administration records of an encounter that carries the PIO's process type. However and unlike the Swimlane Process Mapping, SIPOC requires gathering qualitative information from the parties involved in the business process. This is done usually via focus groups, interviews, meetings, and/or surveys.

The third tollgate, creating a project plan, also cannot be handled by the LSS module. However, this tollgate requires no more than a conventional project management skills and practices to achieve the goals of the tollgate.

5.1.6 The Measure Phase

This phase focuses on quantifying the PIO through two main tollgates: 1) creating a data-collection plan, and 2) implementing the data-collection plan.

Creating a data-collection plan involves many steps that can be completely handled by the LSS module. Figure 26 shows a flowchart that lists the steps involved in the data-collection plan tollgate.

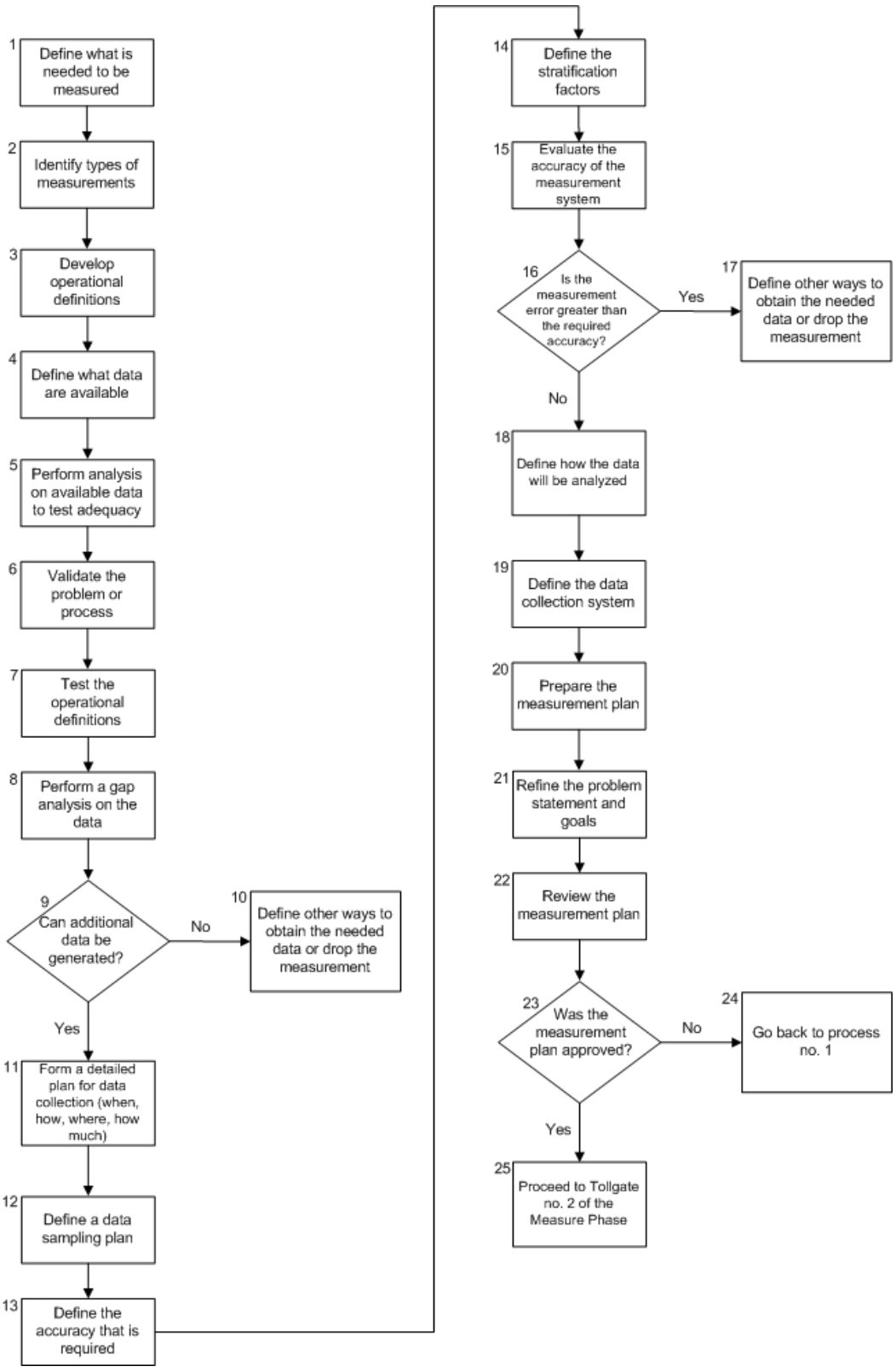


Figure 26: Flowchart of the data-collection tollgate

In order to ensure a comprehensive data collection plan that suits the identified PIO, the measurements have to be defined clearly. This is the first process of the data collection plan tollgate, and it is because all other processes of the two Measure phase tollgates branch out from the defined measures. A good source to identify the measurements is by using three generic requirement tools: Critical-to-Quality (CTQ), Critical-to-Schedule (CTS), and Critical to-Cost (CTC). The analysis of those requirements can be done using the Tree Diagram. This diagram starts from the highest level of customer requirements, vision, and then dissects the requirement to the lowest level that identifies the measures and targets. Figure 27 shows an example of CTQ Tree Diagram used to analyze the CTQ requirements for a chest pain process in the ER.

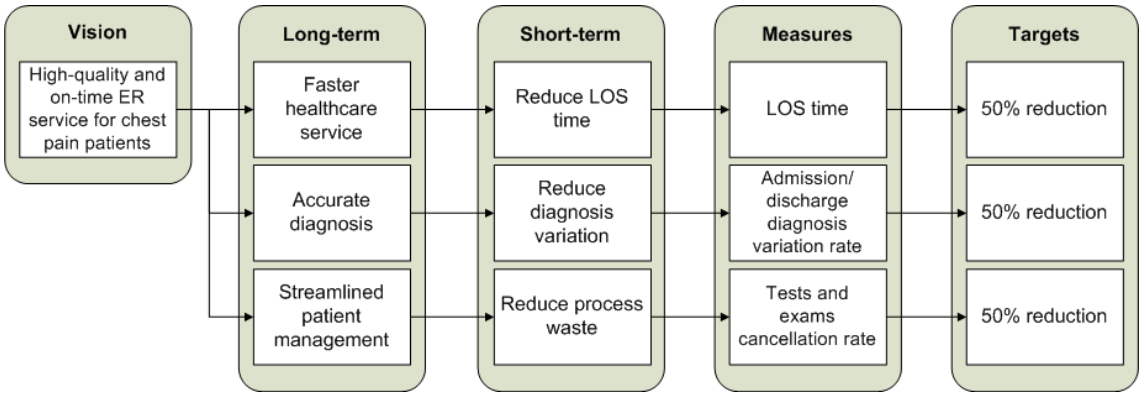


Figure 27: A Tree Diagram that analyzes the CTQ requirements for an ER chest pain process

Using the CTQ tree diagram and with the assistance of the internal and external customer requirements, the PIO and the most important measures can be identified. In the example of Figure 27, a faster healthcare service, accurate diagnosis, and streamlined patient management are the most important requirements. The requirements are then narrowed down to actions that can be performed in the short-term. From those actions, measures can be obtained, and with which, the performance of the actions can be evaluated.

Moreover, targets can be set alongside each measure in order to benchmark against and conclude if the objectives have been met or not.

Steps number two and three in the flowchart of Figure 26 handle the identification of measure types, whether qualitative or quantitative. They also define each measure. These two steps are important for the upcoming processes that involve matching the requirement measures with the attributes or data elements.

In relation to the LSS module, the identified measures are the attributes that exist in the various HIT systems and in the data warehouse of the module. Step four through ten in the tollgate flowchart investigates whether or not the requirement measures can be retrieved from the existing systems. This is a critical step because the unavailability of an attribute that matches a measure would leave the LSS team with three options, 1) creating the missing attribute in the relevant HIT, 2) obtaining the missing attribute through a manual process, e.g. paper-forms, or 3) abandoning the measure completely. Nonetheless, the first option is preferred because it will solve the issue on the long-term. The measure will be needed in this phase, subsequent phases, and even after the LSS is completed, to monitor and maintain the changes that LSS will introduce. The other two options either create data for the measure in a lengthy manner and with low reliability and validity, or completely abandon the measure. In both cases, the LSS process will be negatively affected.

Step 11 through 25 in the tollgate flowchart involve the preparation of the data collection process in tollgate two. The preparation process includes detailed definition of how each data element will be collected. The steps also involve forming a measurement plan and passing it through the approval process in the organization.

Tollgate two of the Measure phase, involve implementing the data-collection plan that was defined in tollgate one. Although many methods can be used to materialize the plan, the ETL component of the LSS module will be the ideal tool for this task. Among its many advantages, the data collection process can be fully automated with minimal maintenance in the future, which extends beyond the LSS process. The ability to copy data-collection jobs to new processes that are relatively similar to existing ones is also a key advantage that shortens lengthy processes, which are necessary for many data-collection plans. Furthermore, data-collection jobs in the ETL tool can also be updated easily by, for example, adding additional measures, if the LSS process is repeated. Figure 28 shows a screenshot of an ETL tool that has a number of LSS data-collection jobs.

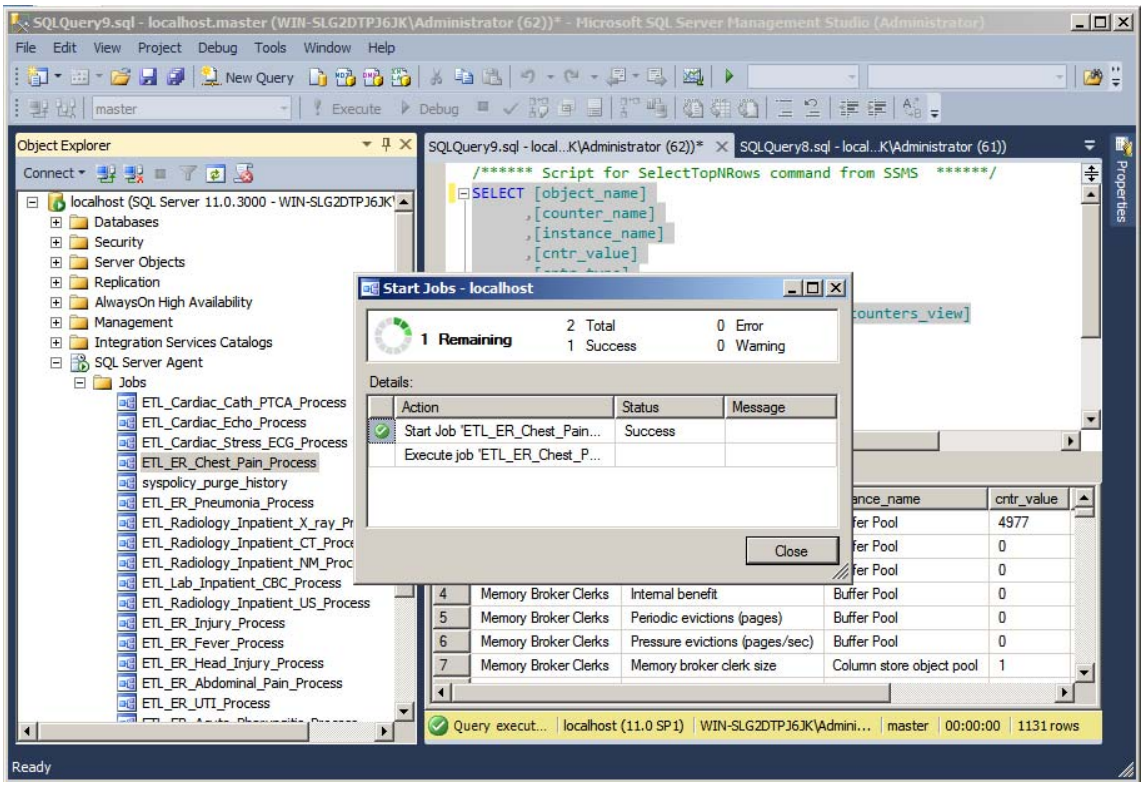


Figure 28: Collecting data using the ETL component of CBI

5.1.7 The Analyze Phase

The Analyze phase involves converting the data, which was collected during the Measure phase, to information. The difference between data and information is mainly related facilitating decisions. Data is a collection of numbers and labels, also known as quantitative and qualitative. Informed decisions cannot be made on those numbers and labels unless they are framed in contexts, and this converts them to information.

According to Harrington, Gupta and Voehl[103], there are six key concepts that the Analysis phase revolves around:

1) Analysis of the measures that are important to the customer
2) Defect analysis – failure to deliver
3) Process capability analysis
4) Analysis for reasons for variation
5) Analysis for stable operations
6) Analysis of the design for Six Sigma

Those concepts can be encapsulated in the three tollgates of the Analyze phase: 1) analyze the data, 2) analyze the process, and 3) analyze the root causes.

Traditionally, analyzing the data that was collected in the Measure phase is done using pure statistical methods and tools. Such techniques are very powerful and are still commonly used in traditional LSS projects. However, the LSS module, through the CBI framework capabilities, can offer a lot of functionalities that can fulfil the Analyze phase's requirements in a more practical manner.

The LSS module can include scorecards that allow the LSS team to benchmark the existing process performance against the customer's requirement. It can also indicate, at

glance, the failure of delivery with different levels of stratification. At a later stage in the LSS process, mainly in the Control phase, scorecards can be easily configured to show a process's performance in the last pre-defined period of time, e.g. three, six or 12 months. Figure 29 shows a scorecard that has been developed for an ER chest pain process.

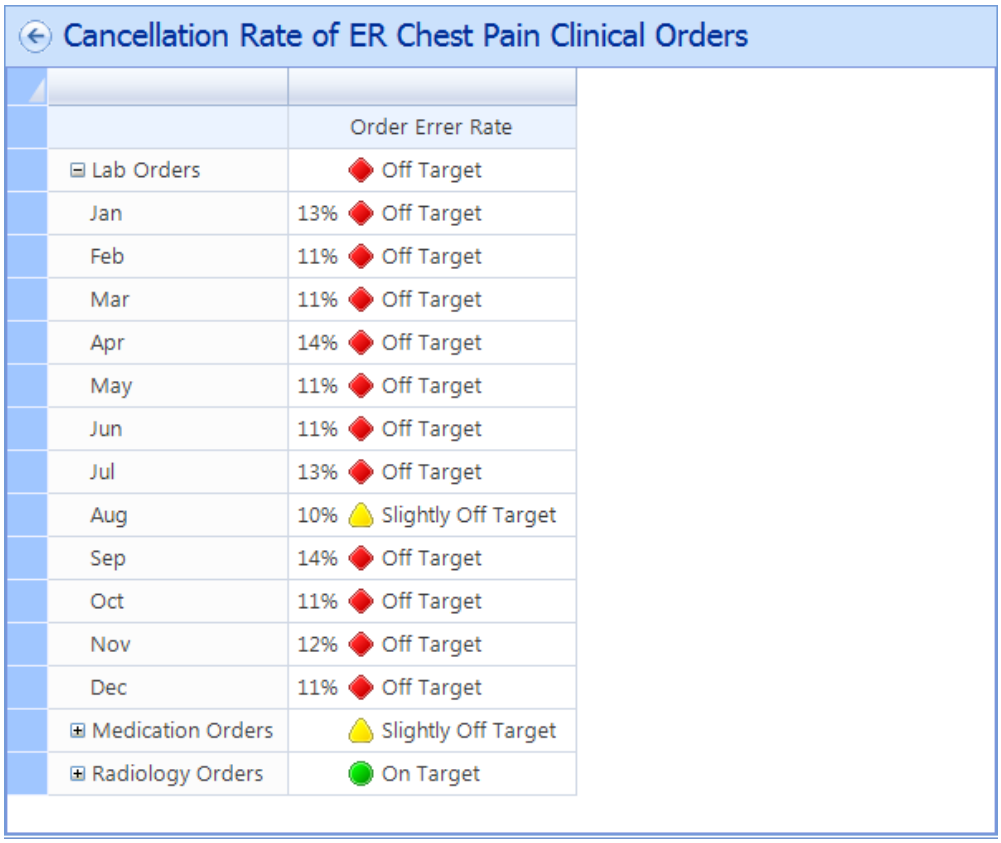


Figure 29: A scorecard, developed using Microsoft BI, showing error rates in the ER for the chest pain process

The scorecard shows the cancellation rates of clinical orders in the Chest Pain process. The cancellation can be caused by different reasons, mainly errors. Nonetheless, any clinical order cancellation should be considered a waste, or error, that should be reduced. This is due to the reason that once an order is initiated, resources immediately start getting allocated and consumed for the execution of the order. Cancelling the order

afterward would mean that the resources that were used to execute the order have been wasted, regardless of the reason.

Nevertheless, it is clear from the scorecard that the lab order process has a high level of waste caused by the high order cancellations. Although it is left to the LSS team to configure based on the customer requirements, the scorecard in this example has been configured to color code the indicators based on how high the cancellation percentage is: 0% – 5% is green, 6% – 10% is yellow and 11% and above is red. From the scorecard, it is clear that the lab order process have major issues in the workflow. The overall indicator for the medication order process indicate a slight off target deviation, which means that the issue is less significant than the lab order process, and therefore, might be given a lower priority for being addressed in the next phase, Improve. On the other hand, the radiology order process is indicated as normal, and therefore, requires no action.

As demonstrated in the previous example, scorecards of the LSS module allow the LSS team and others to analyze the statuses of processes quickly and easily. The sub-processes in the scorecard can also be weighted. For example, lab orders can be given high weight since their impact in the overall patient workflow is very high, considering that 70% of medical decisions are influenced by lab tests[104]. On the other hand, patient education orders can be given low weight because they can be provided at any point during the patient management or after the patient is discharged, through emails, mails, or other communication methods.

The LSS module's analytical graphs can also be used to analyze the aforementioned ER chest pain process. Figure 30 presents a screenshot of an analytical graph for the cancellation rate handled in Figure 29.

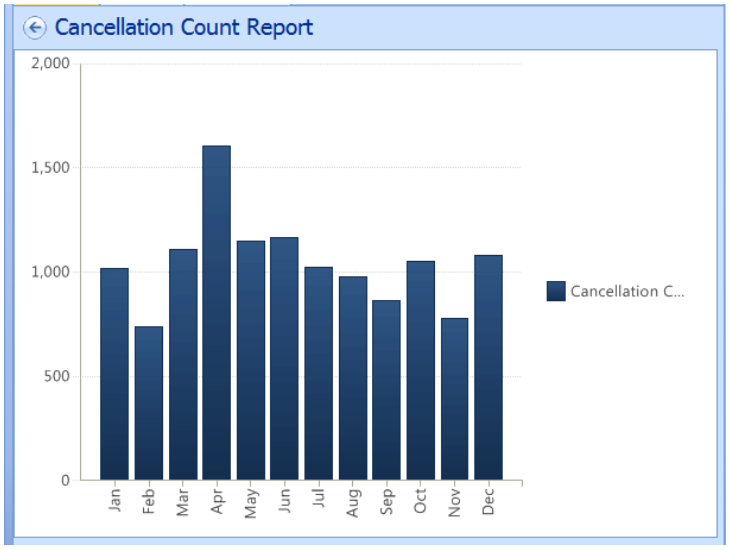


Figure 30: Analyzing the data using CBI analytical graphs

The analytical graphs of the LSS module can offer different features that can be very useful for the LSS process. Instead of just analyzing the presented figures on the scorecard or report, the LSS team can easily drill-down to the cancellation reasons in a specific area of interest. For example, it is obvious that the highest cancellation has occurred in April. To investigate further on what exactly were the root causes of the cancellations, the end-user can right-click on the April bar and launch the tool that allows "slicing and dicing" of this piece of data. Figure 31 shows an example of the drill-down capability.

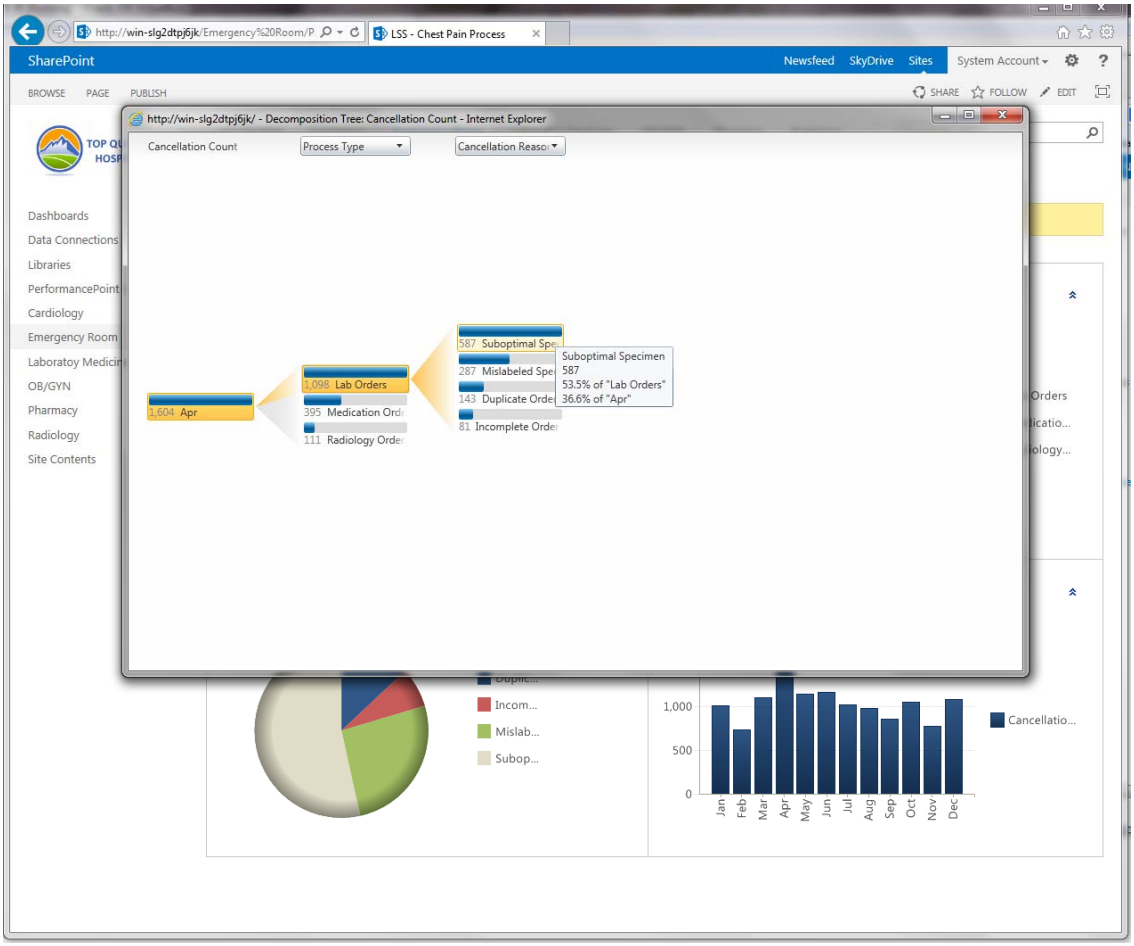


Figure 31: An example of the drill-down capability to identify the order cancellation reasons

In the previous example, the drill-down tool was first launched with only one box that indicates the piece of data being analyzed, the month of April. After clicking on the box, the tool has shown the dimensions, or stratifiers, that the end-user can use to slice the data. The dimensions in this case can include ordering physicians, attending nurses, lab technicians, ordering time periods, order types, cancellation reasons, and others. In this example, the highlight was on the reasons for cancellations in the area that suffers the highest from this issue. By selecting the order type, the tool shows the three order types that are associated with the chest pain process. To drill-down and identify the reasons, the

analyst clicks on the lab orders, where the highest cancellations have occurred, and then selects the cancellation reason dimension. The tool then shows the reasons for cancellations sorted from highest to lowest. The "incomplete Order" reason indicates that necessary information has not been provided when the order was placed. The "Duplicate Order" reason points to having another similar orders that has been placed for this patient. The "Mislabeled Specimen" reason specifies that the specimens have been received without collection time and/or collector's employee number. The "Suboptimal Specimens" reason indicates that the specimens have been improperly collected and/or preserved, e.g. clotted, hemolyzed, contaminated, or did not include sufficient volume.

Based on the findings that were revealed by the drill-down tool, the LSS team can focus on the issues that would yield the highest benefit while demand the lowest possible effort.

5.1.8 The Improve Phase

After the information has been obtained from the Analyze phase, it will be used to make informed decisions on how process improvements or problem solutions can be achieved. This is done by the LSS team and complied in a list of improvement or solutions actions. The Improve phase involves materializing those actions. This phase has two tollgates: 1) generate the solutions, and 2) implement and test the solutions.

The first tollgate is mostly a traditional LSS process. In the previous ER chest pain example, we identified two cancellation reasons: Suboptimal Specimen and Mislabeled Specimen. In this case, the LSS team can conduct an on-the-ground investigation to uncover the root causes of those cancellations. For the Suboptimal Specimen reason, the cause can be related to a faulty refrigerator or temperature control device that is used in the

area. The issue can also be caused by an implemented suboptimal specimen handling process that involves a lengthy time for collecting, storing, and sending the specimens to the laboratory area. The Mislabeled Specimen cancellations could be due to issues in the configuration of the ordering module, CPOE, of the EHR. Alternatively, the issue can be caused by an intermittently faulty labeling printer. Rectifying these issues can reduce the cancellations to a normal level, and consequently, improve the chest pain process in the ER.

The second tollage, implementing and testing the solutions, can be assisted vastly by the LSS module, especially on the solution testing area. Once solutions have been implemented, the different tools of the LSS module that have been previously explained can assist significantly in testing the effectiveness of the implemented solutions.

5.1.9 The Control Phase

The Control phase is the final stage of the DMAIC process. This phase handles how the implemented process improvement or problem solutions can be sustained. Otherwise, the achievements that have been reached in the previous phases can be no more than instant or short-term positive effects and will disappear soon after the DMAIC process is completed.

Two tollgates are involved in the Control phase: 1) determining the methods of control, and 2) implementing the control methods. The LSS module can be very beneficial in both tollgates. As part of determining the control methods, many of the previously discussed LSS module tools can be considered. In fact, most of the LSS module tools can be encapsulated in a CBI web portal that provides a single source of reference for those tools. Besides the LSS module tools that have been discussed earlier, dashboards can

provide quick overview on how improvements are maintained. Figure 32 illustrates a dashboard that was developed for the aforementioned ER chest pain process.

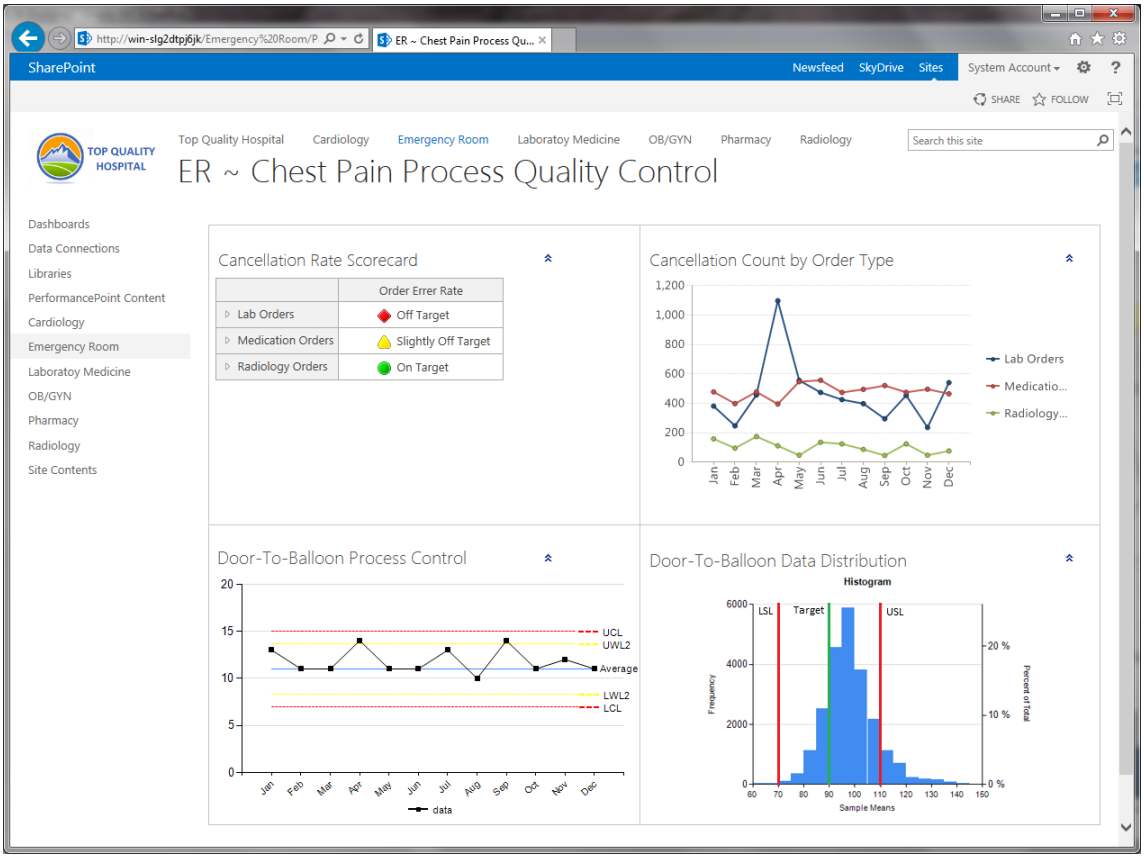


Figure 32: CBI dashboards can be used to control implemented improvements

A set of CBI analytical reports can also be developed to be part of the control methods. Many CBI frameworks now have analytical reports equipped with data alerts and automatic report submission features. The data alert feature triggers the report submission when a pre-defined condition is met. In the ER case mentioned previously, a return to the high order cancellation rate in lab orders can be configured as a condition to trigger submitting a report about this issue to the person who is assigned to perform the control duties. On the other hand, the automatic report submission feature submits reports regularly based on a pre-defined time-frame. Both features are important and complement each

other. The automatic report submission can be used to monitor the status of the process generally and identify triggers for the data alert feature.

CHAPTER VI: SUMMARY AND SUGGESTIONS FOR FUTURE RESEARCH

Nowadays, the healthcare system in the United States is faced with major quality challenges that contribute to the exponential increases in healthcare costs, as well as compromises the values of the services provided. QIMs have been proven to be effective in many industries. However, the environments that produced the most common QIMs are vastly different from healthcare. This has caused issues in the implementation of such QIMs, which significantly conceded their outcomes in some cases, and in others, resulted in utter failures.

Therefore, it is important to implement QIMs in a manner that suites the healthcare environment and integrates with its processes. Health Information Technologies (HIT), with their current wide deployment, can provide an ideal platform that integrates QIMs into healthcare workflows. However, it was unclear whether or not QIMs are implemented using HIT systems in healthcare organizations in the United States.

This study evaluates the status of healthcare organizations in the United Status in relation to the employment of QIMs. It also measures the readiness of the organizations' HIT platforms for integrated implementation of QIMs.

The results of the study unveiled the organizations' immense interest and utilization of various QIMs. The results also showed that different HIT systems have been used as the data platform for the methodologies. However, the results indicated that the manual data collection method is still the main data source for QIMs.

The future study is recommended to involve the development and implementation of a HIT-integrated quality improvement module at a healthcare organization. The study

should then evaluate the feasibility of this quality improvement setup. It should also measure the efficiency, throughput and financial outcomes that are yielded from the implementation of the quality improvement module.

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APPENDICES

Appendix A: Study Measures

No.	Variable Name	Description	Measure Type
1	Vrid	Response ID	Interval
2	Vstatus	Status	Nominal
3	Organization_Type_A	Identifies if the healthcare organization a hospital or a physician practice	Nominal
4	Organization_Location_A	Shows if the healthcare organization is located in rural or urban geographical location	Nominal
5	Organization_City	Identifies the city of the healthcare organization	Nominal
6	Organization_State	Identifies the state of the healthcare organization	Nominal
7	Organization_Zip	Identifies the zip code of the healthcare organization	Nominal
8	US_Region_A	Identifies the region where the healthcare organization is located, i.e. Northeast, Midwest, South, or West	Nominal
9	Hospital_Bedsize_A	Labels hospitals with one of three main size identifications: Small, Medium or Large	Ordinal
10	Hospital_Bed_No_A	Provides the exact bedsize number in hospitals	Interval
11	FTE_No_A	Stores the exact number of Full-Time Employees (FTEs) of the organization	Interval
12	Avg_Efficiency_Outcome_A	The average efficiency outcome across all QIMs	Ordinal
13	Ave_Financial_Outcome_A	The average financial outcome across all QIMs	Ordinal
14	Avg_Throughput_Outcome_A	The average throughput outcome across all QIMs	Ordinal
15	Manual_Data_Collect_4_Qualt_Improv_A	Indicates if manual data collection has been used	Nominal
16	Only_Manual_Data_Collection_Was_Used		
17	Only_HIT_Based_Data_Collection_Was_Used		

18	Is_HIMSS_Stage_6_or_7	Specifies if the healthcare organization has reached stage 6 or 7 of HIMSS EMRAD	Nominal
19	Closed_Loop_HIT_Installed_A	Indicates if the healthcare organization has reached HIMSS Stage 6 and above	Nominal
20	Basic_HIT_Installed_A	Shows if the healthcare organization has installed basic HIT systems, the three ancillaries (LIS, PIS, & RIS/PACS). HIMSS Stage 1 and above.	Nominal
21	HIT_Utilized_in_QIMs	Indicates if HIT systems have been used in QIM implementations	Nominal
22	var51_A	Has the hospital/practice ever implemented any QIM in the past?	Nominal
23	HIT_Utilized_in_LSS	Indicates if HIT systems have been used in LSS implementations	Nominal
24	HIT_Utilized_in_SS	Indicates if HIT systems have been used in SS implementations	Nominal
25	HIT_Utilized_in_CP	Indicates if HIT systems have been used in CP implementations	Nominal
26	HIT_Utilized_in_BPR	Indicates if HIT systems have been used in BPR implementations	Nominal
27	HIT_Utilized_in_LM	Indicates if HIT systems have been used in LM implementations	Nominal
28	HIT_Utilized_in_ToC	Indicates if HIT systems have been used in ToC implementations	Nominal
29	HIT_Utilized_in_CI	Indicates if HIT systems have been used in CI implementations	Nominal
30	HIT_Utilized_in_TQM	Indicates if HIT systems have been used in TQM implementations	Nominal
31	HIT_Utilized_in_Benchmarking	Indicates if HIT systems have been used in Benchmarking implementations	Nominal
32	var52O183	No quality improvement resources are available to conduct quality improvement:What are the reasons for not implementing QIMs?	Nominal
33	var52O184	No financial demands exist to conduct quality improvement at this point:What are the reasons for not implementing QIMs?	Nominal
34	var52O185	No regulatory demands require the hospital/practice to implement quality improvement at this point:What are the reasons for not implementing QIMs?	Nominal

35	var52O182	There is no time available to allocate for quality improvement:What are the reasons for not implementing QIMs?	Nominal
36	var52O188	Quality improvement is generally not needed to be implemented in the hospital/practice at this point:What are the reasons for not implementing QIMs?	Nominal
37	var52O186	other:What are the reasons for not implementing QIMs?	Nominal
38	var52	other:What are the reasons for not implementing QIMs?	Nominal
39	var2O147	Clinical Pathways (CP):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
40	var2O187	Benchmarking:What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
41	var2O145	Lean Six Sigma (LSS):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
42	var2O146	Six Sigma (SS):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
43	var2O148	Business Process Reengineering (BPR):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
44	var2O149	Lean Management (LM):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
45	var2O150	Theory of Constraints (ToC):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
46	var2O151	Continuous Improvement (CI):What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
47	var2O152	Total Quality Management (TQM):What are the QIMs that have	Nominal

		been used at the hospital/practice over the last ten years?	
48	var2O153	other:What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
49	var2	other:What are the QIMs that have been used at the hospital/practice over the last ten years?	Nominal
50	var47O169QN10145	Last 12 Months:Lean Six Sigma (LSS):In what period of time the QIMs have/had been used?	Nominal
51	var47O170QN10145	Between 1 and 5 Years Ago:Lean Six Sigma (LSS):In what period of time the QIMs have/had been used?	Nominal
52	var47O171QN10145	Between 6 and 10 Years Ago:Lean Six Sigma (LSS):In what period of time the QIMs have/had been used?	Nominal
53	var47O169QN10146	Last 12 Months:Six Sigma (SS):In what period of time the QIMs have/had been used?	Nominal
54	var47O170QN10146	Between 1 and 5 Years Ago:Six Sigma (SS):In what period of time the QIMs have/had been used?	Nominal
55	var47O171QN10146	Between 6 and 10 Years Ago:Six Sigma (SS):In what period of time the QIMs have/had been used?	Nominal
56	var47O169QN10147	Last 12 Months:Clinical Pathways (CP):In what period of time the QIMs have/had been used?	Nominal
57	var47O170QN10147	Between 1 and 5 Years Ago:Clinical Pathways (CP):In what period of time the QIMs have/had been used?	Nominal
58	var47O171QN10147	Between 6 and 10 Years Ago:Clinical Pathways (CP):In what period of time the QIMs have/had been used?	Nominal
59	var47O169QN10148	Last 12 Months:Business Process Reengineering (BPR):In what period of time the QIMs have/had been used?	Nominal
60	var47O170QN10148	Between 1 and 5 Years Ago:Business Process Reengineering (BPR):In what period of time the QIMs have/had been used?	Nominal
61	var47O171QN10148	Between 6 and 10 Years Ago:Business Process Reengineering (BPR):In what period of time the QIMs have/had been used?	Nominal

62	var47O169QN10149	Last 12 Months:Lean Management (LM):In what period of time the QIMs have/had been used?	Nominal
63	var47O170QN10149	Between 1 and 5 Years Ago:Lean Management (LM):In what period of time the QIMs have/had been used?	Nominal
64	var47O171QN10149	Between 6 and 10 Years Ago:Lean Management (LM):In what period of time the QIMs have/had been used?	Nominal
65	var47O169QN10150	Last 12 Months:Theory of Constraints (ToC):In what period of time the QIMs have/had been used?	Nominal
66	var47O170QN10150	Between 1 and 5 Years Ago:Theory of Constraints (ToC):In what period of time the QIMs have/had been used?	Nominal
67	var47O171QN10150	Between 6 and 10 Years Ago:Theory of Constraints (ToC):In what period of time the QIMs have/had been used?	Nominal
68	var47O169QN10151	Last 12 Months:Continuous Improvement (CI):In what period of time the QIMs have/had been used?	Nominal
69	var47O170QN10151	Between 1 and 5 Years Ago:Continuous Improvement (CI):In what period of time the QIMs have/had been used?	Nominal
70	var47O171QN10151	Between 6 and 10 Years Ago:Continuous Improvement (CI):In what period of time the QIMs have/had been used?	Nominal
71	var47O169QN10152	Last 12 Months:Total Quality Management (TQM):In what period of time the QIMs have/had been used?	Nominal
72	var47O170QN10152	Between 1 and 5 Years Ago:Total Quality Management (TQM):In what period of time the QIMs have/had been used?	Nominal
73	var47O171QN10152	Between 6 and 10 Years Ago:Total Quality Management (TQM):In what period of time the QIMs have/had been used?	Nominal
74	var47O169QN10153	Last 12 Months:other:In what period of time the QIMs have/had been used?	Nominal

75	var47O170QN10153	Between 1 and 5 Years Ago:other:In what period of time the QIMs have/had been used?	Nominal
76	var47O171QN10153	Between 6 and 10 Years Ago:other:In what period of time the QIMs have/had been used?	Nominal
77	var47O169QN10187	Last 12 Months:Benchmarking:In what period of time the QIMs have/had been used?	Nominal
78	var47O170QN10187	Between 1 and 5 Years Ago:Benchmarking:In what period of time the QIMs have/had been used?	Nominal
79	var47O171QN10187	Between 6 and 10 Years Ago:Benchmarking:In what period of time the QIMs have/had been used?	Nominal
80	var4O33QN10145	Manual Data Collection:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
81	var4O29QN10145	Electronic Health Record:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
82	var4O30QN10145	Radiology Information System:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
83	var4O31QN10145	Pharmacy Information System:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
84	var4O32QN10145	Lab Information System:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
85	var4O90QN10145	CPOE:Lean Six Sigma (LSS):For each of the QIMs selected previously, from where the data came?	Nominal
86	var4O33QN10146	Manual Data Collection:Six Sigma (SS):For each of the QIMs selected previously, from where the data came?	Nominal
87	var4O29QN10146	Electronic Health Record:Six Sigma (SS):For each of the QIMs selected	Nominal

		previously, from where the data came?	
88	var4O30QN10146	Radiology Information System:Six Sigma (SS):For each of the QIMs selected previously, from where the data came?	Nominal
89	var4O31QN10146	Pharmacy Information System:Six Sigma (SS):For each of the QIMs selected previously, from where the data came?	Nominal
90	var4O32QN10146	Lab Information System:Six Sigma (SS):For each of the QIMs selected previously, from where the data came?	Nominal
91	var4O90QN10146	CPOE:Six Sigma (SS):For each of the QIMs selected previously, from where the data came?	Nominal
92	var4O33QN10147	Manual Data Collection:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
93	var4O29QN10147	Electronic Health Record:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
94	var4O30QN10147	Radiology Information System:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
95	var4O31QN10147	Pharmacy Information System:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
96	var4O32QN10147	Lab Information System:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
97	var4O90QN10147	CPOE:Clinical Pathways (CP):For each of the QIMs selected previously, from where the data came?	Nominal
98	var4O33QN10148	Manual Data Collection:Business Process Reengineering (BPR):For each of the QIMs selected	Nominal

		previously, from where the data came?	
99	var4O29QN10148	Electronic Health Record:Business Process Reengineering (BPR):For each of the QIMs selected previously, from where the data came?	Nominal
100	var4O30QN10148	Radiology Information System:Business Process Reengineering (BPR):For each of the QIMs selected previously, from where the data came?	Nominal
101	var4O31QN10148	Pharmacy Information System:Business Process Reengineering (BPR):For each of the QIMs selected previously, from where the data came?	Nominal
102	var4O32QN10148	Lab Information System:Business Process Reengineering (BPR):For each of the QIMs selected previously, from where the data came?	Nominal
103	var4O90QN10148	CPOE:Business Process Reengineering (BPR):For each of the QIMs selected previously, from where the data came?	Nominal
104	var4O33QN10149	Manual Data Collection:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal
105	var4O29QN10149	Electronic Health Record:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal
106	var4O30QN10149	Radiology Information System:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal
107	var4O31QN10149	Pharmacy Information System:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal
108	var4O32QN10149	Lab Information System:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal

109	var4O90QN10149	CPOE:Lean Management (LM):For each of the QIMs selected previously, from where the data came?	Nominal
110	var4O33QN10150	Manual Data Collection:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
111	var4O29QN10150	Electronic Health Record:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
111	var4O30QN10150	Radiology Information System:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
112	var4O31QN10150	Pharmacy Information System:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
113	var4O32QN10150	Lab Information System:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
114	var4O90QN10150	CPOE:Theory of Constraints (ToC):For each of the QIMs selected previously, from where the data came?	Nominal
115	var4O33QN10151	Manual Data Collection:Continuous Improvement (CI):For each of the QIMs selected previously, from where the data came?	Nominal
116	var4O29QN10151	Electronic Health Record:Continuous Improvement (CI):For each of the QIMs selected previously, from where the data came?	Nominal
117	var4O30QN10151	Radiology Information System:Continuous Improvement (CI):For each of the QIMs selected previously, from where the data came?	Nominal
118	var4O31QN10151	Pharmacy Information System:Continuous Improvement (CI):For each of the QIMs selected	Nominal

		previously, from where the data came?	
119	var4O32QN10151	Lab Information System:Continuous Improvement (CI):For each of the QIMs selected previously, from where the data came?	Nominal
120	var4O90QN10151	CPOE:Continuous Improvement (CI):For each of the QIMs selected previously, from where the data came?	Nominal
121	var4O33QN10152	Manual Data Collection:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
122	var4O29QN10152	Electronic Health Record:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
123	var4O30QN10152	Radiology Information System:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
124	var4O31QN10152	Pharmacy Information System:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
125	var4O32QN10152	Lab Information System:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
126	var4O90QN10152	CPOE:Total Quality Management (TQM):For each of the QIMs selected previously, from where the data came?	Nominal
127	var4O33QN10153	Manual Data Collection:other:For each of the QIMs selected previously, from where the data came?	Nominal
128	var4O29QN10153	Electronic Health Record:other:For each of the QIMs selected previously, from where the data came?	Nominal

129	var4O30QN10153	Radiology Information System:other:For each of the QIMs selected previously, from where the data came?	Nominal
130	var4O31QN10153	Pharmacy Information System:other:For each of the QIMs selected previously, from where the data came?	Nominal
131	var4O32QN10153	Lab Information System:other:For each of the QIMs selected previously, from where the data came?	Nominal
132	var4O90QN10153	CPOE:other:For each of the QIMs selected previously, from where the data came?	Nominal
133	var4O33QN10187	Manual Data Collection:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
134	var4O29QN10187	Electronic Health Record:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
135	var4O30QN10187	Radiology Information System:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
136	var4O31QN10187	Pharmacy Information System:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
137	var4O32QN10187	Lab Information System:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
138	var4O90QN10187	CPOE:Benchmarking:For each of the QIMs selected previously, from where the data came?	Nominal
139	var8O34QN10145	Efficiency of Workflow:Lean Six Sigma (LSS):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
140	var8O35QN10145	Throughput of Workflow:Lean Six Sigma (LSS):Have the goals of the implemented QIM(s) been	Ordinal

		achieved? Based on the efficiency, throughput, and financial factors	
141	var8O36QN10145	Financial Improvement:Lean Six Sigma (LSS):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
142	var8O34QN10146	Efficiency of Workflow:Six Sigma (SS):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
143	var8O35QN10146	Throughput of Workflow:Six Sigma (SS):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
144	var8O36QN10146	Financial Improvement:Six Sigma (SS):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
145	var8O34QN10147	Efficiency of Workflow:Clinical Pathways (CP):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
146	var8O35QN10147	Throughput of Workflow:Clinical Pathways (CP):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
147	var8O36QN10147	Financial Improvement:Clinical Pathways (CP):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
148	var8O34QN10148	Efficiency of Workflow:Business Process Reengineering (BPR):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
149	var8O35QN10148	Throughput of Workflow:Business Process Reengineering (BPR):Have the goals of the implemented QIM(s) been achieved? Based on the	Ordinal

		efficiency, throughput, and financial factors	
150	var8O36QN10148	Financial Improvement:Business Process Reengineering (BPR):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
151	var8O34QN10149	Efficiency of Workflow:Lean Management (LM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
152	var8O35QN10149	Throughput of Workflow:Lean Management (LM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
153	var8O36QN10149	Financial Improvement:Lean Management (LM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
154	var8O34QN10150	Efficiency of Workflow:Theory of Constraints (ToC):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
155	var8O35QN10150	Throughput of Workflow:Theory of Constraints (ToC):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
156	var8O36QN10150	Financial Improvement:Theory of Constraints (ToC):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
157	var8O34QN10151	Efficiency of Workflow:Continuous Improvement (CI):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
158	var8O35QN10151	Throughput of Workflow:Continuous Improvement (CI):Have the goals of the implemented QIM(s) been	Ordinal

		achieved? Based on the efficiency, throughput, and financial factors	
159	var8O36QN10151	Financial Improvement:Continuous Improvement (CI):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
160	var8O34QN10152	Efficiency of Workflow:Total Quality Management (TQM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
161	var8O35QN10152	Throughput of Workflow:Total Quality Management (TQM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
162	var8O36QN10152	Financial Improvement:Total Quality Management (TQM):Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
163	var8O34QN10153	Efficiency of Workflow:other:Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
164	var8O35QN10153	Throughput of Workflow:other:Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
165	var8O36QN10153	Financial Improvement:other:Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
166	var8O34QN10187	Efficiency of Workflow:Benchmarking:Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
167	var8O35QN10187	Throughput of Workflow:Benchmarking:Have the goals of the implemented QIM(s)	Ordinal

		been achieved? Based on the efficiency, throughput, and financial factors	
168	var8O36QN10187	Financial Improvement:Benchmarking:Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors	Ordinal
169	var19O85	Clinical systems did not have the needed data elements:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPOE	Nominal
170	var19O92	Did not have access to the databases of the clinical systems:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR	Nominal
171	var19O86	It was easier to collect the data manually:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPOE, LIS, etc	Nominal
172	var19O87	There were technical challenges in retrieving the data from systems:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical syste	Nominal
173	var19O177	QIMs require manual data collection:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality	Nominal

		data manually instead of retrieving the data from clinical systems	
174	var19O178	We do not have clinical systems implemented at the site:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPO	Nominal
175	var19O88	Others:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPOE, LIS, etc)?	Nominal
176	var19	Others:If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPOE, LIS, etc)?	Nominal
177	var20O172	Process Capability Analysis:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
178	var20O173	Statistical Process Control:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
179	var20O154	Failure Mode and Effects Analysis (FMEA):Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
180	var20O155	Cause-and-Effect Diagram (Fishbone or Ishikawa):Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
181	var20O156	Supplier, Input, Process, Output, and Customer (SIPOC or COPIS):Separately or as part of	Nominal

		QIMs, what are the quality improvement tools that have been used by the hospital/practice?	
182	var20O157	System of Work (SOW):Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
183	var20O158	RUMBA:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
184	var20O159	SMARTI:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
185	var20O160	X - Y Matrix:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
186	var20O161	Process Failpoint Analysis Matrix:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
187	var20O162	Waste Analysis Matrix:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
188	var20O163	Five Whys:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
189	var20O164	Process Mapping:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
190	var20O165	SWOT Analysis:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
191	var20O167	SCAMPER Analysis:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal
192	var20O168	other:Separately or as part of QIMs, what are the quality improvement	Nominal

		tools that have been used by the hospital/practice?	
193	var20	other:Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?	Nominal

Appendix B: IRB Approval Letter

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY eIRB ELECTRONIC INSTITUTIONAL REVIEW BOARD

** This is an auto-generated email. Please do not reply to this email message.
The originating e-mail account is not monitored.
If you have questions, please contact your local IRB office or log into eIRB.Rutgers.edu **

DHHS Federal Wide Assurance Identifier: FWA00003913

IRB Chair Person: Robert Fechtner

IRB Director: Carlotta Rodriguez

Effective Date: 12/5/2014

eIRB Notice of IRB Determination

STUDY PROFILE

Study ID: Pro20140000690

Title: THE UTILIZATION OF HEALTH INFORMATION TECHNOLOGY SYSTEMS IN QUALITY IMPROVEMENT METHODOLOGIES AT HEALTHCARE ORGANIZATIONS: A RETROSPECTIVE STUDY

Principal Investigator: Raed AlHazme

Co-Investigator(s): Syed Haque

Review Type: Non-Human

CURRENT SUBMISSION STATUS

Submission Type: Research Protocol/Study **Submission Status:** Approved

Determination Date: 12/5/2014

The activities described in this application do not meet the regulatory definition of human subjects research provided in 45 CFR 46.102. Therefore, this project does not require approval by the IRB as submitted. Please note that changes to the project must be submitted to the IRB for review prior to implementation to determine if the changes incorporate elements of human subjects research activities which require IRB oversight.

ALL APPROVED INVESTIGATOR(S) MUST COMPLY WITH THE FOLLOWING:

1. Conduct the project as submitted to the IRB.
2. **Amendments/Modifications/Revisions**: If you wish to change any aspect of this project, you are required to obtain IRB review and approval prior to implementation of these changes unless necessary to eliminate apparent immediate hazards to subjects.
3. **Completion of Study:** If your school requires, notify the IRB when your study has been stopped for any reason.
4. The Investigator(s) did not participate in the review, discussion, or vote of this protocol.

Appendix C: Usage Agreement for the Dorenfest Institute for H.I.T. Research and Education Database

1. The Database

The Dorenfest Institute for H.I.T. Research and Education Database includes a variety of detailed historical data about information technology (IT) use in hospitals and integrated delivery networks. This data includes the entire library of Dorenfest 3000+Databases™ and Dorenfest Integrated Healthcare Delivery System Databases™ for the period 1986 through 2003 (hereinafter referred to at the 'Database'), and 2004 through 2009 data from the HIMSS Analytics™ database.

Access to and use of this Database at no charge is restricted to universities, students under university license, and U.S. federal, state, and local governments, and governments of other countries that will be using the data for research purposes. Potential users ('Licensees') to this Database must read this Usage Agreement and complete and submit the Application for Access to The Dorenfest Institute for H.I.T. Research and Education Database included within this Usage Agreement.

The Database will be available to the Licensee via a secured Web site.

2. Term of License

Authorized Licensees will receive access to the Database for a period of six (6) months from the time the application is approved.

3. Nature of License

- The Licensee acknowledges and agrees that: (i) the Licensed Data is proprietary to and the confidential property of the Licensor and constitutes valuable information in which the Licensor holds all trade secret rights and copyrights; (ii) the Licensee acquires no right(s) in the Licensed Data except to use the Licensed Data solely within the Licensee's own organization or agency and for the Licensee's own purposes during the License Term in accordance with this Agreement; and (iii) the Licensee and its affiliates will not challenge the rights claimed by the Licensor in the Database and the Licensed Data. The Licensee agrees to treat the Licensed Data in the same manner as the Licensee's most confidential information, but in any event not less than a reasonable degree of care.

- The Licensee will take appropriate measures, by instruction, agreement, or otherwise, to ensure compliance with this Agreement during his or her relationship with the Licensee and thereafter pursuant to this Agreement. Unless the Licensee has obtained the express prior written authorization of the Licensor, the Licensee shall not use all or any part(s) of the Licensed Data for numerical or text quotation(s) for advertising or public relations. The Licensee shall not copy or reproduce in any form any or all of the Licensed Data unless the use of that data is related to the research project described in the Licensee's Usage Agreement and Application for Access to The Dorenfest Institute for H.I.T. Research and Education Database. However, under no circumstances can the Licensee reproduce the Database in its entirety.

- The Licensee agrees to cite the source of the data used from The Dorenfest Institute for H.I.T. Research and Education Database. The following language must appear at the bottom of each page in an article or research paper in which the data is cited:

Data Source: The Dorenfest Institute for H.I.T. Research and Education, HIMSS Foundation, Chicago, Illinois, 2010.

- The Licensee agrees to keep the unique password provided to the Database private and not share it with individuals not covered in the Application.
- The Licensee agrees to submit the written results of the research project (e.g., white paper, research report, thesis, article) to The Dorenfest Institute within 30 (thirty) days after the conclusion of the research project. The Licensor will have the right to post the report, article, or thesis on the Dorenfest Web site, as part of the Dorenfest database, unless the Licensee has submitted the document for publication in a professional journal, magazine or book.
- The Licensee should indicate whether the report, thesis, article, etc. will be submitted for publication.
- Notwithstanding the above, the Licensee shall have no obligations with respect to any information in or about the Licensed Data demonstrated to have already been known to the Licensee before receipt of the Licensed Data, or otherwise is or becomes part of the public domain without violation of this Agreement.

4. Warranty

The Licensee acknowledges that the data in the Database are collected by or on behalf of the Licensor and, while the Licensor reasonably believes such data to be accurate, the Licensor makes and Licensee receives no warranty, express or implied, and all warranties of merchantability and fitness for a particular purpose are expressly excluded. The Licensor shall have no liability with respect to any or all of its duties and obligations under this agreement for consequential, exemplary, special, or incidental damages, even if the Licensor has been advised of the possibility of such damages. In no event shall the Licensor's liability for damages, regardless of the form of action, exceed the amount paid by the licensee for the relevant licensed data.

5. Termination

Whenever the Licensor has knowledge or reason to believe that the Licensee has failed to observe any of the terms and conditions of this Agreement, the Licensor shall notify the Licensee in writing of the suspected breach. If, within 30 days of such notice, the Licensee fails to prove to the Licensor's reasonable satisfaction that the Licensee has not breached this Agreement, the Licensor may terminate the License and this Agreement.

6. Other

- The Licensee may not assign or sub-license to any person or entity its rights, duties, or obligations under this Agreement, to any person or entity, in whole or in part. This Agreement is binding upon the Parties and their respective heirs, assigns, and successors in interest.

- This Agreement and performance hereunder shall be governed by the laws of the State of Illinois without reference to conflicts of laws provisions.
- Notwithstanding anything to the contrary in this Agreement, the Licensee acknowledges and agrees that the Licensor in its sole discretion may change any or all of the format and content of the database at any time.

Appendix D: Survey Instruments

Survey Title: Utilization of Health Information Technology Systems in QIMs

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Question 1

Has the hospital/practice ever implemented any QIM in the past?

QIMs include any technique that targets clinical or business processes for improvement. Examples: Clinical Pathways, Benchmarking, Lean Six Sigma, Total Quality Management, Continues Improvement, etc...

( ) Yes

( ) No

Question 2 of 2

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("No")
Variable name: Array

What are the reasons for not implementing QIMs?*

[ ] No quality improvement resources are available to conduct quality improvement

[ ] No financial demands exist to conduct quality improvement at this point

[ ] No regulatory demands require the hospital/practice to implement quality improvement at this point

[ ] There is no time available to allocate for quality improvement

[ ] Quality improvement is generally not needed to be implemented in the hospital/practice at this point

[ ] other: _____

Question 2 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

Variable name: Array

What are the QIMs that have been used at the hospital/practice over the last ten years?*

[ ] Clinical Pathways (CP)

[ ] Benchmarking

[ ] Lean Six Sigma (LSS)

[ ] Six Sigma (SS)

[ ] Business Process Reengineering (BPR)

[ ] Lean Management (LM)

[ ] Theory of Constraints (ToC)

[ ] Continuous Improvement (CI)

[ ] Total Quality Management (TQM)

[ ] other: _____

Question 3 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

In what period of time the QIMs have/had been used?*

Last 12 Months	Between 1 and 5 Years Ago	Between 6 and 10 Years Ago

Question 4 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

For each of the QIMs selected previously, from where the data came?*

Manual Data Collection	Electronic Health Record	Radiology Info. System	Pharmacy Info. System	Lab Info. System	CPOE

Question 5 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

Have the goals of the implemented QIM(s) been achieved? Based on the efficiency, throughput, and financial factors.*

Efficiency of Workflow	Throughput of Workflow	Financial Improvement

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Question 6 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

Variable name: Array

If you have previously answered that manual data collection has been used, what are the reasons for collecting the quality data manually instead of retrieving the data from clinical systems (EHR, CPOE, LIS, etc...)?

[ ] Clinical systems did not have the needed data elements

[ ] Did not have access to the databases of the clinical systems

[ ] It was easier to collect the data manually

[ ] There were technical challenges in retrieving the data from systems

[ ] QIMs require manual data collection

[ ] We do not have clinical systems implemented at the site

[ ] Others: _____

Question 7 of 7

Logic: Hidden unless: Question "Has the hospital/practice ever implemented any QIM in the past?" #1 is one of the following answers ("Yes")

Variable name: Array

Separately or as part of QIMs, what are the quality improvement tools that have been used by the hospital/practice?

[ ] Process Capability Analysis

[ ] Statistical Process Control

[ ] Failure Mode and Effects Analysis (FMEA)

[ ] Cause-and-Effect Diagram (Fishbone or Ishikawa)

[ ] Supplier, Input, Process, Output, and Customer (SIPOC or COPIS)

[ ] System of Work (SOW)

[ ] RUMBA

[ ] SMARTI

[ ] X - Y Matrix

[ ] Process Failpoint Analysis Matrix

[ ] Waste Analysis Matrix

[ ] Five Whys

[ ] Process Mapping

[ ] SWOT Analysis

[ ] SCAMPER Analysis

[ ] other: _____