ADDIS ABABA UNIVERSITY

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SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

INDUSTRIAL ENGINEERING CHAIR

QUALITY IMPROVEMENT OF HEALTHCARE THROUGH LEAN SIX SIGMA: A CASE OF YEKATIT 12 HOSPITAL

BY

TSINUKAL BEZABIH

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CO-ADVISOR:GEZAHEGN.T(PHD) *Oct, 2019*

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APPROVED BY BOARD OF EXAMINERS

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DEAN, SMIE	SIGNATURE	DATE
DR. AMEHA MULUGETA	…………………….	……..………………
ADVISOR	SIGNATURE	DATE
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DR. ERMIAS TESFAYE	…………………….	……………………..
INTERNAL EXAMINER	SIGNATURE	DATE
DR. EPHREM GIDEY	…………………….	……………………..
EXTERNAL EXAMINER	SIGNATURE	DATE

Author’s declaration

I hereby declared that this thesis entitled as Quality improvement of healthcare through lean six-sigma: A case YEKATIT 12 hospital is my own research work. It has not been and will not be submitted in whole or in part to another university for the award of any degree.

	………………..	………………..
Tsinukal Bezabih	Signature	Date
	………………..	…………………
Dr.Ameha Mulugeta	Signature	Date
	………………...	…………………
Dr. Gezahegn Tesfaye	Signature	Date

Abstract

Health care organizations are now facing different challenges that brought them to a decision to obtain efficiency improvement, quality and cost reduction. The growth in health sectors access and delivery in Ethiopia has been improved markedly in the last decade. Despite the improvement made in expanding access to health sectors, the disease burden is still high and the service utilization rate remains low. According to the study made by WHO patient satisfaction rate is 50% and average length of stay is 6-7 days and patients are forced to spend a prolonged waiting time in different service stations to get served. Uneven distribution of facilities, shortage of workforce and complicated path flows are among the causes of this prolonged waiting time in public hospitals.

This research aims in experimenting the possibilities of process improvement opportunities in YEKATIT 12 hospital by utilizing lean six sigma methodology. In doing so qualitative and quantitative data collection tools and analysis tools have been used. A literature has been reviewed and hospital documents are referred as a secondary source of data. Based on the literatures Yekatit 12 hospital is selected as a case hospital and based on the preliminary data assessment laboratory service station is selected as a case area. Primary source data has been collected from patients, laboratory technologists and management personnel's.

Data has been analyzed by using the DMAIC framework of LSS. The DMAIC clearly shows the existing system and the bottlenecks are clearly defined. In addition to DMAIC arena simulation software have been used for analysis. Then a new process is developed by value stream mapping and it is simulated by arena simulation software. The results after improvement show that Cycle time of processes are reduced which directly reduces the prolonged waiting time within the laboratory department. Therefore, it is safe to conclude that Lean Six Sigma can indeed be applied for process improvement in Hospitals.

Key words: LSS, DMAIC, value stream mapping, process improvement

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List of Abbreviation's

CT -Cycle time

CTS-Critical to satisfaction

DMAIC- Define-measure-analyze-improvement-control

EHRIG- Ethiopian hospital reform implementation guideline

JIT-just in time

LAB -Laboratory

LSS -Lean six-sigma

LT - Lead-time

MOH -Ministry of health

NVA-Non-value adding activity

SPC-statistical process control

SS -Six-sigma

TPM -Total productivity management

TQM-Total quality management

VA-Value added activity

VSM -Value stream mapping

WHO-world health organization

Acknowledgment

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CHAPTER ONE
INTRODUCTION AND BACKGROUND

1.1 Introduction

Health Care organizations today are facing a new and unique set of challenges bringing them under pressure to obtain efficiency improvements and cost reduction. Expenditures have grown steadily, and budgets are increasingly being shortened while requested services and expected quality continue to increase. To overcome these challenges in a sustainable way, Health Care organizations need to improve their services in terms of costs, response times, and service quality as well as resource utilization. Similar challenges occur also in other industries like manufacturing, where Lean Management approaches showed promising results and potential in the reduction of inefficiencies and in increasing value for the customer (Arcidiacono, 2017). Nowadays, in order to improve the organization of care of patients with a specific clinical problem, health care facilities use clinical pathways, which are structured multidisciplinary care plans. LSS, providing a systematic approach, is an ideal tool to develop clinical pathways capable of achieving optimized processes, which are continuously improved with plan – do – check –act cycles (Improta, Lean Six Sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery, 2015).

Costs and quality are two key points concerning the health care industry worldwide: one of the major problems is to find a solution that allows to improve quality and to reduce costs. In particular, Lean Six Sigma (LSS) methodology, thanks to the synergy of both Lean and Six Sigma methodologies, is the most innovative and effective approach in terms of ‘Operational Excellence’. LSS is a combination of Lean Thinking and Six Sigma aimed at the continuous improvement of a production process through the push for speed and flexibility given by Lean Thinking and statistical support provided by Six Sigma. Lean allows for speed and elimination of waste, Six Sigma seeks quality understood as less variability in the results of process (Importa, 2015).

Various business management strategies have been developed to improve the performance of organizations by improving the processes by which they carry out their work. These strategies include Lean and Six Sigma; aim to implement process improvements through a coordinated set of principles and practices that promote greater efficiency and effectiveness, with fewer wasteful practices or errors. Lean and Six Sigma are business management strategies commonly used in production industries to improve process efficiency and quality (Mason, 2015).

Though initially used in manufacturing, LSS has been increasingly gaining acceptance in the healthcare industry, which faces many of the same issues and challenges--how to reduce waiting time, how to increase capacity, how to best deploy resources, etc (Kuo, 2010).

Where the strength of Lean lies in providing a set of proven techniques for eliminating waste, Six Sigma provides a structured methodology based on quantitative analysis for carrying out and sustaining Lean initiatives (or any other initiative for that matter). Lean and Six Sigma thus complement each other in driving process improvement. The standard Six Sigma methodology for process improvement is called the **DMAIC** process (Yeh, 2011).

Despite major strives to improve the health of the population in the last one and half decades, Ethiopia's population still face a high rate of morbidity and mortality and the health status remains relatively poor and the service delivery system is poor even when compared to sub Saharan countries (Ethiopia, 2010). The growth in health sectors access and delivery in Ethiopia has been improved markedly in the last decade. Despite the improvement made in expanding access to health sectors, the disease burden is still high and the service utilization rate remains low. In addition, nothing has been done to analyze and improve the hospital settings using the LSS methodology.

This research proposes the synergistic combination of Lean and SS for process improvement. It aims to experiment the LSS methodology to improve the efficiency and effectiveness of the process.

1.2 Problem statement

According to WHO in any health system, good health services are those that deliver effective, safe and good quality personnel and personal care to deliver to those that needed it, when needed with minimum waste. Ethiopia is among 57 countries in the world identified by WHO to be facing a critical shortage of health workforce. The customer satisfaction rate is 50% and average length of stay is 6-7 days. The pharmaceutical department faces 8.24% of stock wasted due to expiry and procurement lead time is 240days (Ethiopia, 2010). The shortage of facilities, uneven distribution of facilities and workforce, poor skill mix and service utilization and high attrition of trained health professionals remain the major concerns of the country. The health care delivery is so poor even when compared to the sub-Saharan counties (Ethiopia, 2010). There is a prolonged waiting time to get served in every service stations, a fragmented workflow, incorrect and incomplete documentation, excessive motions because of incorrect floor layout and inappropriate placement of hospital utensils and because of this both patients and employees of the hospital are forced to expend extra time searching for information. There is also high process variation because of patients that get served without joining the queue, because of un automated instruments and improper process flows.

1.3 Research questions

1. What is the severity and the contributors of waste in YEKATIT 12 hospital?
2. How can we control process variation in YEKATIT 12 Hospital?
3. How can LSS helps to eliminate or minimize wastes and process variation in YEKATIT 12 hospital in order to improve service quality?

1.4 Objectives of the research

General objective

To experiment the possibilities of process improvement opportunities in YEKATIT 12 hospital through lean Six-Sigma methodology to increase the service quality of the hospital.

Specific objectives

- ✓ Analyzing the existing system to clearly identify the wastes and the causes of the process variation in the hospital
- ✓ To determine the value and non-value adding processes in YEKATIT 12 hospital
- ✓ To develop a framework by using six sigma DMAIC procedure to understand and Improve the process
- ✓ To develop ways to control the process variation in YEKATIT 12 hospital
- ✓ Developing a new model by arena simulation software and measuring the performance of the newly improved system in terms of time.

1.5 Scope

This research investigates the use of lean Six-Sigma methodology in YEKATIT 12 hospital and it develops a way to minimize waste and process variation within the hospital. Thus, in this research the existing system is analyzed and solutions for process improvement are given by using the LSS methodology. Because of the time given for this research YEKATIT 12 hospital is selected as a case among the thirteen public hospitals in Addis Ababa and because of the complexity of the system only one case area is selected and the reason why this hospital s selected is explained in detail in other session of the research.

1.6 Significance of the study

This research will benefit the hospital by reducing costs and increasing revenues and also increase the performance of the hospital by different performance metrics through waste reduction, defect minimization and minimization of process flow time. Minimization of process complications also benefits the employees by reducing overloads and unnecessary motions. And mainly it benefits the main victims of poor health service delivery those are patients by reducing the prolonged queues the face during their stay with in the hospital in various services stations.

The findings of this research will also be used as an input for different researchers in different institutions who will be interested in this particular area.

CHAPTER TWO
LITERATURE REVIEW

In this literature review different articles, reviews, manuscripts, case studies and reports are reviewed to get a thorough knowledge on the area under study. The literature reviews mainly focused on lean, Six Sigma, and the importance of integrating lean and six-sigma, application of lean and Six Sigma in healthcare and previous studies on lean Six Sigma in healthcare sector. As a result, the literature gaps are being identified, areas that need further researching, and the importance of this particular research is identified.

2.1 Introduction

The concept of lean Six Sigma has been used in different manufacturing industries. Though initially used in manufacturing LSS has been increasingly gaining acceptance in the healthcare industry, which faces many of the same issues and challenges. Both these concepts lean and Six Sigma came from quality but Six Sigma was founded by Motorola Corporation and subsequently adopted by many US companies, including General Electrical GE and Allied Signal. Lean management originated at Toyota in Japan and has been implemented by many major US firms, including Danaher Corporation and Harley-Davidson. Six Sigma and lean management have diverse roots**.** As Sharon and Allard (2010), lean (also known as Lean Production, Lean Enterprise, and Lean Thinking) involves a set of principles, practices, and methods for designing, improving, and managing processes.

Six-Sigma is a data-driven process improvement methodology used to achieve stable and predictable process results, reducing process variation and defects. Six-Sigma is defined as: "a business strategy that seeks to identify and eliminate causes of errors or defects or failures in business processes by focusing on outputs that are critical to customers" (Nicoletti, 2013).

Both Lean and Six Sigma emerged as business improvement philosophies in the late 1990's and at that time, many practitioners were set on differentiating one methodology from the other. Today, most practitioners will agree that the two methodologies complement one another and when the statistical approach is used in conjunction with waste elimination techniques, the improvement philosophy is more versatile and complete. Hence, today many publications refer to the philosophy as 'Lean Six Sigma (Scachitti, 2008).

Even if those two concepts used extensively in manufacturing industries at the past now they are dragging high attentions to the service industries especially at the health care sector. Therefore, this review examines different literatures regarding lean six sigma, their tools and techniques and the possible literature gaps.

2.2 Definition and history of lean manufacturing

Among the several quality management concepts that have been developed, the lean concept is one of the more widespread and successful attempts. The concept was introduced at a larger scale by Toyota in the 1950s (Kulkarni *et al, 2010).* The lean philosophy Lean manufacturing extends the scope of the Toyota production philosophy by providing an enterprise-wide term that draws together the five elements of "the product development process, the supplier management process, the customer management process, and the policy focusing process for the whole enterprise" (Peeper and Spedding,2009). Lean management emphasizes on eliminating waste so that all activities along the value stream can create value. It focuses on the reduction of waste and pursuing continuous improvements. Thus, a core element of Lean management is the distinction between value-adding and non-value-adding activities (Huang *et al.*, 2013). So lean is generally understood as to represent a systematic approach to identifying and eliminating elements not adding value to the process. Consequences of this are striving for perfection and a customer-driven pull of the process (Kulkarni *et al, 2010).*

Lean tools and techniques

Lean principles are fundamentally customer value driven, which makes them appropriate for many manufacturing and distribution situations. Five basic principles of lean manufacturing are generally acknowledged:

1. Understanding customer value: Only what the customers perceive as value is important.

2. Value stream analysis: Having understood the value for the customers, the next step is to analyze the business processes to determine which ones actually add value. If an action does not add value, it should be modified or eliminated from the process.
3. Flow: Focus on organizing a continuous flow through the production or supply chain rather than moving commodities in large batches.
4. Pull: Demand chain management prevents from producing commodities to stock, i.e. customer demand pulls finished products through the system. No work is carried out unless the result of it is required downstream (Kulkarni1, 2010).
5. Perfection: The elimination of non-value-adding elements (waste) is a process of continuous improvement. "There is no end to reducing time, cost, space, mistakes, and effort" (Kulkarni *et al, 2010).*

Lean principles do not always apply, however, when customer demand is unstable and unpredictable. The main elements contributing to the elimination of non-value-added activities are the following: excess production, excess processing, delays, transport, inventory, defects, and movement. Varieties of approaches are available for reducing or eliminating waste. These approaches include value stream analysis, total productive maintenance, Kaizen costing and cost analysis, engineering and change management, and document management. Tools used include Kanban cards for pull through the supply chain and the closely related JIT system for inventory reduction (Kulkarni *et al, 2010).*

2.3 History and definition of six sigma

From managerial point of view, Six Sigma is defined as improving the profitability, effectiveness, and efficiency of all operations to meet or exceed customer's needs and expectations by identifying and removing the cause of defects or errors and minimizing variability. From statistical point of view, Six Sigma is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997%, where sigma is a term used to represent the variation about the process average (Huang *et al*., 2012). Six-Sigma could also be described as an improvement program for reducing variation, which focuses on continuous and breakthrough improvements. Improvement projects are driven in a wide range of areas and at different levels of complexity, in order to reduce variation. The main purpose of reducing variation on a product or a service is to satisfy customers (Anderson *et al*., 2006). The fundamental principle of Six Sigma is to take an organization to an improved level of sigma capability through rigorous applications of statistical tools and techniques.

With additional innovations that enhance its effectiveness while expanding its focus, Six Sigma today has become a systematic and data-driven approach to using the define, measure, analysis, improve, and control (hereinafter DMAIC) process and utilizing design for six sigma method. More comprehensive than prior quality initiatives such as TQM, Six Sigma methodology includes measured and reported financial results, uses additional and more advanced data analysis tools, focuses on customer concerns, and uses project management tools and methodologies (Huang *et al*., 2012).

Six sigma tools and techniques

There are usually many different improvement tools used in a six-sigma program. The six-sigma toolbox contains the seven design tools, the seven statistical tools, the seven project tools, the seven lean tools, the seven customer tools, the seven quality control tools and the seven management tools. The tools are often easy to use in both ongoing and breakthrough improvement projects, but there are also some more advanced statistical tools in the toolbox (Anderson et al., 2006).

There are two major improvement methodologies in Six Sigma, DMAIC for already existing processes and DMADV for new processes. DMADV is often used when the existing processes do not satisfy the customers or are not able to achieve strategic business objective. Both methodologies have five phases (Kulkarni *et al, 2010).*

DMAIC provides data-driven practices and tools for improving, optimizing, and stabilizing business processes and designs. Hence it can support Super network framework both in the problem definition phase (where DMAIC can help in identifying causes mainly affecting patient flow) and problem analysis phase (where DMAIC may support in validating outcomes from the optimal problem solution) (Cirrone *et al*., 2015).

2.4 Why lean six sigma

Generally, lean has the advantages of standardized solutions to common problems and its focus on the customer. Lean seeks to prevent the sub-optimization by its focus on the entire value chain. However, Lean is weak on organizational infrastructures, deployment plans, analytical tools, and quality improvement and control. Six-Sigma, on the other hand, offers a structured, analytic, and logically sound approach to problem solving, as well as a strong organizational framework for its deployment. It deploys problem-solving strategies through DMAIC process, and offers an option to sub-optimization. It is characterized by its customer-driven or project-by-project approach, emphasis on decision-making based on careful analysis of quantitative data, and a priority on cost reduction. One perceived weakness of Six Sigma method is its complexity. In the case of simple problems with obvious and easy-to-implement solutions, rigorous adherence to the Six Sigma problem-solving process (DMAIC) may be considered "overkill" and inefficient. Furthermore, Six Sigma typically does not resort to standard solutions to common problems as Lean does. Finally, sub-optimizing a process sometimes will jeopardize the entire value chain due to failing to consider entire system. Thus, the ideal solution is to combine the two approaches. In the following sections, we introduce the integration of Lean management and Six Sigma and how it will work for healthcare sector (Huang *et al*., 2012).

Lean and Six Sigma have complementary benefits. For integration, Lean may use the management structures that Six Sigma offers. For example, Six Sigma's DMAIC approach provides an effective embedding framework to apply Lean principles. Further, Lean does not analyze the economic performance indicators of a process to establish where the main points of improvement are, but focuses on inefficiencies in the process flow, even if that is not where the main opportunities for improvement are. Six Sigma's DMAIC method offers a thorough roadmap for analysis and diagnosis, driven by powerful tools and techniques. However, Six Sigma is a general problem-solving framework. Given the ubiquity of process inefficiencies, Six Sigma projects can benefit from the standard solutions that Lean offers. The key to a successful integration of Lean and Six Sigma is to regard Six Sigma's project management and its DMAIC method as a general framework for problem solving and process improvement, but within this framework, Lean's standard solutions and mindset should find their places. Thus, the value stream map could be found as one of tools used in DMAIC steps of designing improvement actions and improving quality control systems (Koning *et.al*, 2006)

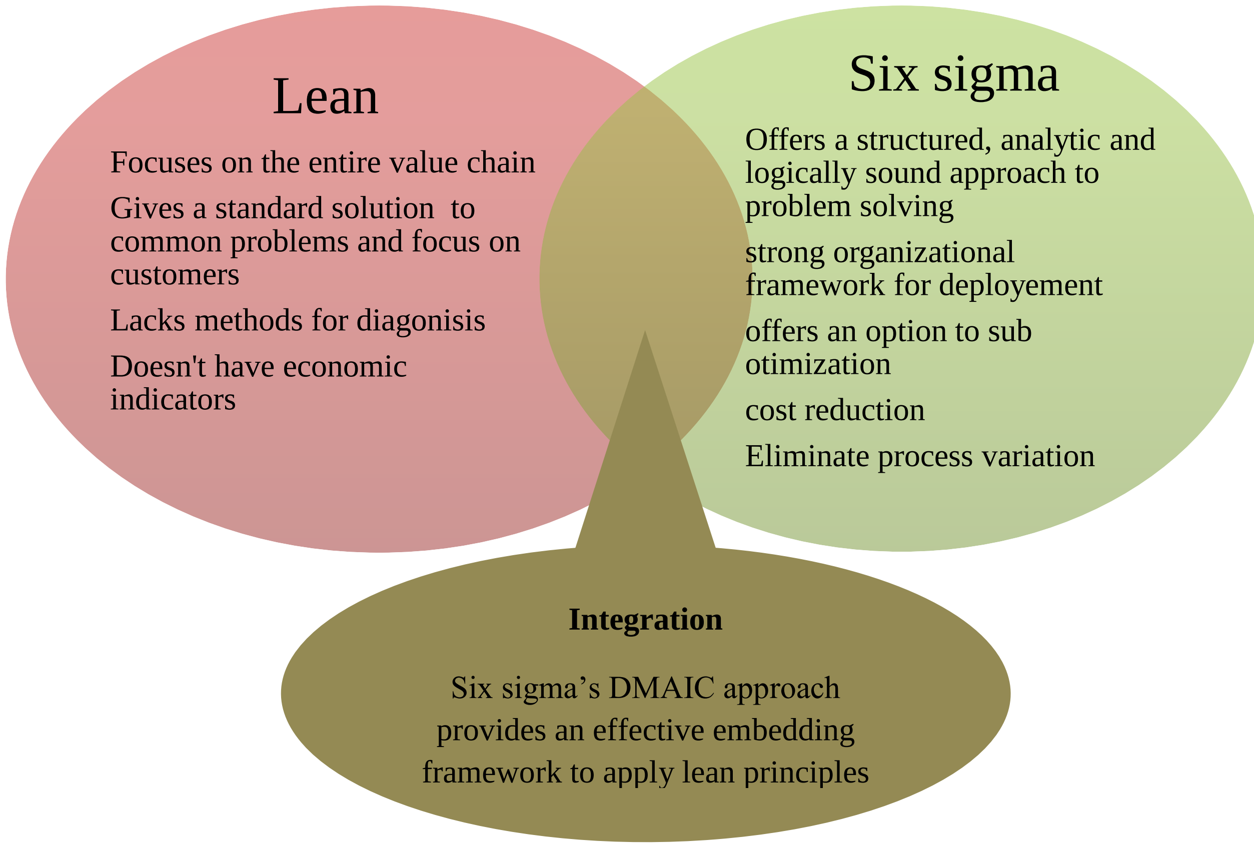


Figure 0: Integration of lean and six-sigma (source Author's analysis)

2.5 Lean six sigma in service industry

Lean Six Sigma has been initially used in manufacturing industries. However, recent researches show that it can also be applied in service industries Such as in healthcare sectors, banking, financial services, utility services, and others. In health sectors, it is applied to increase throughput, decrease cost and to minimize poor patient safety due to high medication, and to decrease high waiting time in different service stations. In banking systems, LSS is applied to reduce customer complaints and to reduce excessive market loses as well as cost. In financial services, it has been applied to reduce high administrative costs. In utility services it is applied to minimize poor service delivery, to minimize high contract complains which resulted in customer dissatisfaction and high costs.

According to Laureani (2009), the service industry has its own special characteristics, like its intangibility, Perishability, Inseparability and variability that differentiate it from manufacturing and make it harder to apply Lean Six Sigma tools. However, there are also great opportunities in the service organizations (George 2003):

- ✓ Empirical data has shown the costs of services are inflated by 30–80% of waste.
- ✓ Service functions have little or no history of using data to make decisions. It is often difficult to retrieve data and many key decision-makers may not be as 'numerically literate' as some of their manufacturing counterparts.
- ✓ Approximately 30–50% of the cost in a service organization is caused by costs related to slow speed, or carrying out work again to satisfy customer needs.

Lean six sigma in healthcare

Lean Sigma is a process of combining Six Sigma quality with Lean speed. Overall Lean Sigma incorporates Lean's principles into Six Sigma's improvement process itself to increase the speed of improvement projects and results. Lean Sigma also incorporates Six Sigma's view of the evil of variation and reduces its impact on the lead-time and process speed. Finally, Lean Sigma has unique advantage of recognizing that unnecessary complexity adds costs, time, and enormous waste to the process (Koning *et al*., 2006).
Health care is a complex business, having to balance continuously the need for medical care and attention to financial data. It offers pocket of excellence, with outstanding advances in technology and treatment, together with inefficiencies and errors (Alessandro, 2010). Patient care significantly involves human element as compared to machine elements, in which the variability is subtle and very difficult to quantify. Therefore, challenge in adopting Six Sigma approach to healthcare is to find a way to leverage the data from Six Sigma to drive human behavior (Jayanta K. and Karen.C, 2005).

Health care organizations, especially large health systems, began studying and adopting industrial quality management methods in the late 1980's including TQM and CQI approaches. Early applications focused primarily on establishing programs and infrastructure to measure quality and enhancing organizational culture surrounding quality issues. Lean and Six Sigma "emerged from the fertile environment" created by TQM. Recent applications of Lean and Six Sigma in health care attempt to improve on previous experiences with TQM by making project deliverables more discrete and measurable, retaining a strong customer (rather than organizational) focus, quantifying results, and attempting to deliver specific quality improvements within a designated time frame (Sharon and Allard, 2010).

Baltimore (2015) describes that different researches has been made regarding the application of lean Six Sigma in USA, Scotland, Turkey, Netherlands, USA, Ireland and Taiwan. According to Baltimore (2015), most of the researches are made in USA as well as the applicability. These researches are made to reduce cycle time, for defect reduction, quality improvement, cost reduction, and waste minimization.

Lean Six Sigma can be applied in different service station within the hospital for different purposes. According to Alessandro(2010) Lean Six Sigma projects so far in the health-care literature have focused on direct care delivery, administrative support and financial administration with projects executed in different process like to increase capacity in x-ray room reducing avoidable emergency admissions , improving day case performance ,improving accuracy of clinical coding ,improving patient satisfaction in Accident and Emergency, reducing turn-around time in preparing medical reports, reducing bottle necks in emergency departments , reducing cycle time in various inpatient and outpatient diagnostic area, reducing number of medical errors and hence enhancing patient safety ,reducing errors from high-risk medication, increasing accuracy of laboratory results, reducing lost MRI films , improving turn-around time for pharmacy orders , improving nurse or pharmacy technician recruitment , improving operating theatre throughput , increasing surgical capacity , reducing length of stay in A&E , reducing A&E diversions , improving revenue cycle, reducing inventory levels ,improving patient registration accuracy and to improve employee retention.

Those researches shows that lean Six Sigma can bring a dramatic change in health sectors especially in countries like Ethiopia in which there is high scarcity of resources, the available resources are not utilized, complicated systems, high wastage etc.

2.6 Previous researches on lean six sigma in health sectors

Different studies have been conducted on the application of lean Six Sigma in both manufacturing and service industries. In addition, countries around the globe tried to implement this concept.

Yeh *et al* (2011) claims that LSS can be implemented to improve the process of hospital. According to them LSS can provide a powerful process improvement solution. Their study applies LSS to improve the medical process of acute myocardial infarction. The 'define, measure, analyze, improve, and control steps' of SS find critical-to quality factors and draw the value stream map to seek out non-value-added activities. The cause and effect diagram is also employed to analyze the root causes of waste and generate the improvement project by brainstorming. Eliminating waste raises the process cycle efficiency. Cycle time of the improved door-to-balloon process decreased by 58.4% and even became less than the ACC/AHA standard (90 min). Process cycle efficiency increased from 32.27 to 51.81%, and the average days of hospital stay decreased by 3 days. Such effects helped save NT$ 4.422 million in medical resource. The study results indicate that LSS not only improved medical quality but also strengthened market competitiveness.

Yara *et al*. (2015) used the lean six-sigma methodology to Decrease the dispatch time of medical reports sent from hospital to primary care. And in order to achieve the objective the DMAIC roadmap have been used and as a result the reasons for the prolonged waiting time was identified and After implementation, 90.6% of the reports were dispatched on the day of the visit.

A study made in Italy shows that the lean six-sigma methodology can be applied to patients undergoing prosthetic hip replacement surgery to reduce the prolonged length of stay and the time is reduced by 44%. In doing so the DMAIC roadmap has been used.

Again, another study made by Montella *et al* (2016) in Italy showed that the lean six-sigma methodology could be applied to reduce the risk that patients are facing. Data has been collected from 20, 000 patients who underwent a wide range of surgical procedures and the pre intervention and post intervention phases were compared to analyze the effects of methodology that was implemented. As a result, the average hospitalization days have been reduced.

A study conducted in India by Antony (2013) addressed the use of lean six-sigma methodology to reduce patient waiting time in outpatient department. In this case, employees were forced more than the working time because of the prolonged waiting time. As a methodology, the DMAIC roadmap has been used along control charts, cause and effect diagram, normality test and other statistical quality control tools. As a result, the waiting time has been reduced from 54minutes to 24.5 minutes and the standard deviation was reduced from 9.27minutes to 31.15minutes.

Summary of reviewed literatures

The reviewed literatures are articles, case studies, reports and reviews from different websites. Generally, 78 literatures are reviewed for this research. However, only 27 literatures were directly related to the case of this research. These 27 literatures are analyzed and discussed based on their methods and structures and based on their objectives.

Summary of literatures based on their objectives

Based on the purpose of the studies the reviewed literatures are categorized as follows:

No	**Authors**	**Objective of the study**
1	*Yara L, et al., (2015), Hseng, et al., (2011), Sandy, et al., 2011, Mehmet, et.al.,(2013), Jeroen, et al.,(2011), Ahmed,(2017), Susan, et al., (2014)*	Process improvement
2	*Patricia, et al., (2016), Rahul, (2014), David, (2011)*	Waste reduction
3	(Federico Barnabè, 2016)	To maximize productivity
4	*Emma, et al., (2016), Andrea, (2012)*	Risk reduction
5	*E.V Gijo, et al., (2013), Mathew, (2016), Gloria, et al., (2010)*	Reduction of prolonged waiting time
6	*De.Lama, et al., (2013) , Berna, (2010), Gloria, et al., (2010)*	Maximizing efficiency
7	*Nabeel, et al., (2011)*	Increasing productivity
8	*G.Muthukumaran, et al., (2013), Sara, (2017)*	The advantage of integrating lean and six sigma
9	*Barabe, (2016)*	Performance evaluation
10	*G.Importa, (2015)*	Cost reduction

Table 1: purpose of reviewed literatures(source: Author's analysis)

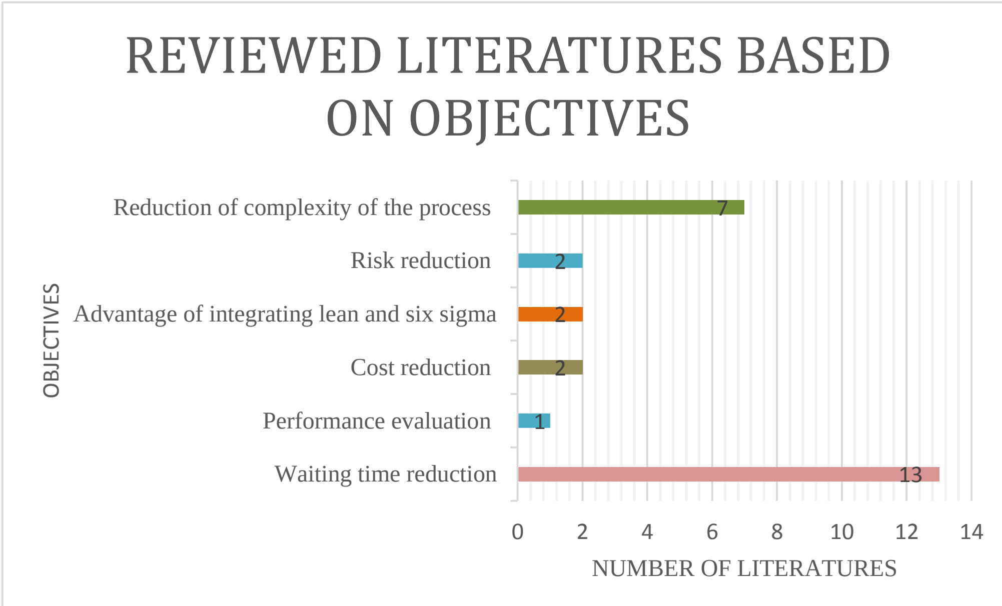


Figure 1: Reviewed literatures based on objectives

Those researches resulted with different outcomes by using the concept of lean six-sigma methodology. They are able to reduce cycle time and maximize process cycle efficiency, reduced average length of stays during hospitalization, decrease dispatch time, minimize the prolonged waiting times in different service stations and reduce the risks that patients are facing inside the hospital. They are also able to reduce costs, optimize patient flow, minimized patients risk and able to improve quality of service. They also deduce that lean six sigma can bring a significance difference if it got applied in health sectors and it can able to strengthen market competitiveness.

Hospitals have different wastes but most of the reviewed literatures are concerned on waiting time reduction and inappropriate processing. The researcher agrees this wastes have a high impact on the service delivery as well as on the profitability of the hospital but the other wastes also needs high attention as well as these ones. Therefore, this research focuses on waste of unnecessary motions too other than inappropriate processing and waiting time.

Methodological review of literatures

Among the 27 literatures that has been reviewed three of them are reviews which explains about the use of lean six sigma in health care sector. The next five literatures are case studies, which do not use any six-sigma framework. However, in order to analyze and understand the process these literatures used SIPOC, value stream mapping, cause and effect diagram and brainstorming.

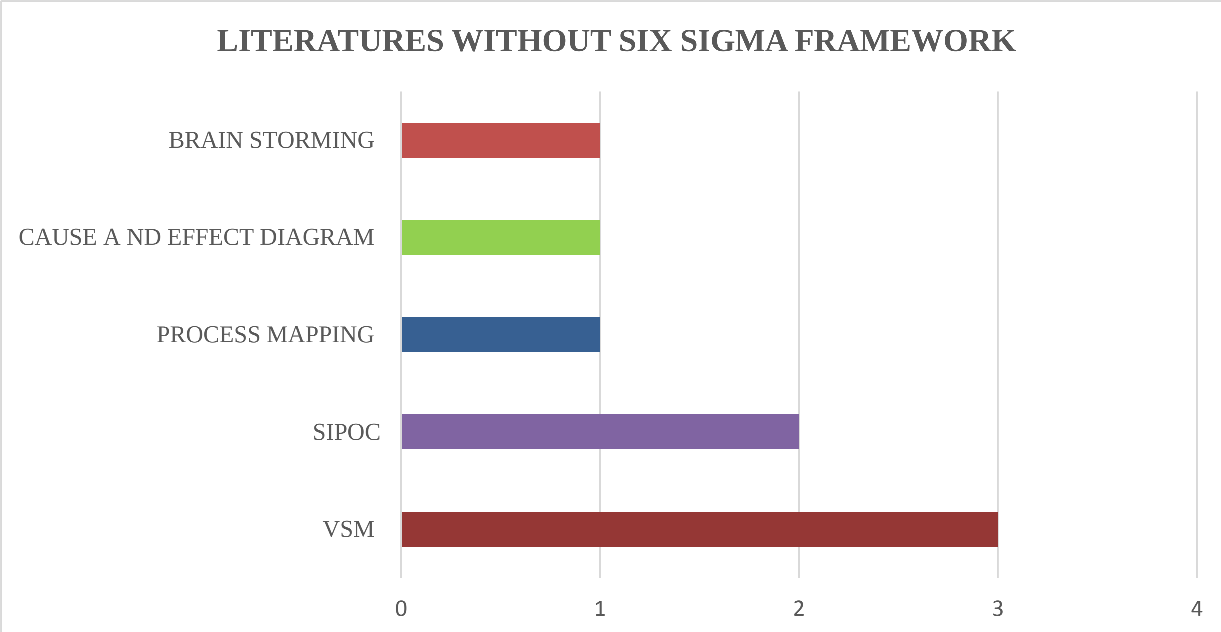


Figure 2: Methodological review

The remaining 17 literatures use case studies illustrate the application of lean six sigma for process improvement using the DMAIC roadmap of six-sigma along with lean tools. In doing, so all literatures used different ways of integration.

Under the define stage of DMAIC the researchers used critical to quality, SIPOC, pareto analysis, cause and effect diagram, process flow and FMEA to define and select the project.

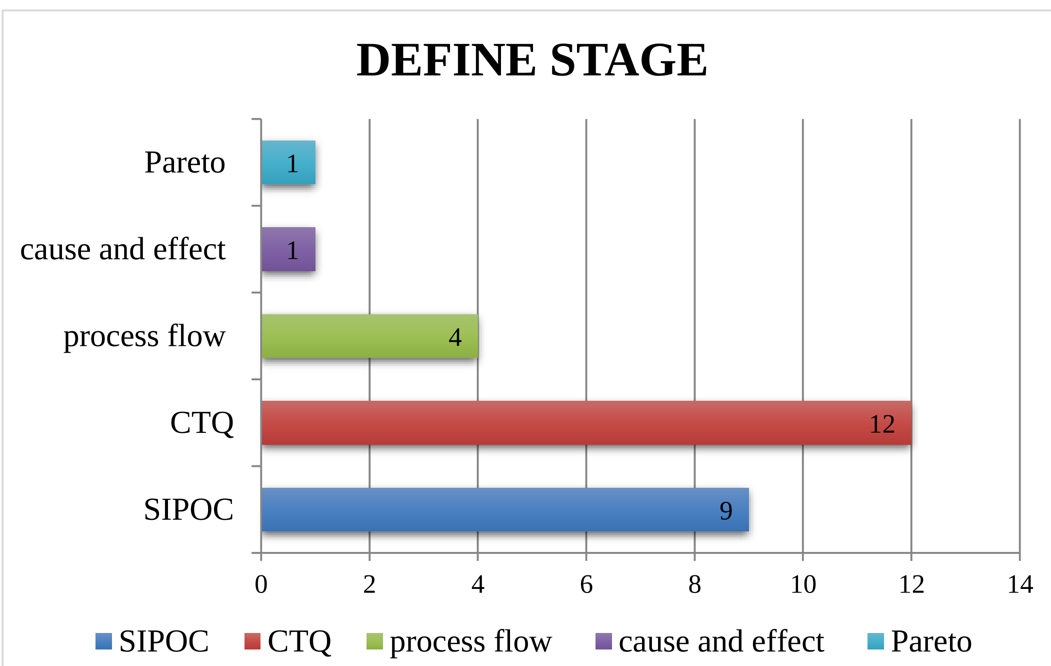


Figure 3: Methodological review of Define stage

Methods	Steps	
CTQ (5)	Pareto (1) SIPOC (1) SIPOC(1)	Process mapping
SIPOC(1)	CTQ(4)	Process mapping (1)
Cause and effect	Process mapping (1) FMEA(1)	SIPOC Pareto
Process flow	SIPOC	

Table 2 : Methodological review of Define stage

Under the measure phase of DMAIC CTQ, time measurement, fishbone diagram, process mapping, cheek sheet, histogram, control charts, SIPOC and VSM has been used.

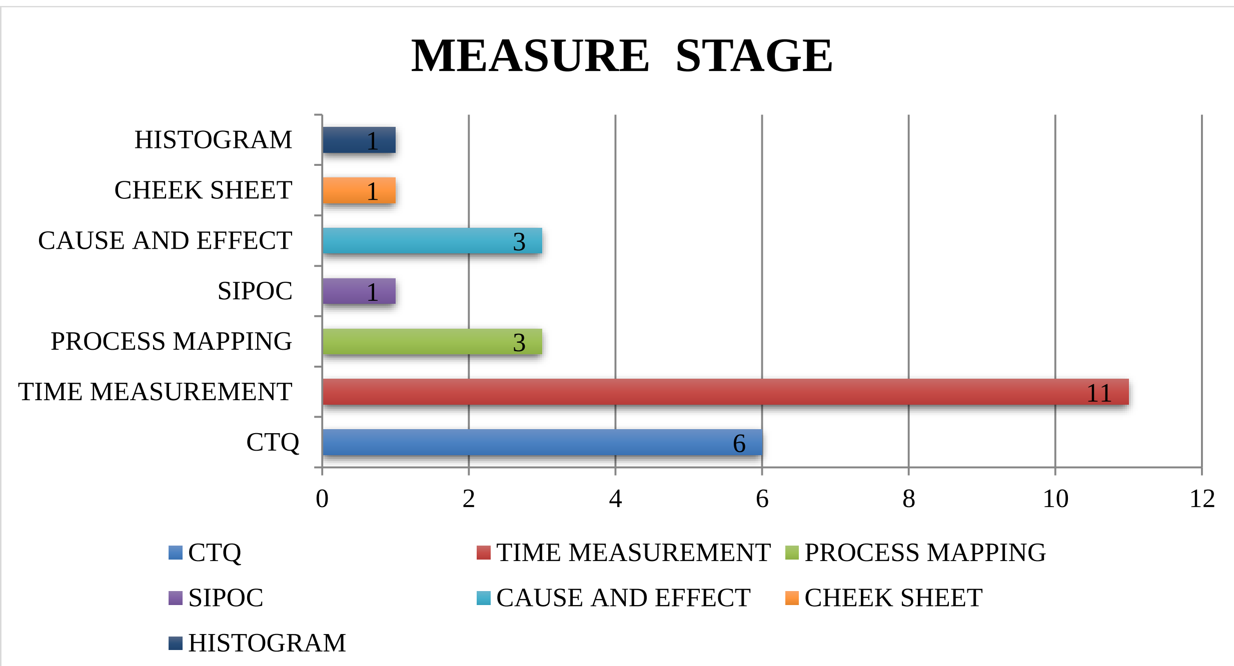


Figure 4; Methodological review of Measure stage

METHODS	STEPS	
CTQ	Time measurement (2) Cause and effect diagram Histogram	
TIME MEASUREMNT (5)	Control charts	
CHEEKSHEET	Check sheet	
PROCESS MAP	CTQ Time measurement	Time measurement
VSM	Cause and effect diagram CTQ	
SIPOC	Process mapping	Cause and effect

Table 3: Methodological review of Measure stage

During analyze stage value stream mapping, cause and effect diagram, pareto, histograms, control charts, time measurement, brainstorming and FMEA has been used.

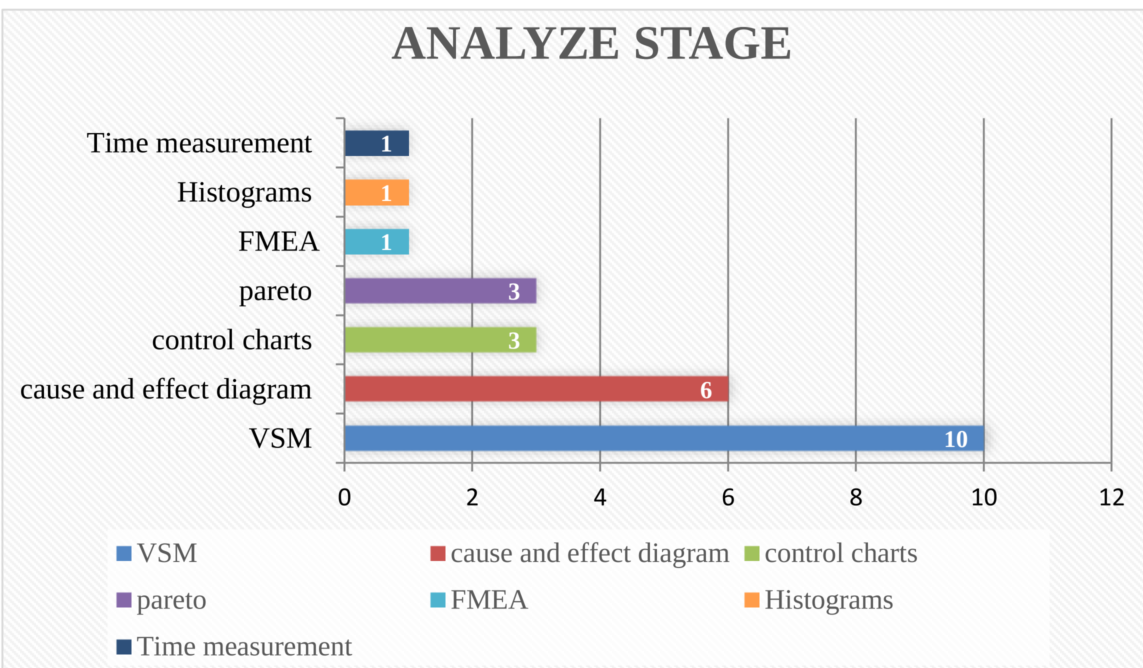


Figure 5: Methodological Review of Analyze stage

Methods	Steps	
VSM (5)	Cause and effect diagram (2) Control charts Pareto	
Cause and effect diagram	VSM (2)	Control charts (2)
FMEA	Cause and effect diagram	Pareto analysis
Control charts	Histogram	Chi square
Pareto	Control charts	
Time measurement		
Brainstorming	Cause and effect diagram	

Table 4: Methodological review of Analyze stage

From the above collection of literatures, it can be concluded that different researches have been done on the application of lean Six Sigma in healthcare. Most of the researches have been focused on minimizing the prolonged waiting time during hospitalization in different service stations. This shows how much long waiting time in hospitals is affecting the quality of health care sector. Most of the reviewed literatures lacks integration between the tools, redundant use of methods and value is defined by the customers. Based on the methodological review of the literature the researches develops a framework that can able to address the problems of YEKATIT 12 hospital by filling the gaps which are mentioned above.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methods in which data is being collected and analyzed. Both qualitative and quantitative data collection and analysis methods are being used in this research. Data has been collected by direct observation, by interviewing patients, through Questionnaires and time measurement. Management personnel's, laboratorians and patients were the sources of data for this research study. It also explains how the case is selected among different public hospitals in Ethiopia and how the research is organized starting from the preliminary assessment and observation to the extermination by Arena simulation software. Mainly the research study has two main parts, system analysis or the ASIS and the about to be improved system which is the TO-BE. Both are analyzed by the DMAIC framework of LSS. Under the ASIS, the existing process of the hospital is analyzed by value stream mapping to differentiate the value and the non-value adding activities in the existing system, pareto study, time measurement, cause and effect analysis and etc. Those tools clearly showed where the bottlenecks exist within the process and the areas that needs major improvement. QI Macros and arena simulator software's are also used for analysis and improvement. In addition, problems related to process variation are clearly defined under the define stage of the DMAIC framework. Under the TOBE process, solutions are given for the bottlenecks, being identified on the ASIS and the newly improved process is simulated to measure the performance of the new system. Purposive sampling is used as a sampling method and data has been collected from 304 patients from each department.

Case hospital selection:

Ethiopia has a three-tier system of primary, secondary and territory care. The territory care system includes specialized hospitals, which are expected to cover a population of 3.5-5millions, and Black Lion Hospital is the only territory care hospital in the country. The secondary hospitals include general and primary hospitals with an expectation of covering a population of 1-1.5millions and at last, the primary care system includes rural and urban health sectors with an expectation of covering 10,000-25,000 population. Depending on the number of patients to be treated on those care systems, the concern of this research is public hospitals.

There are twelve public hospitals in Addis Ababa, and those hospitals are mainly categorized into two, which are federal hospitals and health bureau hospitals.

- ALERT Hospital
- St. Amanuel Hospital
- Armed forces Hospital
- Black lion Hospital
- GANDI Memorial Hospital
- MENELIK II Hospital
- RAS DESTA Hospital
- St. Paul's Hospital
- St. Peter Hospital
- YEKATIT 12
- ZEWDITU Memorial Hospital

According to The Ethiopian health center reform implementation guideline(EHRIG) the performance of these hospitals is assessed independently based on 124 hospital management standards. Some of these hospitals are under the federal ministry of health and some of them are under Addis Ababa health Bureau. Hospitals under federal are TIKUR ANBESA referral hospital, St. PAWLOS, ST. PETER, Amanuel and Alert. Whereas hospitals under Addis Ababa health bureau are GANDI, MENELIK, YEKATIT 12, RAS DESTA, ZEWDITU and TIRUNESH Beijing. Among those hospital TIKUR ANBESA and St. PAUL gives services for highly complicated cases. Hospitals like Alert, St. Amanuel, St. Peter give specialized services. The researcher considers versatility as a case selection criterion so these hospitals aren't selected as a case for this research study.

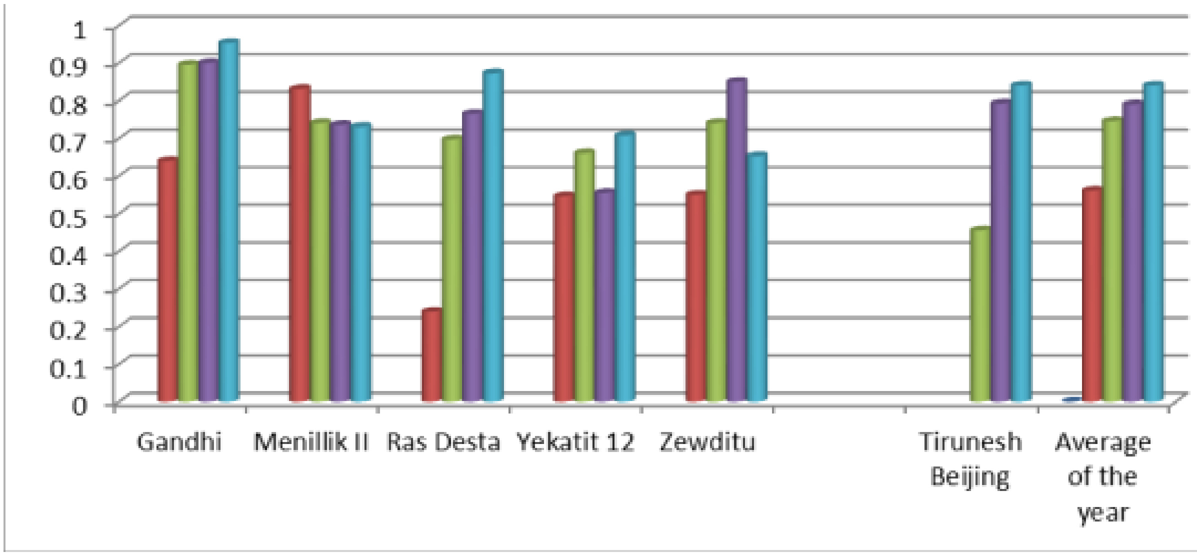


Figure 6: EHRIG adherences of Addis Ababa Health Bureau Hospitals for the Past four years starting from 2012 (WOLDEGEBRIEL, 2016)

The EHRIG includes 124 hospital management standards that assess 13 functions, namely, leadership and governance, patient flow, medical records management, pharmacy services, laboratory services, nursing care, infection-prevention, facilities management, medical equipment management, financial and asset management, human resource management, quality management and monitoring and reporting. By assessing those functions of the hospital, the report shows that YEKATIT 12 Hospital has the lowest performance, which is below 75%. From the listed functions patient flow, medical records management, facilities management and quality management are the concerns of this research. So based on this data YEKATIT 12 hospital is selected as a case hospital.

3.2 Research phases

Research Framework

A preliminary assessment is done to have a general overview about the hospital. Following the preliminary assessment, a problem statement is stated with an objective of investigating process improvement in Yekatit 12 hospital through lean six sigma methodologies. The research framework shows how this research went through starting from the preliminary assessment and observation to the last experimentation by arena simulation software. The framework shows how data has been collected, analyzed and what tools are deployed for the improvement.

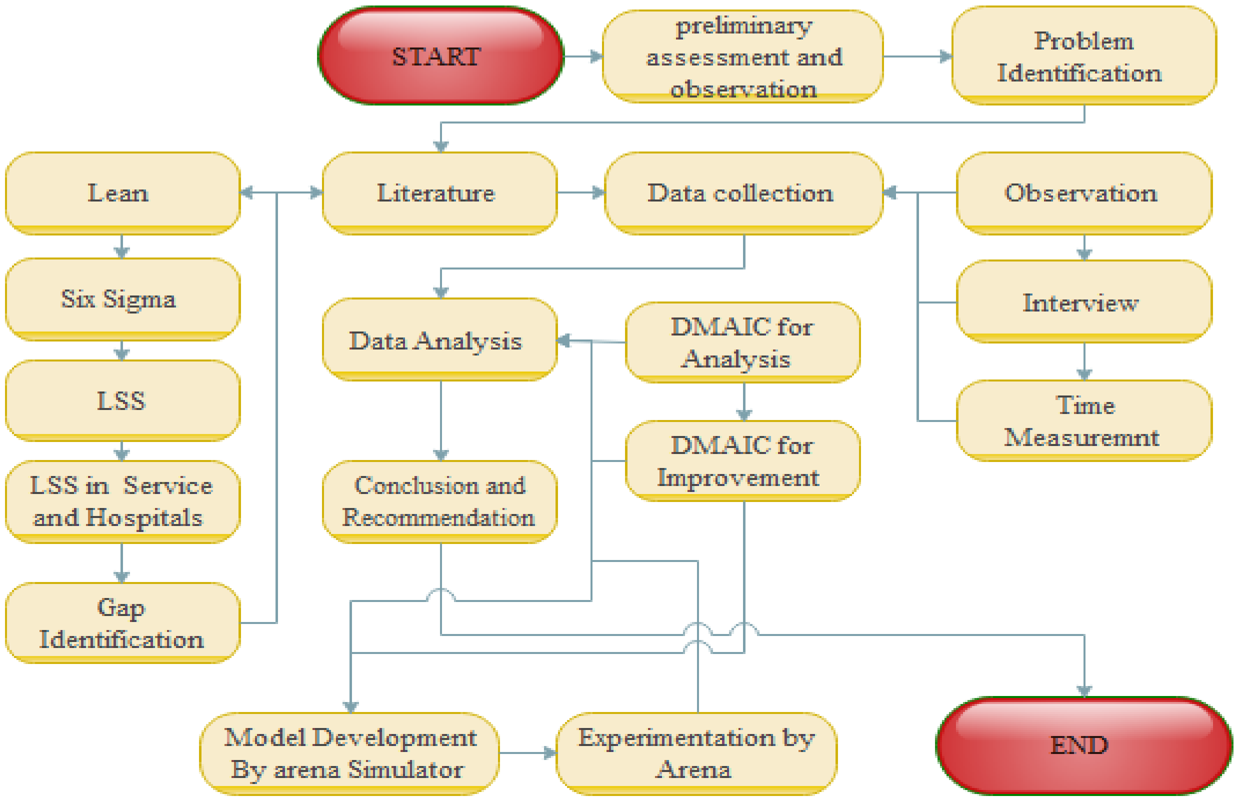


Figure 7: Research framework

Data collection

Both qualitative and quantitative data collection methods are employed for this research as well as both primary data sources and secondary data sources have been employed for this research. As a primary sources direct observation, questionnaires, semi structured interviews and time counting are used. In addition, as a secondary data source by different literatures, journals, reviews, reports, hospital documents and visual aids are referred.

Literature review

Different articles, reviews, journals, case studies and reports are reviewed in the literature review to get a thorough knowledge on the research area being studied. The literature reviews mainly focused on lean manufacturing, Six Sigma, and the importance of integrating lean and Six Sigma, application of lean and Six Sigma in healthcare and previous studies on lean Six Sigma in healthcare sector. As a result, the literature gaps are being identified, areas that need further researching and the importance of this particular research is identified.

Observation: In this part, the observed variables are how the process is organized and prioritized, the process flow, the value stream map, number of queues, assignment of professionals, number of beds, pharmacy stocks, laboratory supplies, and the queue structure and so on. By observing all this variables, a value stream map is done to diagram and document the patient flow, information flow or flow of supplies in order to see where value is being added and waste is occurring. In order to observe some of the variables instruments like Video camera and stopwatch is used.

Interview: A semi structured interview is prepared to define the areas to be explored in the hospital. The interviewees are patients, physicians, nurses, receptionists, laboratorians and so on.

Interview structure

A semi structured interview is prepared based on the literature review. The interviews have three parts and they are designed to meet the first two objectives of the study.

Part I: This part of the interview is prepared to conduct general information about the hospital. It includes questions about how the existing system of the hospital is structured, number of service stations with in the hospital and so on. These interviews are prepared for the management personnel's.

Part II: This part of the interview is prepared to assess the possible areas of wasteful activities within the hospital and it is prepared for employees of the hospital.

Part III: This part of the interview is prepared to know the reasons of patient's dissatisfaction based on quality of services being provided by the hospital. Needs of patients are also assessed.

No	Main objectives		Interview contents
1	To know how the existing system of the hospital is structured	**Part I**	○ Number of employees ○ Number of equipment's
2	To determine wasteful activities within the hospital	**Part II**	○ What are the wastes within the laboratory department? ○ How do you measure them? ○ Is there any recorded data?
3	To determine causes of patient dissatisfaction and needs of patients	**Part III**	○ Responsiveness ○ Timeliness ○ Delivery characteristics

Table 5: purpose of objective

Time study: The time that it takes to get served with in the care units is recorded using stop watch in order to calculate the service time and arrival rate of patients.

No	Type of data collection	Necessity	Source of data
1	Observation	To know how the process is organized and prioritized, value stream mapping, number of queues, arrival and service time of patients, laboratory supplies, queue structure	Different service stations within the hospital
2	Interview	To have an overview of what the hospital is lacking and what measures should have been taken To assess how the process is organized and how operations are being carried out within the laboratory department	Management personnel's, patients and hospital employees

3	Questionnaire	To understand the voice of patients	Patients
4	Time study	To get measurements of arrival and service time of patients	Patients

Table 6: Data collection

Data analysis

Both qualitative and quantitative data analysis methods are employed for this research. The analysis methods which are employed for this research are:

As described on the previous chapters Six Sigma's DMAIC roadmap is used along with lean tools for process improvement. The first stage of DMAIC is Define, with the purpose of selecting and defining a problem. So at this stage SIPOC is used to understand the inputs, the outputs and the process in general. In this stage the general process map of the hospital is drawn and CTQ is defined.

The second stage of DMAIC is intended quantify and refine the problems. On this stage process mapping, time study, Pareto analysis and value stream mapping are used. From the methodological reviews in the previous chapter a DMAIC roadmap is framed for this research based on the requirement of the hospital.

Those tools help to narrow down the problem and to determine value adding activities and non-value adding activities (wastes) within the processes. Under the time study, the researcher used a stopwatch to record the time patients are forced to spend to be served.

The third stage of DMAIC helps to understand the causes of the problems that are being identified on the second stage from different directions. In addition, the control charts use the data from the time study to analyze the current performance of the process in terms of process capability and sigma level.

The fourth stage of DMAIC uses mainly lean standard tools for problem solving Under this stage, the researcher redesigned the process in a way to insure optimal use of resources. Layout arrangements, time standardization using time study and developing a new value stream mapping are parts of this stage.

Finally, at the control stage of DMAIC the researcher recommends to use control charts to measure the process capability of the improved system. In addition, Arena simulation software is used to measure the performance of the newly improved system in terms of time. Generally, the tools which are used in this research are summarized on the table below.

No	Data analysis tools	Inputs for analysis	Necessity	Expected results
1	CTS	Response of questionnaires and interviews from patients	To understand the voice of the patients	Patients complaints
2	Pareto analysis	Ishikawa diagram	To prioritize problems	Definition of major factors of process variation
3	SIPOC	Observation of processes, interview results from management personnel's and employees and hospital documents	To show the AS IS system (inputs and outputs of process, patients and suppliers)	Problem identification
4	Process mapping	Observation of the existing system	To clearly understand the process under investigation	
5	Time study	Time recording using stopwatch	To know the time it takes to get served within different service stations and to know how much time different activities will take	Average service rate and average arrival rate

6	Value stream mapping	Observation of processes and results from employees' interview	To diagram and documented patient flow, information flow and flow of supplies	Definition of wastes
7	Cause and effect diagram	From staff interviews results and value stream mapping	To explore possible causes of certain problems	Causes of a certain problem
8	Control Charts	Time study	To measure whether the process is capable or not before and after improvement	Process variation

Table 7: Analysis used for the research

No	Software's used for analysis	
1	QI Macros	To generate control charts, pareto, SIPOC, fish bone diagram and value stream mapping
2	Arena simulator	Will be used to simulate the improved processing order to measure the performance of the improved process as a qualitative way of data analysis

Table 8: software used for the research

Discussion, Conclusion and recommendations

These parts are the final sessions of the research study. Under this session of the research study results which are obtained from the collected and analyzed data are presented. The DMAIC roadmap along with its tools is expected to result a well-defined and analyzed problem in the first three stages. Those problems are quantified through time study and VSM. The time study resulted with the average service time and average arrival rate of patients. Then control charts diagnosed the performance of a particular process and the Pareto analysis resulted with the potential influence factors. Under the fourth stage of DMAIC the researcher expects an optimal process setting, reduced process complications, waiting time reduction and a new process map by using time study and VSM. In addition, the simulation results are expected to show the performance of the newly improved setting. The last stage of DMAIC is expected to determine whether the process is in control or not.

In the discussion part findings are interpreted and the significance of the findings are discussed thoroughly and suggestions for further researches are given and the findings are logically synthesized. Those findings helped the researcher to explore possible improvements that can be made in order to further develop the concerns of the research, which are recommendations.

Finally, conclusion is presented with an intention of describing the contributions made by the overall research based on the results obtained.

3.3 Sampling technique and procedures

The researcher uses purposive sampling (deliberate selection of service providers such as medical doctors, management personnel's and data management staffs (clerks)) this is the most commonly used sampling method in clinical research. The sample is chosen based on the convenience of the investigator. Often the respondents are selected because they are at the right place at the right time. Convenience sampling is most commonly used in clinical research where patients who meet the inclusion criteria are recruited in the study.

304 patients for interview from adult OPD, inpatient, emergency, card room and laboratory (304 patients) from each department. This means data has been collected from 1520 patients through interview. And five peoples involved in the data collection processes including the researcher. The inclusion criteria for this research is a person who is older than 18 years' old and patients who aren't in critical health conditions.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

This chapter presents the analysis and outcomes of the interview and the time measurement results. Data is well summarized and presented based on the objectives of the research.

4.1 BACKGROUND OF YEKATIT 12 HOSPITAL

YEKATIT 12 medical college is a public hospital established on 1915E.C. The hospital is under the ministry of health for a long time but starting from 1987 it became under Addis Ababa health bureau. Now the hospital serves also as a medical college beside as a hospital.

YEKATIT 12 has many service stations and for all the service stations, it has 1134 employees. Among those employees, 35 of them are laboratory technicians and laboratory Technologists. The hospital generally has 36 service stations.

4.2 Data collection results

Data collection results are presented with tables and by pie charts and the collected data shows interview, and time measurement results. The interview is conducted in March 2010E.C and five individuals including the researcher are involved in the collection process. Based on the Interview results customer complaints are categorized into six main problems. These are timeliness, layout related, information related, documentation related, care related and others. The Table below shows the complaints under those six main categories and the number of patients that responded under each complaints. This preliminary data collection helps to decide on which service station should this research focus and what the main problems of the hospital are that causes patient dissatisfaction. Data has been collected from 1520 patients and their complaints are compiled below on the table below.

Interview results

1520 patients have been interviewed from five service stations. Those five departments are Laboratory, Adult OPD, emergency, cardroom and inpatient. 304 patients have been interviewed from each department, means a total of 1520 from all five departments. Five peoples are involved in the data collection process including the researcher. Each individual interview one department.

Patients are asked about the service system of the Hospital, about the challenges they face in the hospital during treatment, and they answered questions. From the patients that are involved in the interview 90% of them complained about laboratory department as shown on the pie chart below.

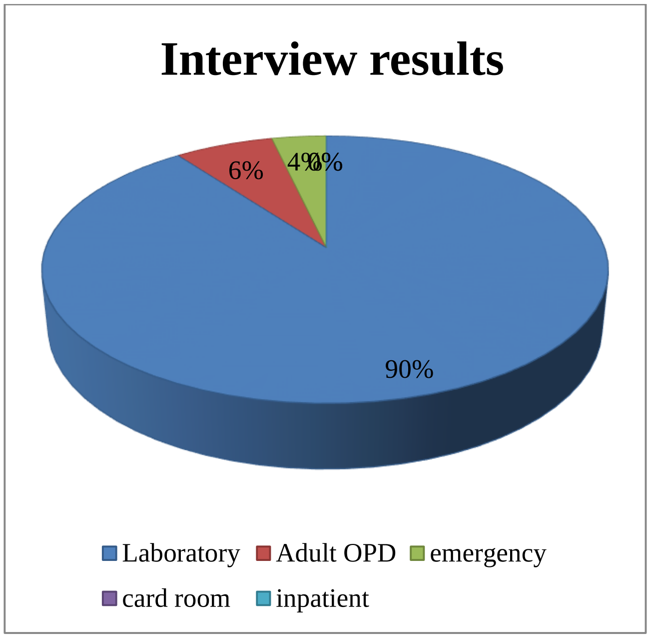


Figure 8: Interview Results

The interview results show that among the service stations that the hospital has patients have a major complain in the laboratory department.

Customer complains on service

Timeliness	**Layout related**	**Information related**
Long waiting time (275)	Path complication (72)	Lack of information (32)
		Medicines are not well explained (17)

Documentation related	**Care related**	**Others**
Losing of cards (17)	Nurses behavior (156)	Sanitation (6)

Searching for cards for a long time (64)	Empathetic attitude of Doctors (79)	Confidentiality of information (2)
		Compliant channel (31)

Table 9: complaints of patients

The table above shows the kind of complaints that the patients have on the service system of the hospital. Based on the results the problems are categorized into six main groups. Among those problems raised, most patient complaints come from a prolonged waiting time. The six categories are namely

- ✓ Waiting time related
- ✓ Layout related
- ✓ Lack of information
- ✓ Documentation related
- ✓ Care related and others

Depending on those complaints the CTS's are

- ❑ CTS 1-long waiting time
- ❑ CTS 2-path complication
- ❑ CTS 3- searching for cards for a long time

So the interview results show that 90% of complaints come from the laboratory department, 6% from adult OPD and 4% from emergency department. In addition, the main problems that should be solved to address customer complaints are prolonged waiting time, path complication and searching for cards for a long time within the card room.

Time measurement results

Time has been measured from Adult OPD, Inpatient, Emergency, Card room and laboratory. Data has been collected from 1520 patients from each department. Time measurement within those departments was the very challenging part of the data collection. Because the patient that wants to get served in one station will come to the service station and most of the time left the area until the appointment time reaches or to pass to the next station and tracking those patients was very challenging. All the data collectors including the researcher tried to identify the patients by recording their physical appearance or the kind or color of clothes they wear and so on. All five data collectors were engaged on the time measurement session too. The areas that time measurement were held were, Adult OPD, card, laboratory, emergency and inpatient. The results show that patients are forced to spend an average of 122 minutes’ n Adult OPD, 92 minutes in inpatient, 40 minutes in emergency, 36 minutes in card room and 236 minutes in laboratory.

Department	Average waiting time
Adult OPD	122 minutes
Inpatient	92 minutes
Emergency	40 minutes
Cardroom	36 minutes
Laboratory	236 minutes

Table 10: Time measurement results

Service station selection: Since the hospital is too broad and too complex to understand, the researcher is forced to select one specific area among those different service stations. Based on the preliminary data collection results, it is safe to conclude that among the service stations in the hospital the laboratory department has many customer complaints. As the results showed among 1520 patients 90% of said, they faced many problems in laboratory department rather than the other stations and based on the time measurement results the laboratory department has the highest waiting time of all, so this researcher focuses on laboratory department only.

The laboratory service station

The laboratory service station has 35 laboratory technicians and laboratory technologists. In addition, it has many departments in it, which give different services. The departments under laboratory service station are

- ✓ Urinalysis
- ✓ Parasitology (stool and blood test for parasites)
- ✓ CBC
- ✓ Serology (Blood group)
- ✓ CD4
- ✓ Chemistry
- ✓ Blood bank service (cross match)
- ✓ Microbiology (sensitivity test, culturing, cell count)
- ✓ Electrolyte (identification of -ve and +ve charges)

4.2 Data analysis

As described in the methodology session one of the popular methodology that many literatures used in lean six-sigma is the DMAIC approach. Based on the 27 literatures which are directly to related to the case of this research the researcher reviewed each and every of them based on their methodological approach and based on their purpose. And develops a DMAIC road map which will fit the problems of the case under study. DMAIC road map is necessary to analyze and improve the process within the hospital. So based on that framework detailed data is collected and is analyzed. The framework developed for this research is shown below.

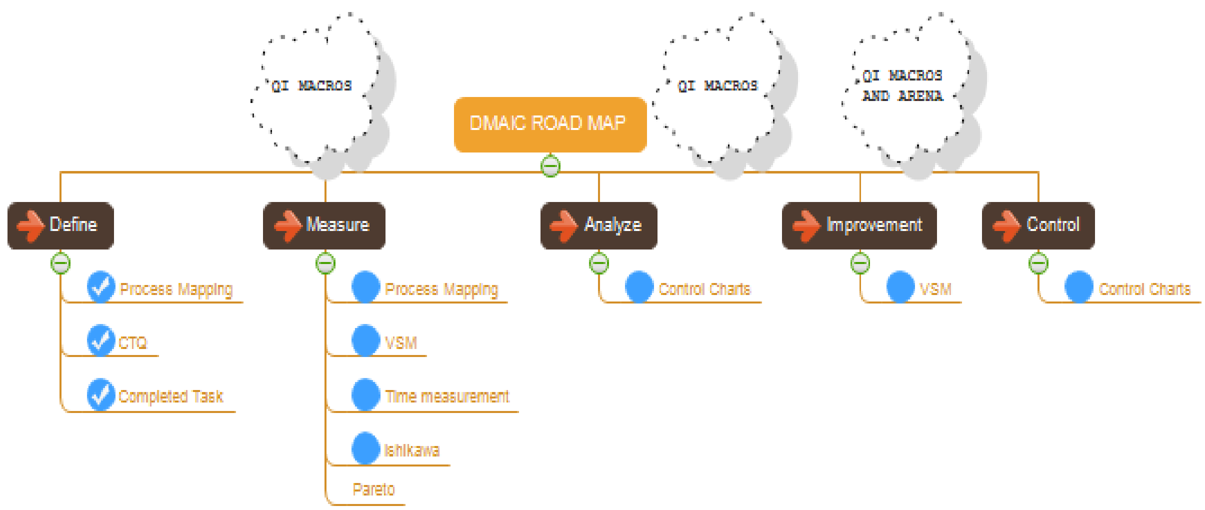


Figure 9: DMAIC framework(Source: Author's Analysis)

DMAIC ROAD MAP

DEFINE

As stated in the previous chapters Six Sigma's DMAIC roadmap is used along with lean tools for process improvement. The first stage of DMAIC is Define, with the purpose of selecting and defining a problem. Under the define stage there is process mapping, CTS and SIPOC respectively. Process mapping helps to understand what the existing process in the hospital looks like and SIPOC is used to understand the inputs, the outputs and the process in general. In this stage, the general process map of the hospital is drawn and CTS is defined.

Process mapping: The process map of YEKATIT 12 is shown below. The process map shows the existing process starting from patient arrival until patients exit from the system. It shows the flow and the different stations within the hospital.

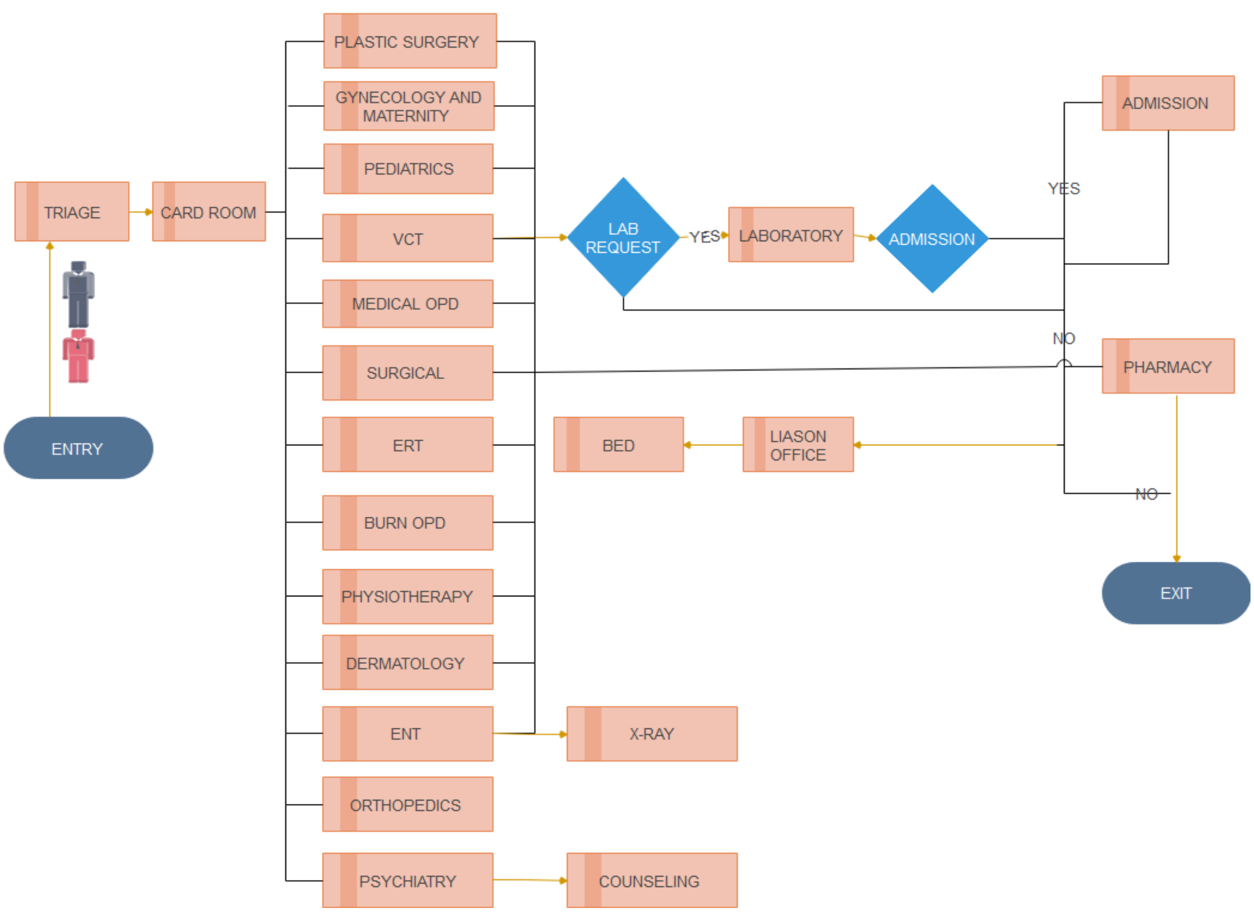


Figure 10: process Map of YEKATIT 12 Hospital(Source: Author's observation)

As shown above on the process-mapping patients arrive to the hospital and join the queue at the triage. In the triage, station patients are sorted out based on their case, illness or injury. After sorted out they will go to the card room and get card and based on that they will go to different service stations based on their cases like pediatrics, orthopedics and etc. After being diagnosed on those service stations, they go to laboratory service station if there is any laboratory request. Then after getting the laboratory results they will go back to the service station they came from and if admission is necessary they will get admitted if not they will go to pharmacy to buy the subscribed drugs and they will exit from the system. From the different processes on this map the focus of the researcher is the laboratory service station because of the reasons and the results presented in the previous sessions.

CTS

CTS helps to understand the critical problems that needed to be solved in order to satisfy patients. From the preliminary data collection, the researcher identifies what the CTS's are, which are

- CTS 1-long waiting time
- CTS 2-path complication
- CTS 3- searching for cards for a long time

This means the prolonged waiting time in the hospital is a great factor of patient satisfaction and patients get challenged a lot because of the complicated path of the hospital and the time that the employees in the card room for searching a card is very tiresome for the patients.

SIPOC: SIPOC is used to understand the inputs, the outputs and the process in general. Now that we understand the existing process in general and defined the critical things to satisfaction the next step is to focus on the specific service station which is laboratory service station. In the SIPOC laboratory requests come from different departments such as Medical OPD, Surgical OPD and etc. Then the receptionists receive the requests, patients will go to the preparation room to give blood or to receive cup/container and then they will get appointed. The laboratory technologists will perform the analysis and return the result paper to the preparation room and the results will be returned for the patients. The outputs of the analysis are urinalysis results, stool results, sputum results, chemistry, CBC and etc. In addition, the customers of the hospital are external patients and staffs. The SIPOC diagram is shown below:

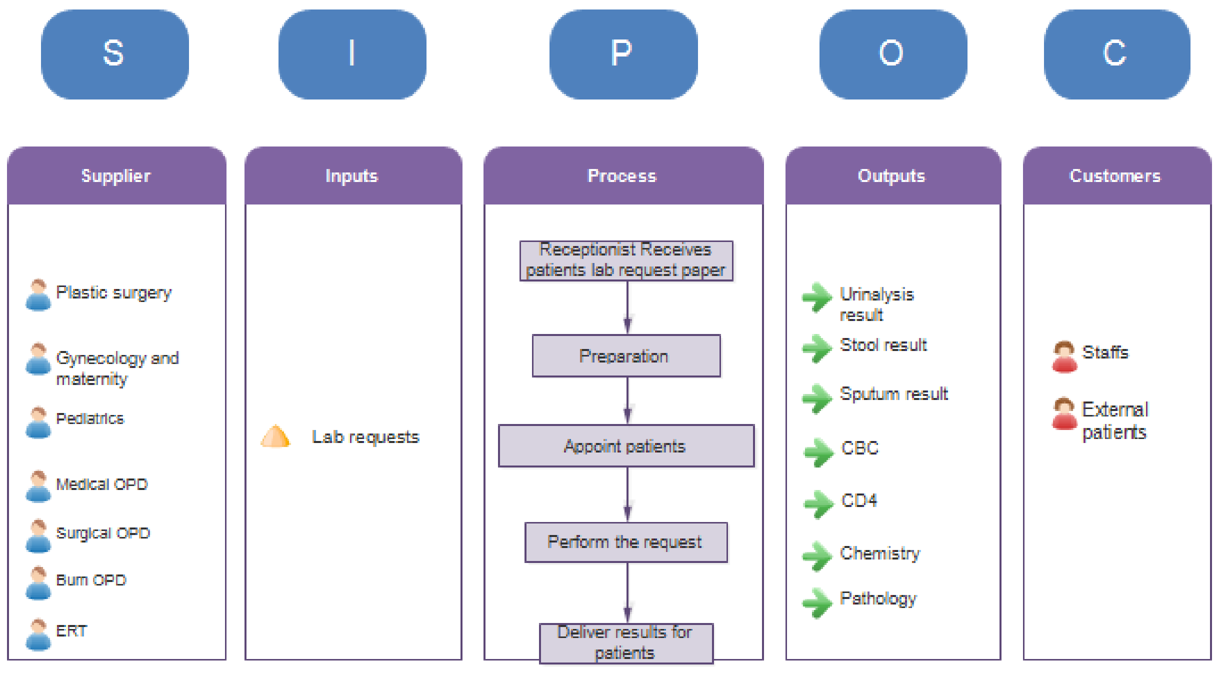


Figure 11: SIPOC of laboratory department (Author's) observation)

MEASURE

The second stage of DMAIC, which is Measure, is intended to quantify and refine the problems in detail. As stated in the DMAIC framework the measure phase of The DMAIC stage constitutes process mapping of the laboratory department, which aims to show how the laboratory service station is organized. The second one is Value stream mapping which shows the value adding and non-value adding activities in detail and in this part wastes in laboratory department are defined. The next step of measure stage is time measurement, which is necessary to count how much time every activity in the laboratory service station needs. Now that the process is clearly defined and problems are well articulated then Ishikawa will come to the picture to understand the causes of the problems. After the causes of the problems are, articulated pareto analysis will be done to understand which problems influence the most.

Process Mapping

The figure below shows the process mapping of the laboratory service station. As shown on the process-mapping patients will arrive to the waiting line and join the queue and the receptionist will receive the lab request. If their request is urinalysis or stool they will get cup/container and they will move to the bathroom to poop/urinate if not, they will give a blood sample and get appointed then the analysis on the requests will be performed. Then when the appointment time reaches they will accept the results and leave the laboratory.

The process mapping of the laboratory service station shows that many departments are available in the station. It has reception, urinalysis, parasitology, CBC, serology, CD4, chemistry, blood bank, Microbiology and electrolyte. Those departments analyses different testes based on the requests that they receive. The departments have many equipment's and machines to perform the different operations. Like CD4 analyzer, Mindray, Beckman, Microscope and so on are the equipment's that the station uses. Among those departments within the laboratory department the researches chooses four only namely CBC, Chemistry, Urinalysis and stool analysis and the selection is based on the number of requests that they receive per day which is an average from 200-50requests/day.

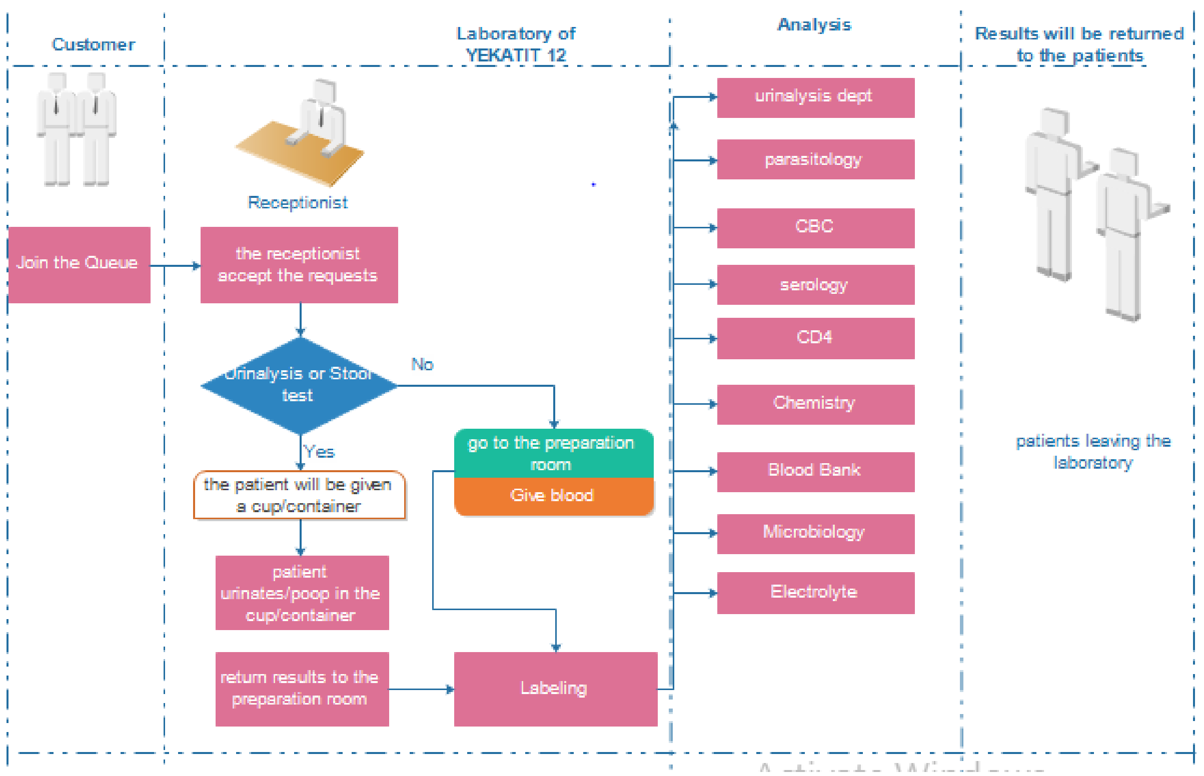


Figure 12: process mapping of the laboratory service station (Author's observation)

Process mapping of urinalysis

Urinalysis is a laboratory test to detect problems from urine. The abnormality of organs like lung, kidneys, urinary tract, skin, and bladder might affect our body on how to remove wastes and toxins. The focus of this research is a simple urinalysis test that takes minutes to finish not culturing. The department has one laboratorian/ shift and the main equipment that they use is Microscope in addition to the other small utensils. In this department, first, a patient will come to the reception holding a request and if the request says urinalysis a cup will be given for the patient then she/he will go to the bathroom to urinate. After urination, the patient should come back with a sample and he/she will give the sample to the lab assistant in the preparation room that will do the labeling and then pass it to the urinalysis department for analysis. Then the laboratorian will adjust his microscope and will take a sample of urine and start examining. After finishing the examination, the lab technologist will wait until he/she collect 20 results and then he/she will return the results for the employees who will return the results and sometimes they themselves will return the papers.

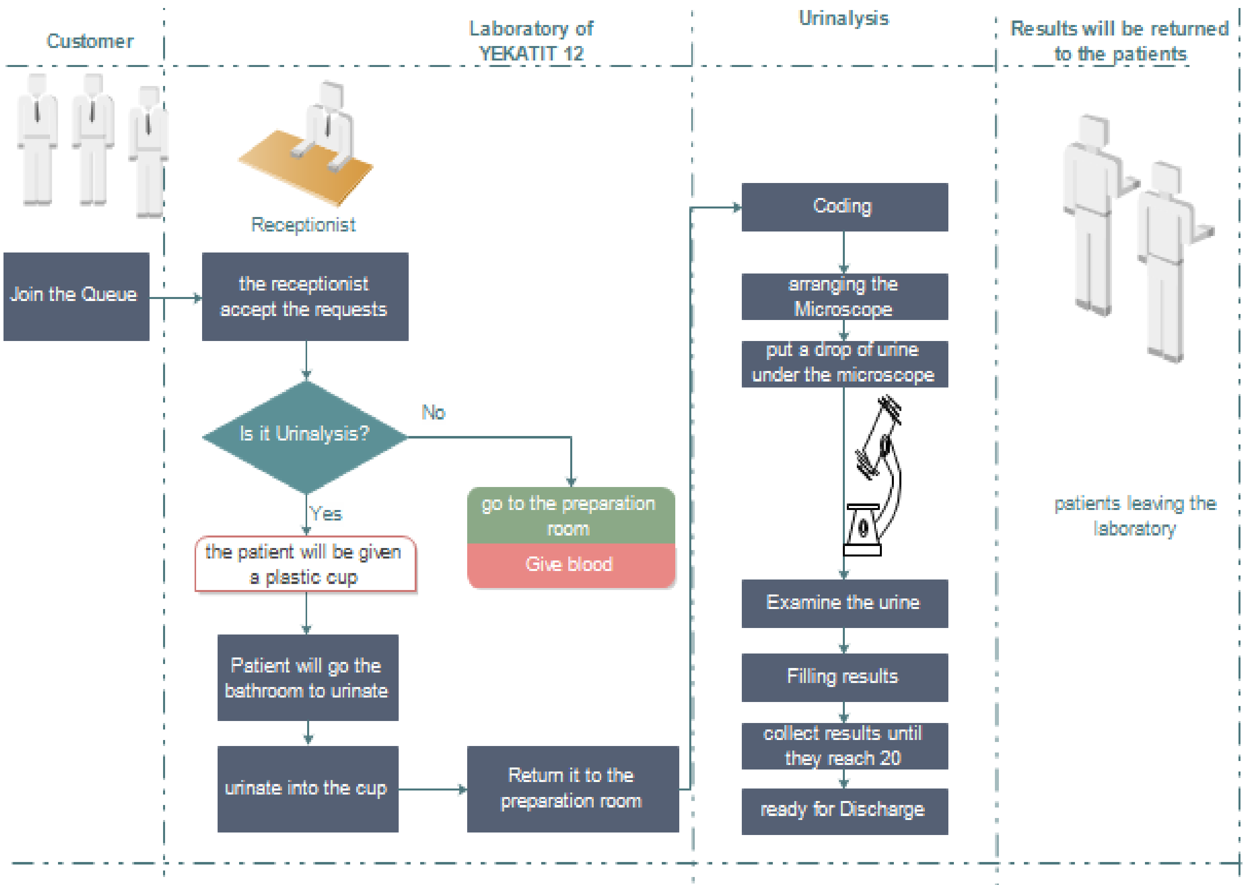


Figure 13; Process mapping of urinalysis(Author's observation)

Process mapping of stool analysis

A stool analysis is a test done on a stool (feces) sample to help diagnose certain conditions affecting digestive tract. This might be an infection from parasites, viruses or bacteria.

The other session in laboratory service station is stool analysis under the name of parasitology. This department is almost similar to urinalysis. First, a patient joins the queue and when give the request for the receptionist, the receptionist will give the patient a container, and the patient will take the container and go to the bathroom to poop. After the poop the patient will come back with a sample and give it to the preparation room then the laboratory assistant in the preparation room will label the container and give the sample for the laboratory analyzer. The lab analyzer will then adjust his /her microscope, took a sample, and examine it. After filling the results on the request paper, the lab analyzer will then wait until the results reach to twenty and return the results for patients. The process mapping of stool analysis is shown below. Every activity in this department are explained in detail

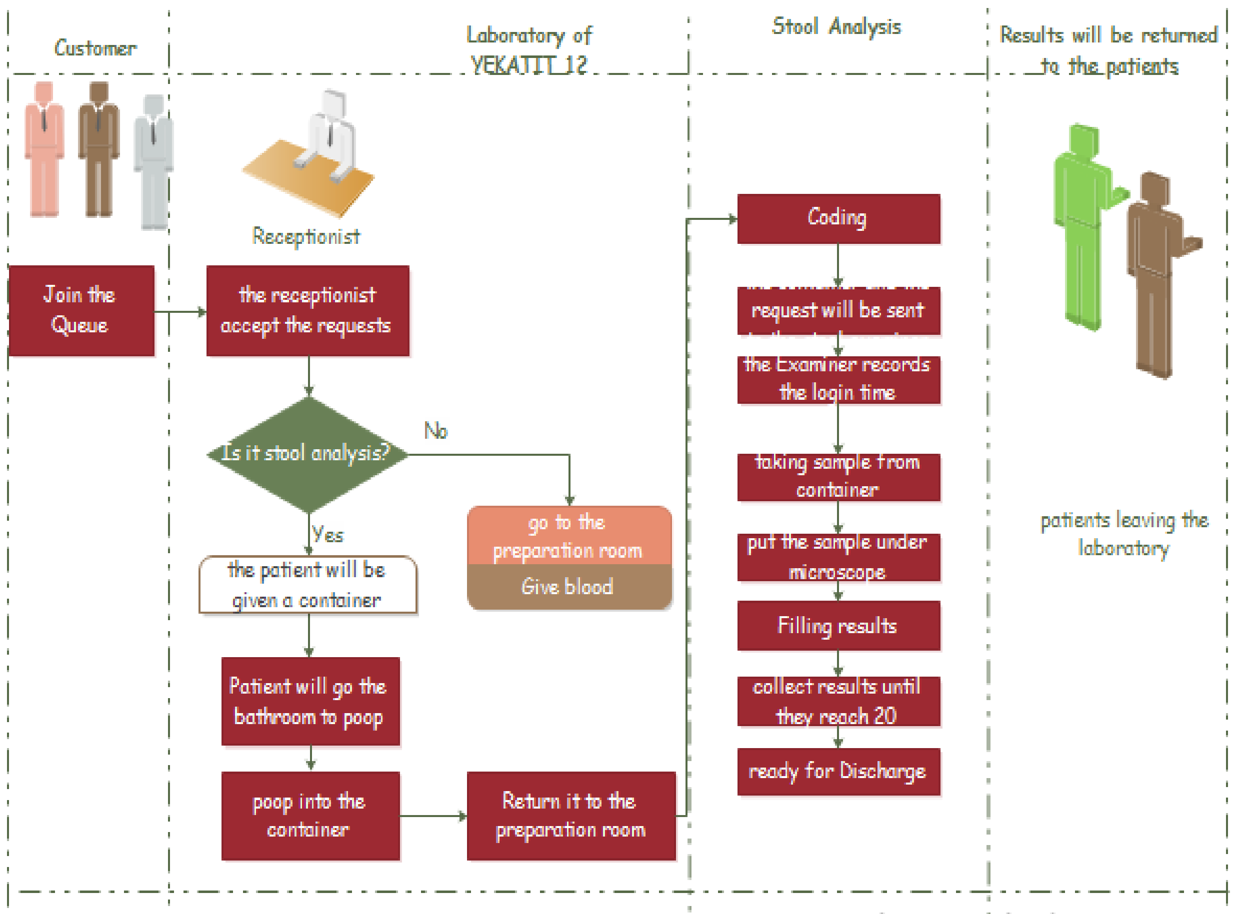


Figure 14: process mapping of stool analysis**(Author's observation)**

Process Mapping of CBC

CBC (complete blood count) is a test that determines if there are any increases/decreases in the blood cell counts. The laboratory report from CBC tells whether your blood cells are normal under your age or not. It can help diagnose anemia, cancer etc. CBC measures red blood cells, white blood cells and platelets. just like the other processes getting a CBC analysis has also its processes. The patient needs to join the queue first and go to the reception to and he / she should give blood. After giving a blood sample, the sample will get labeled and pass to the CBC analyst. The CBC analyst will then turn on the Mindray machine and will check whether re-agents are available or not. Then sample preparation will follow and centrifuge and then the blood will be poured from tube. Then the sample will be put inside the Mindray and results will come out. If there is no problem on the results the result will pass and the examiner will write the results on the computer, then on the request paper and finally return the results. The activities in CBC department are shown below in detail.

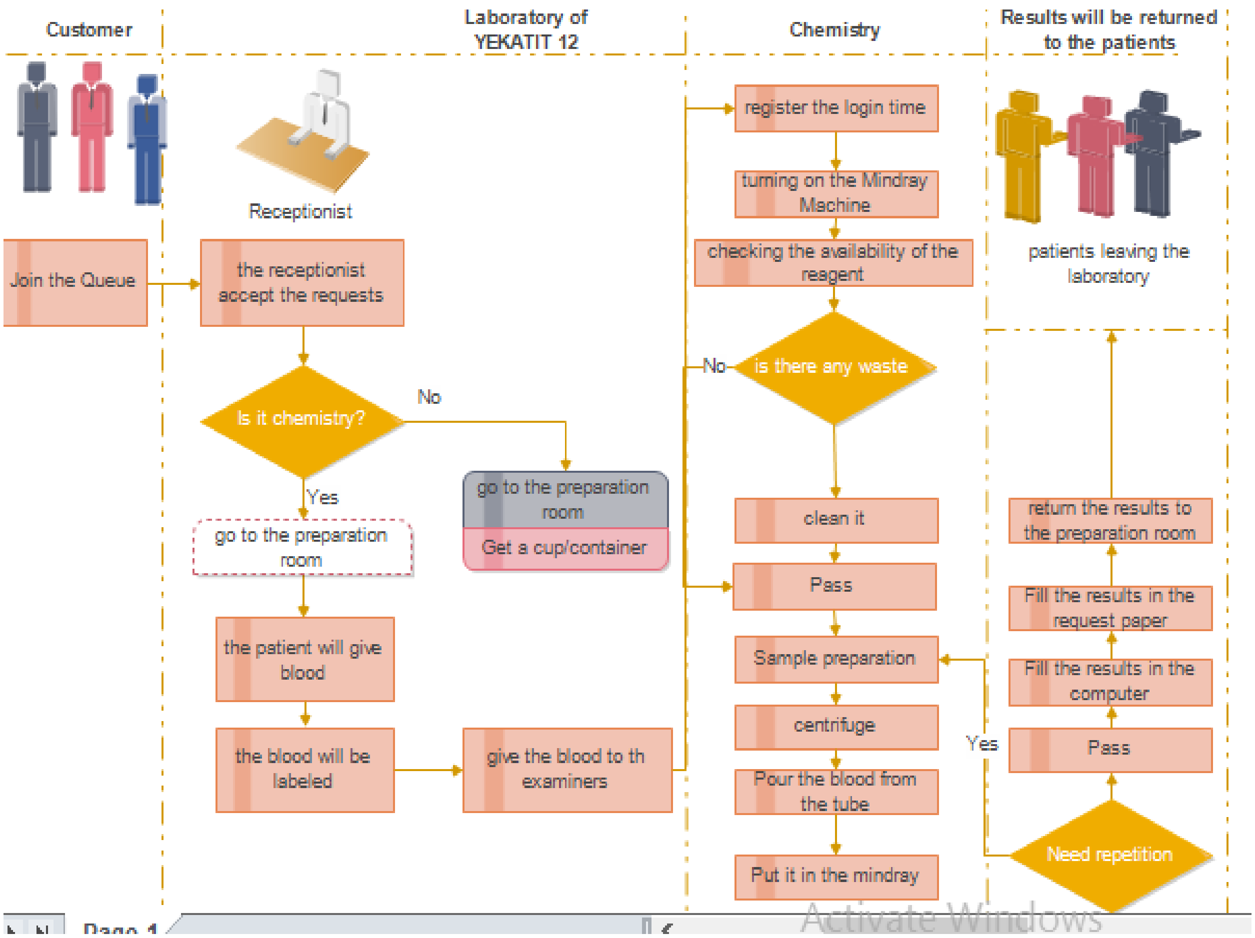


Figure 15: process Mapping of CBC(Author's observation)

Process mapping of Chemistry

Clinical chemistry is area of chemistry, which is generally concerned, with the analysis of body fluids for diagnostic purposes. Chemistry is the last department under study on this research. In order to get a chemistry analysis a patient will first join the queue and go the reception as usual.

Then a blood sample will be taken out of his/her arm and that sample will be labeled in the preparation room. The labeled sample will then be taken to the chemistry analyst then the chemistry analyst will start entering data to the computer and then she will manually match the number and enter the data. Then the Beckman machine will examine the blood and the laboratory technologist will fill the results on the computer and on the request paper. Then finally give the results back for the patients. The figure below shows the detailed activities of chemistry department.

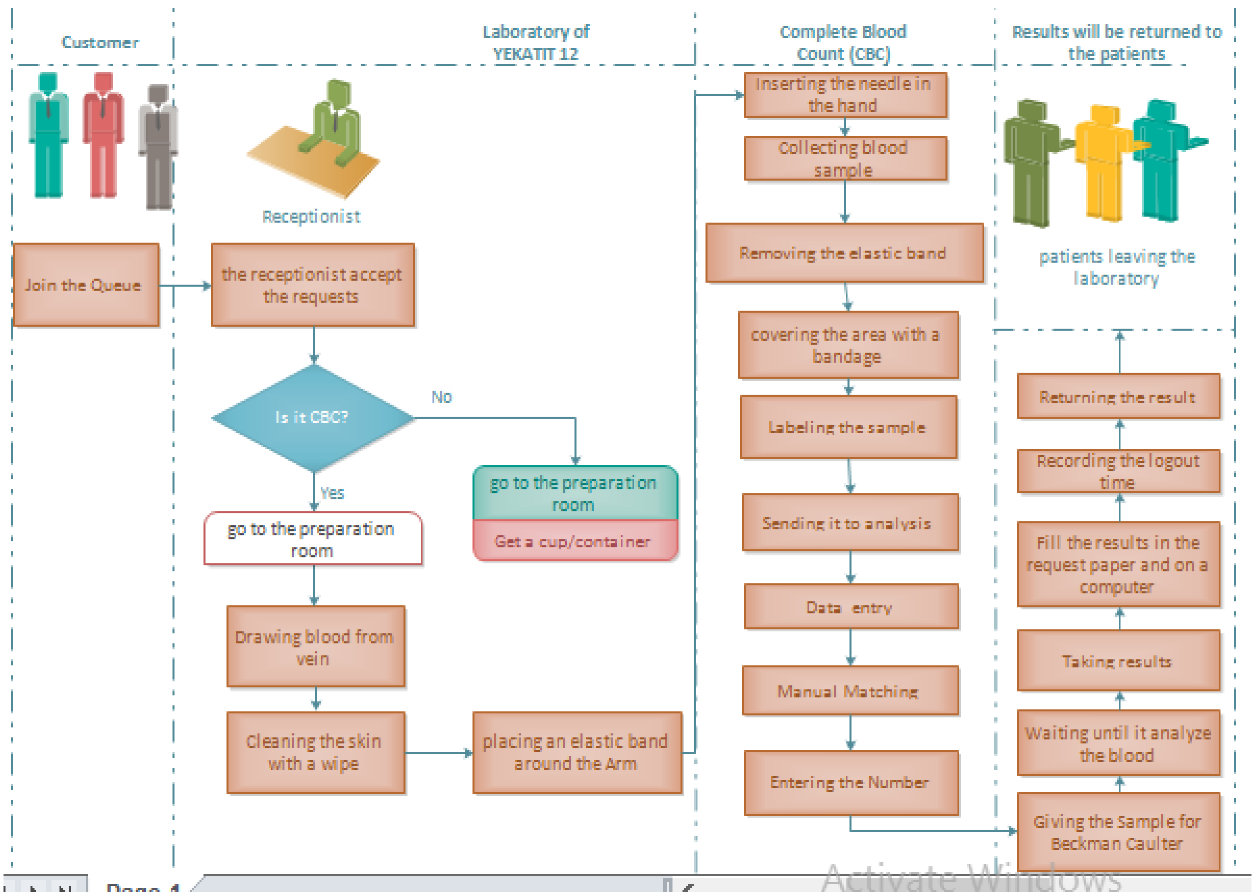


Figure 16: process mapping for Chemistry(Author's observation)

Value stream Mapping (VSM): value stream mapping (VSM) is a map that clearly shows a value adding activities and non-value adding activities in process clearly. It is a widely used lean tool, which highly helps in identification of wastes within different activities or processes.

VSM of chemistry

Value stream mapping shows the value adding activities and the non-value adding activities. The VSM of chemistry starts with giving requests in the reception and ends with delivering laboratory results for patients.

Non-value adding activities in Chemistry: placement of reagents, which is far from the machine. the examiner start examining when the number of requests reaches 40 which takes a longer waiting time and filling data manually in filling the data on computer. The cycle time in chemistry department is 157.5minutes.

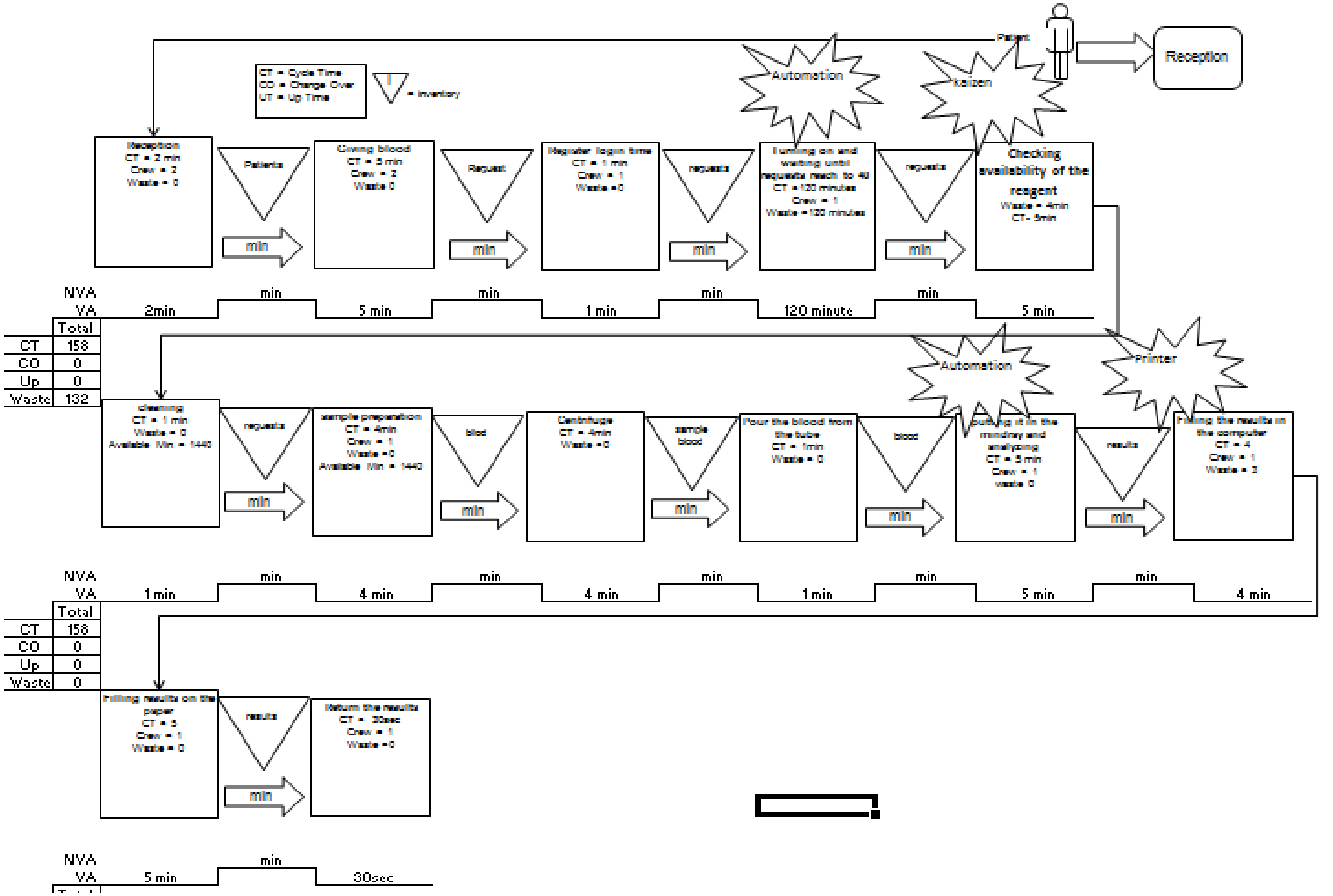


Figure 17: VSM of chemistry (Author's observation)

VSM of urinalysis

Value stream mapping of urinalysis: the value stream mapping of urinalysis shows the process starting from when a patient goes to reception until a result is delivered for patients. The non-value adding activities in this map is only the laboratory technologist waits to deliver results until 20 requests are examined which in turn creates a prolonged waiting time. The cycle time of urinalysis is 53.5 minutes.

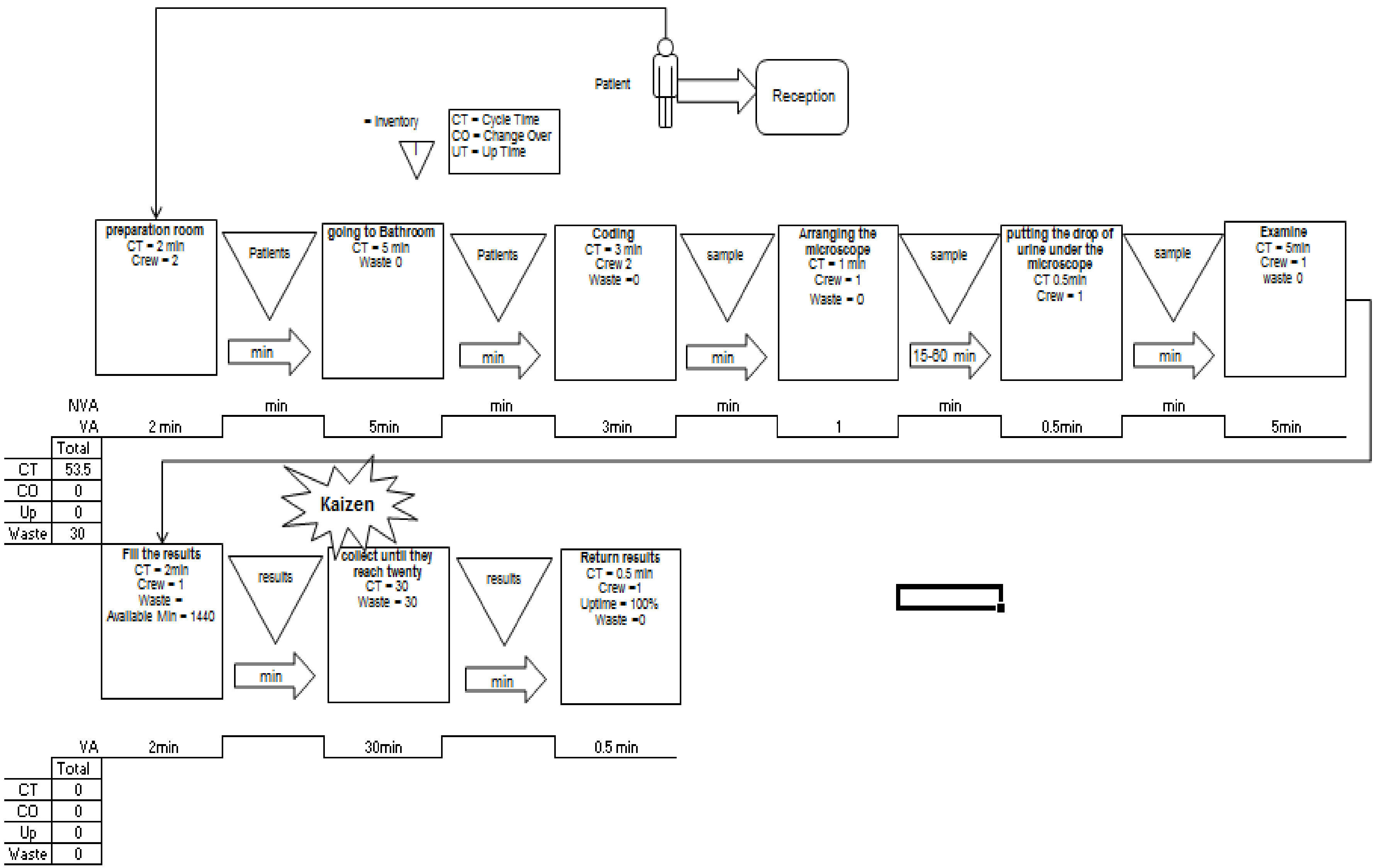


Figure 18: VSM of urinalysis (Author's observation)

VSM of stool analysis

Value stream map of stool analysis: the value stream map of stool analysis shows the value adding activities and the non-value adding activities in the stool analysis session, which is under parasitology department. The non- value adding activity in stool analysis is the time that the examiner took to return the result papers until it reaches to twenty. The other non-value adding activities consumes time they can't be avoided. The cycle time in stool analysis is 50minutes.

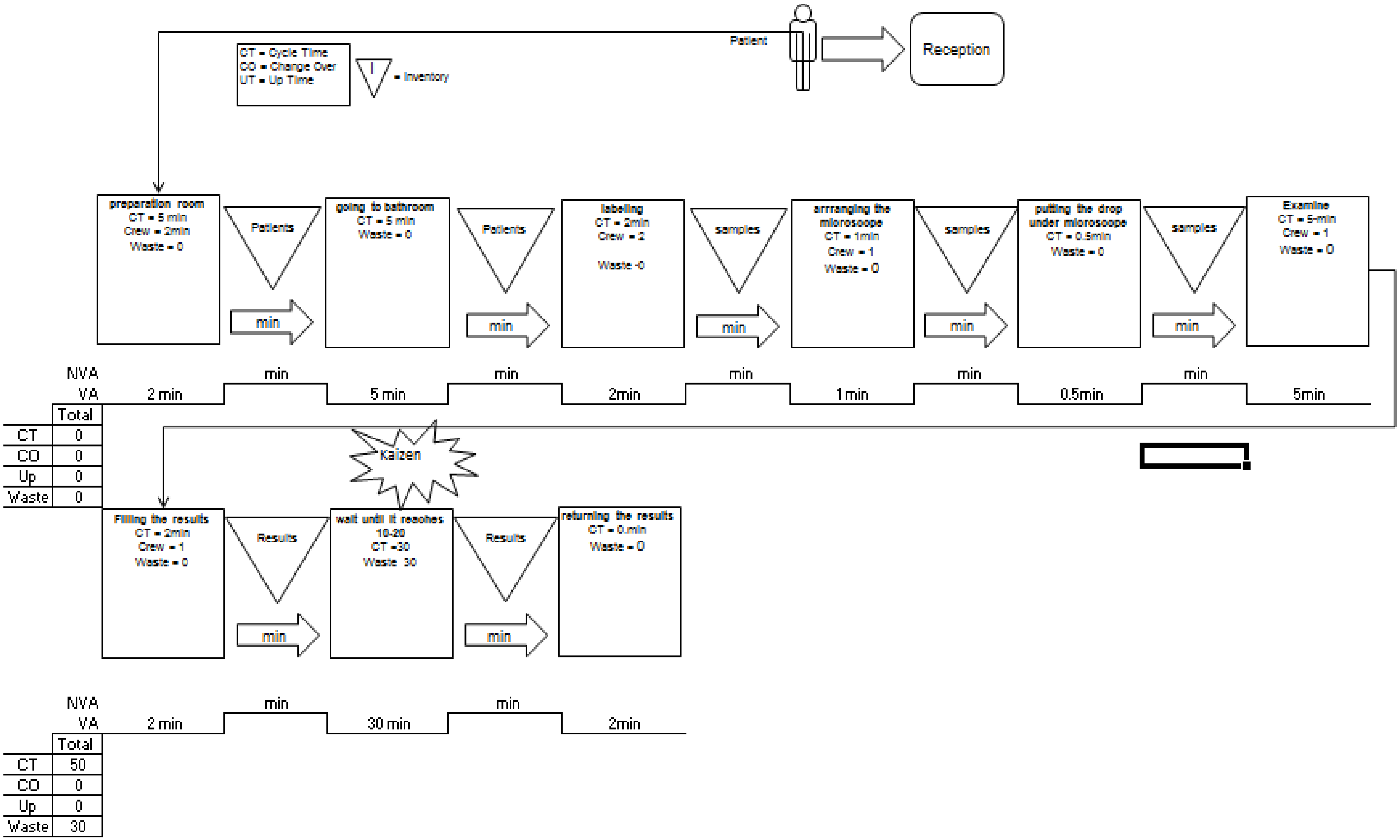


Figure 19: VSM of stool analysis (Author's observation)

VSM of CBC: The value stream map of CBC shows the value and non-value adding activities in CBC. The non-value adding activities in CBC are manual and matching of sample and requests, which takes unnecessary time. Entering number manually, and the Beckman machine only takes only one sample at a time and the examiner waits until she collects three results in order to return results for the patient.

The cycle time in CBC is 40.5 minutes.

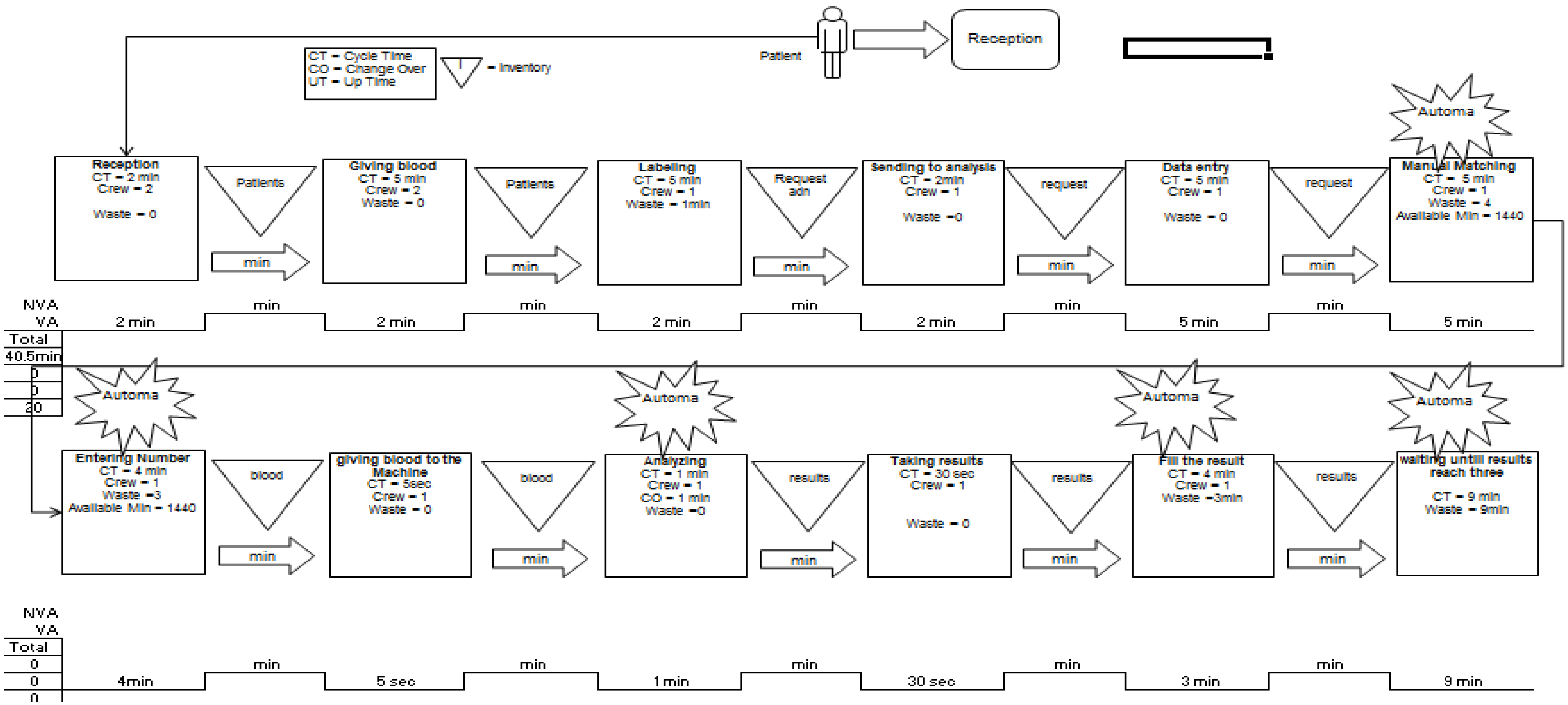


Figure 20: VSM of CBC (Author's observation)

Time measurement:

The hospital's recorded time shows the average time that patients spent in urinalysis, stool analysis, CBC and chemistry. In addition, in order to check whether the recorded times are going accordingly with the time standard or not the researcher checked company documents to know the standard of he processes. The time has been shown on the table below

Note: source of standard time is the hospital

Process	Existing time	Standard time	Wastes
CBC	40 minutes	5 minutes	35 minutes
Chemistry	150 minutes	60 minutes	90 minutes
Urinalysis	40 minutes	15 minutes	25 minutes
Stool Analysis	35 minutes	15 minutes	20 minutes

Table 11: standard and existing time of laboratory processes

Ishikawa diagram

Ishikawa diagram (cause and effect) diagram analyses the causes of the problems with in the laboratory department. From the previous data's the main problem within the service station is high waiting time. The causes of these problems are analyzed by interviewing the laboratory technicians and by observing the process. And also from the hospital time measurement results there is high deviation of time from the standard and the actual. In order to get answers for these questions laboratory staffs are interviewed and observations were made. Some of the causes for this problem are process complications, lack of automation, discharging by batch and etc.

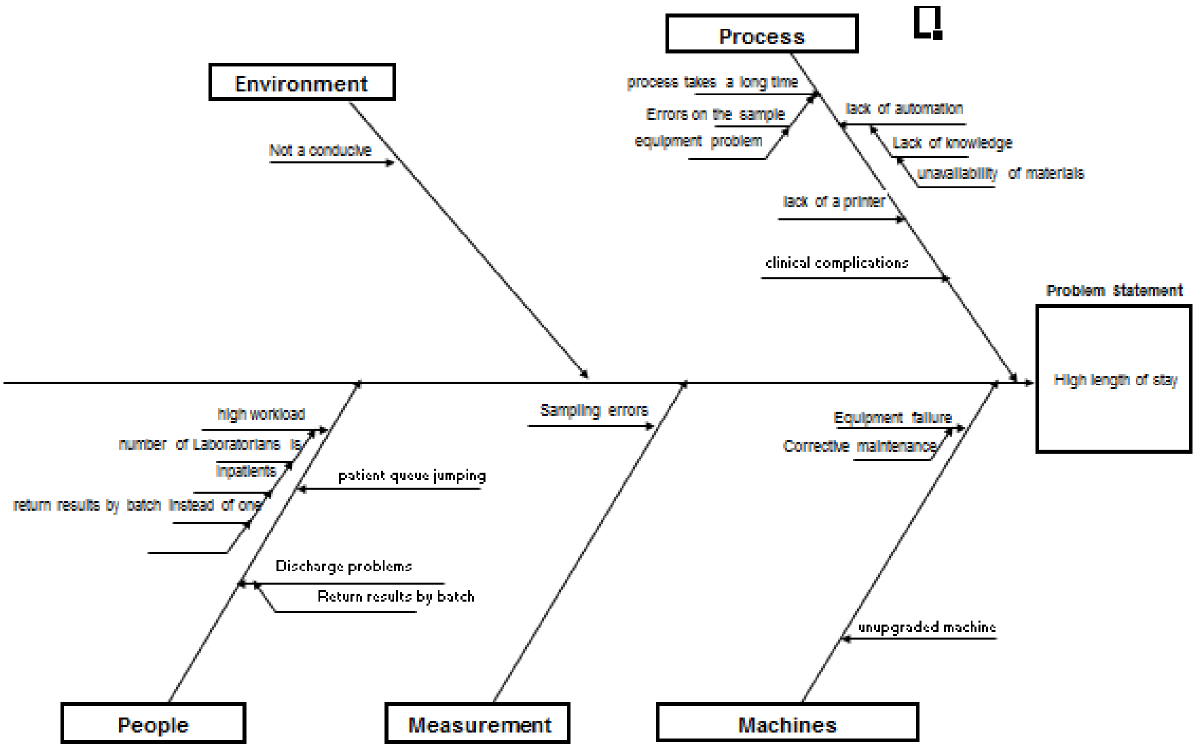


Figure 21: Ishikawa diagram

Pareto chart

In order to analyze which causes of prolonged waiting time are more influencing a Pareto diagram is done. This diagram is done based on an educated guess by the laboratory Technologists.

Pareto for stool analysis

The pareto is done based on an expert opinion from laboratory staffs. They made an educated guess in order to assume the severity of the problems with in the departments. So based on that educated guess the main cause for longer waiting time in stool analysis department is patients queue jumping. The patients that jump queues are inpatients and staff of YEKATIT 12 Hospital.

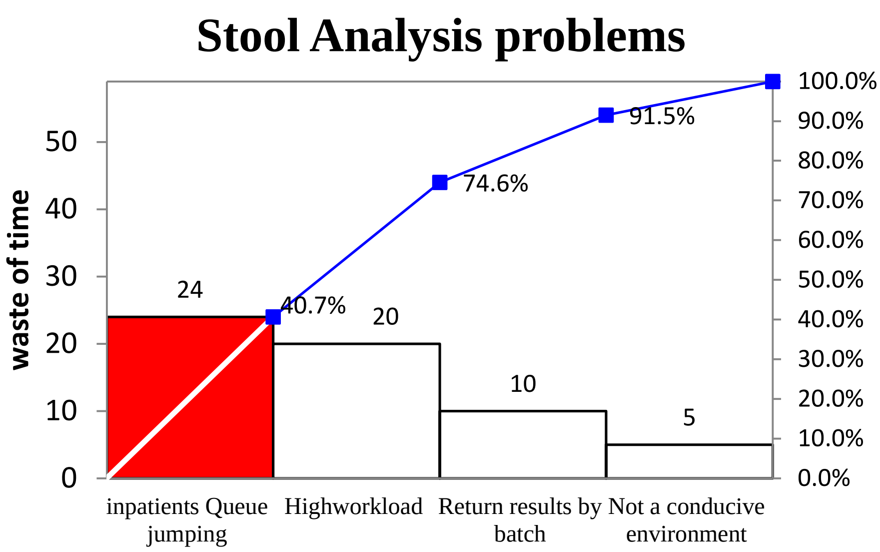


Figure 22: Pareto for stool

Pareto for CBC problems: The Pareto for stool is made by educated guess and expert opinions in stool analysis department. Based on the expert's opinions the main cause for prolonged waiting time in CBC is lack of automation.

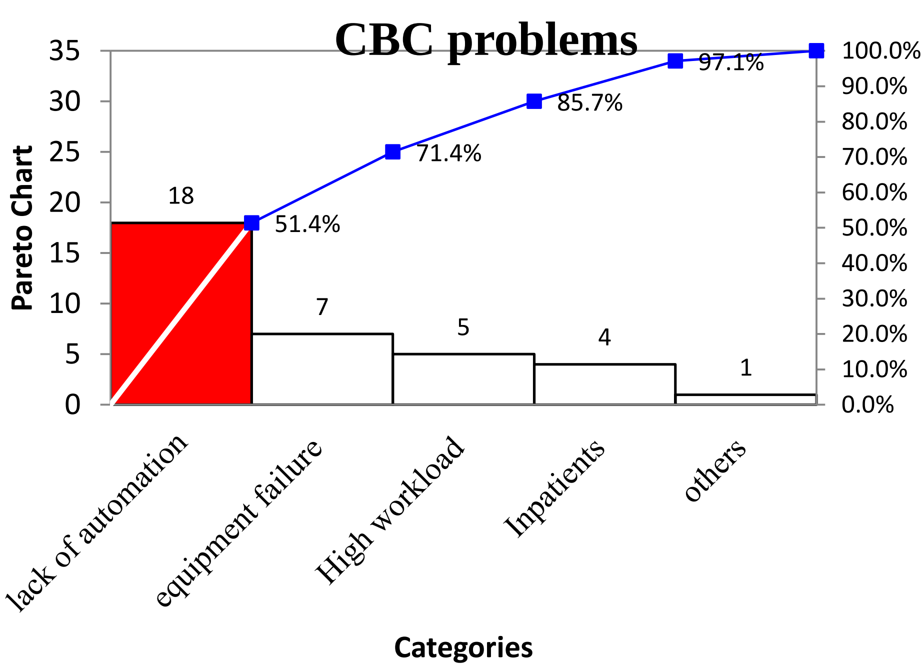


Figure 23: Pareto for CBC

Pareto for chemistry: There are different reasons that caused in chemistry department. The main causes of long waiting time which is based on The Pareto analysis made based on the experts opinion is process takes long time because of sample error, equipment problems and lack of automation.

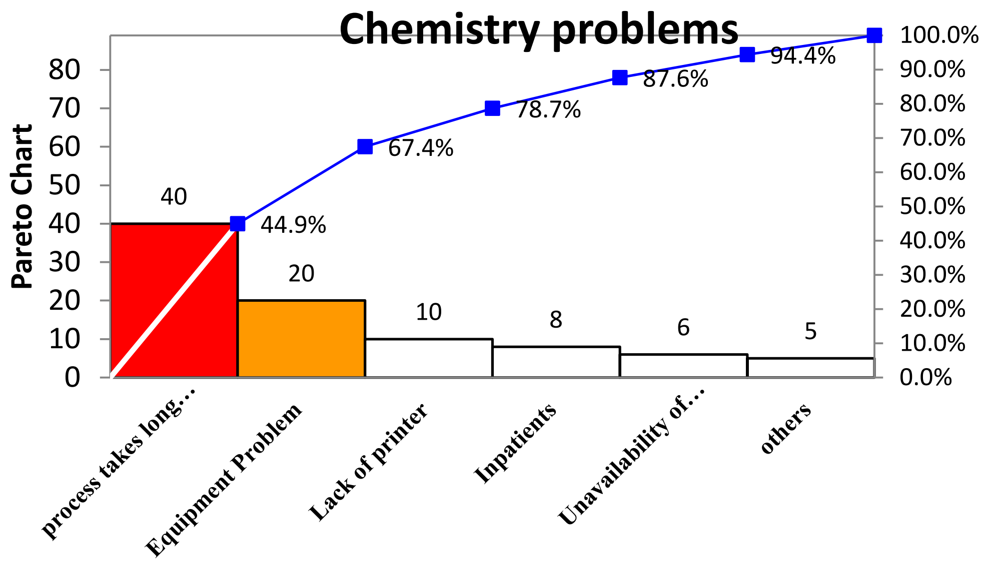


Figure 24: Pareto for chemistry

Pareto for urinalysis problems: Based on the expert's opinion made by laboratory staffs a Pareto analysis is made for the causes of prolonged waiting time in urinalysis department. The main cause for that is examiners return results by batch until they reach to twenty, which hurts the patient who was in the first queue. In addition, high workload is a problem. There is only one examiner per shift and 400-500patients might come per day.

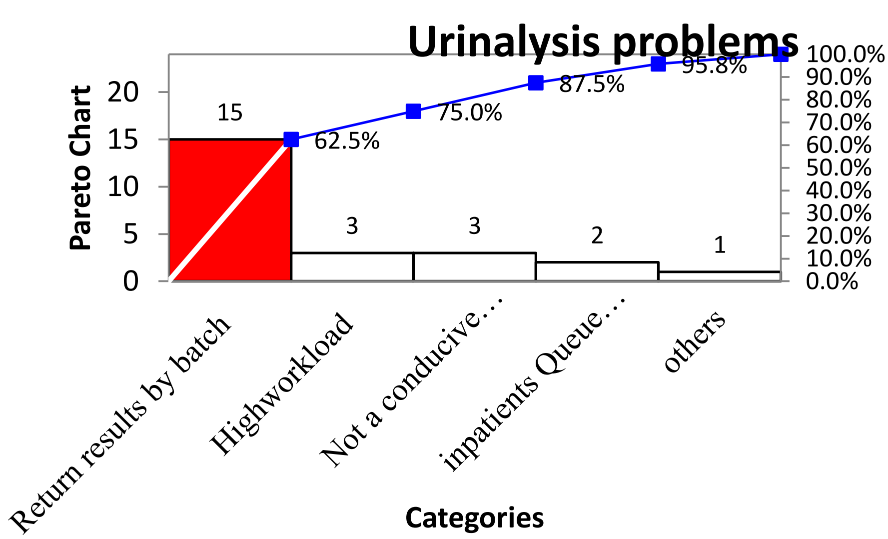
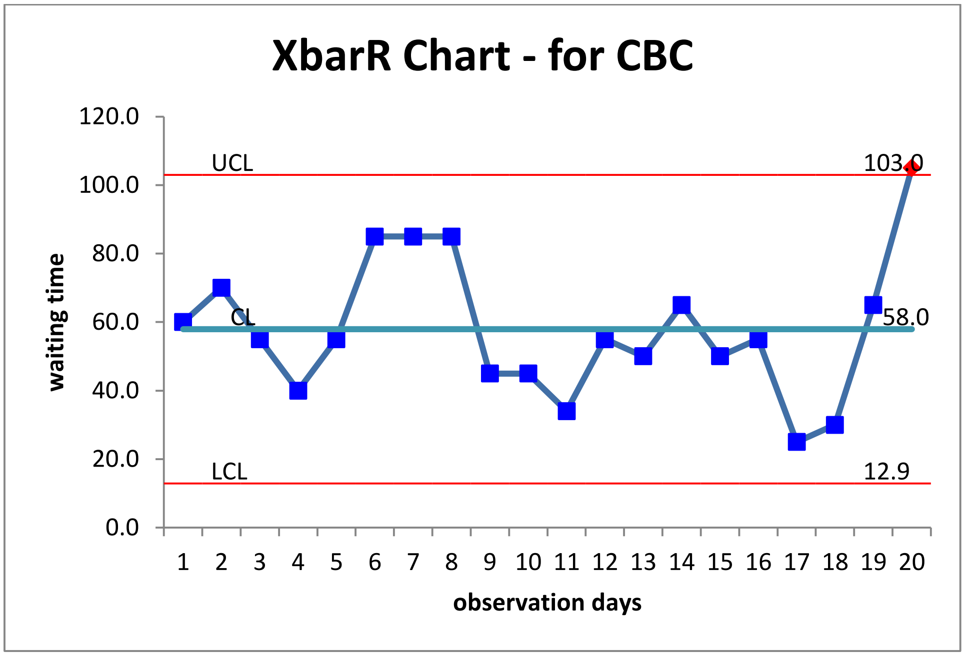


Figure 25: Pareto for urine

ANALYZE

In this stage, control charts are used to check the process variation. Control charts helps to know whether the process is under the control limits or not. These control charts are sigma tools.

Control charts for CBC: the control charts in CBC shows that all variables are under control. Even if the values fluctuates from the mean, it is still under control. The values in the control chart are observations made on waiting time.

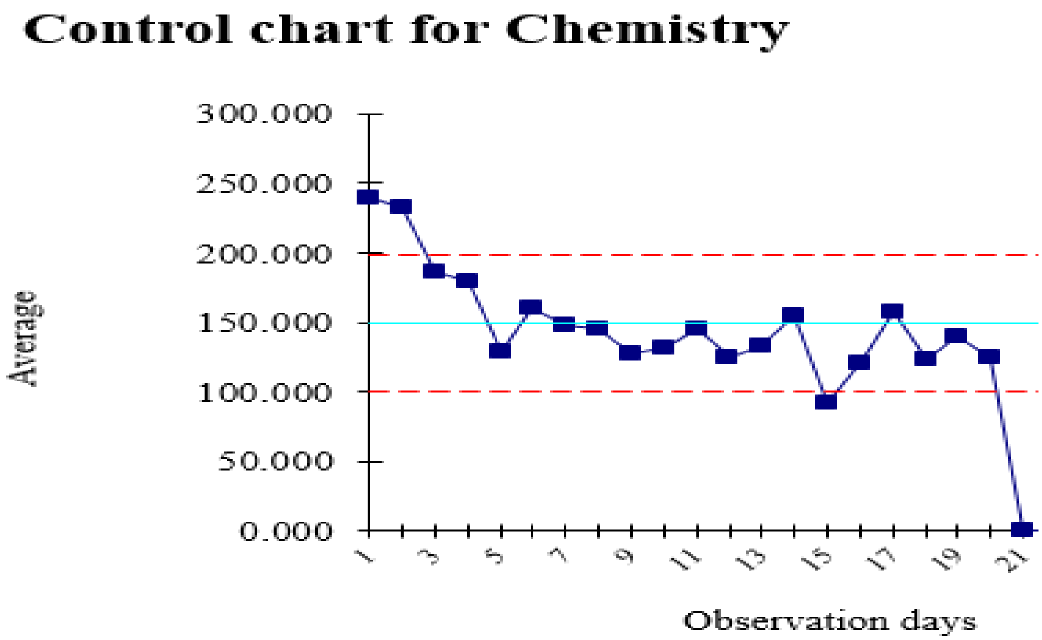


USL	103.02
LSL	-22.82
N	200

Table 12: control chart for CBC

Control charts for CBC:

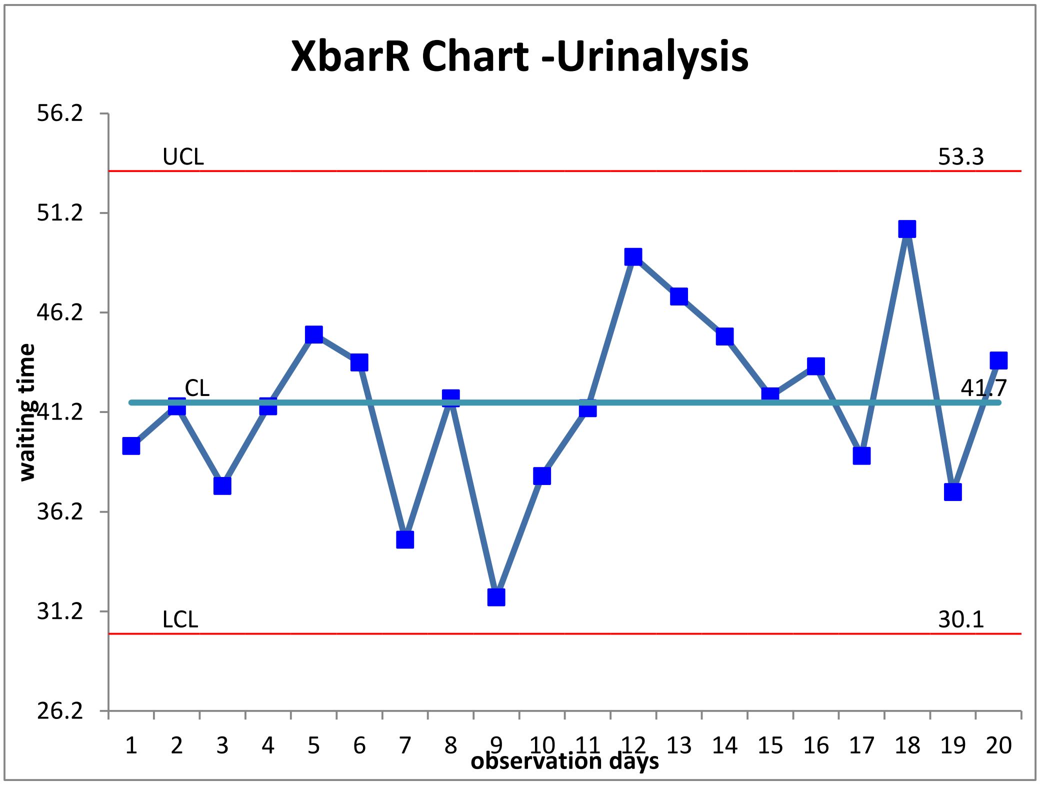
Waiting times are observed for twenty days to understand the variation. In chemistry department some values are under and below the upper and lower control limits. This means that there is variation with in these departments. The reason for this variation is that the examiner waits until requests reach 40 to start examining that means the first request and the 40th got their results with almost the same time but the waiting time for the first patients and the last patient is completely different.



USL	237.76
LSL	-58.49
N	200

Table 13: control charts for chemistry

Control chart for urinalysis: Waiting times are observed for twenty days to understand the variation. In urinalysis department, some values between the upper and the lower control limit. Therefore, that means the variation in this department is normal.

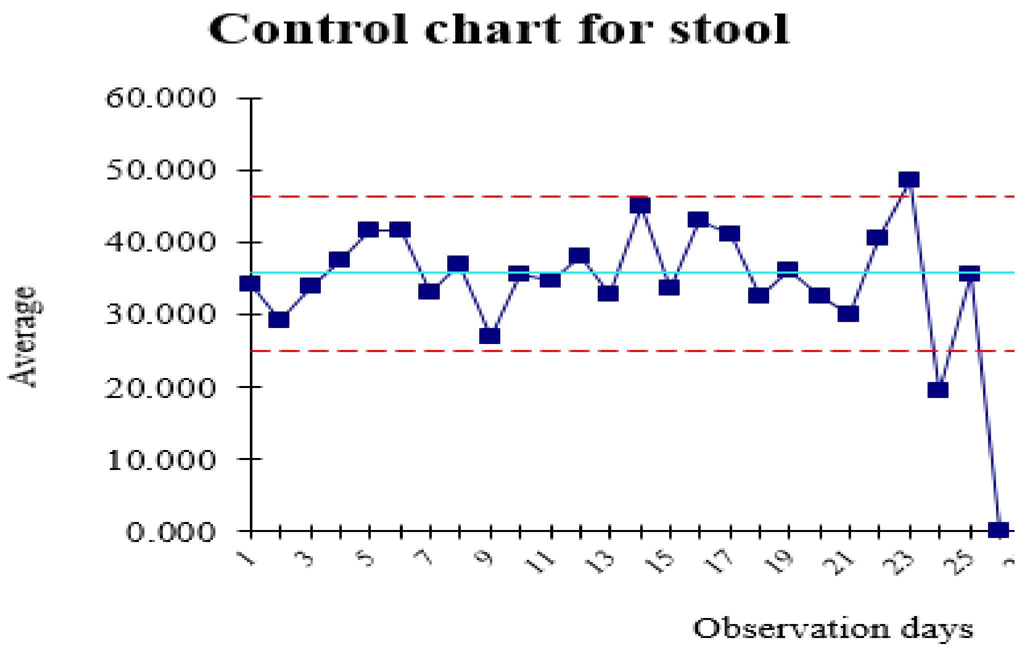


USL	80.81
LSL	1.79
N	200

Table 14: control charts for urinalysis

Control chart for stool analysis:

Waiting times are observed for twenty days to understand the variation. In stool analysis department some values are under and below the upper and lower control limits. This means that there is variation with in this department. The reason for this variation is that the examiner waits until results reach to twenty that means there is a long time difference between the first patient inline and the last patient in line. The other reason for this variation is that queue jumping from the inpatients and staffs. That means they will affect the outpatients who were in the line and get results way very soon before them.



USL	77.17
LSL	-5.79
N	250

Table 15: control charts for CBC

IMPROVEMENT: The fourth stage of DMAIC is Improvement. The existing process is improved and a new value stream map is designed to improve the process.

Improved VSM for CBC: In improved VSM of CBC, the Beckman machine is adjusted to examine five samples at a time instead of one. In addition, the writing and matching values value are omitted by adding a bar code reader on The Beckman machine. In addition, a printer is added for printing, which in turn reduces the time to record results**.** The cycle time of CBC analysis is reduced to 16 minutes.

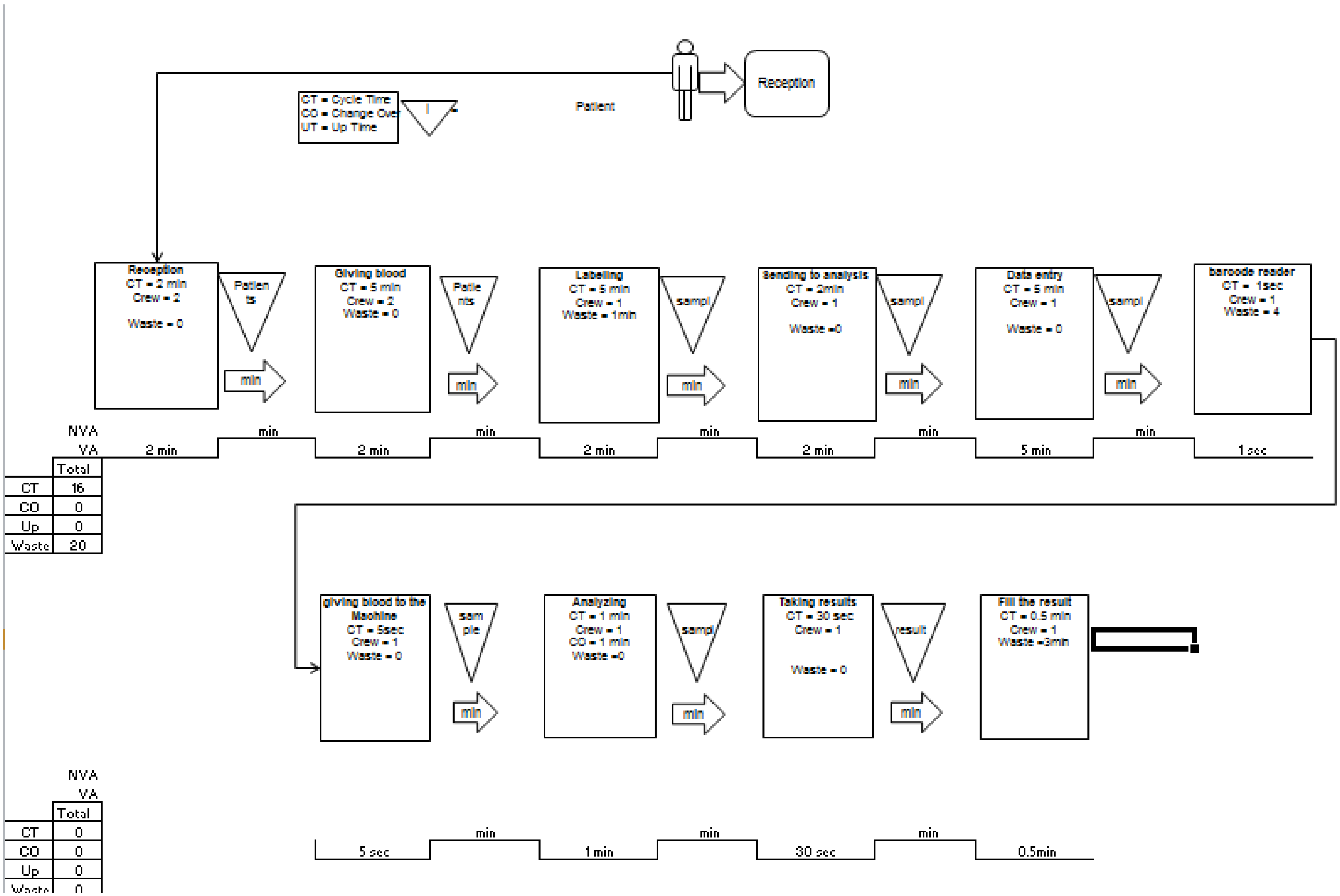


Figure 26: Improved VSM of CBC

Improved value stream map of chemistry: In improved VSM of chemistry. The examiner waits until requests reach 40 to start examining. That process is now omitted and when five requests arrive, the examining will start. In addition, a printer is added for printing, which in turn reduces the time to record results**.** The cycle time of chemistry analysis is reduced to 44minutes.

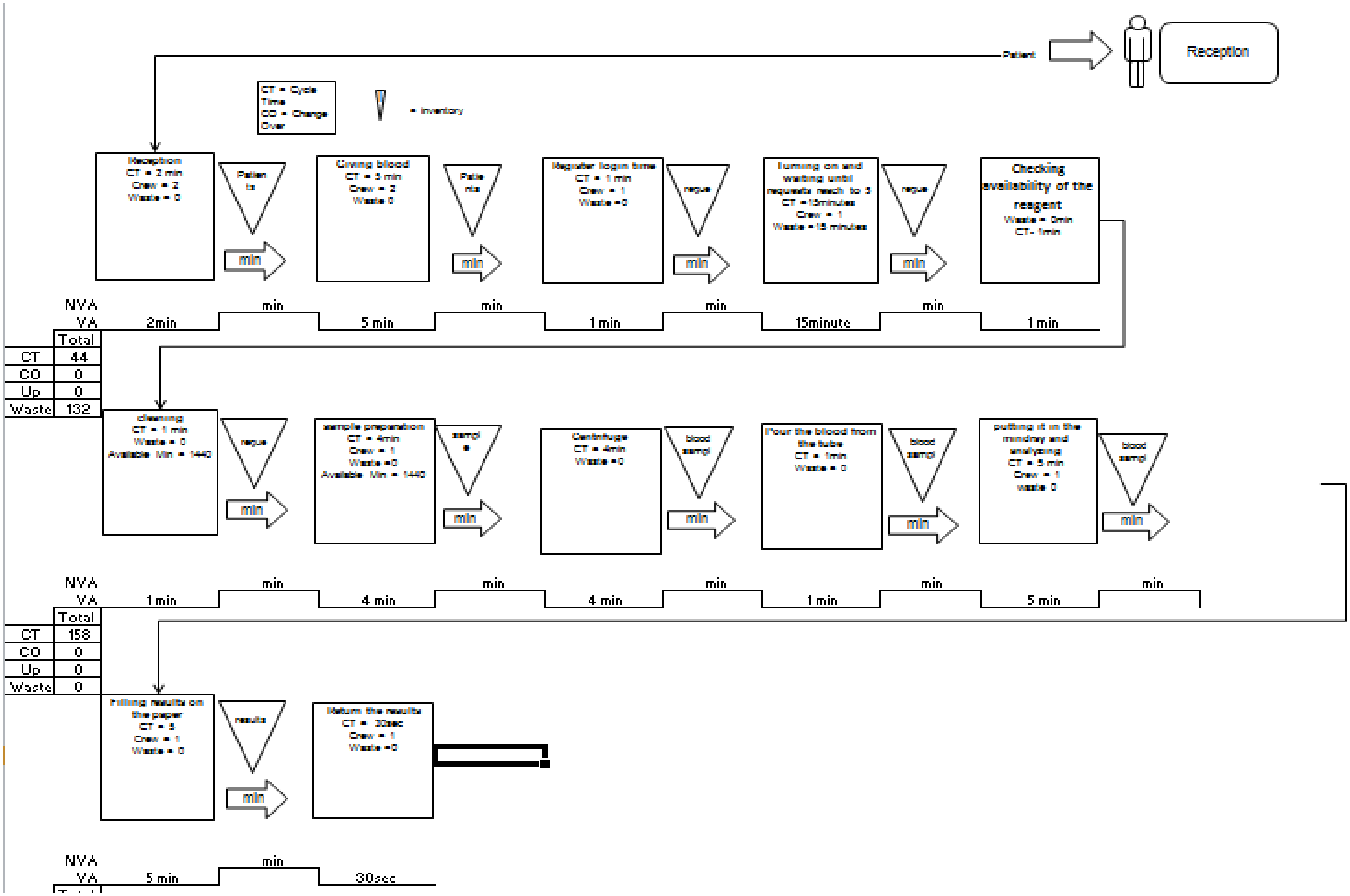


Figure 27: Improved VSM for Chemistry

Value stream map of stool analysis: The non-value adding activity in this process was the examiner holds results until they reach twenty and that process is now omitted and one request will be returned at a time. In addition, the cycle time is now reduced to 22 minutes.

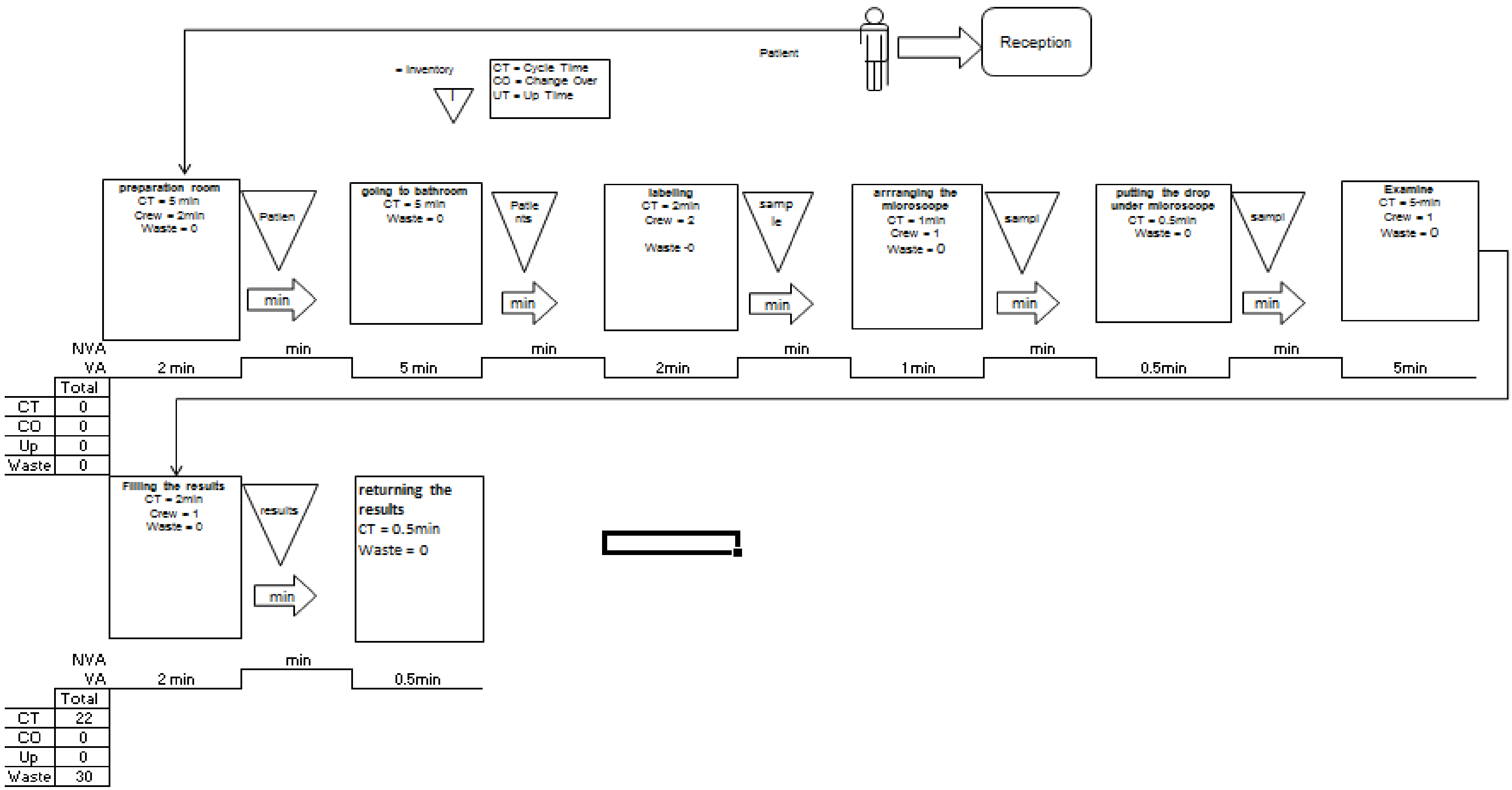


Figure 28: Improved VSM for Stool Analysis

Value stream map of urinalysis: The non-value adding activity in this process was the examiner holds results until they reach twenty and that process is now omitted and one request will be returned at a time. In addition, the cycle time is now reduced to 19 minutes.

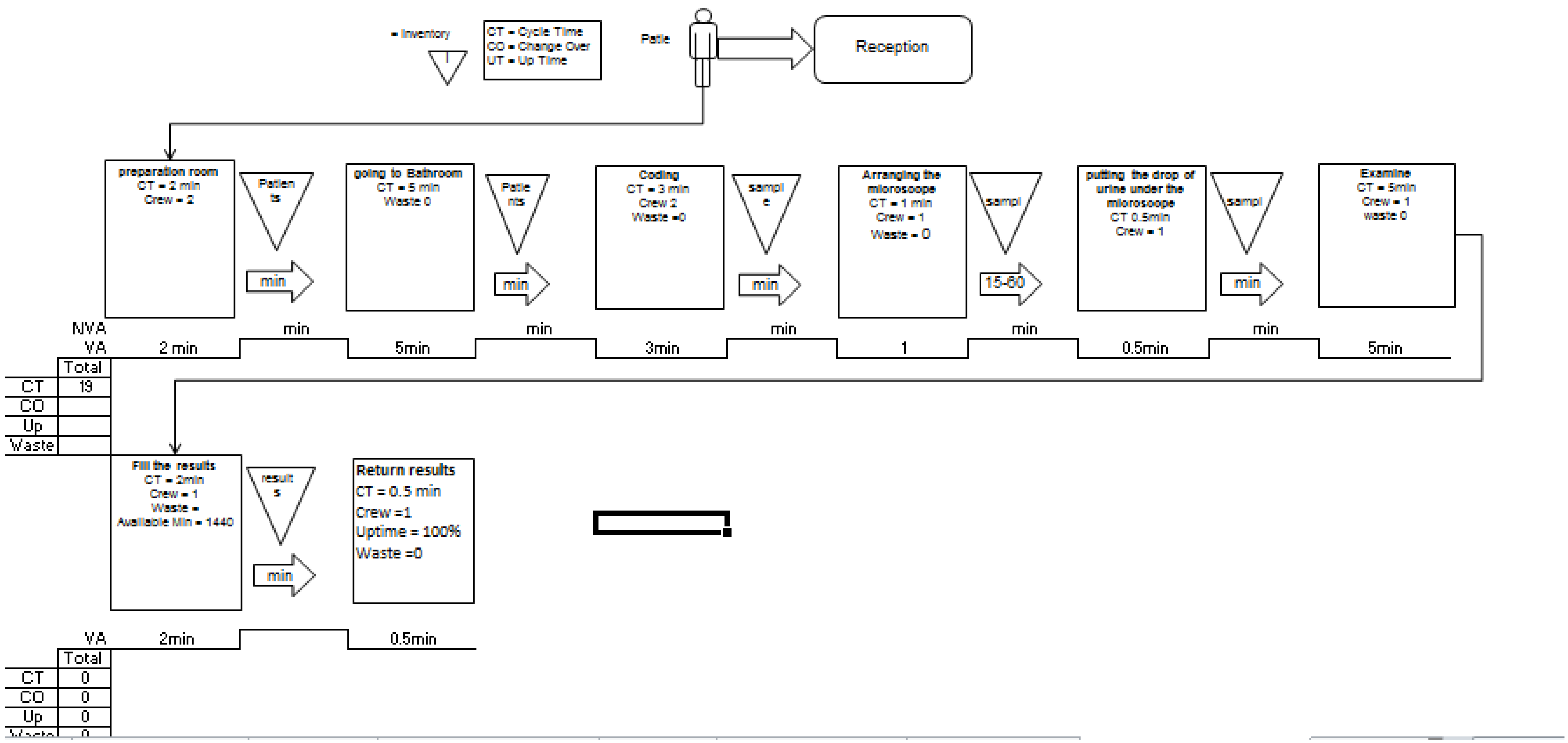


Figure 29: Improved VSM for urinalysis

Simulation of the new VSM: The simulation results of the improved VSM shows that the performance of the newly improved system is better than the before. The simulation is done by simulating the newly improved value stream mapping. The patient arrival data is used by the previously collected data and the distribution is made by input analyzer whereas the other processes are defined by a constant distribution and the values of the process are constant too.

Simulation of Urinalysis:

The simulation results of the newly improved value stream map

Process name	**Improved cycle time**	**Simulation results**
Urinalysis	19 minutes	25.93minutes

Table 16: Simulation results of Urinalysis

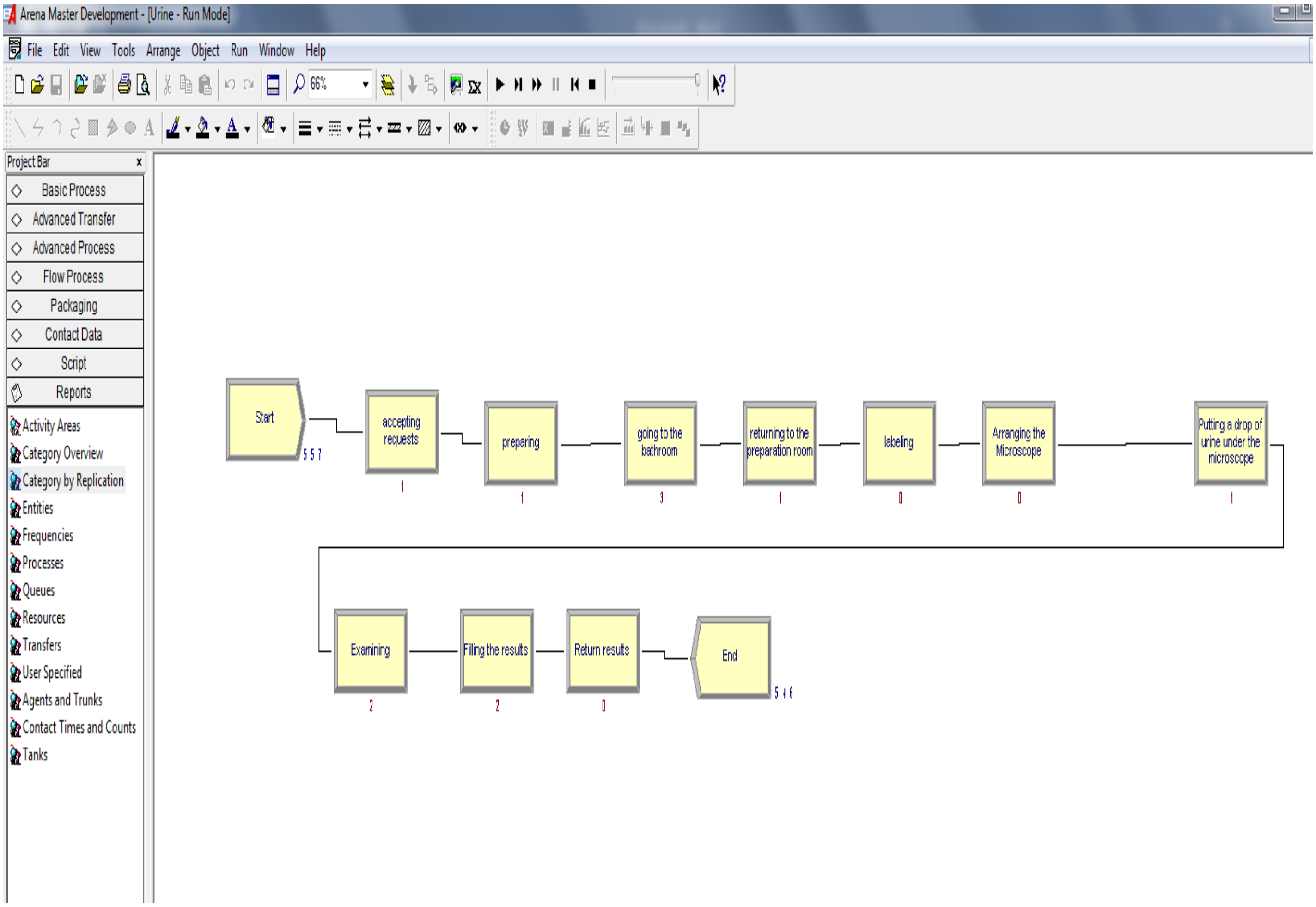


Figure 30: Simulation of Urinalysis

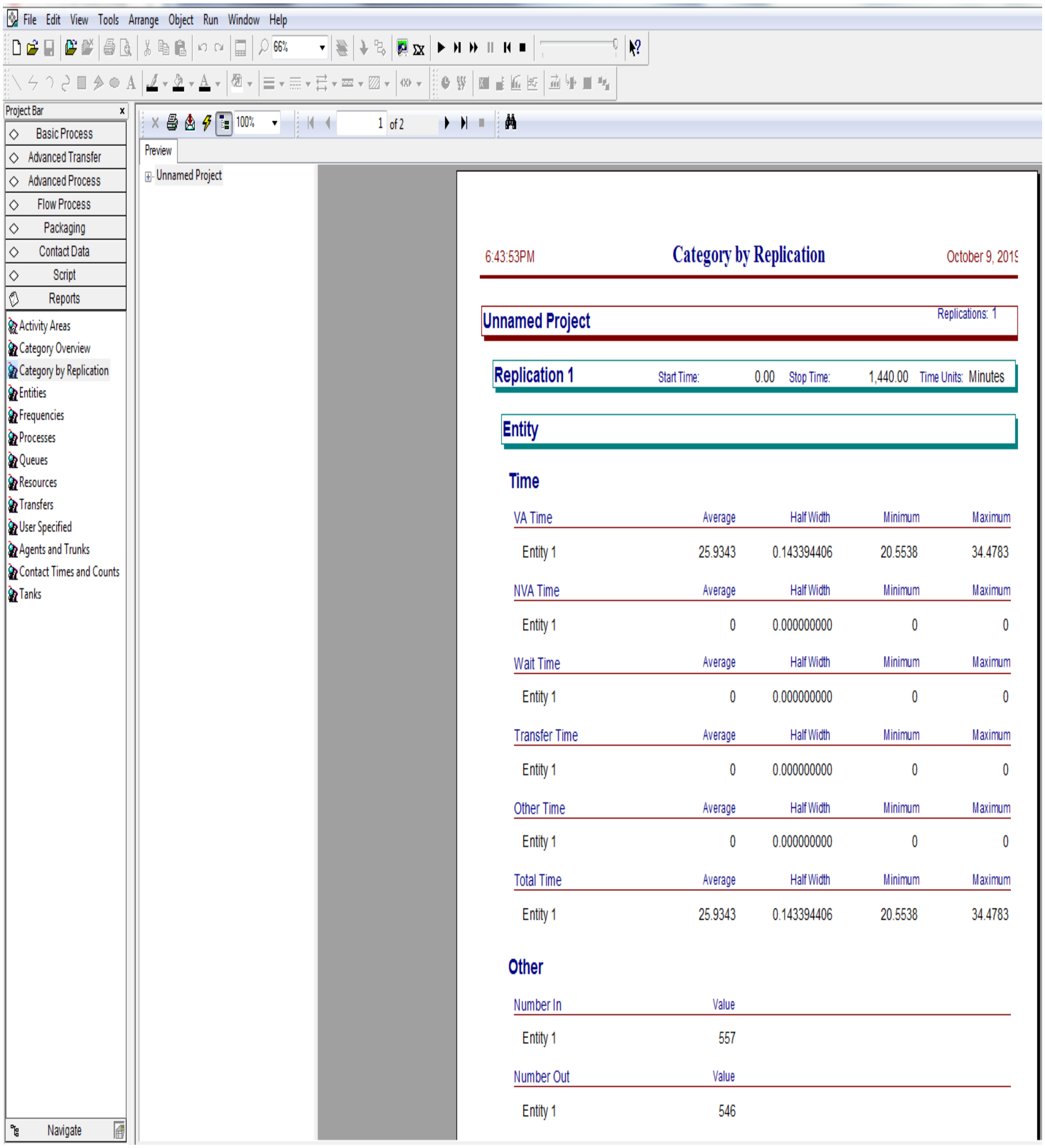


Figure 31: Simulation results of Urine

Simulation results of chemistry: The simulation of chemistry is done by simulating the newly improved system. In addition, the contribution of patient arrival is done by previously collected data

Process name	**Cycle time of the newly improved VSM**	**Simulation results**
Chemistry analysis	44.5 minutes	72.87 Minutes

Table 17: Simulation results of Chemistry

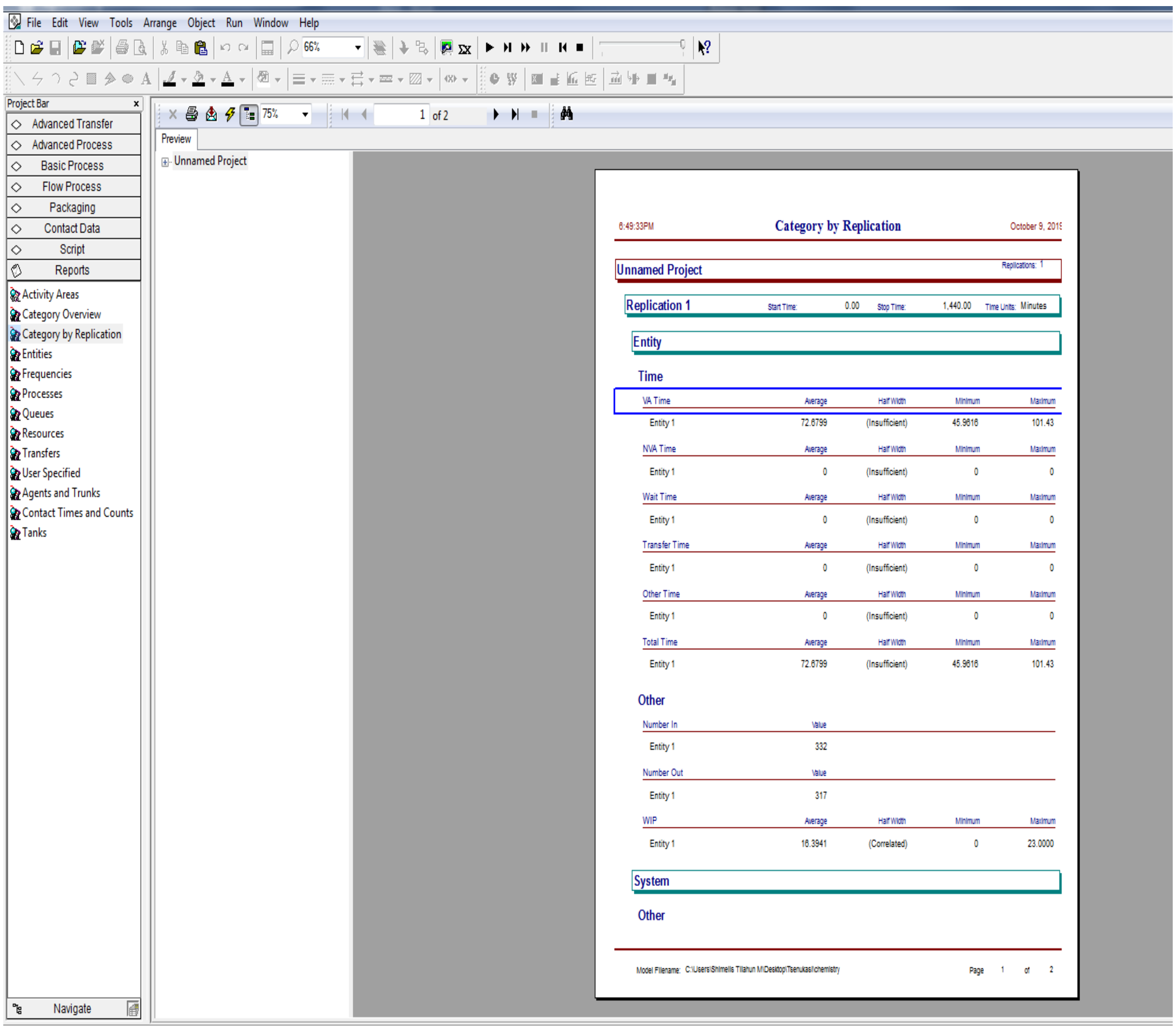


Figure 32: Simulation results of chemistry

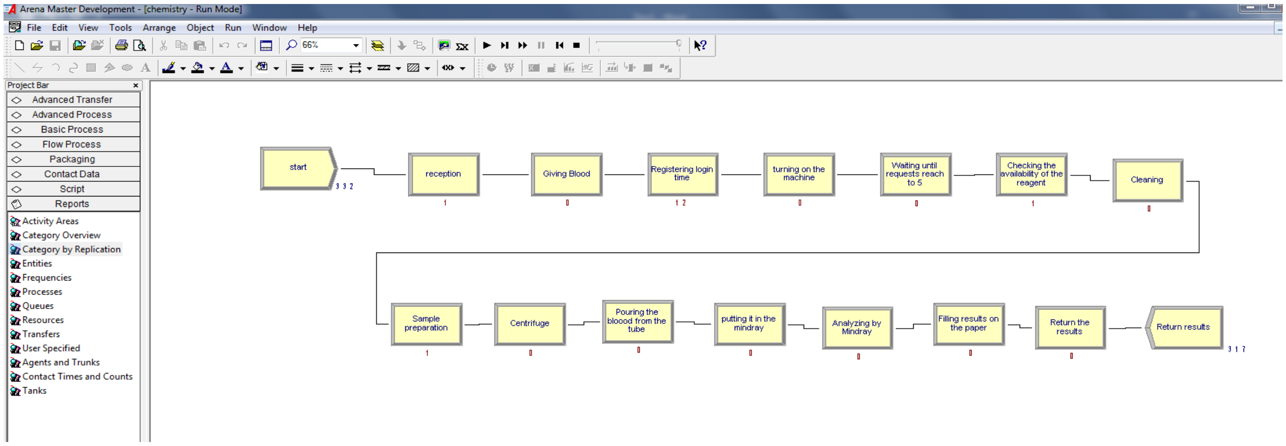


Figure 33: Simulation of Chemistry

Simulation of stool analysis:

The simulation of Stool analysis is done by simulating the newly improved system. In addition, the contribution of patient arrival is done by previously collected data.

Process Name	**Cycle time of the improved VSM**	**Simulation results**
Stool Analysis	22 minutes	23.17 minutes

Table 18: Simulation results of stool analysis

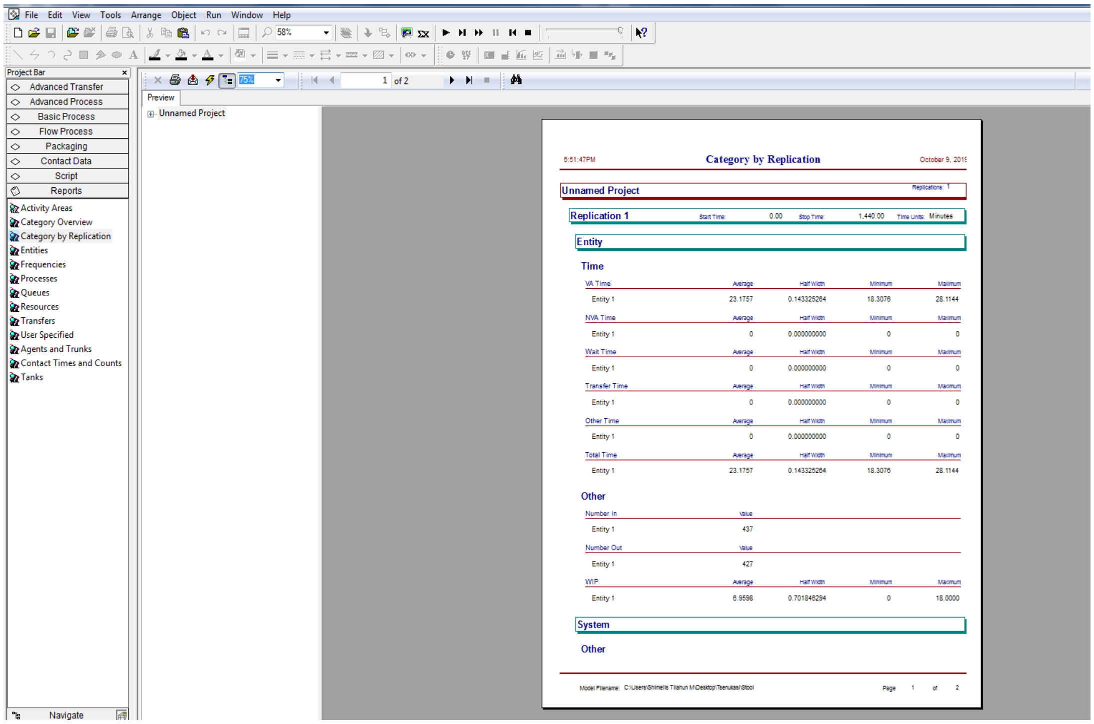


Figure 34: Simulation results of stool Analysis

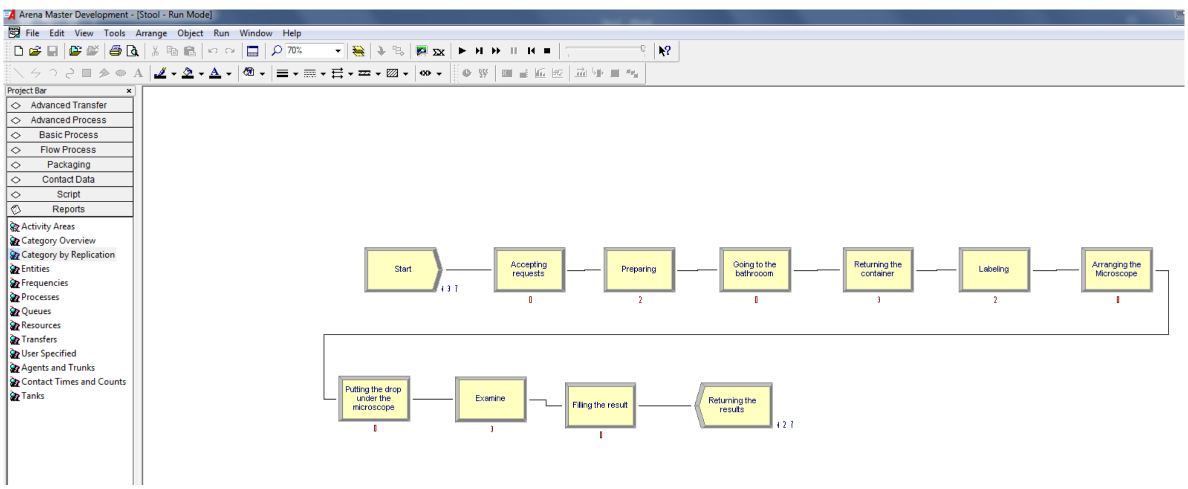


Figure 35: Simulation of stool Analysis

Simulation of CBC:

The simulation of CBC done by simulating the newly improved system. In addition, the contribution of patient arrival is done by previously collected data.

Process Name	Cycle time of the improved VSM	Simulation results
CBC	15 minutes	15.72 minutes

Table 19: Simulation results of CBC

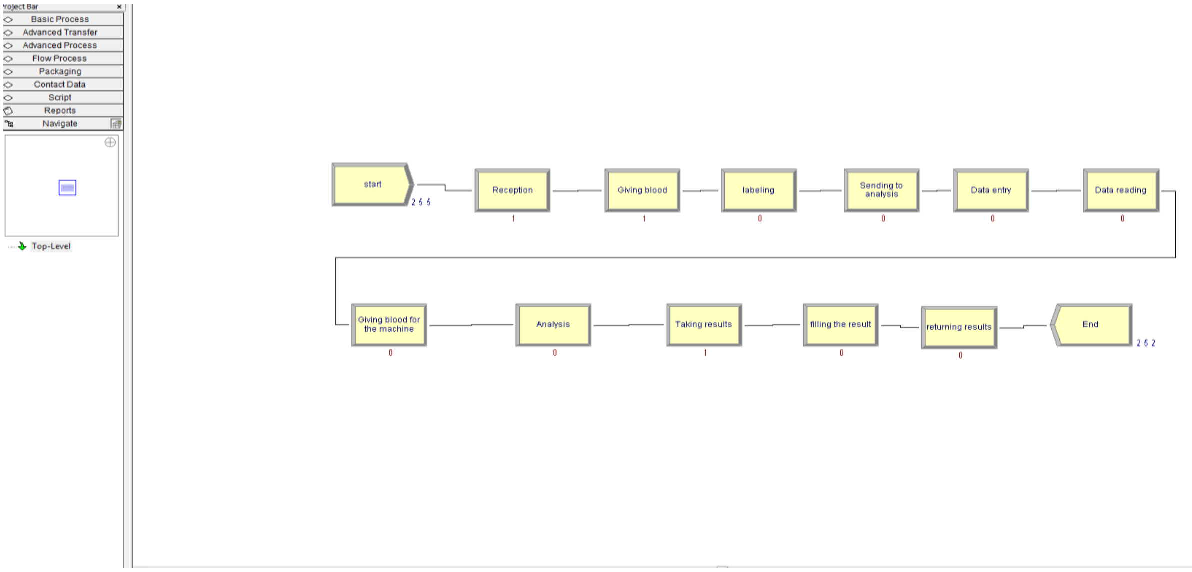


Figure 36: Simulation of CBC analysis

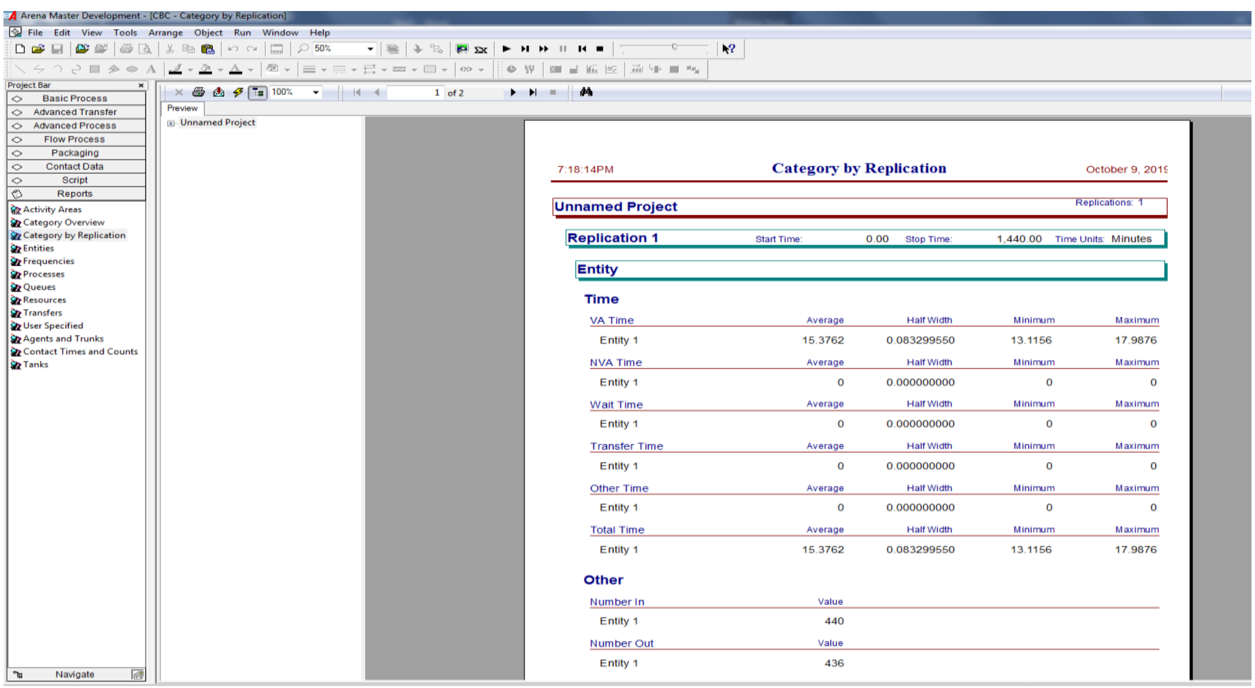


Figure 37: Simulation results of CBC

4.2 Discussion

Data has been collected from different service stations in the hospital and the station with highest waiting time and customer complaints is laboratory department. Data has been collected from 1520 patients in five departments 90% of them complained about laboratory department. Besides that, from time measurement results in laboratory service station patients are forced to spend an average of 236 minutes in laboratory, which is a high waiting time from the remaining four service stations. After the preliminary data collection leads to laboratory department the researchers focus on the process of laboratory department, which are CBC, chemistry, stool analysis and urinalysis. The DMAIC road map is experimented on these departments. On the define stage of the roadmap process mapping and SIPOC are done to understand and define the problem.

In the measurement stage of DMAIC VSM has been done and from the maps different non value adding activities are sorted out such us collecting results for a specific number of time without passing the results for patients, lack of automation, holding requests until they reach to 40 to start examining and etc. (discussed in detail in Analysis part).

Those non value-adding activities are omitted and a new VSM is developed and cycle time has been reduced in each departments

Name of process	Cycle time before DMAIC	Cycle time after DMAIC	Simulation results
CBC	40.5minutes	15minutes	15.72Minutes
Chemistry	157.5minutes	44minutes	72.87 minutes
Urinalysis	53.5minutes	19minutes	25.93minutes
Stool analysis	50minutes	22minutes	23.17 minutes

Table 20: cycle time of the before and the after

The simulation results show that the newly improved system can improve the waiting time in the laboratory. Generally, DMAIC is a remarkable methodology to understand variation and wastes in hospitals and to improve processes.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1Conclusion

In a competitive world like this it is must for service providers to satisfy the customers that they are serving. Quality of service in healthcare has different attributes by standard key performance indicators and based on the patient's requirement too. In Ethiopia the healthcare services do not reach the whole population not just that but the available healthcare services have so many problems starting from the shortage of resources (labor and material) to inefficient and ineffective quality of service. And the hospitals aren't that active in exploring different ways to improve the existing process and to improve the quality of healthcare especially in public hospitals.

This research study experiments different possibilities to improve the healthcare service by addressing the requirement of the patients through lean six sigma. To do so a case hospital is selected based on the performance report of the EHRIG. Based on the report Yekatit 12 hospital has a low performance and data has been collected from different departments within the hospital. Finally, from the results of the collected data laboratory department is selected as a case area.

Laboratory service station was the case area selected for this research and there are many departments under this service station. The existing system of the service station is analyzed by the DMAIC methodology of LSS. Based on the collected data laboratory service station faces a prolonged waiting time and there is variation in some of the process within the services station.
LSS clearly identifies what the problems and based on the results a new process developed by VSM to minimize those problems. The existing process and the newly improved process is simulated by arena simulation software.

In the value stream mapping the value adding activities and the non-value adding activities are clearly identified and the control charts showed some processes are out of control and there is variation within the processes. Waiting until results reach to some specific numbers in stool analysis and urinalysis, the lack of automation and lack of printers and unnecessary processes in CBC and Chemistry are avoided. By avoiding those problems and non-value adding activities a new Value stream map is developed. And the cycle time is reduced from 53.5minutes to 19minutes in urinalysis, from 50 minutes to 22 minutes in stool analysis, from 157.5 minutes to 44minutes in chemistry and from 40.5minutes to 16minutes in CBC. And the results from the VSM are checked on arena simulation and the simulation results shows that the performance of those departments can be improved by the newly designed value stream mapping.

Timeliness is one of the requirement and health care sectors should seriously consider the delivery time of their services. Finally, the researcher concluded that integrating lean and six-sigma can really improve processes in hospitals and DMAIC methodology should be applied in health sectors.

5.2 Recommendations

From findings and data collections results of this research, the researcher recommends the following suggestions

- The Beckman Machine can be automated with few adjustments, which as a result will ease the process by avoiding unnecessary activities. The bar code reader will avoid the data entry manually and connecting it to a printer reduces the time that the laboratorians take to write on computes and on papers.
- The adjustment on Beckman Machine will also help to take samples in a batch instead of one at a time so that will improve the waiting time that patients spend waiting and it will also increase the number of patients treated per day within the hospital.
- The inpatients and the staffs should need to have another waiting line instead of jumping in the queues. Because the jumping of the queues is one of the reasons that create variations between the waiting times.
- One additional laboratory assistant should be employed to deliver results for patients especially in urinalysis and stool analysis. In the current case, the laboratory technologists hold the results until the results reaches 20 and this creates a prolonged waiting time so a laboratory assistant should be hired and give results one by one.

5.3 Future Study area

This research considers the use of automated machines and adding a human resource in order to minimize the prolonged waiting time in the Laboratory department but it did not consider the cost that deploying this resources will take incurs so as a future study area the researcher suggests cost benefit analysis should be any side with the process improvement.

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ANNEX

Interview questions Quality improvement of healthcare through lean six-sigma

Dear Participant,

Addis Ababa Institute of Technology is conducting MSC research entitled "Quality improvement of healthcare through lean six-sigma." TSINUKAL BEZABIH carries out this research under the supervision of AMEHA MULEGETA (PHD). The study aims to investigate process improvement in YEKATIT 12 hospital through lean six-sigma methodology. This semi structured interview aims mainly to assess how processes are being carried out in this hospital, which activities have wastes and to assess causes of patient dissatisfaction.

We would like to reassure you that responses given will solely be used for academic purpose and aggregate results will be disclosed in the study report. Answers provided will be analyzed anonymously and your specific information will not be revealed in any way.

Your participation in this study is voluntary. You are free to withdraw your consent to participate in this study any time. Refusal to participate or withdrawal will not affect you in anyway. You have been given the opportunity to ask any questions regarding the research and to receive answers concerns areas you did not understand.

It takes approximately only 20 Minutes to fill out the questionnaire, and I am kindly requesting to answer the interview questions in a professional manner with utmost honesty, at a suitable time. Thank you in advance for your cooperation and professionalism in answering the questions. For any inquiry, please contact TSINUKAL BEZABIH at 0912374068 or email bezabihtsinukal@gmail.com.

Concerns about any aspect of the study may be referred to AMEHA MULUGETA (PHD), Thesis advisor, email amehamulu@gmail.com and phone number 0911- 94-80-14.

I voluntarily consent to participate in this study. In this signing form I certify that I am 18 years of age and older. I will be given a copy of this consent form.

____________________________________ ___________________________

Signature of participant Date

I certify that I have presented the above information to the participant.

____________________________________ ___________________________

Signature of the investigator Date

Patient ID Number

____

Age

____

<u>This semi structured interviews are designed for patients of YEKATIT 12 hospital</u>

1. Were you served in this hospital before this time?

   YES ☐ NO ☐

2. If your answer is no what is the reason?

   ____

   ____

3. If your answer is yes, how many times did you served in this hospital?

   ____

4. In which service stations were you served?

   ____

   ____

5. In which service station did you spend more time?

   ____

   ____

6. What was the path you followed?

   ____

   ____

7. Do you think the system is easily understandable?

   YES ☐ NO ☐

8. What problems did you encounter at the time of your service?

9. Compared to other health services, this hospital's service is relatively.

   GOOD ☐ BAD ☐ VERY GOOD ☐ EXCELLENT ☐

10. Among the problems you encountered during your stay at the hospital, which problems are severe?

Semi structured interview questions for the laboratory department

1. Describe the type of services you deliver in this department.
2. What types of equipment's are used to deliver your services?
3. Describe the method used to coordinate patient/material movements from each service station to the service stations.
4. Per service range, how many hours of a day is productive and how many are idle?

What is to be observed?

- ✓ Delivery time for patients in each service stations
- ✓ Flow process steps from patient entry to exit
- ✓ The range of times (fastest to slowest) taken to make/provide services in each service station from entry to exit?

- ✓ The layout of every service stations within the hospital

Summary

The semi structured interviews, which are prepared for the laboratory department aims to identify wastes within the service stations. Finally, a waiting time waste and patient flow is quantified by observation and time study.

No	Title	Author	Objective	Methodology	Outcome
1	Decreasing the dispatch time of medical reports sent from hospital to primary care with Lean Six Sigma	*Yara L. Basta et.al*	To dispatch 90% of medical reports on the day of the patient's visit by improving the logistic process.	DMAIC	After implementation, 90.6% of the reports were dispatched on the day of the visit.
2	Lean Six Sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery	*G. Improta et al.*	To show that Lean Six Sigma represents an appropriate methodology for the development of a clinical pathway which allows to improve quality and to reduce costs in prosthetic hip replacement surgery.	DMAIC (*Define*, *Measure*, *Analyze*, *Improve*, *Control*) roadmap	The average length of stay was reduced from 18.9 to 10.6 days (−44%).
3	The application of Lean Six Sigma methodology to reduce the risk of healthcare–associated infections in surgery departments	*Emma Montella et.al*	The application of the Lean Six Sigma (LSS) methodology to reduce the number of patients affected by sentinel bacterial infections who are at risk of HAI.	Data on more than 20 000 patients who underwent a wide range of surgical procedures between January 2011 and December 2014 were collected to conduct the study using the departmental information system and DMAIC roadmap	20% reduction in the average number of hospitalization days between pre intervention and control phases, and a decrease in the mean (SD) number of days of hospitalization amounted to 36 (15.68), with a data distribution around 3 σ.

4	Reducing Patient Waiting Time in Outpatient Department Using Lean Six Sigma Methodology	*E. V. Gijo and Jiju Antony*	To reduce the longer waiting time by using LSS methodology	DMAIC roadmap, cause and effect diagram, value stream map and statistical tools	The average waiting time reduced from 57 min to 24.5 min and the standard deviation was reduced to 9.27 from 31.15 min.
5	Applying lean six sigma to improve healthcare	*H.Long et.al*	Application of LSS to improve the medical process of acute myocardial infarction**.**	DMAIC, value stream mapping and cause and effect diagram	Cycle time of the improved door-to-balloon process decreased by 58.4%, Process cycle efficiency increased from 32.27 to 51.81% and average days of the hospital got decreased by three days.
6	Application of Lean-Six Sigma to Improve Quality in Healthcare Industry	*Suman.K et.al*	To identify the current challenges being faced by health care industry and ways to tackle them using Lean-Six Sigma	DMAIC, failure mode analysis, cause and effect diagram, value stream mapping and pareto chart	50% improvement is made in capacity, 36% in idle time and 31% in utilized time.
7	Axiomatic Design of a Framework for the Comprehensive Optimization of Patient Flows in Hospitals	*Dominik T et.al*	To discuss a comprehensive, system-based approach to achieve a factual holistic optimization of patient flows.	Axiomatic design framework	A holistic optimization of hospital patient flows, by reducing the complexity of the system.
8	Applying lean Six Sigma to reduce linen loss in an acute care hospital	*Sandy L. Furterer1*	To apply the Lean Six Sigma problem solving methodology and tools to improve the linen processes.	Six Sigma DMAIC (Define-Measure Analyze-Improve-Control) problem solving approach.	improve the key linen operational metric, soil to clean linen ratio by 16% and saved $77,480 for the first year
9	Using Six Sigma tools to improve internal processes in a hospital center through three pilot projects	*J. De la Lama et.al*	Reduce the variability scheduling pre-anesthesia consultations, (2) reduce absenteeism of outpatients and reduce delays, and (3) increase the efficiency of Internal Medicine Rehabilitation ward.	Data of hospital stays, occupancy rates and discharges were studied.	The delay is minimized

10	Improvement of management process by using lean six sigma tools in some big organization of food industry	*Alicja Maleszka and Magdalena Linke*	To evaluate the impact of Lean Six Sigma tools on the certain management process to eliminate or reduce wastage	DMAIC FMEA Pareto chart Value stream mapping Regression and correlation TPM Hypothesis tests Visualizations Poka- yoke SMED	Reduced wastage and cost reduction
11	Performance Enhancement and Continuous Improvement in Healthcare: How Lean Six Sigma "Hits the Target"	*Barnabè et.al*	Discuss the potentials of LSS in healthcare, highlight the factors enabling a LSS intervention in a Healthcare setting and to evaluate performance improvement in a hospital	House of quality Design for six sigma DMAIC Pareto chart Cause and effect diagram	Deduced that applying LSS in hospital can able to reduce cost, waste reduction and it can increase efficiency
12	Applying lean six sigma improvement methodology to increase catheterization laboratory efficiency	*Berna Umut and Peiman Alipour Sarvari*	To increase catheterization laboratory efficiency	Value stream mapping Root cause analysis Process improvement actions	Risk minimization Waiting time reduction Efficiency maximization
13	Formation of Six Sigma Infrastructure for the Coronary Stenting Process	*Tolga et.al*	To reduce the number of complications occurring during coronary stent insertion process	DMAIC Failure mode effect analysis Root cause analysis	Areas that caused the complications has been identified
14	Application of Lean Sigma to the Audiology Clinic at a Large Academic Center	*Matthew G.et.al*	To improve audiology scheduling and utilization in a large tertiary care referral center	Value stream mapping Schedule utilization and lead time were measured for five months	Block utilization is increased Lead time is reduced Booked appointment is increased
15	Integration of Six Sigma Methodology to Reduce Complications in a Private Hemo dialysis Center	*Celil.G et.al*	To evaluate the complications occurred during and after the Hemodialysis sessions made in a private Hemodialysis center in terms of their sigma levels	Pareto chart SIPOC Trainings Total count of complications	Causes of the complications are identified and improvement actions are taken

			and severity.		
16	Process Improvement in Healthcare	*Jeroen.M et.al*	Develop a unifying and quantitative conceptual framework for healthcare processes from the viewpoint of process improvement	Breaking down work into micro processes, tasks, and resources	Opportunities for process improvement are identified from a diagnosis of the process under study. By providing conceptual models and practical templates for process diagnosis, the framework relates many disconnected strands of research and application in process improvement in healthcare to the unifying pursuit of process improvement.
17	Process improvement based on an integrated approach of DMAIC and multi-method simulation	*A. Ahmed, J. Page and J. Olsen*	To improve and control processes, reduce non-value-added activities and support decision-making by using Six Sigma's methodology alongside Any Logic; using agent-based, discrete event, and system dynamics models	DMAIC AnyLogic simulation	Six sigma methodology along with AnyLogic simulation can able to reduce defects in a process
18	Application of Lean Six Sigma tools to minimize length of stay for ophthalmology day case surgery	*Nabeel. M et.al*	To streamline processes and enhance productivity of a hospital's ophthalmology department.	DMAIC Value stream mapping	Reduction of patient length of stay in hospital
19	Improving Timeliness and Efficiency in the Referral Process for Safety Net Providers	*Gloria J.et al*	To increase the efficiency and the timeliness	DMAIC Cause and effect diagram Control charts	Total process time is reduced
20	Risk management and cost reduction of cancer	*Andrea Chiarini*	To understand whether Lean Six Sigma tools are useful to reduce safety and health risks to	DMAIC FMEA Value stream mapping	Reduction of capital Improved safety Improvements are made in terms of motion and transportation

	drugs using Lean Six Sigma tools		nurses and physicians who manage cancer drugs and to analyze economic improvements reached by the means of lean six sigma		
21	Deployment of Lean Six Sigma in Care Coordination	*Susan.E et al*	To describe a systematic approach to the discharge process aimed to improve transitions of care from hospital to post–acute care, utilizing Lean Six Sigma methodology	SIPOC Cause and effect diagram	It can able to reduce avoidable readmissions
22	Impact on integration of Lean Manufacturing and Six Sigma in various applications	*G.Muthukumaran et.al*	To present the concept on how to merge lean and six-sigma in industries to improve quality of a product and to reduce process variability	Computer and Google searches towards lean, six sigma and lean six sigma	Lean six sigma can bring a dramatic change in any industrial process and it can able to improve the quality of a product
23	Evaluation of environmentally sustainable actions in the medication process	*Patrícia.O et.al*	To analyze sustainable actions from an environmental point of view in the medication process, from the reception of the prescription of the pharmacy to waste discard by nursing	Process Mapping with the identification of problems, Brainstorming, 5 Why's, Impact Effort Matrix and Effect Cause Matrix	Reduction of 74.8% of chemical, infectious and sharps waste, an increase of 33.3% of common recyclable and 20% of common non-recyclable In nursing, there was a reduction of 22.5% of chemical, infectious and sharps waste, an increase of 22.9% of common recyclable and an increase of 20% of common non-recyclable
24	The application of Lean Six Sigma to the configuration control in Intel's manufacturing R&D environment	*Rahul. P et.al*	To provide an example of Lean Six Sigma (LSS) application in research and development (R&D) organizations to eliminate waste and improve systems based on available	Collecting baseline data Value stream mapping DMAIC Pareto chart FMEA	60% reduction in idle time

			data that in turn improves the innovative environment		
25	Observational study using the tools of lean six sigma to improve the efficiency of the resident rounding process	*DAVID.V CHAND*	To use a data driven approach to eliminate examples of waste and variation identified in resident rounding using lean six sigma methodology	Surveys Observation DMAIC T-test	Non value added time is reduced by 64% per patient Pre rounding process is eliminated
26	Lean Six Sigma, Root Cause Analysis to Enhance Patient Safety in Healthcare Organizations: A Narrative Review, 2000-2016	*Sara O. Salem et.al*	Aims to describe the principles and objectives of LSS and RCA tools with a special focus on their diverse roles in healthcare organizations.	A computer searches of PubMed, OvidSP, and Google Scholar (2000-2016) were made using keywords such as Lean, or Six Sigma or lean six sigma or medication errors (MEs) or adverse drug events or RCA which retrieved thousands of references but only 110 articles were included in this paper	Lean, Six Sigma, LSS, and RCA are powerful quality improvement tools that prevent adverse events, produce better quality services and result in enhancing patient satisfaction and safety. These quality tools also decrease costs, work performance variance, waste and increase customer satisfaction and the work performance of healthcare professionals
27	The Applicability of Lean and Six Sigma Techniques to Clinical and Translational Research	*Sharon A. Schweikhart, and Allard.E Dembe*	Concerned on the potential use of Lean and Six Sigma to improve the processes involved in clinical and translational research	Available literatures involving applications of Lean and Six Sigma to health care, laboratory science, and clinical and translational research are reviewed	Lean and Six Sigma process improvement methodologies are well suited to help achieve NIH's goal of making clinical and translational research more efficient and cost-effective, enhancing the quality of the research, and facilitating the successful adoption of biomedical research findings into practice.