A COMPARISON OF DIFFERENT WORKFLOW MODELING TOOLS

A COMPARISON OF DIFFERENT WORKFLOW MODELING TOOLS: CHOOSING THE MOST ACCURATE TOOL FOR DESIGNING A RELIABLE HEALTHCARE SYSTEM

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TITLE: A Comparison of Different Workflow Modeling Tools: Choosing the Most Accurate Tool for Designing a Reliable Healthcare System

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Dedicated to my family

ABSTRACT

The growth of software use in healthcare increases the need for designing and developing accurate systems, which raises our need to find precise tools for designing the digital flow of lab order process.

This study consists of two main parts: first, determining the best BPM (Business Process Management) tool for designing *digital* lab order process flows. The chosen tool was used to design an improved digital lab order process flow for Humber River Hospital's lab order process in a highly advanced way; the new workflow tool enables the workflow process developer to better represent and analyze the process tasks based on the needs of the process flow.

In the first part of the study, we selected 15 open source workflow tools, and filtered them based on certain criteria, which include the availability of: analysis done by the tool, tool features, support, a graphical editor, an execution engine, and simulation. We chose four tools (YAWL, Together, Bonitasoft, and NOVA) that satisfied these criteria.

We evaluated each tool based on the outcome of the new workflow design by using the four selected workflow tools separately to design the new workflow process. We evaluated the tools by following a mixed qualitative and quantitative methodology by collecting qualitative data supported by the quantitative data generated by the tools.

Based on results from following the mixed methodology, as well as the results that were derived from studying the designated workflow process f*uture* lab ordering designing outcomes – we recommend YAWL (Yet Another Workflow Language) as the best workflow tool to use in the design of the new *digital* lab order process flow design.

In the second part of the study we examined the *current paper-based* lab order process at Humber River Hospital; this included analyzing the process information to define the

crucial points of errors in the process, bottlenecks of the process, most time consuming process tasks, and the main process points where improvements could be applied. The last part of part two was the design of a new fast and reliable *digital* lab order process system that used the Business Process Modeling (BPM) software tool selected in the second part of the thesis.

During the research we collected lab order process data and used a qualitative methodology to analyze the data and find the critical phases in the current process in order to improve the new *digital* lab order process flow design.

The results of this research will help in the development of future eHealth system processes by providing valuable data and recommending the right tool for designing a new process system. The new *digital* lab order process flow design will save healthcare time and money in addition to contributing to patient satisfaction. It will also provide more security to patient information than the old paper-based system. Notably, the chosen workflow tool has unique design features and components, which allow tool users to manage, control, and finish a successful workflow design efficiently, resulting in reliable digital lab order process flow design.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

AGV: Automated Guided Vehicle: a laser navigated vehicle that can be used to transport and deliver lab order samples to the lab.

BPML: Business Process Modeling Language, an XML-based advanced UML language used to develop tasks with certain conditions and guidelines in YAWL.

BPEL: Business Process Execution Language, used by process designers, programmers or technical analysts in the implementation stage of the life cycle of business process design.

BPMN: Business Process Modeling Notation, used by business analysts in designing and improving the business process modeling life cycle.

CBC: Complete blood count, an abbreviation used in lab orders when physicians order complete blood count test.

CPOE: An abbreviation for Computerized Physician Order Entry, a system for placing lab or pharmacy orders online by using electronic health record software.

CSS: Cascading Style Sheets is a language used for describing the formatting of XML or HTML files.

Cytology & Histology: A procedure where the pathologist checks samples of tissue or cells under the microscope.

ebXML: Electronic Business Process using extensible Markup Specification Language

EMR/EHR: EMR is an abbreviation for Electronic Medical Record, a patient's medical record within a healthcare setting (clinic, hospital or practice), patient information will stay within the organization.

EHR is an abbreviation for Electronic Health Record, electronic storage of patient and other data (practitioners, medical letters etc.) belonging to the healthcare system and available to authorized practitioners; patient information moves beyond one healthcare organization to specialist, hospital or clinic and contain more than patient medical record and contain all patient medical and nonmedical information related to the patient.

HTML: An abbreviation for Hyper Text Markup Language, for designing website pages.

IEEE: An abbreviation of the Institute of Electrical and Electronics Engineers.

IHE: Integrating Healthcare Enterprise, an automated system to share clinical data and tasks between healthcare organizations using software applications.

J2EE: A Java Platform, Enterprise Edition; a platform for developing software.

JavaScript: A computer programming language typically used to control web applications.

Kardex: A medication record or a legal report of the drugs administered to a patient at a hospital or a department, used by health care professionals.

Lab order workflow process or Lab round trip: The complete process of all the lab orders performed in all the departments of a hospital from the beginning of placing the order, including all the processes, concluding with adding the results to the patient record.

LAN: An abbreviation for Local Area Network, a computerized network used to connect computers in an institution or a small area like a home or library.

Medical Laboratory Technologists: Sometimes called Technologists, a healthcare professionals who perform tests on a laboratory samples and monitor, operate laboratory instruments to analyze and provide information to physicians to monitor and prevent disease.

MS Project: Microsoft Office Project software tool, a timeline tool designed by Microsoft Corporation to set the time, tasks, roles, and resources of any potential project

MT: An abbreviation for the MT electronic health record platform. Used by healthcare professionals to record or update patient health record, it supports clinical decision software plugins and is used for writing reports, physician notes, and computerized physician orders; the software comes in different versions: 6.0 is the latest.

Order sets: A set of lab or pharmacy orders preset by physicians using a specified feature in MT health record software.

PDA: Personal Digital Assistant, or Personal Data Assistant: a mobile device used as a note or information organizer.

Processing time: The time from when lab order samples originating in the lab are placed in the process analyzer to the completion of the test and the submission of the results into patient health records.

PTT: An abbreviation for Pneumatic Tube Transport system, a *lab order* sample delivery system consisting of a pneumatic tube network running between all of the hospital's units and labs using pneumatic capsules to deliver collected samples from these units to the lab.

STAT: An abbreviation used in lab orders to specify a lab test as urgent.

Turnaround Time: The completion time of a lab order including all process stages, starting from the time the order is placed through all the processes and steps, to the end of the process when the results of the test are submitted to the MT system.

WFMC: Workflow Management Coalition

WSDL: Web Service Description Language

XML: Extensible Markup Language, which expresses a set of rules to form a readable language by machines and humans.

XPath and XQuery: A data model based on the XML information set, allowing a user to select data from an XML document. For example, XPath can be used to create an unordered list of data from a subset of an XML document, while XQuery can be used to create a more complex list; XPath is an essential part of XQuery.

XPDL: XML Process Description Language, a process format for storing a representation of a process diagram.

YAWL: *Yet Another Workflow Language* is an open source software platform used to design workflow patterns. It has design features to set rules and conditions for the workflow process.

1. CHAPTER ONE: INTRODUCTION AND PROBLEM STATEMENT

In recent years, computer use in hospitals has increased dramatically. Hospitals have switched many of their administrative operations from paper-based to electronic by using different types of software and technology, such as Electronic Medical Record (EMR) and Electronic Health Record (EHR) systems, see Pappas et al [1].

These new computer systems have saved processing time and provided the opportunity to all related hospital departments to edit, to follow up with the updates of their data, and to save documents in a secure database for future needs, as shown by Jenkins and Eckel [2] and Russello et al [3]. The main reason behind selecting the topic of this thesis is to find the best workflow business process modeling and designing tool for this environment. The need for a reliable modeling tool required us to find the best practice and tools to use for designing the new digital lab process environment of the new Humber River Hospital as its healthcare system continues to develop.

Confidentiality in eHealth is an important aspect when designing a new process; this drives many healthcare developers towards looking for reliable tools when designing a new process. The work in this thesis will help process developers to choose the right workflow tools for their designs and to create reliable eHealth applications to carry out necessary tasks with maximum security. The study by Russello, Dong and Dulay [3] defines the process of designing an "access right" framework that can provide controllable entities capable of fulfilling their duties. The authors chose an eHealth application due to its direct involvement with "flexibility and security" when they designed their framework.

Some studies shown that workflow tools are advantageous tools and can be used to design different systems. The study by Pappas et al [1] presents the idea of using

workflow automation tools to create "Ward-In-Hand," a patient management tool. This tool allows the hospital ward staff to access patient records wirelessly and permits physicians and nurses to use these records for day-to-day activities through PDA devices through an IEEE 802.11 wireless LAN.

This research aims to answer two important questions. First, which workflow modeling tool is the best to use when designing a new digital lab order process system in a healthcare system? Second, why should we switch from using a paper-based lab order system to using digital-based lab order system?

The research goal is to investigate two essential problems in eHealth and the healthcare system: First, the need for reliable workflow tools that can be used to design a new digital process in the healthcare system, by examining and comparing different workflow tool and choose the best tool for the new design. Second, the need for switching from the old paper-based system used in the healthcare setting (as in Humber River Hospital) to a new electronic system capable of adhering to digital technology in the healthcare system, by exploring the benefits of saving lab order processing time, managing the flow of lab orders, controlling lab processes, and securing patient information.

To reach the first goal of the study successfully, we examine 15 workflow tools and recommend the best tool based on certain criteria, then use the selected tool to help in designing the new *digital* lab order process. Workflow tools can play a crucial role in designing a successful process and providing secure environments for developers or users when working with patient data.

We collected current lab orders data from all process stages and found that current lab order process orders consisted of the following: placing an order, printing labels, receiving the order, collecting the samples, delivering the samples to the lab, processing the sample, and analyzing and submitting the results. These work process orders were paper-based and required manual procedures. The current process affects numerous

aspects of the healthcare system; the paper-based system uses more resources, requires more time to complete, and has more possibility for errors.

The second part of the study is to determine the main design steps of the new lab order process, and then start designing the new process based on the requirements of a new digital system.

The main design steps include: designing the new *lab order process* work tasks, drawing the process workflow diagrams, and defining the roles of the staff involved in the lab orders. The analysis of the collected data shows that the current paper-based order has multiple issues: lab orders take a long time to be completed, they contain mislabeled sample errors, the processing cost of samples increases due to the long processing time, there is a lack in mobility with current order placement, and blood sample collection process needs major improvement in its stages.

After gathering all the required information described before for the current lab order process, the next step was to analyze this information to design the new digital process. The new process flow consists of the following tasks: ordering, receiving the orders, collecting the samples, delivering the samples, processing the samples, delivering the results, and order confirmation and verification.

The first part of the study is dedicated to examining and choosing a reliable workflow tool to help in designing the new *digital* lab order process. Due to some limitations of time, duration of the study, and preset criteria, we examined various open source workflow tools, but chose only 15 tools.

Some studies have previously reviewed some of the workflow tools, as shown by Fish et al [4] and Brogi et al [5]. A study by Adriansyah et al [7] about the design and implementation of performance tools analyzes a variety of performance criteria using information from existing process models logs; these tools also help in making more effective improvements and decisions. The authors chose the YAWL process model

language for applying their techniques. A comparison is performed between process instances and YAWL process models and "performance characteristics, obtained from replaying the log in the model", are projected onto the model.

The study by Fish et al [4] identifies some workflow concerns and difficulties researchers found with previous research; the authors try to examine some workflow challenges that other researchers missed; the study focuses on how to identify some fundamental factors that need to be considered when performing "teleretinal readings" by specialists.

Another Study by Brogi et al [5] explains the approaches used for "translating Business Process Execution Language (BPEL) processes into YAWL workflows". The authors chose the YAWL language because of its well-defined formal semantics; hence, the methodology they recommend outlines a YAWL pattern for each BPEL activity; the authors chose YAWL for its ability of "handling complex data transformations and Web service integrations" as an advanced specification when compared with other tools.

However, our study is the first to identify and examine multiple open source workflow tools and assess them based on preset criteria to choose the best, easiest, and most useful features across all the tools, an essential first step toward the ultimate goal of developing a digital flow process.

The intention of the first goal of the study is to find the most accurate workflow tool and use it to accomplish the second goal of designing the new digital lab order process. The information about tool descriptions and evaluations is collected by studying each workflow tool individually. We use the workflow process testing model to evaluate the capability of the selected tools and categorize the tools based on certain criteria such the availability of an analysis tool, tool features, support, graphical editor, execution engine, and simulation.

We examined 15 workflow tools based on the mentioned criteria and all but four did not meet the specified criteria (YAWL, Together, Bonitasoft, and NOVA).

The eliminated tools are: bpmn2bpel Workflow Tool, Apache Airavata Workflow Tool, jBPM Tool Workflow Tool, Anduril Workflow Tool, Kepler Workflow Tool, nexusBPM Workflow Tool, Aperte Workflow Tool, Joget Workflow Tool, ProcessMaker Open Source Workflow Tool, RunaWFE Workflow Tool, and Yaoqiang-BPMN-Editor-2.1.21 Workflow Tool, see Table 1.

Tool Name	Availability of an analysis tool	Tool modeling features	Vendor support	Graphical editor	Simulation	Execution engine	User manual	Qualified tool
bpmn2bpel		X		X				No
YAWL	X	X	X	X	X	X	X	Yes
nexusBPM				X			X	No
Kepler				X				No
Aperte		X		X	X			No
Apache Airavata		X			X	X		No
NOVA	X	X	X	X	X	X	X	Yes
jBPM Tool		X		X				No
Joget		X		X				No
Bonitasoft	X	X	X	X	X	X	X	Yes
Anduril						X		No
Together	X	X	X	X	X	X	X	Yes
ProcessMaker			X				X	No
RunaWFE		X		X			X	No
Yaoqiang-BPMN-Editor-2.1.21		X		X				No

Table 1: Tools elimination table

We evaluated each of these four tools separately based on the outcome of a new workflow design sample created for this purpose. Each tool was used separately to design a new workflow process test model (future lab ordering). The model represents a lab

order process; more details will follow in the coming chapters. The work also involved studying all the tool-design capabilities by referring to related studies, user manuals, and web pages to gather and learn more about these tools. This included using quantitative and qualitative methodologies to evaluate the tools based on certain criteria, see Table 1.

We followed a quantitative methodology to collect workflow tools information results by filtering, examining and comparing the workflow tools; then followed by a qualitative methodology for an in-depth analysis of the workflow tools. We recommend YAWL (Yet Another Workflow Language) as the best workflow tool to design the new digital lab order workflow process for the Humber River Hospital.

The YAWL workflow tool has unique features and components that allow users to manage, control, and design a successful workflow process. We chose the best workflow tool based on different factors. We considered user perspectives to be of fundamental importance. Workflow tool users prefer reliable, fast workflow tools; they also prefer to use tools that give the designer the ability to control the flow of process and provide design options that will support finishing a workflow design within a minimum time.

The tool that was chosen to help design the tasks of the *digital* lab order process workflow and direct the process flow was based on the needs of the flow process. For example, delivering a blood sample from one of the hospital departments to the hospital laboratory can be done in three ways: using the Pneumatic Tube Transport (PTT), Automated Guided Vehicles (AGV), or by sending the sample with one of the hospital staff (nurse or a lab technician) to the lab.

The benefits of using a powerful BPM tool gave us the opportunity to design the process flow so that if one of the delivery methods mentioned above worked, the system would automatically cancel the other two modes of delivery, see Figure 1.
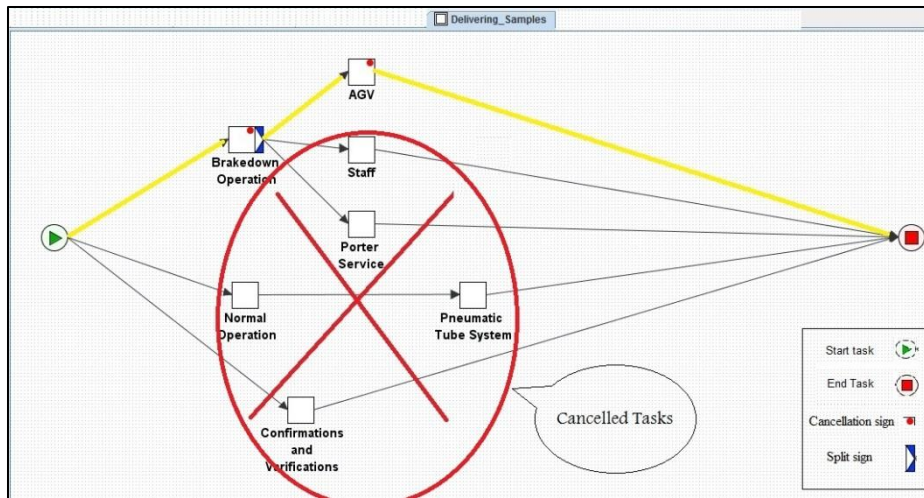
Figure 1: Sample Delivery Cancelation

The new *digital* lab order process flow design will save the healthcare organization time and money and contribute to patient satisfaction. It will also give the healthcare staff (physicians, lab technicians, nurses, etc.) the opportunity to control and manage all the new lab orders in a more efficient way. With the new lab order digital system, physicians will have the ability to order lab order by using the Computerized Physician Order Entry CPOE as one of the ways of placing an order.

In the second part of the study, we calculated some of the new digital process outcomes based on information from lab technician, ongoing and future processes, digital lab order process plans designed by the lab director, and the capabilities of the new digital process lab *Pre and Post Analytical Instrument* that was planned by Humber River Hospital.

The new digital process is expected to have a tremendous impact on operations in the Humber River Hospital such as improvement of turnaround time from 135 minutes for the *paper-based* system to 40 minutes for the *digital* system. Other improvements can include: reduce human errors caused by wrong sample labeling and providing a more secure environment for patient information when working with patient data.

The result of this research ca benefit the future of the healthcare system by recommending the right tool for designing a new process system and providing valuable data for future processes. Workflow process designers and users need to have a reliable process modeling tool to design new healthcare process flow systems; the research can improve the healthcare system and facilitate developer efforts when designing a new digital lab order process.

2. CHAPTER TWO: LITERATURE REVIEW

The field of eHealth is evolving quickly; many healthcare organizations are switching their daily operations to involve eHealth applications. eHealth technologies provide powerful tools to gain more control and management over many healthcare processes. With the help of reliable workflow tools, designing a new healthcare system will become easier and more manageable.

2.1. eHealth Applications

We need a reliable and flexible workflow tool when designing a new ehealth applications process. The study by Russello et al [3] defines a process of designing an "access right" framework that can provide controllable entities to fulfill specified duties. The authors chose eHealth application for its direct involvement with "flexibility and security" and used workflow tools to create a flexible process to allow users of eHealth application to access necessary tasks with maximum security.

There are many contributing factors in the design of a reliable healthcare process. A powerful and dependable workflow tool is one of these factors. The first thing that comes to a mind when thinking about designing a successful process is the workflow tool.

With workflow tools, process designers have more control of the process. In Pappas et al [1], the authors state that to create and manage proper execution based on the needs of the process, suitable operation of workflow automation tools is necessary. Using a workflow tool helped them to design a system that provides doctors and nurses with a list of tasks to be executed; these tasks used a workflow process to schedule new tasks, based on the activity being considered.

2.2. Patient Safety

Patient safety is an essential component of quality. Most studies define safety as protecting patients from unnecessary or potential harm due to healthcare practice errors. Patient information security is considered as a factor of quality; it becomes difficult to ensure secure care due to the sheer number of people working in healthcare, ranging from doctors to lab technicians and medical laboratory technologists, unless the design of the system facilitates complete information made available to all health care professionals in a secure way.

Labeling error is one of the factors that can lead to adverse events, which affect patient safety Miller, and Zhan [8]. The study of the current lab order in our research also showed that labeling errors are the most frequent errors that occur in the current ordering system.

Recently, in December 2004, the Institute for Healthcare Improvement (IHI) launched the 100,000 Lives Campaign in the Unites States. Their primary goal was to set firm targets and timelines for healthcare improvement, see Berwick et al [9].

One important aspect in improving patient safety is designing a reliable system. To reach this goal we need a reliable workflow tool to design a system that can provide accurate process steps and lead to a safe practice environment. There are multiple workflow tools available, but not every tool has the necessary and required *workflow analysis* feature that a workflow designer needs when designing a reliable workflow process.

2.3. Workflow Tools

A study by Van Der Aalst et al [10], defines the implementation of system supporting YAWL and creates a tool that would be able to provide direct support for a multiple pattern concept. YAWL is based on an accurate analysis of existing workflow management systems and related standards using an inclusive set of workflow patterns.

Another study by Adriansyah et al [7] investigates the design and implementation of performance tools; these tools help to analyze a variety of performance metrics using information from existing process model logs. These tools also help in making more effective improvements and decisions.

These authors chose the YAWL process model language to apply their techniques and compare performance of process instances, YAWL process models, and "performance characteristics, obtained from replaying the log in the model, which are projected onto the model". The same paper demonstrates the use of this approach in an insurance company's activities, where activities were kept for auditing purposes. These activities were mostly used for analysis.

2.4. Workflow Languages

A study by Brogi et al [5] investigates the adaptation of web services into new "heterogeneous applications" by providing an approach for "semi-automated aggregation". The intention of this study was to aggregate and deploy a new BPEL service by translating BPEL processes into YAWL workflows. The authors chose the YAWL language because of the well-defined YAWL formal semantics; hence, the methodology they recommend outlines a YAWL pattern for each BPEL activity.

The authors also chose to use YAWL because of its ability to "handle complex data transformations and web service integrations" as an advanced specification when compared with the other tools. For example, the Web Service Description Language (WSDL) interface provides only a syntactic description of the supported operations which could "severely affects the process of (semi-)automated service composition as composed services may lock during their interaction".

2.5. Use of Workflows in Healthcare

The study in this thesis involves choosing the right workflow for designing lab processes in a healthcare setting. Workflow languages have been used before to facilitate workflow processes. A study by Jenkins and Eckel [2] about "analyzing methods for improved

management of workflow in an outpatient pharmacy setting" represents work done by the authors as a time motion of "workflow analysis at a large central outpatient pharmacy". In the case studied here, a central outpatient, "pharmacy dispenses typically" 250 prescriptions per day. The analysis performed through direct observation of this pharmacy's operations for a period of eight weeks, the pharmacists' dispensing-oriented activities were characterized as either value-added or non-value-added. The suggestions resulting from this study were to shift pharmacist time more toward value-added and away from non-value-added activities.

The same study defined an application of two proposed models of the enhanced workflow: model A and model B. "Model A (expansion of pharmacy technicians' standard duties to include prescription preparation, stock-container retrieval, and prescription processing)", predicted a reduction in the pharmacist non-value time by about 6 minutes or 55% of time spent, and model B "(technician performance of checkout procedures in addition to expanded standard duties)" projected a reduction of 74%.

2.6. The Power of Workflow Tools

Workflow tools give process designers control of directing a process based on the needs of the work. In our study we focus on finding a reliable workflow tool that will help the designer of a workflow process to gain control when designing a digital lab process.

The study by Geebelen et al [11] defined the need for a portable dynamic framework able to enforce and manage adaptive work policies based on the job required by workflow tasks, using a "General purpose language". This language was applied to certain conditions and rules in a work flow task that needs to perform multiple activities by different users for different purposes, based on the path required. This study includes specifying four requirements for the adoption of the framework. The first requirement focuses on providing reusability and avoiding complexity by separating the modularization of workflow tasks and functional workflows from the adoption logic in

order to support reusability. The second requirement concentrates on providing a flexible policy implementation. The third requirement provides for workflow implementation using extensible and flexible solutions to enforce any type of policy. The fourth requirement demonstrates that the designated workflow should be able to handle a Separation of Duty (SoD) type of policy, where two tasks can be performed separately by two different users.

2.7. Workflow Limitations

Designing an appropriate workflow system is not without difficulty; the research in this paper aims to facilitate this work by using appropriate workflow tools. Significantly, some previous studies have focused on finding and analyzing "Workflow Concerns and Workarounds of Readers in an Urban Safety Net Teleretinal Screening Study". For example, Fish et al [4] discuss workflow concerns and difficulties that have been found by researchers. These authors examine workflow challenges that other researchers have missed. Their study focuses on how to identify certain fundamental factors that need to be considered when performing "teleretinal readings" by specialists.

This study also used a "qualitative, descriptive method" to collect data through interviews with all of the following: the project's reviewers, clinical staff, and patient focus groups. Data was also collected through observation of clinic workflows. The authors defined some key issues that could arise when evolving workflow protocols for the "safety net and their broader applicability in telemedicine".

Another part of this same study shows that telemedicine could be a means of improving care services if used for safety in clinics or in a resource-poor setting or in an area where the population of uninsured patients is expanding. At the same time, the authors suggested that adoption of telemedicine in a healthcare workflow setting is not an easy switch, and could become another problem in developing "standardized workflows and patient care protocols".

2.8. The Use of Business Process Languages and Business Rules

Business process languages are used for a variety of purposes. Among them a study by Dogac et al [12] about integrating healthcare enterprise (IHE) profiles by using "ebXML" Business Process Specification Language, the study describe the fundamental steps in IHE profiles. This particular paper demonstrates different examples of IHE profiles integration, specifying some of the approaches in integration by using a standard interface with two transactions together: first, outlining the transactions describing the collaboration between the IT systems, and second, clarifying the "workflows describing the real life process".

"There are many IHE profiles and each profile has been designed to fit the business need of the vendor or the enterprise to support different sets of user profiles. Yet, combining these profiles requires determining the precedence of all the involved transactions manually".

The same study also defines the stages of grouping IHE actors, in order to design the business process automatically. The authors considered IHE profiles and used "OASIS ebXML machine processable language and the Business Process Specification (ebBP) Language" for the purpose of defining precedence rules in transactions of the IHE Profiles by using a graphical tool to let the users select the actors for grouping. IHE uses the standard profiling approaches of "business processes describing selected real-world use-cases" to accomplish both effective integration and interoperability in the eHealth domain.

A study by Hüsemann et al [13] defines how a Health Insurance Company can improve business agility using flexible business processes for "Building flexible eHealth processes using business rules". The study places an emphasis on how to improve business processes in healthcare, and illustrates some examples about the use of "widely used" information systems in healthcare organizations such as Electronic Medical Records (EMRs), telemedicine, and business process management (BPM).

That study focuses on the business and technical views of the modeling and execution of healthcare BPM systems based on workflows used in health insurance companies. The authors investigate two questions for each businesses view: "What does eHealth in the health insurance industry have to do with process improvement?" and "What are the business rules and why are they important for business agility?" Two technical questions were also examined: "Where do business rules reside in traditional information systems?" and "What architecture is enabling eHealth information systems in the insurance industry to be adapted rapidly to the changing political, judicial, and business environment?".

The paper also presents a short case study concentrating on "claims processing and fraud detection in a major private health insurance company." It analyzes how to use forms to display rules, enhancing "the flexibility of their processes and to automate manual tasks".

2.9. Related Work

Comparing workflow modeling tools is a comprehensive topic; different studies researched different areas of workflow comparisons, but none of the available studies compared 15 workflow tools the way we did, and recommended the best and more reliable tool to design a fully digital workflow process for a healthcare setting.

A study by Rosemann and Muehlen [14] about "Evaluation of Workflow Management Systems - A Meta Model Approach" compares two meta models of workflow management systems, WorkParty (Siemens Nixdorf) and FlowMark (IBM). The research analyzes the usefulness of a meta models in a "(pre-) selecting" of an appropriate workflow management. The authors used "Evaluation of the Organisational Meta Models" and "Evaluation of the Process Meta Models" as the methods of evaluation in the research; evaluating the process meta models was based on the outcomes of the graphical models and the "pre-defined process components" of the proposed models.

Another study by Lei and Singh [15] focused of comparing multiple workflow metamodels (Task-flow based metamodel, State-transition based metamodels, Relationship-capturing metamodels, and Communication-based metamodels). The study

identified major categories of "workflow metamodels, and a list of criteria to use as evaluation dimensions"; the evaluation was based on how the metamodels handle tasks and control flow, as well as the available advanced features such as concurrency, role-binding, and transaction and commitment support in the models.

Another study by Murray [16] investigates the "Strategies for the Successful Implementation of Workflow Systems within Healthcare: A Cross Case Comparison", a multiple case study to analyze the "implementation of a commercially available healthcare workflow system". The study researches on how to implement a workflow system successfully in an organization. The study presented cross-case comparison, and implemented a multiple case study design. The cases were selected based on five criteria: "similar environments, version of the, workflow product purchased, stage in the implementation process, internal institutional characteristics, and potential willingness to participate in the study".

A study by Kano et al [17] about "U-Compare: A modular NLP workflow construction and evaluation system" investigates how workflow comparison and evaluation could help in the development of "natural language processing (NLP) applications" by discovering the nature of NLP problems. The study concentrated on how to enhance an NLP application. Adding a customizable comparison and evaluation system was one of the features the authors used along with other features into their "U-Compare system".

2.10. Summary

Through this review of previous studies we found that workflow languages can be used to help develop eHealth application, to attain better service, and to facilitate the design of new systems in which workflow processes can be controlled and managed, based on the required work environments.

We also found that the healthcare system is changing from the old paper-based systems to new digital systems. The old systems have had many issues that led to errors or have

affected patient safety. Thus, designing a new system based on a reliable workflow tool is an effective way of reducing or eliminating these errors.

In both issues we found that in comparison to related work, the problems of this thesis have not been solved in any of the studies, no such paper is exists that compares, examines and tests workflow modeling tools or analyzes the current paper-based system and recommends a new design of a digital system.

3. CHAPTER THREE: METHODOLOGY

3.1. Design

It is necessary to have the most reliable workflow process tool to improve the current *paper-based* workflow process in a healthcare setting and develop a new *digital* lab order workflow process. We conducted an in-depth study and used a mixed qualitative and quantitative methodology in part one and two of the study.

3.2. Participants and Setting

The first part of the study involves examining 15 open source workflow tools: YAWL, Together, Bonitasoft, NOVA, bpmn2bpel, Apache Airvata, jBPM, Anduril, Kepler, nexusBPM, Apert, joget, Process Maker Open Source, RunaWFE, and Yaoqiang-BPMN-Editor-2.1.21. The final selection of the best tool in section one of the study helps in the design of a new *digital* lab order process flow.

The second part of this study consists of lab order processes in all Humber River Hospital departments that involve laboratory work (Laboratory, ICU, Oncology, Emergency, Outpatient, Acute care, Birthing, Mental Health, Surgical, Nephrology, Dialysis, and Inpatient). Information was collected from a variety of sources: the head of physicians, the laboratory service director, departments' resource nurses, departments' clerks, four lab technicians, one lab technologist, departments' clinical leaders and managers, two pathologists, six nurse practitioners, four special care nursing, a porter service manager, one porter employee, a chief nurse officer, three endoscopy nurses, a director of surgery, and one respiratory therapist.

3.3. Procedures

The study was performed in two parts. Part one of the study involved collecting information and examining 15 workflow tools; this investigation is the first to assess workflow tools with the best, easiest, and most useful features across all 15 tools, an

essential first step toward the ultimate goal developing digital flows in a hospital lab environment.

Information about the chosen tools was collected by studying each workflow tool individually. We analyzed and filtered the 15 tools and eliminated 11 tools that don't have specified criteria as the Availability of an analysis tool, tool features, vendor support, graphical editor, execution engine, and simulation, see Table 1.

We chose four tools which have the mentioned criteria and examined them by using these tools separately to design a sample workflow process; then we evaluated each tool based on the outcome of the workflow sample design. The work also involved studying all tool design capabilities by referring to related studies, tool user manuals, and web pages to gather and learn more information about these tools. Such effort included evaluating the tools based on certain quantitative and qualitative criteria.

Part two of the study consists of studying the lab order process flow, and was made up of four phases. Phase one involve collecting information about the current lab order process, including observing the workflow process for all the departments of the three Humber River Hospital's sites (Church site, Keele site, and Finch site) as well as the hospital laboratory.

The work included designing the information form to collect data through interviews and observation. It also included writing step by step the lab orders process. Each observation and interview had the following components: unit name, project name, interviewer name and job title, interviewee name and job title, date, time, and location; refer to the model in Figure 2 for the recording tool used to capture 29 interviews and 19 observations data, see Figure 2 for a sample form and see interviews questions and answers in Appendix B for complete interview questions and answers.

----------------------------- Unit / interview questions	
Project name	in Clinic
Interviewer name / job title	
Interviewee name / job title	
Date	
Time	
Location	

Figure 2: Model of interview information

We designed a questionnaire form to record the required answers based on the available processing information and the needs of the new *digital* lab order process. We used the form to capture data through 29 interviews; see Figure 3.

----------------------------- Unit / interview questions	
Project name	in Clinic
Interviewer name / job title	
Interviewee name / job title	
Date	
Time	
Location	

1. What type of samples do you collect at these clinics?

2. How many orders normally placed per day?

3. Who is placing the orders?

4. How are physicians placing an order?

5. What are the methods of adding another test request to a sample?

6. Where are labels printed (or received from)?

7. Do the nurse / technician confirm the information in labels with the test request?

8. How is staff notified, if there is a test needed?

9. Who is collecting the samples (nurse or lab technician)?

10. How do the nurse / technician identify the patient for sample collection (for sample test)?

11. Is there any difference in flow between different samples?

12. Where samples are normally collected?

13. Where collected samples are normally labeled?

14. How are samples delivered to the lab?

15. How do the clinics receive the results?

16. How long will it take to receive the results?

17. What do you do if results are not received (missing)?

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

19. Are there any issues with the current system?

20. Recommendations and suggestions?

21. Do you use blood bank services & how do you order?

Figure 3: Sample interview questionnaire used to collect data

Phase two consisted of analyzing the collected information and creating step-by-step flowcharts of the current *paper-based* lab order process. We created a general flowchart for the lab orders role in the hospital, see Figure 4 for the current general flow chart.
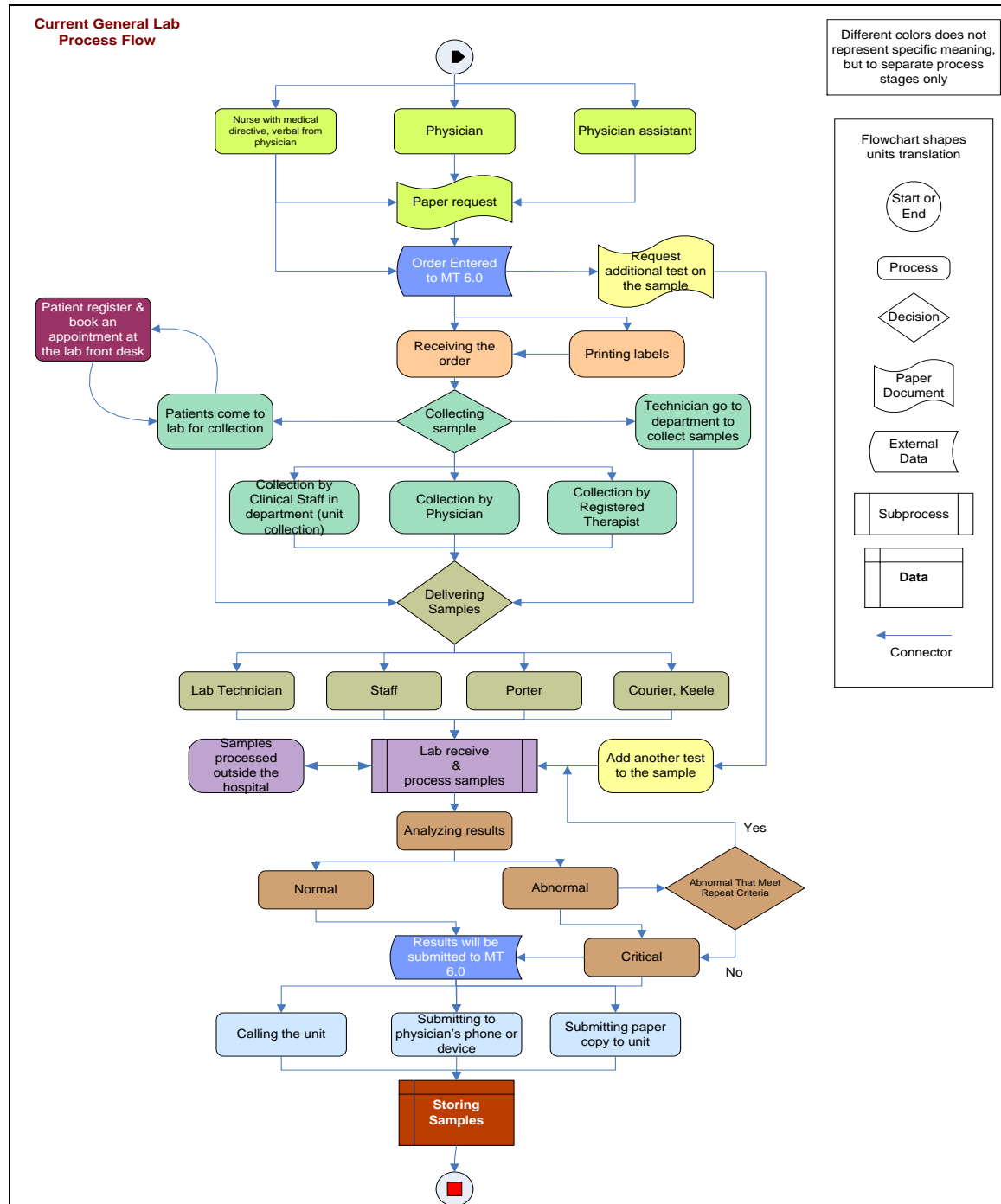
Figure 4: Current lab order process design

In phase three, follow-up interviews were conducted with the hospital departments' managers after the completion of phase two to confirm that the data was recorded correctly and to verify the design of the current lab order workflow process.

Phase four involved designing a Draft of the new digital lab order process as a first step toward the final design of choosing a workflow tool. We used the recommended YAWL workflow tool to design the new digital lab order process, see Figure 5.
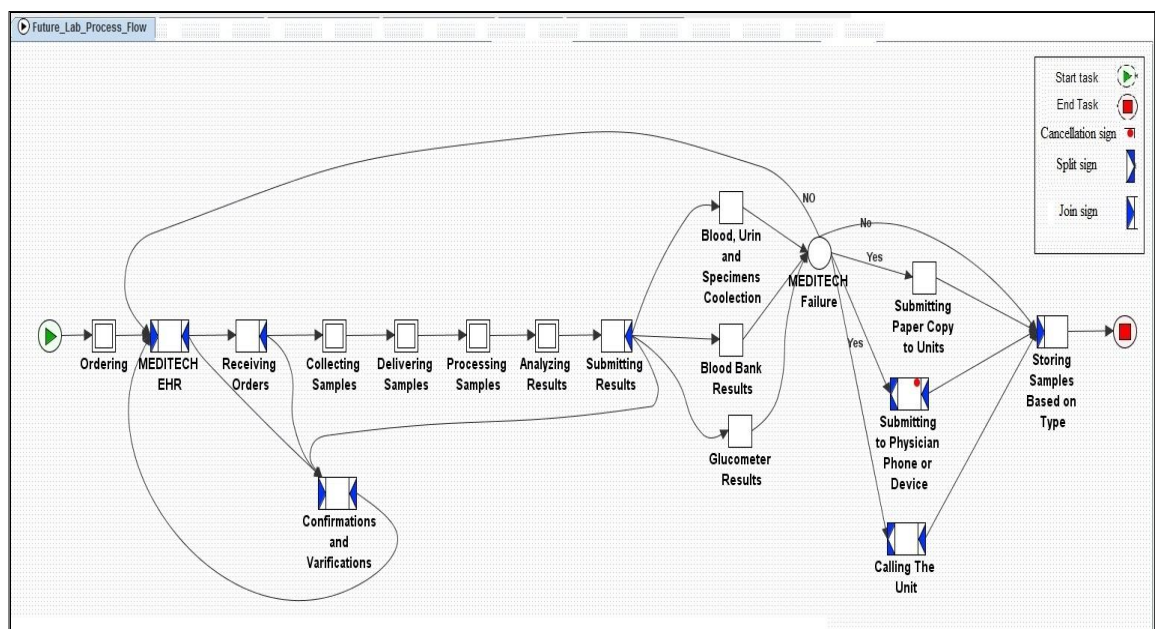
Figure 5: Future lab process, using YAWL

3.4. Data analysis

The intention at the beginning of the study was to analyze the data from the workflow tools and categorize them to assess and choose the workflow tool with the best, easiest, most useful features across all 15 tools. The study categorized the tools based on certain criteria, filtering the tools based on the Availability of an analysis tool, tools features, support, graphical editor, execution engine, and simulation see Table 1.

We used the collected data to evaluate the tools by following mixed (qualitative and quantitative) methodology, collecting qualitative data supported by quantitative data of the tools. The evaluation criteria of the tools were set to compare the scoring of the tool's features. We gave 1 to an available feature, and 0 to a non-available feature in the tool; we then calculated the total scores of each tool and compared them with other tools to define which tool has the most features among the rest of the workflow tools.

We specified two types of features in the tools *technical and non-technical*. Technical features are the analysis tool, split and join, and cancellation features, which used directly in the tool for the purpose of designing a workflow process. While non-technical features are the free tool download, support available, and training, which used for general purpose of the tool? See Table 2, Table 3.

	Workflow Tools Evaluation			
Technical Features	**YAWL**	**Together**	**Bonitasoft**	**Nova**
Executable model	1	1	1	1
Generate code	1	1	1	1
Can be simulated	1	1	1	1
Analysis tool	1	0	0	0
Define workflow designing problems	1	1	1	1
Identifying bottlenecks	1	1	0	0
Can declare participants and their type: system, human, etc.	1	1	1	0

Split and join	1	1	1	1
Manual, automated, and routing tasks	1	1	0	0
Multiple instance atomic & composite tasks	1	0	0	1
Conditions	1	1	1	1
Cancellation	1	0	0	0
Duration of activity	1	1	1	0
Discover infinite loop	1	0	0	0
Unreachable states	1	0	0	0
Probability of failure	1	1	0	0
Access to graph	1	1	1	1
Access to XPDL	0	1	0	0
Activities	1	1	1	1
Process parameters	1	1	1	1
Create variables	1	1	1	1
Manage property	1	1	1	1
Sub-process	1	1	1	1
Timer event	1	1	1	0

Message event	0	0	1	0
Call event	0	0	1	0
Total Score	23	19	17	13

Table 2: Workflow tools technical features

	Workflow Tools			
Non-Technical Features	**YAWL**	**Together**	**Bonitasoft**	**Nova**
Number of programming languages the tool supports	4	3	3	2
Use in eHealth	1	1	0	1
Free tool download & install	1	1	1	1
Open source software	1	1	1	0
Access to source code	1	1	0	0
Support available	1	1	1	1
User & Technical Manual	1	1	1	1
Training	1	1	1	0
Total Score	11	10	8	6

Table 3: Workflow tools non-technical features

The work includes not only defining the features but also making sure the features are useful when designing a new process. We collected other data from designing a designated *Future lab ordering* workflow process, see Figure 7, Figure 8, Figure 9, Figure

10; this data was used to compare the workflow process designing time by measuring the time of designing the workflow process sample using the selected four workflow tools individually, see Table 4.

	Workflow Tools			
	YAWL	Together	Bonitasoft	Nova
Design time in minutes	30 minute	60 minute	40 minute	90 minute
Error fixing time in minutes	15 minute	15 minute	15 minute	30 minute
Total time in minutes	45 minute	75 minute	55 minute	120 minute

Table 4: Workflow sample designing time

We analyzed the data, which we collected from following a qualitative methodology, and performed an in-depth analysis of each tool to investigate all tool designing capabilities; we explored all tool features, then reviewed and studied the tools by following the following qualitative parameter: flexibility of the tool, reliability of the design, quality of the process, performance of the tool, information available to the users, ease of tool use, and information access.

The study also collected data from following a quantitative methodology in order to support the results gathered earlier from the qualitative methodology by providing statistical data collected from analyzing the workflow tools.

In the designs of the *lab order workflow sample*, we listed the workflow components used in each design such as: tasks needed, start tasks, end tasks, and number of branches used based on the capability of each workflow tool; and used it in a table to calculate the

total number of components used in each workflow tool to examine the usability of each tool and determine which tool is the easiest when designing a digital system, see Table 5.

Workflow Components used in the design of the designated Future lab ordering	Workflow Tools			
	YAWL	Together	Bonitasoft	Nova
Tasks needed	15	15	15	49
Start tasks	1	1	1	1
End tasks	1	1	1	1
Branches (flows)	30	40	41	60
Total components used	47	57	58	111

Table 5: Workflow components used in the sample design

The information we gathered from analyzing the current process, plus choosing a reliable workflow tool, would help in designing a better process and avoid unnecessary workflow steps being used in the current flow. Comparing and examining the workflow tools helped us to choose a tool that contains the required features for analyzing and designing a new electronic process that satisfy the needs of the new lab order digital process.

The second part of the study consists of collecting the current *paper-based* lab order information: number of orders, who can place orders, how to place an order, what form of requisition to use, and where labels are printed, see Figure 3.

Analyzing the data consists of two parts: The first part was to investigate the current lab order process technology to determine the process performance, deficiencies, and errors. The second part was to compare the current process with the future digital process, including all the activities (collecting, labeling, processing, etc.) needed to achieve the goal of digital flow.

Information was collected from the hospital staff in all of the departments of the three Humber River Hospital sites, (Church site, Finch site, and Keele site). Information was then obtained through three types of methods: questionnaires, interview, and observation by analyzing the collected data. We found the delay of the current process is caused by deficiencies and errors issues in the process; and current process can result in more critical outcomes if new technology is not implemented.

We used the captured data to write the current step-by-step workflow process, see Figure 4. We analyzed the data by using different tables and comparisons to identify strategic objectives, current standings, deficiencies, and plans needed, see Table 6.

Strategic Objectives	Current Standings	Deficiency	Action plan
To identify the lab order and clinical laboratory services, systems, interfaces and processes	Most of the services are running on a paper-based process	Current paper-based process has multiple errors issues	Use a digital system as the main base of service electronic process can decrease the number of errors
To map and identify the existing lab services	Currently the lab covers most of the services required for the hospital, either the process done inside or outside the hospital	Some test processes that require specific instruments are sent outside the hospital for processing, and this action could result in delaying the service	The plan is to process most of the required tests in the hospital by purchasing the required instruments as part of the new complete lab

			equipment
To develop a discrete list of business and technical requirements for a long term solution in order to replace the current lab instrument in the main hospital lab, and to supply new equipment to other clinics as needed	Current lab services cover most of the tests required, except for some services where more equipment and instruments are required	Increase processing time and as well as the waiting time to get results. Doing these tests outside the hospital may add extra costs to the hospital and there is a negative potential to disclose confidential patient information	Buy most of the required lab instrument for the new hospital.

Table 6: Strategic data analysis

The data has also been categorized, in different tables to identify the processes, current technology used, proposed technology for the digital process, and if change is required, see Table 7.

Process	Current technology	Proposed Technology	Required for the new system
Ordering	Paper-based	CPOE, Direct entry to MT	Yes
	Too many steps to get to the status	Status board	Yes
	Duplicated orders	Detection system	Yes
Printing labels	Labels printed in lab or unit	Mobile devices or bar-coded tubes	Yes
	Verification by staff	Mobile scanning verification	Yes

Receiving lab orders	No specific method	Mobile devices & notification system	Yes
Collecting samples	Collection time	Management system	Yes
	Initial on labels	Mobile labeling device Scanning verification	Yes
	Filling up cart supplies	Carts contain supplies on board/ set rules	Yes
	Labeling	Mobile devices or bar-coded tubes	Yes
Delivering samples	Manual process	Pneumatic Tube Transport	Yes
Processing samples	Processing time	Pre/Post Analytical Instrument	Partially
	Process location	Implement the required instruments	Yes
Analyzing results	Mostly manual process	Automated Instrument	Partially
Submitting results	No Notification available when result submit to MT	Notification system	Partially
	Unnecessary paper copy	MT 6.0 update	Yes
Storing samples	Manual	Automatic storing system	Yes
Confirmation	Not available in most departments	Confirmation system	Partially

Table 7: Process data analysis

4. CHAPTER FOUR: RESULTS

4.1. Workflow Tool Evaluation

This section contains an overview and the evaluation result of the workflow BPM tools. The results of the analysis and evaluation of the workflow tools consist of both qualitative and quantitative data.

Sixteen workflow tools were selected and examined. We filtered the tools based on the specified criteria and selected four tools to perform an in-depth analysis and evaluation, see Table 1. The results of the analysis and evaluation of the four workflow tools were collected and shown as follows:

YAWL Workflow Tool Results

YAWL is a workflow language based on Petri nets theory, which will be discussed in (chapter 5) with a graphical representation and well-known workflow patterns YAWL User Manual 2.3 [18]. The tool offers comprehensive support for control-flow patterns, resource patterns, and exception handling. With YAWL, the users always get an instant update about the workflow design in the analysis result tab provided at the bottom of the tool. The tool has the advantage of having a *cancellation* feature which is not available in other tools (Together, Bonitasoft, and NOVA). Workflow designers using the YAWL tool can design any workflow task and direct the process flow based on the need of the flow by using this cancellation feature.

The analysis of the workflow tools revealed that YAWL editor workspace is designed in an efficient way. The graphical editor is designed to make the work easy for the users when working with a workflow design. Users can configure the YAWL engine-based on several parameters and the requirements of the process such as enabling persistence (used for backup and restore work in progress when engine restart), default work list (to handle

the works that aren't passed for process), enabling logging (to record data of running process for later analysis), allowing generic admin ID (allows the "admin" to be disable user account when password changed by using the generic "admin" account), initialization announcement timeout (used in some process when waiting for response), enabling hibernate statistic gathering, and interface X listener (used to receive event notification on interface. The YAWL tool provides simulation support by "Process mining environment" (ProM) through the link www.processmining.org. ProM is an open source framework for Windows, Mac OSX and UNIX platforms [19].

YAWL provides several options through the tool analysis to help users define workflow specification problems. The available options consist of a verification option, analysis option, note and problem panel, engine and resource service status, hint and message panel, and data type validation YAWL User Manual 2.3 [18].

The verification option is to verify the process design specification file against YAWL's schema and also to check if there is a validation problem in the workflow design. The analysis option includes using the WofYAWL analysis algorithm, use the reset net analysis algorithm, check for unnecessary cancelation regions, and check for unnecessary or-joins (different analysis options allows broader examination of the process design); more information is in Chapter 5.

The verification and the analysis options use the *note and problem* panel to display a description of any note or problem. The engine and resource service status panel is to display the status when running the execution engine, and also to display the status of the resource service available.

The YAWL workflow tool captures the data perspective by using XML Schema, XPath and XQuery. The tool has multiple modeling capabilities; mapping tasks to human participants or use web services and external applications. The tool is also capable of using split and joins tasks, or assigns task as manual or automated, routing tasks, atomic, composite tasks, multiple instance, and set conditions to a process path.

The tool has the powerful modeling feature concurrent duration of activities. However, the most significant feature that the YAWL tool has is the *cancellation* feature; this feature is not available in any other tool except YAWL and is useful when designing the sample delivery process of the new digital lab order process, see Figure 6 and Figure 1.
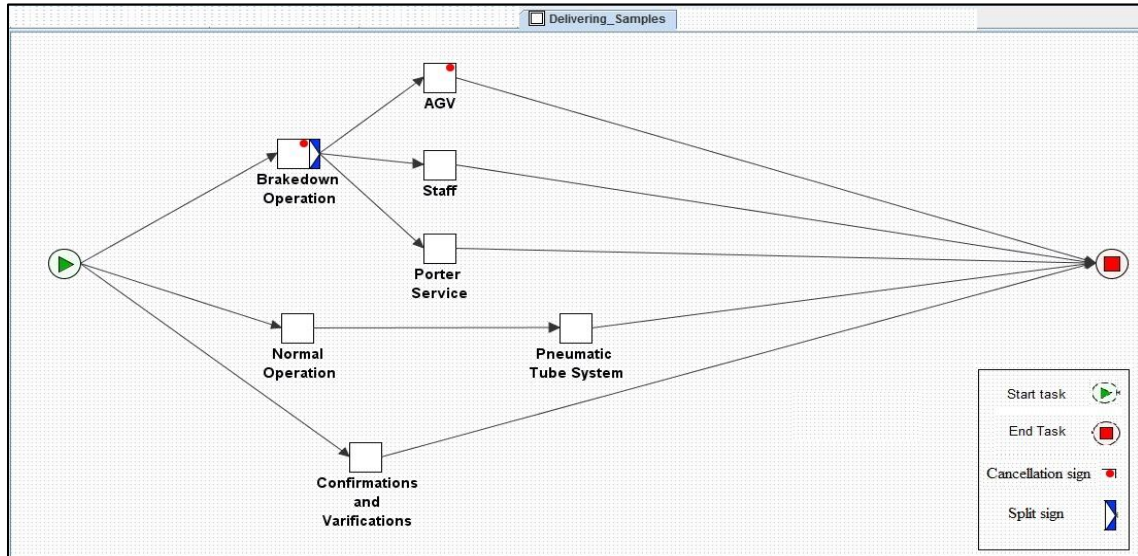
Figure 6: Delivering sample process

YAWL is an open source software, and provides a variety of support for the users including: free tool download, access to Java source code, the YAWL foundation forum where one can ask and answer questions, user and technical manual, tutorials, teaching videos, commercial support, contact support and email address, case studies, examples, screen shots, a YAWL book, and FAQ's. YAWL Foundation [19].

The results of the tool evaluation reveal that the tool is a reliable workflow tool and an easy to use tool containing all the necessary aspects of a dependable workflow tool. The tool gained the highest ranking in our measurements scales, among the four workflow tools (YAWL, Together, Bonitasoft, NOVA) based on the evaluation we performed. The YAWL workflow tool has 23 technical workflow features and 11 non-technical features. When designing the designated workflow process *Future lab ordering*, the YAWL tool

took 45 minutes to complete the design and used 47 workflow components (tasks and branches), see Figure 7.
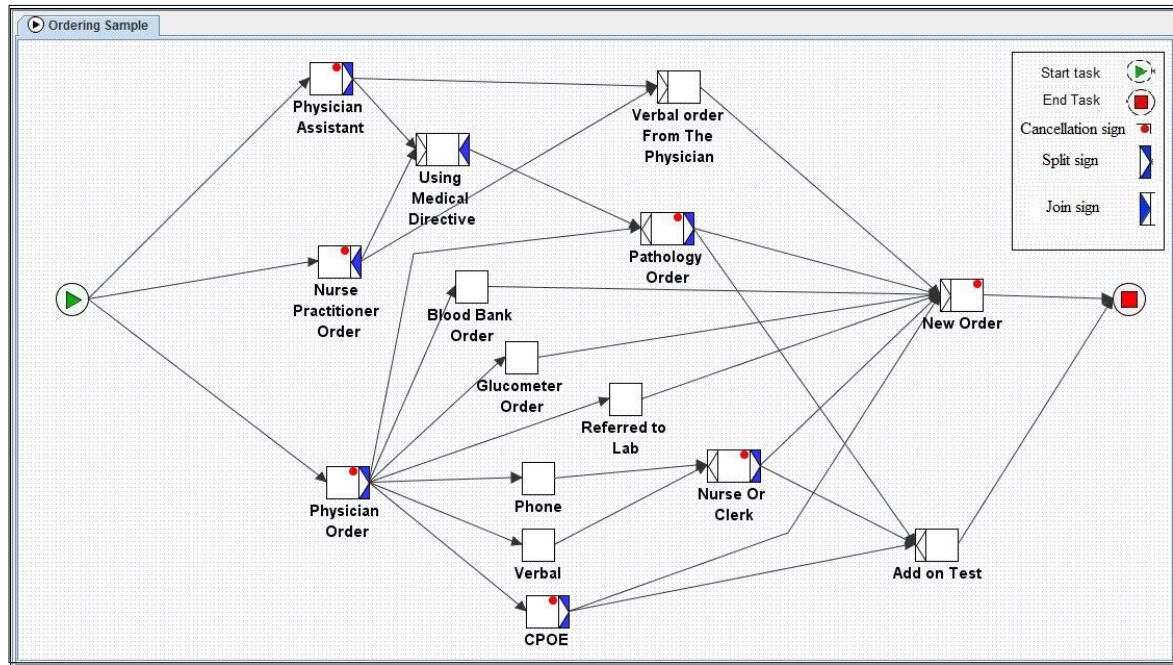
Figure 7: YAWL workflow ordering design

Together Workflow Tools Results

Together Workflow Editor (TWE) is a Java workflow editor for creating, editing, managing and reviewing workflows. The tool relies on Workflow Management Coalition (WfMC) and XML Process Description Language (XPDL) Specifications V2.1 using the Business Process Modeling Notation (BPMN) graphical notation process definition files [6]. The variety of functions in the graphical editor helps the user to find activities, participants, applications, or errors in the model. By using the standardized WfMC XPDL schema, the editor produces a final output in an XML file which makes it easy to be executed by all WfMC XPDL compliant workflow engines.

In TWE, users can determine the responsibilities of the participants in the package or the process by selecting the *re-definable* header tab from the package property. Users of

TWE also have the ability to either specify a public access level or specify a private access level of a process, see the Together User Manual [20].

The user interface of TWE is configured to provide easy access to the tool features when designing a workflow process. The workflow designers use the graphical editor to create, manage, edit, and review graphical workflow and XPDL process files. Together Workflow Tool uses the open source WfMC XPDL "Enhydra Shark" workflow engine to run and execute the workflow design. This engine interprets and executes the final XML file output produced by the workflow editor.

The TWE tool provides users access to simulation information. The tool has a check validity feature which can produce a problem list by checking the XPDL model's validity based on the WfMC specification, same as YAWL, but in TWE the information viewed in a table contains type, description, element, and location of the error or warning. More information will be followed in the coming chapters.

The tool generates XPDL and XML codes with its workflow systems to run and execute the workflow process. The tool has multiple modeling capabilities for declaring participants and their type, including: system, human, or configure a role, resource and resource sets.

The graphical editor has easy access to: graph and XPDL views for package and process, a navigator and tree area, property, problem, and WFXML components. The Together Tool supports XPDL, XML, Java Languages, and is available as open source software. It also offers free and commercial support [6].

The study we performed on TWE and the examination of the tool revealed that the Together Workflow Tool has 19 technical workflow features and 10 non-technical features. The tool took 75 minutes to complete the design of the designated sample

workflow process *Future lab ordering* and used 57 workflow components (tasks and branches) see Figure 8.

The TWE uses swim lanes to specify the sub process under the main process platform, these swim lanes specify the type or actor in the sub process. The elements of the process is arranged in the lanes to clarify the tasks of each process path; starting the process in the *starting order lane* or the types of orders a physician can order in the *physician lane* are some examples of these elements and tasks, see Figure 8.
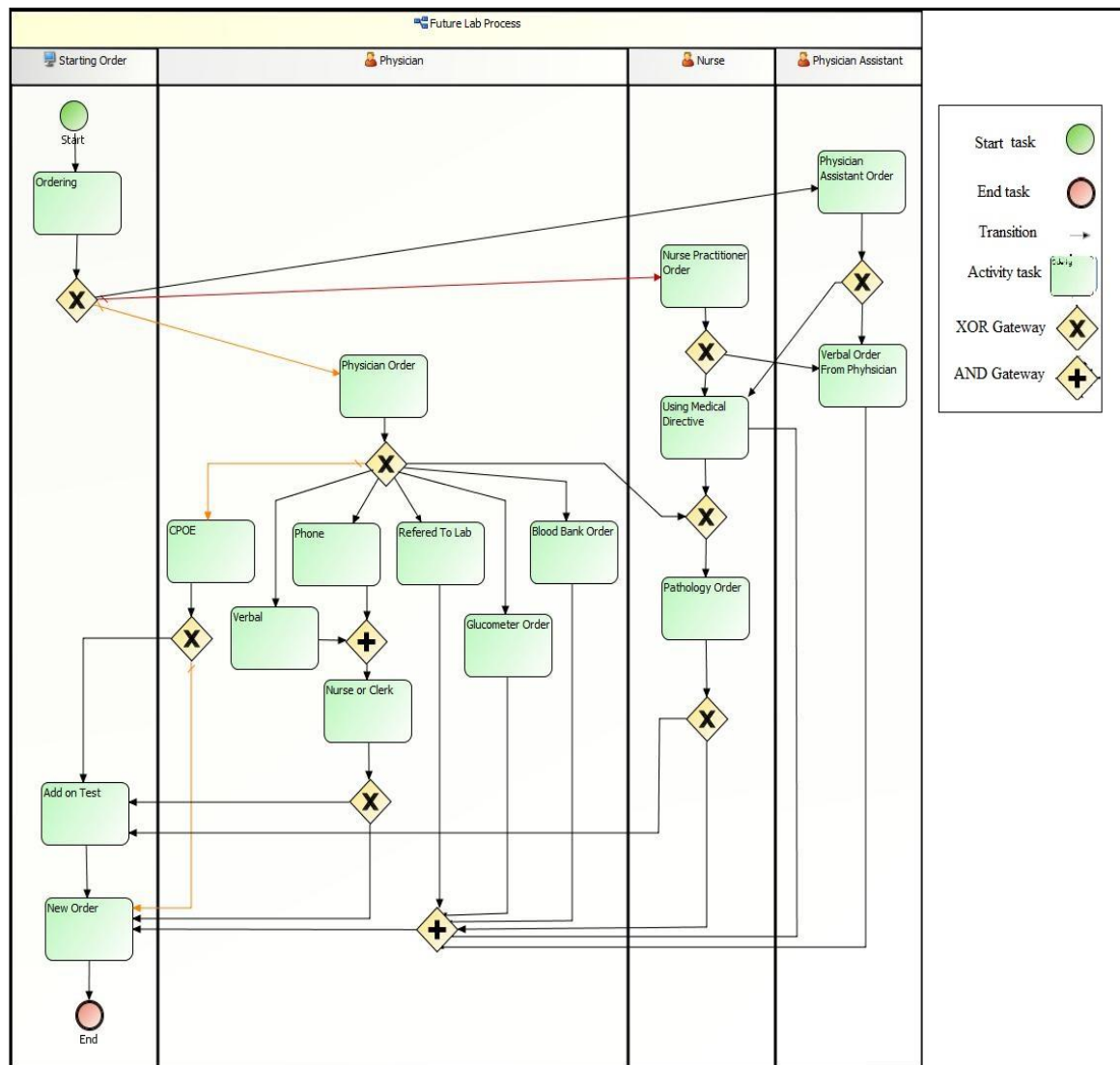
Figure 8: Together workflow ordering design

These aspects together, make the design easy for users when designing a new workflow process, see Table 5.

Bonita Workflow Tool Results

Bonita Open Solution is a combination of a user interface, process modeling studio and a BPM and workflow engine. The graphic interface of Bonita studio allows the user to draw processes directly by using a notation compatible with the Business Process Modeling Notation (BPMN) standards. The Bonita execution engine runs behind the graphical interface, which connects the processes to the existing system to deploy and run the process.

The Bonitasoft tool has decision tables, add and test connectors, multi instantiations, timer configuration, and conditions, a selection of workflow designing options, which can be useful when designing the lab order process for a healthcare setting. The Bonita tool uses the Hibernate lightweight relational database with the Bonita execution engine[21].

Although the tool has a lot of useful features, the tool does not generate code for users to modify, and users will have no excess to the html, css and Javascript codes that the tool uses to generate the applications. With the Bonitasoft tool, users can add a timer event and call activity. Users can also define two types of variables: *global variable* for the entire process and *local variables* for an individual task.

With the Bonitasoft tool graphical interface users can start designing a new workflow diagram by drawing one or more process diagrams, or drawing one or more pools. The Bonita execution engine is used to execute or run the process in a development environment–for testing purpose only, and not for deploying a process in a productive environment. The tool provides a simulation option to evaluate the process under multiple conditions (resources and load).

The tool can be used for simulation, run, and executed. Different process actors can be selected and assigned data. Variables can be global, local, single, multiple, and can have a list of options. The tool modeling capability consists of multiple activities including creating a service task, a human task, calling an activity, gateways, transitions, events, and event sub-processes.

The Bonitasoft workflow tool processes data in multiple formats including Java Objects and XML. The applications generated with Bonitasoft use standard html, css and Javascript. The tool is available as free software or as commercial software for subscription or expertise pack.

The Bonitasoft workflow tool has 17 technical workflow features and 8 non-technical features. It took 55 minutes to complete the design of the designated workflow process sample *Future lab ordering* by using the Bonitasoft tool and used 58 workflow components (tasks and branches), see Figure 9.
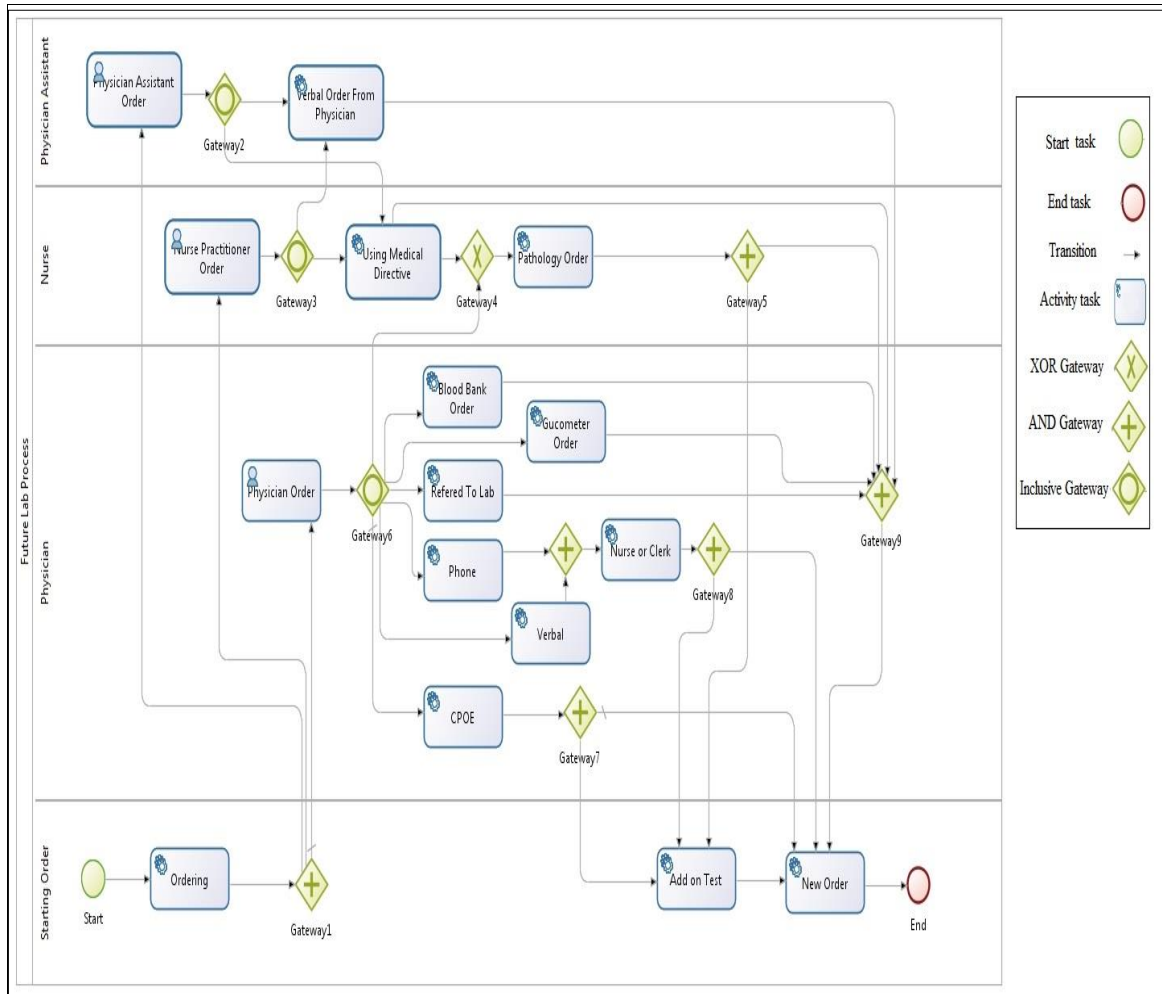
Figure 9: Bonitasoft workflow ordering design

The designing time of this tool is reasonable for users when designing a new workflow process, see Table 5.

NOVA Workflow Tool Results

This tool was developed with consideration of compensable transaction and formal verification. This workflow model framework uses a formal graphical language proposed by "StFX University, Antigonish, Nova Scotia Centre of Logic and Information" (CLI) and is called the Compensable Workflow Modeling Language (CWML), see [22]. The framework includes a graphical editor, a translator and a workflow engine. The graphical editor of the tool is an eclipse plugin and uses Hibernate and Spring Framework, workflow components, and DeVinE model checker for models execution.

Although the tool uses a unique language and has some workflow designing features, it is not as easy to use as the other tools (YAWL, Together, or Bonitasoft). The workflow engine instructions are mostly for programmers and the user manual is missing instructions on how to create or modify all of these required files and classes in a workflow design.

Users of the tool are required to have some coding knowledge or need to have worked with eclipse before. The NOVA workflow tool uses the eclipse user interface as the tool graphical editor plus some extra workflow features. The NOVA workflow engine was developed using the Hibernate and Spring Framework, the NOVA workflow engine and the client application needs a certain configuration in order to be ready to run.

The NOVA workflow tool uses the "DIVINE" model checker to simulate and verify the workflow process models by reviewing any required design correction in the problem panel, the description include specifying the description, resource, path, location, and type or the error or warning, according to the NOVA Workflow User Manual 2.0 [23] ; more details are in Chapter 5.

The tool offers run, debug, error message, and quick fix features as an analysis features through the eclipse tool. The tool uses NOVA workflow translator to reading the

workflow model and its properties file and translate it to a DIVINE process, the initialize method will be translated first, then action, and finalize methods at last.

The DIVINE model checker uses two types of variables (global or local) in the task property file. Most of the available tasks are human use tasks and are not to be run automatically by a system.

The analysis of the tool showed that the tool contains limited set of features, and conditions, task properties, and split join features are constricted when used in the designing of the designated *Future lab ordering* sample. The NOVA workflow tool supports Java and CWML. The tool is free to download and offers the required plugin, but it is not open source software.

Through examining the tool we found that the NOVA workflow tool has 13 technical workflow features and 6 non-technical features. Designing the designated workflow process sample *Future lab ordering* took 120 minutes to complete when using the NOVA tool, and used 111 workflow components (task and branches) to satisfy the design, see Figure 10.
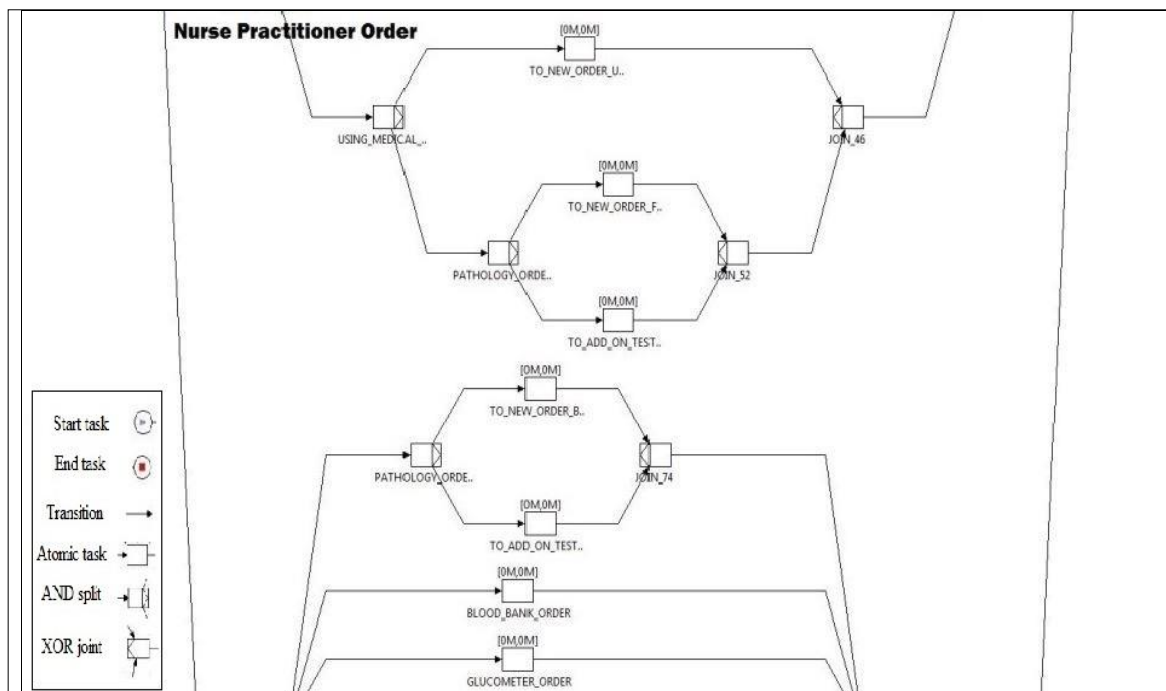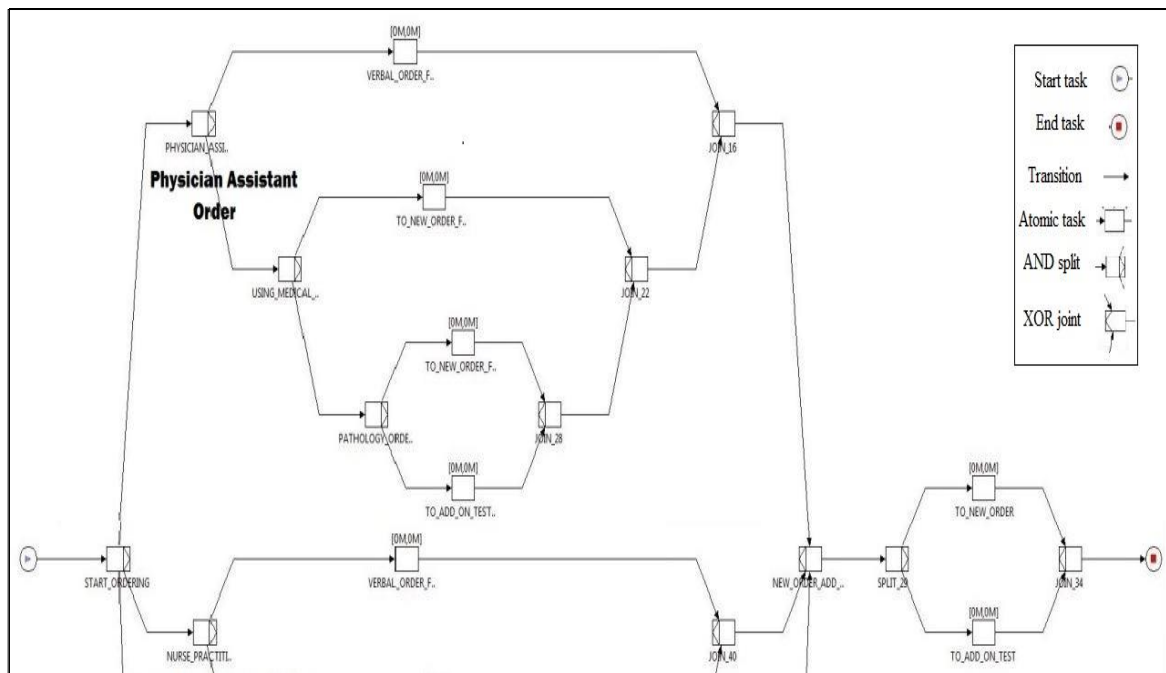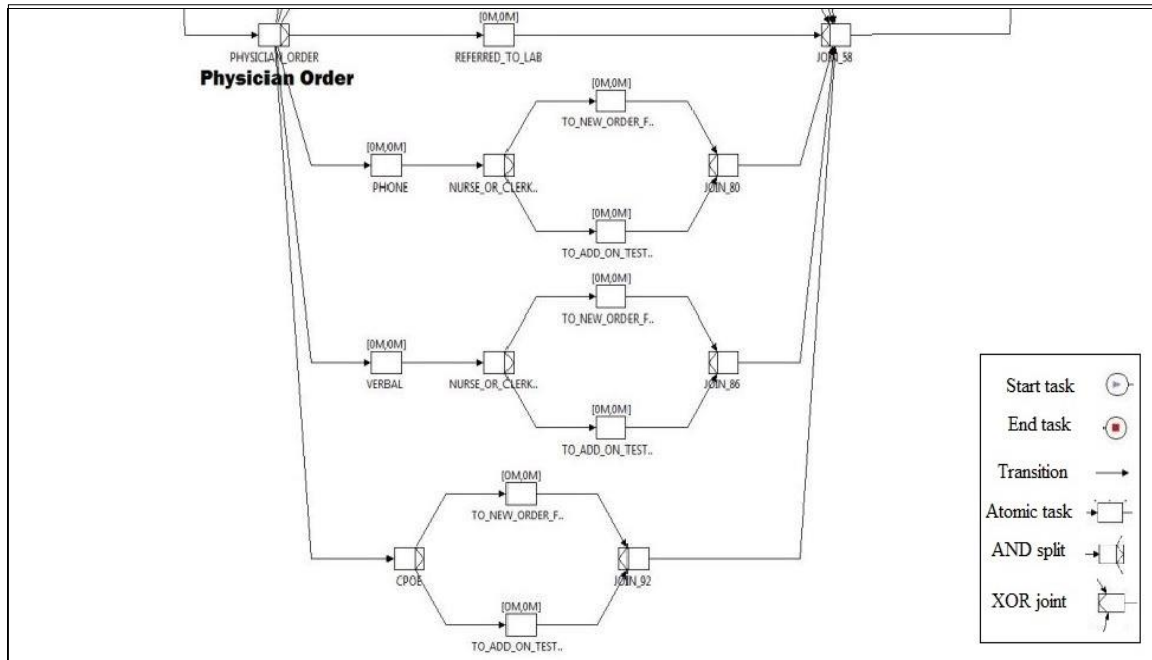
Figure 10: NOVA workflow ordering design

Together, all of these aspects act as a barrier for users when designing a new workflow process, and will not help the users when designing a workflow process, see Table 5 for a comparison between the tools.

4.2. Current and Future Order Processes

This section contains descriptions of the lab order process and results of studying current and future lab order processes.

Current Situation Summary

The current *paper-based* lab order process starts with placing lab order either by a physician, physician assistant or nurse practitioner in all departments where blood samples or specimens need to be collected (emergency, intensive care unit, nephrology,

etc.). The main method of placing a lab order is a *paper-based method*, and the process consists of the following steps:

Ordering, placed as paper requisition only by physician, physician assistant, or nurse practitioner. A nurse or clerk enters it into a MT electronic health record later.

Printing labels by the MT system automatically after completing and entering the order.

Receiving the order by the person who performs the collection of the sample, and managed by the lab technicians.

Collecting samples can be assigned based on the order type or the status of the patient.

Delivering the sample can be done in four ways: porter service, lab technician, staff, or courier.

Processing the sample in the hospital laboratory, done based on the required test. Samples can be processed either in the hospital or outside the hospital based on the equipment available and type of test.

Analyzing the results, specified as normal, abnormal or critical by the laboratory technologists.

Submitting results to MT automatically by the laboratory instrument system.

Storing the samples based on the sample type. For example, blood samples are stored for days while urine samples are stored for hours only.

We performed a data analysis on the collected information from the questionnaire and observation of the current process. The recorded data shows multiple deficiencies and issues in the current lab process, see Table 8 and Table 9.

We also collected future process data based on the information from the questionnaires and proposed equipment features and capabilities and compared the future process data with the current process data—see Table 11—to show the benefits of the future process—see Table 10—and the difference in the turnaround time of both current and future process, see Table 12. The data analysis showed that the current lab process described above is not satisfactory for many reasons:

- Lab order takes a long time to be completed based on the observation of the process
- Lab orders contain mislabeling errors of samples based on the information collected from the hospital laboratory
- Long processing time, causing an increase in processing cost of samples due to increase the time of using the resources
- No mobility with the current order placing cannot place order using mobile devices from inside or outside the hospital
- Needing to improve quality of sample taking current sample takers are not following the proper procedure

The current lab order process flow has been performed using some old methods that could lead to multiple issues in different areas of the process. An explanation for every process will follow:

Ordering

Ordering procedure followed now is represented by:

- A paper request.
- Physicians having no access to CPOE.
- Verbal & phone orders will be entered into MT by a nurse or clerk.

Confirmation & Verifications

- There are no current confirmations on the pickup and delivery of the samples in most hospital departments except for *Endoscopy and the Operation Room (OR)* which have recently implemented a signature sheet for a nurse, porter, and lab to sign once they have received the samples.
- No notification available when results are ready in MT unless results are critical.

- Most of the time the lab tech or nurse, does not confirm the test's information on labels with test request order.

Collecting Samples

Collecting samples can be done by physicians, nurses, lab technicians, and registered therapists. Collecting samples could have the following issues:

- There is no defined way on how to inform nurses in a unit about new lab order requests
- In most departments, nurses do not have proper training for blood collection
- The current system is unable to determine duplicated orders.
- Sample collectors do not always following collection procedures.
- Using insufficient lab carts can delay the process.
- Departments have noticed a delay in service between 2:00PM-3:00PM when lab technicians change shifts.

Labeling issues

Labeling the samples in the current system is done by using paper labels, and performed in many ways depending on the type and environment of the collection location, and has the following issues:

- Labeling errors.
- Labeling normally takes place outside the room.
- Lab technicians prints labels in the lab and bring them to the units.
- Dates on labels represent the printing date, not the test date.
- Initial of the sample collector on the label does not always represent the person who collects the samples especially in the endoscopy department.

Delivering Samples

In the current system, delivering samples depends on a manual process, and no automated delivery system is available at this time except in the *Emergency department* of the Finch site and the *Emergency department* at the Church site. The former site uses a pneumatic tube system, the latter a chute tube for delivery.

Delivering samples also has the following issues:

- In some departments, samples stay for 4 hours before pick up (e.g. the endoscopy department).
- Due to reported issues from some of the hospital departments, porter service slowly responds to requests and samples are easily lost during delivery.
- Samples from the Keele site are always sent by a carrier or a taxi cab to the lab at the Finch site.
- Some samples stay in cart with lab technicians until they go back to the lab to deliver them.

Processing Samples

Labs process samples automatically and manually at the same time. The laboratory instruments normally comes in three parts or groups *pre analyzer, analyzer, and post analyzer*, and the lab instrument currently available at Humber River Hospital is missing the automated *pre and post* parts. Plus some of the process confirmations are done manually by the technologists. These issues result in a delay in the complete process of the lab order flow.

Time issues

- Collection time shown in MT is the time that technicians put manually in the system.

- The current processing time is calculated from the time of placing the order in MT, not from the time of processing the sample.

Submitting Results

In the current system, submitted results can be done in different ways, depending on the type and status of the test:

- Direct submission to MT
- Calling the unit and informing them if results are critical
- Calling physicians or sending the results to their devices when results are critical
- Sending a paper copy to the department's printer, mostly done as an unnecessary action in most departments even when the department didn't request a paper copy

Storing Samples

Samples are normally stored based on their type. The lab stores blood and specimen samples for days but store urine samples only for hours.

Current Strategies

The current strategy mostly depends on a manual process flow in all of the processing stages and tasks. No automation is available in the current system except in some parts of the process and in the submission of the result to MT.

Analysis Process

The analysis used questionnaires, interviews, and observation as the three types of methods to collect necessary information of the process, see Figure 11 for sample of the questionnaire form used in the collection of the data to categorize the processes and issues of the current system.

Medicine, Nephrology / interview questions

Project name	Lab work process flow in Medicine, Nephrology unit
Interviewer name/job title	Ammar Kamil
Interviewee name/ job title	██████████
Date	Aug 15, 2012
Time	9:00 AM
Location	Church site

1. What type of samples you collect at these clinics?
   INR, Electrolyte, CBC, Potassium, etc…

2. How many orders normally placed per day?
   > 30 / day

3. Who is placing the orders?
   Physician, Nurse (Sometimes for INR, Potassium)

4. How physicians placing an order?
   Give paper chart to nurse to confirm & enter it to MT

5. What are the methods of adding another test request to a sample?
   Give paper chart to nurse to confirm & enter it to MT

Figure 11: Sample interview & questionnaire form

The plan targets to capture the current lab order process performance, deficiencies, and errors and to design a new digital lab order process flow, including all the activities surrounding that process in order to eliminate these errors and deficiencies and avoid any process that could lead to these errors.

Future Process

The future process consists mostly of the same main current process stages except the contents of the stages would be more advanced and digitally controlled. The plan is to use the following strategy for the future process:

- **Ordering**

  Use of CPOE

- **Confirmation and Verification**

Use of MT system

- **Collecting samples**

  Use of bar-coded tubes or mobile labeling machines

- **Delivery system**

  Use of a pneumatic system (PTT) and AGV vehicles

- **Submitting results**

  Use of MT system

- **Inventory system**

  Use of the commuter system

We analyzed the current data, by entering the collected data into two designed tables, and categorized it based on the requirement of a new digital system. The first table shows the strategy objectives, current standings of the process, deficiencies, and action plan for the new design, for more details see Table 6. A second table shows the process type, current technology, proposed technology, and whether or not this technology is required for the new design; see Table 7.

Current Process Finding (Weak Points)

Based on the analysis of the *current process* data, we found the following weak points in the current lab order process system:

Lab related

  Time
  - Collection time showed in Meditech MT is the time that technicians put manually in the system
  - The current system calculates the time of processing a sample, from the time an order entered to MT. The system calculates the sample delivery time as part of process, while the calculation of the processing time should start after delivering the samples to the lab, some samples could take 1:30 hour to be delivered to the

lab, and 30 minutes to be processed, and based on the current system calculation, the 1:30 hour delivery time will be added to the 30 minutes processing time and the process time will show as 2 hours.

- Oncology tests take longer due to the nature of the test and a required portion of oncology tests are done manually.

- Priority or type is determined based on the letter on the right side of the label number (0566:C00045R) where the *R* means routine lab order.

Delivery & Confirmation

- Methods of delivery consist of the following: porter, nurse, lab technician, volunteer, carrier, and taxi cab. All of these methods delay the process and could cause a loss of samples.

- There are no current confirmations of the pickup and delivery of samples in most of the hospital departments, therefore making it easy to lose a sample except in Endoscopy and OR departments where they have a signature sheet for nurses, porters, and lab technicians to sign when they receive the samples.

- Porters carry blood tube by hand. No basket or special bag is available.

Labeling

Labeling the samples is done in many ways depending on the type and environment of the collection location.

- In some isolated patients rooms, lab technicians apply labels outside the room as part of a precaution procedure. Lab technicians need to disinfect the sample tubes from outside by using alcohol which could erase the printing on labels.

- The labeling on a *24 hour urine collection bottle* normally done after a patient brings the bottle back to the clinic, not before taking it home.

- Some departments delay entering orders or printing labels until after the collecting of the samples.

- Most of the labels are normally printed in the lab and brought by the lab technician to units.

- A collection will not take place if a label is not available or if there is no identification bracelet ID on patient.

- The collected information that we gathered from the lab technicians shows that there are at least 1 to 2 specimen labeling errors exist in the process every day.

- According to the collected information from lab technicians, nurses, and department's administrators, labels are not designed well: priority of test is not well visible, labels are printed every other row (leaving one row of labels empty and print on the other one), in labour and deliver department the baby's mother name is not on the baby's blood sample label.

General

- The current system is unable to determine duplicated orders.

- Lab technicians need to go back to the lab to get supplies every time supplies run out.

- Lab carts are not designed sufficiently and specifically for lab use, could delay the process of collecting samples.

- There is no place on the cart to write on the labels.

- A sample's tubes are not being isolated or protected from the surrounding environment; cleaning materials containing alcohol could erase the printing on labels.

- Lab technicians having difficulties carrying more than one collection tube, technicians sometimes need to collect 8 samples from one patient, in which case they do not have the proper basket or container to put in these tubes; this would result in the lab tech having to going back and forth many times to the cart outside the room.

- Departments noticed a delay in service between 2:00PM-3:00PM (when lab technicians changed shifts).
- The available set of lab instruments is missing the post-analyzer.
- No automated inventory system; it is all done manually.

Ordering

- The ordering procedure followed now is represented by:
    - A paper request is filled by the physician and given to the clerk for entering the information into MT.
    - Adding another test on a sample is performed by submitting a paper request by the physician, then, a clerk or a nurse enters the order using the *Add on Test* feature in MT.
    - Physicians have no access to CPOE.
    - Blood bank orders are done on paper.
    - Glucometer orders are done on paper.
    - Nurses or clerks enter verbal and phone orders into MT.
    - Nurses with a medical directory can place an order.
- No notification is available when results are ready in MT unless results are critical.
- To check the order status a nurse or clerk is needed to login and check the order page in MT.
- In some departments, lab order needs to be done a day before the appointment to guarantee the receipt of the results due to the delay in the process flow or the nature of the test needed.
- MT electronic health record has a lot of issues that need to be fixed:
    - Needs more order terms specification to be available to physicians.

- Physicians prefer to have a list of the available tests show up when a physician enters the test short name. For example, entering *UA* should show *Urine Analysis*.
- The implementation of the new MT 6.0 changed some test names.
- Using MT is time consuming; it is slow and needs many steps to go to a page.
- Some blood bank orders cannot be seen by staff.

Nurses

- Most of the time, a lab tech or nurse does not confirm the test's information on labels with test request order.
- Some departments receive unnecessary paper copies of the test results.
- Lab order page on MT has a lot of issues:
  - A Complete blood count (CBC) blood order on MT is always defaulted to *STAT*.
  - Labels will not be printed until a nurse or clerk changes the order status in MT to *collected*.
  - The labour and delivery MT first page has the baby's mother's name by default; in the second page, the mother's name should be entered manually, and third page has no field for the mother's name. (The mother's name needs to be on the three pages by default to eliminate errors).
- Caesarean section room:
  - Has only one computer in the room which is used by the physician, no other computer to use for orders, nurses have to wait until the physician finishes working with the computer, which led to an increase of processing time.

- Has no labelling machine available there.
- When blood is drawn from the baby, the baby needs to be registered first, and then the order and labels can be printed and placed on the sample.
- There is no available notification to inform nurses in a unit about new lab order requests; nurses sometimes know from:
  - Order sheet
  - Patient chart
  - MT page
  - Kardex
  - Verbal communication from physician
- No manual is available to know where to send bronchiole samples (Respiratory).
- Sometimes the initial on labels does not represent the persons who collect the samples (Endoscopy).
- In some departments, samples stay for 4 hours and are later picked up (Endoscopy).
- In most departments, nurses have no training for blood collection.
- Most night blood collection will go missing.

Current process issues and deficiencies

The previous information contains relevant data for developing a new lab order process, but not all of the data is useable, but the collected data is essential; however, some of it is used to develop the new digital lab order process. We used the previous information to develop two tables. Both tables were discussed with the lab director, lab technicians and nurses for authentication and approval.

The sources of these collected data are from the questionnaires, interviews, and observation of the daily lab order processes, and no other substantiation is available. The

first table shows the current process deficiencies (process and issues), metrics (performance, quality, and patient safety), and the proposed technology. Please see Table 8 for more details.

Deficiencies		Metrics			Proposed Technology
Process	Issues	Performance	Quality	Patient safety	
Ordering	Paper-based	Time consuming, increases the waiting time	Writing errors	Missing records, lost tests, wrong test	CPOE, Direct entry to MT
	Too many steps to get to the status	Time consuming	Require human resources		Status board
	Duplicated orders	Time consuming			Detection system
Entering orders to MT	Nurse or clerk required	Time consuming	Errors when entering orders	Increase adverse events	CPOE, Direct entry to MT
Printing labels	Labels printed in lab or unit		Possible labels lose	Confidential patient info	Mobile devices or bar-coded tubes
	Labels design	Labels not designed very well for some department/labour & delivery	Major error when mother's name is not on baby's blood label	Missing records, lost tests, adverse events	Mobile labeling device Scanning verification
Receiving lab orders	No specific informing way	Delay the service	Increase patient waiting time	Increase patient diagnostic and	Mobile devices & notification system

					treatment time	
Collecting samples	Collection time	Depend on collection type	Delay in delivering the samples		Management system
	Initial on labels	Not always represent the person who collected the samples	Potential error		Mobile labeling device Scanning verification
	Filling up cart supplies	Delay the collection process	Increase patient waiting time	Possibility of losing labels during this action	Carts contain supplies on board/ set rules
	Labeling	Possible mislabeling	Delay the service	Critical on patient safety	Mobile devices or bar-coded tubes
Delivering samples	Manual process	Time consuming	Depend on human resources availability		Pneumatic delivery system
Processing samples	Processing time	Some process requires human interaction	Vary between test types	Critical in some cases if delayed	Pre/Post Analytical Instrument
	Process location	Possible delay if sample sent outside	Delay the result	Increase patient diagnostic and treatment time	Implement the required instruments
Analyzing results	Manual process	Required previous patient record in some cases.	Space for error	Critical on patient health if miss judged	Automated Instrument

Submitting results	No notification available when results are submitted into MT	Keep staff busy checking all time			Notification system
	Unnecessary paper copy	Printer resource wasting	Wasting staff time		MT 6.0 update
Storing samples	Manual	Serious if sample mis-stored	Require time and resource		Automated storing system
Confirmation	Not available in most departments	No prove of action	Missing or losing samples	Increase patient diagnostic and treatment time	Confirmation system

Table 8: Current process deficiencies

We used the same collected data to create a second table and outlook the main issues in the current process to specify the performance, quality, and patient safety in the lab order process; for more details, please see Table 9.

Process	Issues	Performance	Quality	Patient safety
Ordering	Paper-based	Time consuming, increasing waiting time	Writing errors	Missing records, lost tests, wrong tests
Entering orders to MT	Nurse or clerk required	Time consuming	Errors when entering orders	Increase adverse events
Printing labels	Labels printed in lab or unit		Possible labels lost	Confidential patient info
Receiving lab orders	No specific way of informing	Delay the service	Increase patient waiting time	Increase patient diagnostic and treatment time

Collecting samples	Collection time	Depend on collection type	Delay in delivering the samples	
Delivering samples	Manual process	Time consuming	Depends on human resources availability	
Processing samples	Processing time	Some processes require human interaction	Vary between test types	Critical in some cases if delayed
Analyzing results	Manual process	Required previous patient record in some cases.	Space for error	Critical on patient health if misjudged
Submitting results	No notification available when results are submitted to MT	Keeps staff busy checking all time		
Storing samples	Manual	Serious if sample mis-stored	Require time and resource	
Confirmation	Not available in most departments	No proof of action	Missing or losing samples	Increase patient diagnostic and treatment time

Table 9: Current process issues

We developed the future process based on eliminating the errors and weak points from the current lab process, considering all the new surrounding environment and equipment of the new process; the key aspects of its future state is as follows:

ORDERING

Online ordering

Ordering is the first sub-process of the main lab order process, for future ordering. The physician, nurse, or Physician assistant will use *online ordering* instead of the paper-based form used in the current process. Through online ordering, the person who places the order can use either *Order Sets* (orders set in advance) or the CPOE module by using the electronic health record MT.

Decision Support

The new digital lab order process will have a decision support feature for physicians to support their order decision. It will also provide the opportunity to review past orders in the same context as placing the new order, and physicians can look at all lab tests previously performed as well as already ordered (but incomplete) tests; this new feature will assist the physicians with the meaningfulness of the test.

Mobility

One of the important features of the new digital design is *Mobility*; physicians can place orders on-line from their mobile devices anywhere in the hospital, outside the hospital, and anytime during their duties or out of duties (in case of emergencies).

Voice command

The new process design provides voice command technology to allow the physician to place the order verbally (this will be something like SIRI, the voice command function featured in iPhones or iPads). This feature is a voice version of the touch interface to the mobile device so the physicians can see the actions of the voice command. However, this is not speech transcription.

Receiving orders / dispatching

Lab orders in the current lab order system is dispatched manually between lab technicians. When the lab technicians receive paper copies of the new orders, lab technicians divide the orders among themselves based on the current available technicians in the lab regardless of whether there are some technicians on the hospital floors.

Dispatch software

The new digital lab order system will have dispatch software to dispatch jobs previously done by the lab technicians; this software works out who should collect the specimen if this order is for a nurse or if it is for a lab technician. If a lab tech is required, then the software works out who the best technician is to do the job.

This dispatching is performed based on the location of a lab technician, priority of orders for that patient or department, and current backlog of orders based on priority. The software then will notify the person who needs to do the collection by sending a message to their device; the person needs to accept the request within a certain time so that everybody knows that the job has been assigned.

The suggested dispatching software is also responsible for creating a proposed dashboard (status board) of *jobs* that managers can review on a hand-held and on a status board placed in the hospital lab, see Figure 12 for a status board *proposed prototype* with the data supposed to be displayed in it.

Order #	Patient Name	Physician Name	Order Type	LabTech/Nurse Name	Date & Time	Status
5	David Martin	Dr. Smith	Routine / blood	N/A	24/08/2012 9:02 AM	Ordered
4	Andria Sheen	Dr. John	Routine / Blood	T.A / Unit	24/08/2012 8:30 AM	Accepted
3	Bob Tailor	Dr. Smith	Urine	G.T / Lab	24/08/2012 8:13 AM	Delivered
			DI		24/08/2012 8:00 AM	In Process
			X-ray	M.R /	24/08/2012 7:13 AM	Completed
2	Martin Johns	Dr. Broun	Sputum	T.S / Lab	24/08/2012 7:22 AM	In Process
			CT		24/08/2012 7:32 AM	Completed
			MR		24/08/2012 7:45 AM	Completed
1	Nadia Sheen	Dr. Broun	Stat / Blood	T.S / Lab	24/08/2012 6:30 AM	Completed

Figure 12: Status board

Collection

Lab technicians collect samples on their floors unless the collection is a PICC line collection (peripherally inserted central catheter) a flexible blood collection tube inserted into the patient's vein in the upper arm, in this case a sample will be collected by the nurse and not the lab technician.

The indication is that the lab technicians roam the hospital halls and go from patient to patient to collect samples. In the current state they always go back to the lab to deliver samples and get work orders and pick up tubes. On the other hand, with the new digital system, lab technicians receive work orders electronically from their devices so they know what they need to do and can go back to their base (lab) when their work is complete.

Lab technicians do labeling and bedside verification using their mobile labeling device (a wireless portable label printer placed on the cart).

Pre-bar coded sample tubes

The other proposed ideal states for labeling are pre-bar coded sample tubes. With this proposed technology, the tech would grab tubes and other specimen bottles while with the patient and scan the bar code on the tube. They would then scan the patient and confirm that the order has been used. Finally the lab technician would scan himself/herself so the system can capture all of the required information and send it to the white board.

Delivery

Pneumatic Tube Transport (PTT) System

With the new process design, technicians deliver the samples back to the lab via the Pneumatic Tube Transport (PTT) system. The lab technician or nurse would then pop the tubes into the PTT and deliver the samples to the lab. When the samples arrive at the lab, the tubes are then manually transferred from the PTT station to a lab track (pre-analyzers), and at this point the lab will confirm its receipt of the tubes.

Processing and Analyzing

The new lab will be fully automatic (pre-analytical processor, analyzer, and post-analytical processor). The pre-analytical instrument will scan the incoming tubes and will determine the work required for process, update the status of the sample stage to *in process* on the whiteboard, and update the process starting time.

The lab technologists will then follow up with the automated process and intervene when required. The automated analyzer will analyze the sample results and determine if reprocess the sample required (based on repeat criteria), see Figure 13.
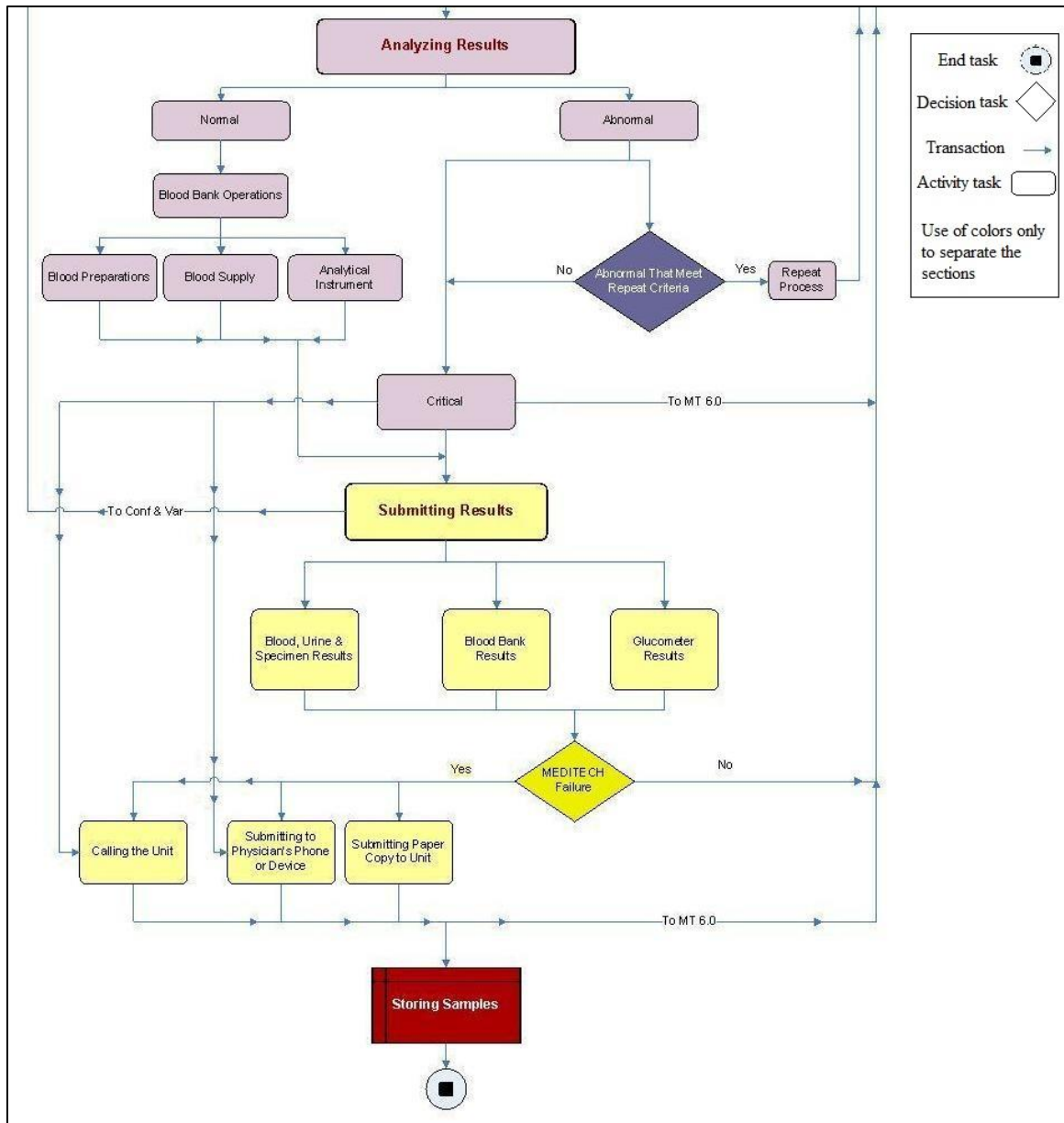
Figure 13: Draft of future workflow analysis and submission of results

Results Submission

The MT system will store the results automatically. If they are critical, the system will send a notification to the ordering physician as well as the floor staff or nurse.

Confirmation and Verification

With the new digital lab order design, a confirmation system will confirm the receipt or submission of the sample and update the order page on MT and the status board in the lab. A verification system will verify the patient's ID by scanning the patient bracelet, and then interact with the patient's EHR record before finally placing the order.

Dispatch software will determine to whom to send the order based on priority of the order, location of the technicians, and the technician work list.

Future process benefits

The new process will have more benefits to the healthcare organization than the old process. We illustrate these benefits in a table containing the benefits and metrics for each related process. Please see Table 10 for more details.

Benefits		Metrics		
Process	Technology	Performance	Quality	Patient safety
Ordering	CPOE	Time saving, decreases the waiting time	Reduce errors	
	Status board	Time saving		Reduce patient care time
Entering orders to MT	Automated entry to MT	Time saving		
Confirmation & Verification	Scanning & verification	Confirm patient ID	Eliminate error	Prevents adverse events
	Confirmation system	Prove of action	Update the status	
Receiving orders	Mobile device & notification system	Speed up the process	Staff management control	decrease treatment time
	Management system	Send orders based on	Speed up the	Eliminate errors

		specified parameters	process	
Collecting samples	Scanning system	Identify patients, and associate their records	Update the status, prepare labels	Eliminate errors
	Mobile device or bar-coded tubes	Efficient labeling	prevent mislabeling	Prevents adverse events
	Carts contain supplies on board	Speed up the collection process	Decrease patient waiting time	
Delivering samples	Pneumatic Tube Transport	Time saving	Speed up the process	
Processing samples	Pre/Post Analytical Instrument	Cut down processing time	Time saving	
Analyzing results	Automated Instrument	Cut down processing time	Eliminate errors	Eliminate diagnostic misjudging
Submitting results	Automated MT update system	Quick result submission	Efficient	
	Notification system	Results notification	Allow quick response by physicians or staff	Could prevents adverse events
Storing samples	Automated storing system	Better sample management	Quick sample location	

Table 10: Future process benefits

Process comparison

We use the information obtained from analyzing the current and proposed processes to develop a process comparison table comparing current and future processes, making it easier for the reader to see the differences between the two processes, see Table 11 for more details.

Process Activity	Current Process	Future Process
Ordering	Paper-based (transferring physician's paper-based test order to MT order) The current system is unable to determine duplicated orders	CPOE
Confirmation	No current confirmations on pickup and delivery except in Endoscopy and in OR specimens where they use a signature sheet for the nurse, porter, and lab tech to sign when they receive the samples	Easy to access sample tracking and confirmation system
Receiving order	In the MT (lab) there is no specific way to inform nurses in the unit about new lab order requests. Nurses only sometimes know due to the following: order sheet, patient chart, MT page, verbally from the physician, or from the nurse checking the Kardex	Confirmation system, MT, Status board, Mobile devices
Collecting samples	Technicians run between the lab and clinics, delivering samples or to get supplies Using insufficient lab carts	Computerized specimen collection process (mobile labeling, or coded-tubes)
Labeling	Technicians carry labels from lab Labelling outside patient room Labeling error, printing every other one, in labour & delivery mother's name is not on baby's blood label	Mobile labeling devices or bar-coded tubes
Delivering samples	Porter, Nurse, Lab Technician, Volunteer, Carrier, and Taxi Cab	Pneumatic Tube Transport system (main), porter, AGV, Staff
Processing samples	Technologists perform multiple duties including lab instruments pre and post analytical process	Pre- analytical processor, analyzer, and post-analytical processor
Analyzing results	Manually	Automated (main), Manual
Submitting results	MT & Paper copy for some clinic, Phone call	MT (main), Devices, Phones, Paper

Storing & Inventory	Manually	Automated process using bar code system to identify the lab samples for storing and detect any shortages in lab supplies to order as needed

Table 11: Process comparison table

Turnaround time

Turnaround time is an essential issue of future digital process benefits. We developed a turnaround table showing the difference between the current lab order process time and the future digital process time.

The current process time is measured based on a regular lab order process, and data obtained from the three sources of information (questionnaires, observations, and interviews). The information of the current process is acquired from the lab technicians, lab technologists, and the director of laboratory who is responsible of following the order from the time of issue to the receiving of the results, the information include the time of process and capability of the laboratory instruments.

The calculation of the current process time involved calculating a real time lab orders process by observing the processes from the time of placing the orders to the submission of the results to the hospital department where orders take place.

 The future digital process is predicted based on information we received from the questionnaires interviews with the laboratory director, and from the specification of the new instruments involved in the new digital process.

The result of the turnaround time shows a clear difference between the current and future process times, see Table 12.

Process	Current process turnaround time	Future process turnaround
Ordering	5 minutes	1 minutes
Entering orders to MT	15 minutes	0 minutes
Receiving orders	15 minutes	5 minutes
Collecting samples	15 minutes	10 minutes
Delivering samples	30 minutes	2 minutes
Processing, Analyzing, Submitting	55 minutes	22 minutes
Total Minutes	135 minutes	40 minutes

Table 12: Process turnaround time

With the current process, a complete lab order takes 135 minutes to complete; while with the new digital process, a complete lab order will take 40 minutes to complete. A difference of 95 minutes between the two processes highlights the benefits of the new design, see Figure 14.
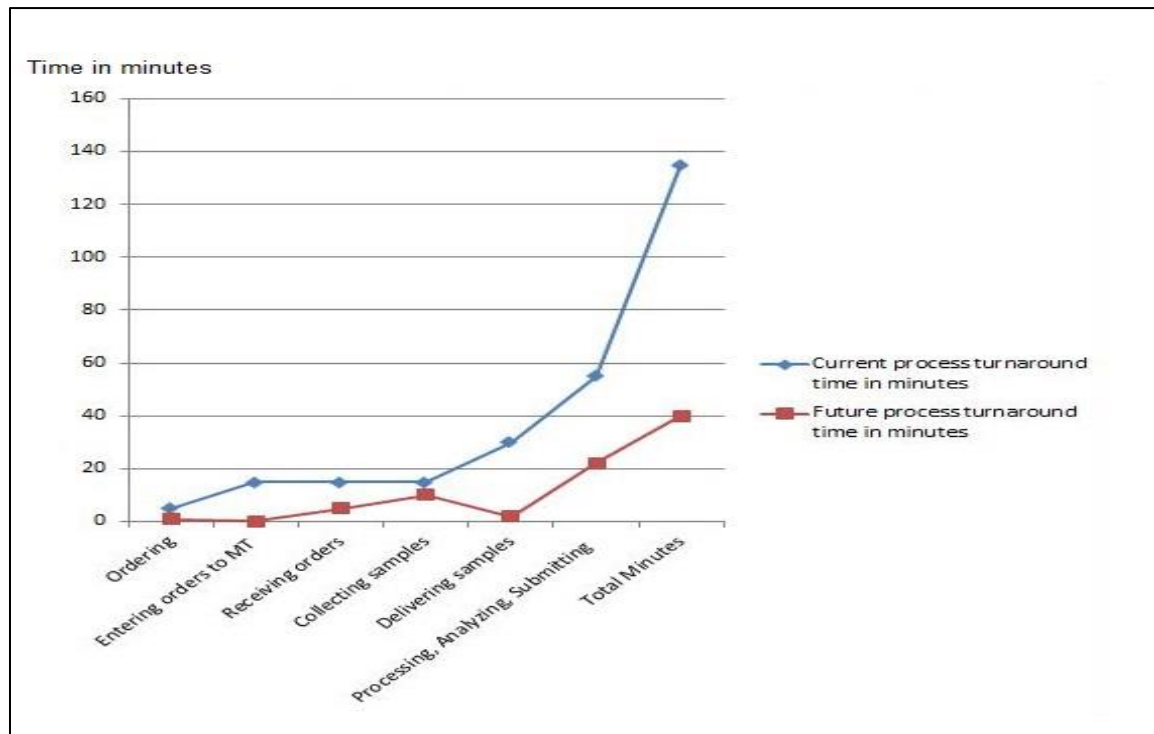
Figure 14: Current and future process turnaround time

5. CHAPTER FIVE: DISCUSSION

We divided the discussion into two parts to encompass all of the content and cover the two parts of the study. The first part of the discussion will discuss the work on the workflow tools. The second part of discussion is dedicated to talking about current and future lab order process flows.

5.1. Introduction to Workflow Tools

There are multiple workflow tools available for use in designing a workflow process, we selected only 15 open source workflow tools to investigate, due to some limitations exist, such as duration of the study and pre-set criteria. We chose the following tools – YAWL, Together, Bonitasoft, NOVA, bpmn2bpel, Apache Airvata, jBPM, Anduril, Kepler, nexusBPM, Apert, joget, Process Maker Open Source, RunaWFE, and Yaoqiang-BPMN-Editor-2.1.21–and filter them to choose the best tool to design a new *digital* flow for Humber River Hospital's lab order process.

The study identified the selected workflow tools and discussed their similarities and differences for examination. Information concerning tool descriptions and evaluations were collected through studying each workflow tool individually. We finally chose four tools (YAWL, Together, Bonitasoft, and NOVA) and examined them separately to design new workflows process, studying all tool designing capabilities, and evaluating the tools based on certain quantitative and qualitative criteria, see Table 1.

Introduction to Petri Nets

Studying workflow tools include understanding the concept of Petri Net and its relation to the workflow models; we can understand that Petri Net represents a mathematical form in a workflow tool. Workflow models used events, conditions, and transections to specify and control a process; places and transitions in Petri Net represent the conditions and events in a workflow model.

Petri Nets are a graphical tool that represents a visual communication, similar to flow charts, block diagrams, and networks. Study by Murata [24] define Petri Nets as a graphical and mathematical modeling tool applicable to many systems to describe and study information processing systems (distributed systems). Petri Nets are considered modeling tools applicable for many systems characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. Petri nets are broadly used in the workflow analysis to detect errors in a workflow model at design time.

A Petri Net is a directed graph consisting of two types of nodes. In graphical representation, places were drawn as circles, and transitions were drawn as rectangles. The places and transitions are connected by arrows which show the direction the components flow. The arrows are called arcs, where arcs could represent directions from places to transactions or from transactions to places. Arcs are labeled with their weight token (w(p, t) from P to T, or w(t, p) from T to P).

Places and transitions are used in modeling as *conditions and events*, where places represent conditions and transitions represent events. In modeling the input and output places for transition (event) are denoted as pre and post-conditions of the event, see Figure 15.
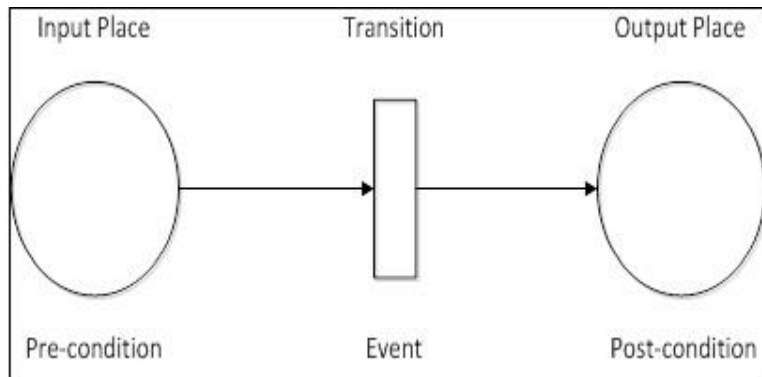
Figure 15: The interpretation of Places & Transitions

The Petri Net theory has rules for transition enabling and firing, represented by the activity of the transitions. The transition acts as a key to enabling the firing and transferring of data or action between two or more places. The firing rules determine the state or marking in Petri Nets to simulate the dynamic behavior of a system.

The study by Murata [24] defines that marking assigns to each place a non-negative integer. For example, if we assign a place a a non-negative integer k, we can say that place a is marked with k tokens. K tokens inside the places represent the truth of the condition, indicating that k data items or resources are available, see Figure 16.
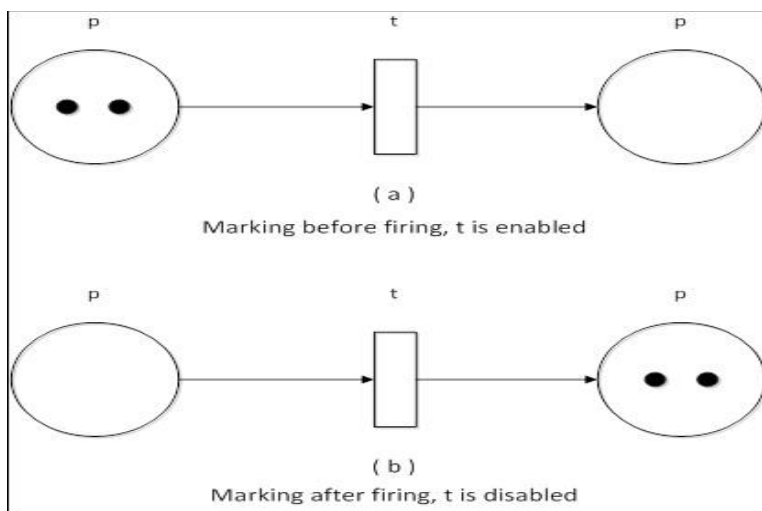
Figure 16: Illustration of transition firing (rule)

In mathematical terms, we can explain Petri Net as PN = (P, T, F, W, M_o), where the finite set of places are represented as P = {p_1, p_2, p_3, …., p_m}. Finite sets of transitions are represented as T = {t_1, t_2, t_3, …., t_m}. The set of arcs are represented as F ⊆ (PxT)∪(TxP), the weight function as W:F→{1, 2, 3, …}, and the initial marking as M_0:P →{0, 1, 2, 3, ….. }. Note that P ∩ T = ∅ and T ∪ P ≠ ∅ , Murata [24].

YAWL Workflow Tool

Tool overview

YAWL (Yet Another Workflow Language) is a new workflow language based on Petri Nets theory with a graphical representation and well-known workflow patterns. YAWL uses a control-flow perspective pattern and manages to extend *Petri Net's* lack of support for patterns such as cancellation, multiple instance, and the generalized OR-join with dedicated constructs to deal with the data perspective, resource perspective, and exception handling patterns YAWL User Manual 2.3 [14][18].

Developers of the YAWL workflow tool stated that their analysis showed that other XPDL, BPML, and BPEL4WS workflow systems, and theoretical models like Petri nets have problems supporting essential patterns; as a proof of concept, they have developed a workflow management system supporting YAWL, "It should be noted though that YAWL is not simply a set of macros defined on top of Petri nets. Its semantics is not defined in terms of Petri nets but rather in terms of a transition system" Van Der Aalst et al [10].

The authors also present the design and implementation of the YAWL system, which fully supports the YAWL language. They clarified the creation of the YAWL system as a result of analyzing more than 30 workflows and standards.

We chose the YAWL workflow tool in the design of the digital lab process design for its support and use of multiple patterns and particularly cancellations, which are not supported by other workflow tools. YAWL uses Petri nets, which provide a more theoretical approach. "Petri nets form a model for concurrency with a formal foundation, an associated graphical representation, and a collection of analysis techniques" Van Der Aalst et al [10].

The YAWL tool offers comprehensive support for control-flow patterns, resource patterns, and exceptional handling. The tool uses Hibernate (hibernate.org) as a database framework which provides a transparency layer between YAWL and the back-end database used to support it.

With YAWL, the users always get an instant update about the workflow design in the analysis result tab provided at the bottom of the tool. Analysis results show the task name, problem type, and suggestions to fix the problem. When there is no problem, the analysis results tab still shows a note of not finding any validation problem with the current design YAWL User Manual 2.3 [18].

The YAWL tool has an advantageous *cancellation* feature which is not available in other tools (Together, Bonitasoft, and NOVA). Workflow designers using the YAWL tool can design any workflow task and direct the process flow based on the need of the flow by using this cancellation feature. We used this cancellation feature with the design of the new digital *delivering sample process*, see Figure 1.

Requirements

To install and run YAWL workflow tool, a user need the following software YAWL User Manual 2.3[18]:

- Java SE Runtime Environment (JRE), 1.6 or greater (java.sun.com).

- YAWL4Study for Linux requires installed xdg-utils (portland.freedesktop.org), which should be supported by the desktop environment (GNOME and KDE do support xdg-utils), in order to visualize YAWL editor menu entries.

YAWL 2.3 has been successfully run on:

- Windows XP, Vista,Windows 7, Server
- Linux: Ubuntu (9.10), sidux, Debian (Etch);
- Mac OSX: Tiger, Leopard, Snow Leopard, Lion.

Graphical editor

This section describes the YAWL graphical editor version 2.1. The YAWL graphical editor is the first place where the designers should start when designing a new workflow process. This tool allows YAWL users to create, configure, validate, edit, and analyze the workflow process. The YAWL editor is a Java archive file; when users click and start YAWL editor, they start the *YAWLEditor2.2.jar* file ([14][18], p 41).

YAWL editor workspace is designed in an efficient way. The graphical editor is designed to make the work easier for the users when working with a workflow design. The graphical editor workspace contains the modeling canvas in the middle, surrounded from the top with a grouped tool bar (specification maintenance, specification verification and analysis, net maintenance, edit options, alignment options, size options, cancellation sets, zoom options). From the left side, users will find workflow elements and tools, task icons, decorations and join/split panel. At the bottom, the tool has a note and problem panel, an engine/resource service status, and hints and messages.

The menu bar in YAWL contains an overview of the same components available in YAWL editor. Users have the choice of working with components through the tool bar or the menu bar.

Execution engine

The work of the YAWL engine starts after completing the workflow process design in YAWL editor. The YAWL tool saves the workflow process specifications in an XML file, and this file contains the information of the control flow, data, and resources. The role of the YAWL engine is to interpret the control flow and data files, then pass the contents of the resource file to a dedicated custom service (resource service) YAWL User Manual 2.3 [14][18].

Users can configure the YAWL engine based on several parameters such as enable persistence, default work list, enable login, allow generic admin ID, enable hibernate statistic gathering, initialization announcement timeout, interface X listener, and observer gateway.

Simulation

Simulation in YAWL is used for operational and technical decision making. YAWL tool create simulation model that precisely reflect the designated real-world process supported by workflow management system. YWAL workflow system creates event log every time an activity is enabled, started, completed, or cancelled, the system also record the event enacted time with who has enacted it, so the system will have all specifications historical data that has been executed before.

In simulation, YAWL system creates function to extract the historical data of a specification from the YAWL engine and export it in an XML mining log format. YAWL workflow system exposes the model data through an interface using "ProMImport" interface. The YAWL tool provides simulation support by "Process mining environment" (ProM) through the link www.processmining.org. ProM is an open source framework for Windows, Mac OSX and UNIX platforms. YAWL Foundation [19].

Analysis the Tool Can Perform

Definitions

YAWL provides several options to help users define the workflow specification problems. The available options consist of verification option, analysis option, note and problem panel, engine and resource service status, hint and message panel, and data type validation.

Analysis role

The analysis role is to spot the deadlock situations, unnecessary cancellation set members and unnecessary or-join decorators at run-time, discover infinite loops, unreachable states, and probability of failure workflow problems (YAWL User Manual 2.3[18], pp.91). The verification role is to allow users to "validate the specifications against YAWL syntax and semantics" (YAWL User Manual 2.3[18], pp.43).

The verification and the analysis options use a *note and problem* panel to display a description of any note or problem. The engine and resource service status panel displays the status when running the execution engine, and also displays the status of the resource service available.

The 'hint and message' panel provides any hints or messages to users when needed. The other option is the data type validation which is a unique feature available in YAWL; its role is to alert the user about any invalid data type definitions by turning the whole XML code to a red color or to green when the data type definition is valid.

Most of the previously mentioned tool features, the use of the tool analysis to spot the workflow problems, unnecessary or-join, note and problem display panel; where used when designed the workflow sample process and future lab order process.

Analysis configuration

There are two options to configure YAWL analysis. The first choice is to *Reset Net Analysis*, which allows users to select the necessary options from the configuration dialog box; examples of *Reset Net Analysis* are, using YAWL reduction rules before analysis for optimization, checking for unnecessary or-joins, or showing observations in analysis results. The second option, *WofYAWL Analysis*, allows more options for the users but will be available in the configuration dialog if "the optional YAWL specification analysis utility wofyawl.exe is supplied in the same directory as the editor" (YAWL User Manual 2.3 [14][18], pp.92), see Figure 17.
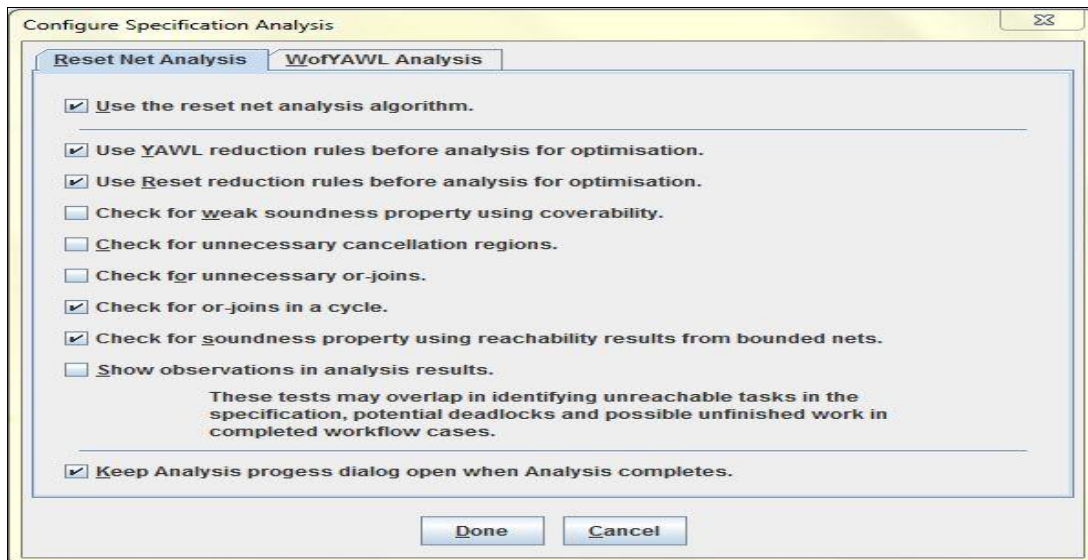
Figure 17: YAWL analysis configuration

Progress dialog box

The progress dialog box displays updates and messages about the progress of the analysis; this information is useful to the user in understanding the status of the process design, and resolves any fix required, see Figure 18.
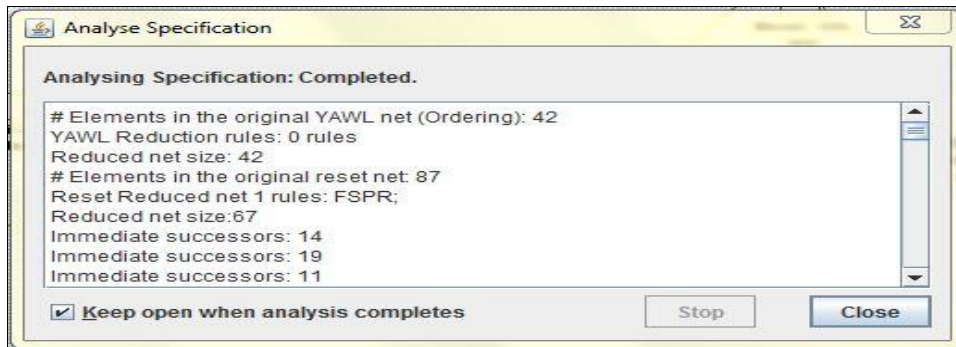
Figure 18: YAWL analysis progress box

Analysis result notes

The results of the analysis will reveal some of the following information about the workflow design, examples as shown below:

- The number of elements in the original YAWL net (with mentioning the name of the net)

- Number and name of YAWL reduction rules used in the analysis, example (2 rules FSPY; FAND)

- Duration in milliseconds

See Figure 19 for analysis result of *Current general lab work process* workflow.
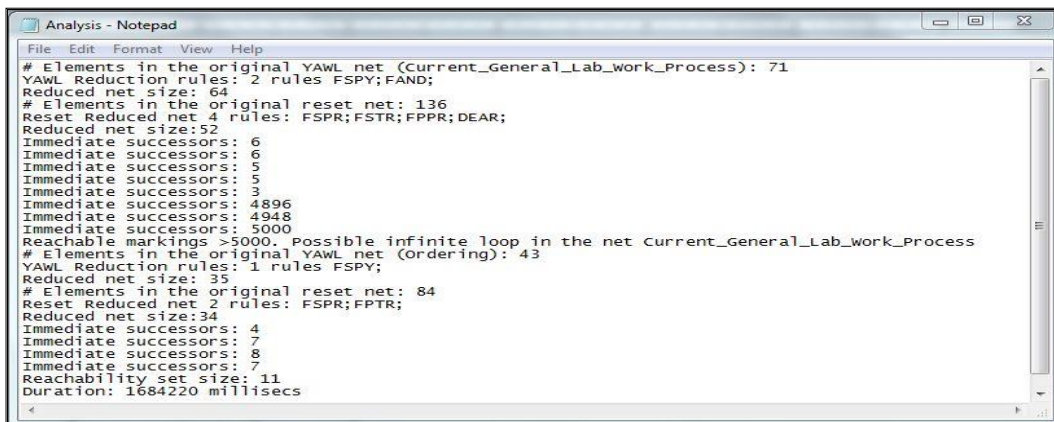
Figure 19: YAWL analysis notes

Technical Issues

Executable model

The YAWL workflow tool captures data perspective by using XML Schema, XPath and XQuery. The tool offers simulation support and conducts post-execution analysis. The tool is also capable of identifying bottlenecks in the process. YAWL Foundation [19].

The data in YAWL are passed as an XML documents from net to task and back, all parameters in YAWL are defined using XML schema language, YAWL also allow users to define their own languages.

XPath expressions are used in YAWL tool to specify how data is passed between the net and task, theses expressions are needed to fetch and populate the values of parameters with that of its corresponding net parameters. XQuery parameters are defined using XQuery expressions, input or output parameters use an XQuery expression to specify a value that can be passed to single selected task or net variables, see YAWL User Manual 2.3 [18].

Identifying bottlenecks is done by conducting post-execution analysis of YAWL process through the link with the ProM (www.processmining.org) environment to extracting information from event logs. The use of process mining is to observe deviations and compare the observed elements with predefined models or business rule, see YAWL User Manual 2.3 [18].

Identifying bottlenecks is useful when designing the digital lab order process. For example, in the design of sample delivery process using YAWL tool, the process analysis showed that the process of defining the delivery path is time consuming, and by using the cancelation feature we were able to eliminate the wasted time and the system was able to choose the right process path based on the choice of the user. Identifying the bottlenecks

in the process helped accelerate process and shorten the delivery time, and affect the total lab processing time as well.

Tool modeling capability

The tool has multiple modeling capabilities and consists of the following: mapping tasks to human participants, web services, external applications and Java classes. The tool is also capable of using split and join, manual, automated, routing tasks, atomic, composite tasks, multiple instance, and conditions YAWL User Manual 2.3 [14][18].

Modeling features

Concurrent duration of activities is one of The YAWL tool powerful modeling features, but the most significant feature that the YAWL tool has is the *cancellation* feature. This feature is not available in any other tool except YAWL. The cancellation feature allows users to set the process to follow a unique path and cancels all the other paths, making it easier for the users when designing a workflow process as well as more efficient for the system when considering the path to follow YAWL Foundation [19], see Figure 6 for sample of the delivering process, and Figure 1 for sample delivering cancelation.

Non-Technical Issues

Language support

The YAWL workflow tool supports XML Schema, XPath, XQuery, and Java. YAWL Foundation [19].

Use in eHealth

Based on YAWL sources, the YAWL workflow tool is used in some eHealth studies and designs of some healthcare processes of the Academic Medical Center (AMC) University hospital in Netherland. A healthcare process and YAWL modeling design of 325

activities and patient visiting to the gynecological oncology outpatient clinic of the AMC hospital [19].

Tool cost

YAWL is open source software and free to download. The tool also provides free support and commercial support through the "Acclario BPM" company.

Support available

The tool provides multiple support methods, YAWL workflow tool is free to download and users have access to Java source code, the YAWL foundation forum is available for asking and answering questions.

Other supporting tools, the user and technical manual, tutorial and teaching videos, commercial support, contact support and an email address, case studies, screen shots examples, a YAWL book, and FAQ's are also available with YAWL workflow [19].

Together Workflow Tool

Tool overview

Together Workflow Editor (TWE), or also known as "Enhydra JaWE," is a Java workflow editor for creating, editing, managing and reviewing workflows. The tool relies on Workflow Management Coalition (WfMC) and XML Process Definition Language (XPDL) Specifications V2.1 using the Business Process Modeling Notation (BPMN) graphical notation process definition files [6].

The TWE sources and user manual provides users with a clear understanding and extensive overview of process definitions. Using BPMN graphical notation, the editor symbolizes all *XPDL* graph components and elements graphically through property

panels. Together User Manual [20]. Although there is no clear indication in the TWE sources about using Petri Nets in the TWE workflow tool, but from understanding the concept of Petri Net and its relation to the workflow models, we can realize that Petri Net represents a mathematical form in the TWE workflow tool. Workflow models use events, conditions, and transitions to specify and control a process, and places and transitions in Petri Nets represent the conditions and events in a workflow model.

The TWE workflow tool provides analysis of a workflow model to specify any problem related to the workflow. The TWE list the problems or errors in a problem table, see Figure 20. The display of errors at the designing time is one of Petri Net concepts used in analyzing workflow errors in a workflow model.

A number of functions in the graphical editor help the user find activities, participants, applications, or errors in the model. By using the standardized WfMC XPDL schema, the editor produces a final output in an XML file, which makes it easy to be executed by all WfMC XPDL compliant workflow engines.

TWE is a tool for process definition modeling. It has three main goals: defining the process through graphical representation, exporting process definitions to XPDL, and importing any valid XPDL and its graphical representation.

In TWE, users can determine the responsibilities of the participants in the package or the process by selecting the *Redefinable* header tab from the package property. Workflow variables can also be declared in the package property by selecting the workflow variables tab, then specifying the properties of workflow variables ([20], pp. 40-42).

In TWE, users have the ability to specify a public access level (where a process could be invoked by an external system or application). Users can also specify a private access level of a process, (where a process may only be invoked from a SubFlow Activity).

Declaring a data type as *Basic* in the TWE tool could mean one of the following data types: string, integer, reference, float, date time, boolean, or performer. The user of the tool is also able to set an activity to start or end automatically or manually.

Moreover, TWE provides *composing transition condition* help. Users can click on an arrow in the text box of entering condition, to get a list of possible variables which can be used within the condition. Together User Manual [20].

Requirements

The only prerequisite to be able to run TWE on Windows or Linux system is Java JRE 1.7 installed on the machine. There are several binary packages for Windows and Linux operating systems that can be used to install TWE [20].

- TWE for Windows uses twe-x.y-z.exe package.
- TWE for Linux uses twe-x.y-z.noarch.rpm package.

Graphical editors

Together Graphic Editor, also referred to as the *TWE user interface*, is the most essential section in the workflow tool. The user interface is configured to provide comprehensive access to designing a workflow process. TWE users use the graphical editor to create, manage, edit, and review graphical workflow and XPDL process files.

The graphical editor is designed in such a way that it allows users to see all of the required features at once. The user interface consists of four main parts. The first two are the graphic and XPDL panels located at the center of the user interface surrounded from the top side by the (tool, menu, and info) bars. From the left side, it is surrounded with a *special* area containing the external package relation, workflow overview, and transient package pool. The left side also contains navigation and package tree panels. The fourth part of the user interface is located at the bottom side of the interface and contains the property, search, problems, WfMC XML (WfXML), and LDAP-based system panels. Together User Manual [20].

Although the graphic and XPDL panels are surrounded with all the required features, the graph layout itself contains all the required components. "It offers the possibility to insert

new elements into the graph and to visually define the flow / logic of the workflow process you are modeling" (Together User Manual [20], pp.10).

Execution engine

The Together Workflow Tool uses the open source WfMC XPDL "Enhydra Shark" workflow engine to run and execute the workflow design; this engine interprets and executes the final XML file output produced by the workflow editor. Together User Manual [20].

The available configuration for Together Execution Engine is the "configuration specific to TWE usage with shark engine, including a specific property panel for editing some of the extended attributes" Together User Manual [20]. To run the engine, users need WfMXL components and a valid registry service URL to be able to connect to the engine.

Simulation

The Together Workflow Tool provides users with access to simulation information. Simulation information is available as part of the activity property panel. Using the tool, users can define: multiple or individual instantiation, cost, waiting time, working time and duration. Together User Manual [20].

Analysis the Tool Can Perform

Analysis definition

The tool has a check validity feature which can produce a problem list by checking the XPDL model's validity based on the WfMC specification, to check if the workflow performs as designed and results as expected.

Analysis role

The role of the problem tab is to spot workflow problems (errors and warnings) as a list of the workflow problems. This problem list of errors or warnings, are designed to display all of the necessary information in order to fix any errors or warnings that could potentially affect a workflow design. Together User Manual [20], see Figure 20.

Figure 20: Together problem tab

The analysis of the TWE workflow tool is different than that of the YAWL workflow tool. With the analysis tool of YAWL workflow, users can define more configurations than with the analysis tool of TWE workflow, which results in more error detection and better workflow design.

Analysis configurations

The available configuration in TWE sets the design-time validation to either true or false. Based on the TWE user manual, setting the option for design-time validation to 'true' will refresh the problem list automatically if the option for design-time validation is set to 'false', the problem list will not be refreshed automatically. Together User Manual [20].

87

Analysis results

The problems tab contains useful information for the workflow tool users about any workflow design problem. The analysis categorizes the problems as follows:

- Problem type, to represent a process problem type (error or warning) by an icon
- Error/warning type, to specify if the problem is an error or warning (logic, conformance, connection or schema)
- Description, to describe the error or warning in details
- Element, to specify the element involved in error or warning (variables, activity)
- Location, to show any details, the *error or warning* location in the workflow (package, process, sub-process, task)

[20], see Figure 20.

Technical Issues

Executable model

The TWE tool generates XPDL and XML code with its workflow systems to run and execute the workflow process. The tool make use of the options, whether the activity is instantiated once or multiple times, cost, waiting and working times and duration, in a simulation information tab for defined different simulation information Together – Professional Open Source [6].

Tool modeling capability

The tool has multiple modeling capabilities, including declaring participants and their type: system, human, configuring a role, resource and resource sets. The tool also has different types of activities such as normal activity, task-application, sub-flow, block, and

route. It can also work as packages, and a package could contain multiple processes too Together – Professional Open Source [6].

Modeling features

The graphical editor has easy access to: graph and XPDL views for package and process, a navigator and tree area, property, problem, and WFXML components. Variables of the workflow and tasks can be created, initiated, edited, and deleted through manage variables, and process or package properties. The sub-processes can be done as a new lane for existing participants.

The tool defines the transitions type and color based on the BPMN specification, and offers uncontrolled flow, condition flow, default flow, exception flow, and default exception flow. TWE offers start, end, normal, task application, sub-flow, and block activity. It also provides access to manage process parameters and extended attributes Together – Professional Open Source [6].

Non-Technical Issues

Language support

The Together Tool supports XPDL, XML, and Java Languages Together – Professional Open Source [6].

Use in eHealth

Based on TWE sources, TWE editor is used in eHealth study of clinical decision support functionality. The TWE workflow tool used in the "Implementation of workflow engine technology to deliver basic clinical decision support functionality" biomedical research, the researchers used TWE editor and engine to create "HealthFlow" system for clinical decision support system, see Together – Professional Open Source [6].

Tool cost

The tool is available as open source software; it is also available as commercial for those who want to use it in a large organization or for those who require more support.

Support available

The tool offers free and commercial support. The free support includes the workflow editor manual, the XPDL tutorial, a free download, an email address, a phone number, a frequently asked questions page, and server support. Commercial support is also available, including development of project "specific" extensions, integration into other environments, projects, commercial training, and custom development Together – Professional Open Source [6].

Bonitasoft Workflow Tool

Tool overview

Bonita Open Solution is a workflow tool consisting of two major parts. First, Bonita BPM Studio which is the graphical environment for creating a process and contains the designing tools, the whiteboard, and the form builder. Second, Bonita BPM platform which is the deployment and testing platform for the processes, Bonita BPM platform contains the web portal, the engine, and the database.

The graphical interface of Bonita studio, called the *whiteboard*, allows the user to draw processes directly by using notation compatible with the Business Process Modeling Notation (BPMN) standards. The Bonita execution engine runs behind the graphical interface, which connects the processes to the existing system to deploy and run the process. Bonitasoft User Guidance [21].

The Bonita tool has a variety of workflow designing options: conditions, decision tables, add and test connectors, multi instantiations, and timer configuration. The Bonita tool uses the Hibernate lightweight relational database with the Bonita execution engine [21]. Although the tool has a lot of useful features, the tool does not generate code for users to modify, and users will have no excess to the html, css and Javascript codes that the tool uses to generate the applications.

The tool can be useful for developers, end users, and management users, and also for human resources, IT management, quality management, and corporate finance organizations. However, there is no mentioning of its use by healthcare organizations or if the tool is used in any of the studies concerning eHealth applications. Bonitasoft Overview [25].

With the Bonitasoft tool we can add a timer event; this feature would be useful when designing the *digital* lab order process and could be assigned to the event of assigning order to available lab techs or nurses.

Additionally, the tool has message flow and call activity features. Examples of message flow include throw, catch, start, end, and boundary messages. The message feature is different from send email feature, and the message flow event would also be useful when designing the *digital* lab order process by using it when sending messages to a physician or a department when lab results are critical. Bonitasoft Overview [25].

Messages can be sent between pools (process) and used to send information from one process to another, but it cannot be sent within one pool. Sending information between pools or to multiple receivers requires using signals. Sending messages requires a data mapping which is sometimes called message configurations, the procedure of transferring data between parent process and sub-process variables and back.

The other feature is the call activity; it is a sub-process can be set to run automatically. When the main process reaches it and when this sub-process ends, the main process will

run again. The call activity could be used as an alternative to the message flow when designing the *digital* lab order process.

With the Bonitasoft tool, users can define two types of variables: global variables for the entire process, and local variables for an individual task. To define a variable, users have to choose the pool by clicking it (for global variable), then they must choose the task by clicking it (for local variable). Next, from the general detail panel, they must choose data, and then add the variables[21].

When defining the variables, users will also have the choice of defining the variable either as a single variable or as multiple variables. Users can also define checkbox or dropdown list as variables from the same add variables window.

With the Bonitasoft tool, users can define conditions of the transitions to determine the path of the transition in the process workflow. Defining a condition on a transition can be done in many ways. Bonitasoft User Guidance [21]:

- By defining the transition as default flow
- Entering script directly into a condition field
- Create a script by using the expression editor
- Create a script by using decision table

Requirements

To run Bonita workflow tool, a user needs to install Java Runtime Environment (JRE) version 6 or 7 installed. To develop software using Bonita workflow, a user you need the Java Development Kit (JDK) version 6 or 7.

The following JRE/JDK versions are supported:

- Oracle Java SE Runtime Environment 6 u30 and Oracle Java Runtime Environment 7 u3 (available from the Oracle web site and installed according to these instructions).
- OpenJDK 6-b24 (available from the OpenJDK web site).

For process deployment, you also need a JEE application server. The following are supported: Tomcast 6.0.35, JBoss 4.2.2 GA, JBoss 5.1.0.GA, Glassfish 3.1.2.2, and Oracle Weblogic server 10R3. Bonitasoft User Guidance [21].

Graphical editor

With the Bonitasoft tool graphical interface (the whiteboard), users can start designing a new workflow diagram by drawing one or more process diagrams or by drawing one or more pools. Note that each pool is a complete process.

The interface consists of six parts. The diagram panel (whiteboard) is in the middle of the screen surrounded from the top by menu bars and the tool bar (cool bar), and left by the design palette (activity, task, connectors) From the bottom, it is surrounded by the overview panel and the detail panel (general, applications, appearance, and simulation panels).

The Bonitasoft tool interface is connected directly to the execution engine, and the execution engine connects the process to the existing system to deploy or run the process. Bonitasoft User Guidance [21].

Execution engine

The Bonita execution engine is used to execute and run the process in a development environment for testing purpose only, not for a deploying process in a productive environment. "Clicking the run button installs the process on a test application server (jetty by default)" Bonitasoft User Guidance [21].

The execution engine can run a process for a test when it is "fully defined and configured." Pools are saved as an individual *Bonita archive file* but can be deployed together or separately. Users need to define all the parameters (dependencies), define organizations, and define and map actors to the organizations to be able to run the process. Bonitasoft User Guidance [21].

Simulation

The Bonitasoft workflow tool provides simulation option to evaluate the process, under multiple conditions (resources and load). To run successful simulation on a process, users should define the simulation parameters of the process tasks and define simulation resource and load; the tool will generate a report to show the results of the simulation. Bonitasoft User Guidance [21].

Analysis the Tool Can Perform

Analysis definition

The Bonitasoft analysis tool consists of different useful features in Bonitasoft workflow editor. The process problems are detected directly or indirectly throughout checking BMPN models, running, debugging, testing a connector, and processing simulations.

We can identify *Check BPMN model* as the most important among the rest of the analysis features in Bonitasoft tool. This feature detects whether there are errors or problems in the workflow design, for example choosing the wrong gateway (Join or split) between two activities (tasks), and then proceeds to display it directly on the workflow graphic design where the error or problem takes place as a red *X* sign. Users can display the descriptions of the error by passing the pointer over the *X* sign, and a window with the error description will appear[21], see Figure 21.
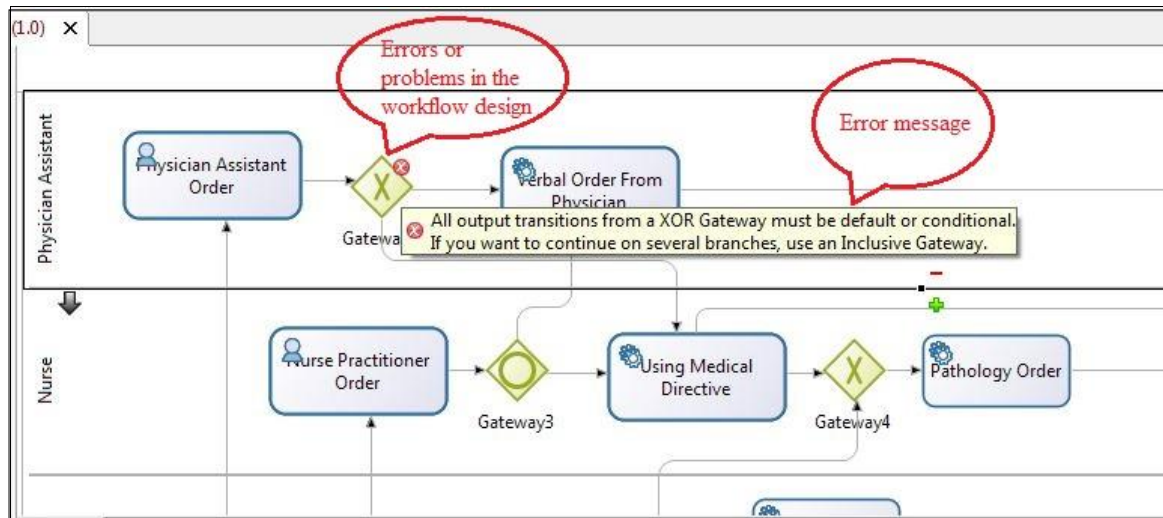
Figure 21: Bonitasoft error message

Analysis role

Each of the analysis features has its own role. They are described below. Bonitasoft User Guidance [21]:

- **Check BPMN model** role. This feature screens the tasks of the process model for any error or missing configuration "as you design a process, when a task in a process model is incomplete. For example, when missing an actor or a connector configuration, a red X appears in the upper right corner of the element. This indicates that there is a correction needed"[21].

- **Run a process.** This feature is used to test the process through executing it. "To run a process from inside Bonita Studio is one means to "execute" it - in a development environment, to be used for testing as you develop a process".

- **Debug.** This feature is used to re-run the process in development or test mode to disconnect any unsuccessful connectors. "Use Debug in Bonita Studio to disconnect any connectors that you know cannot run successfully when you run the process in development or test mode".

- **Test a connector.** With this feature "you can test the function of some types of connectors while still in design/development mode".

- **Process simulation**. This feature is used to assess the process path or technique "using simulation to evaluate the way a process runs under different resource availabilities and different load profiles".

Analysis configurations

Since there is no analysis tool for the *Bonitasoft workflow tool*, there is no configuration as well. The available problem detection features have different configurations based on the purpose of every feature.

The available options for *check BPMN model* feature are *activate* or *deactivate*. The users can activate the feature if they want to see any missing configuration in the process, or deactivate the feature if the users want to share or print a clean diagram. For the *run* feature, users need to define the process parameters and define the organization and actors. The *Test a connector* feature requires database connections extra configurations. To configure the *process simulation* feature, users need to define simulation parameters on individual tasks as well as define simulation resources[21].

Analysis results

The different problem detection features have different results as follows. Bonitasoft User Guidance [21]:

- o Check BPMN, detect if the tasks or connections in the workflow design needs any corrections like misconfiguration.
- o Run a process, to diagnose the process execution problems.
- o Debug, to rerun any connectors that cannot run successfully.
- o Test a connector, to test a connector in a design mode.
- o Process simulation, to evaluate the process running under different conditions (resources, loads).

Technical Issues

Executable model

The Bonitasoft workflow tool can run simulation and execution to evaluate a process. Different actors can be selected and assigned data. Variables may include: global, local, single, multiple, and list of options.

The Bonitasoft tool uses connectors to connect a task or process to the external information system by taking input from users and execute Java code. Some connectors take value from end user and return outputs data back to Bonita solution. Connectors can be configured (by adding or creating a connector), and can be tested while in the development   mode.

Tool modeling capability

The tool modeling capability consists of multiple activities such as creating service task, human task, call an activity, gateways, transitions, events, event sub-process.

Modeling features

The Bonitasoft workflow tool has the following modeling features: define and configure tasks data, actors, priority, type, connectors, set the validation, define transitions, conditions, and decision table. The tool also has useful features: timer events, message events, generating process documentation, multi-instantiation, and changing the appearance of design elements [21].

Non-Technical issues

Language support

The Bonitasoft workflow tool processes data in multiple formats, including: "Java Objects" and XML. The applications generated with Bonitasoft use standard html, css and Javascript for. Bonitasoft Overview [25].

Use in eHealth

There is no indication or proof that the tool is used for healthcare or eHealth study.

Tool cost

The tool is available as free software or as commercial software requiring subscription or an expertise pack.

Support available

The free support available consists of a free download and install, free user manual, and introduction tutorials. The subscription support pack includes phone support, online resources for an unlimited number of issues, training paid online or in Bonita facilities, as well as open sessions available for different types of training and in 6 *human languages*. Additional expertise support includes an expertise monitor (talking with a mentor – 1 day, proof of concept – 1-5 days, set-up jumpstart – 2 days, deployment jumpstart – 2 days), remote development guidance, and inquiries. Bonitasoft Overview[25].

NOVA Workflow Tool

Tool overview

Our study shows that the NOVA workflow tool was developed in consideration of compensable transaction and formal verification. This workflow model framework uses a

formal graphical language proposed by StFX University, Antigonish, Nova Scotia Centre of Logic and Information (CLI). It is called the Compensable Workflow Modeling Language (CWML) [22].

The framework includes a graphical editor, a translator and a workflow engine. The graphical editor of the tool is an eclipse plugin. The role of the translator consists of transferring a workflow model language to the language of the model checker DeVinE for simulation and verification.

The workflow engine uses Spring and Hibernate J2EE framework to execute the verified workflow model. The tool needs multiple plugins – Hibernate and Spring Framework, workflow components, and DeVinE model checker – in order to complete the required workflow design. NOVA Workflow User Manual 2.0 [23].

Requirements

To run NOVA workflow tool, a user need to have the following. NOVA Workflow User Manual 2.0 [23]:

One of these operating systems

- SUN Solaris 2.6, 7, 8, 9 or 10[sparc]
- Linux- Red Hat Enterprise Linux/Fedora, Debian etc
- Windows 2000/2003 Server, Advanced Server
- Windows 2000/XP/Vista/2007

Any of these application servers

- BEA Weblogic Server 8.1/9
- Resin 3.0.x
- Apache Tomcat 5.0.x

Any of these database servers

Oracle 9i Release 9.2

MySQL 5

Sybase 12.5 or higher

PostgreSQL 8

Java Devleopment Kit

SUN JDK 1.6

Open source software's

Spring Framework 1.2

Hibernate 3.5.4

Eclipse Indigo 3.7

Android SDK

Graphical editor

The NOVA workflow tool uses the *eclipse* user interface as the tool graphical editor, plus some extra workflow features (workflow components plugin). The workflow components plugin panel contains all of the necessary features for designing a workflow process, including: tasks, joins, property setting, selecting or deleting tasks, making composites, creating Java script classes, opening subnet workflow, detaching subnet, workflow setting, deleting workflow, and selecting elements.

The NOVA workflow tool graphical editor produces a structured workflow and stores the workflow in XML format. The graphical editor is the eclipse SDK Java tool plugin; it contains the graph panel in the middle surrounded by the tool bar and the menu bar from the top; to the left is the package explorer; at the bottom are the workflow components and problem panel; and from the right is the outline panel.

Execution engine

The NOVA workflow engine was developed using the Hibernate & Spring framework. It is little bit different from other workflow tools; the engine and the client application need a certain configuration in order to be ready to run.

The NOVA workflow component panel has a useful feature which can help users to configure the workflow engine and the client application by entering the following information: container location, workflow name, file name and prefix, base and database URL, database name and password, to the workflow setting panel.

After configuring the workflow engine, users need to generate service classes by using the *create service classes* feature in the component panel; this feature will generate *Hibernate* mapping files and *application context.xml files* which are required for the execution of the engine. The *create service classes* feature will also configure the client application. Execution will be ready after that.

Simulation

The NOVA workflow tool uses the "DeVinE" model checker to simulate and verify the workflow process models. The model checker translates the model for simulation and verification by using a reduction algorithm to accelerate the verification time of a normally large and complicated workflow model. NOVA Workflow User Manual 2.0 [23].

Analysis the Tool Can Perform

Analysis definition

The NOVA workflow tool offers the analysis features run, debug, error message, and quick fix features through the eclipse tool. When using the run or debug feature, eclipse determines whether there is an error or warning associated with the workflow design. It then displays it in a problem's tab with some definition to help the user solve the problem.

Analysis role

The role of the available analysis features is to spot workflow design problems (errors and warnings) such as missing libraries or build path error, then list them in the problems tab as in, see Figure 22, or display it as a message in a message window, see Figure 23.
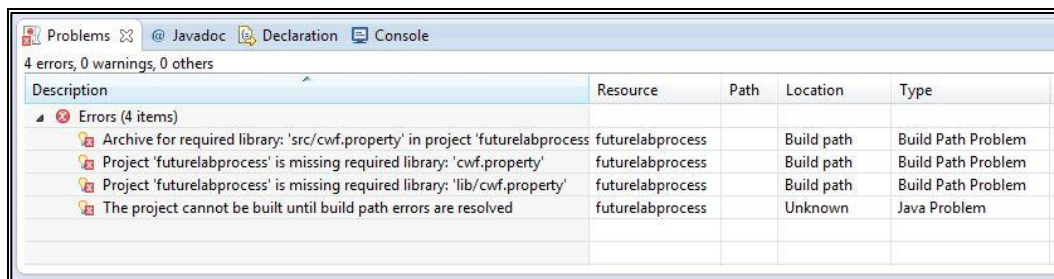
Figure 22: NOVA problem tab
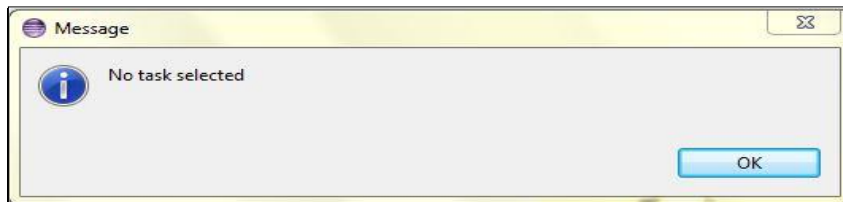
Figure 23: NOVA error message

This problem list of errors or warnings was designed based on the *eclipse* tool configuration in order to display all of the necessary information to fix any error or warning. It offers some suggestions through a quick fix feature from the eclipse problem tab; the quick fix feature provides suggestions to fix only a Java code error of the classes, and not for the process design like with other tool (YAWL, Together, and Bonitasoft), see Figure 24 and Figure 25 for examples of problem window and editor window.
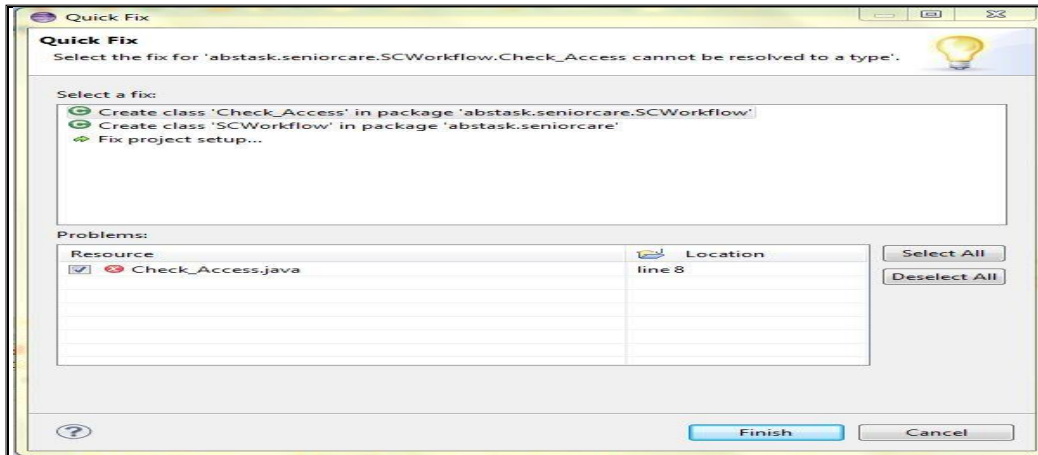
Figure 24: NOVA quick fix from problem window
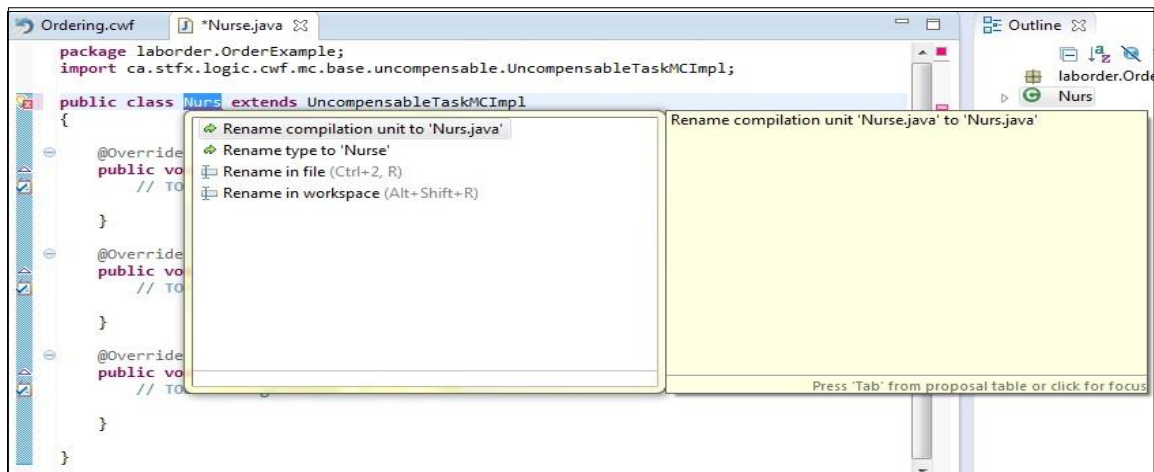
Figure 25: NOVA quick fix from editor window

Analysis configurations

The available analysis configuration in the NOVA workflow tool was derived from the configuration of *eclipse* features such as run configuration and debug configuration. This tool does not allow users to have much control when trying to change configurations except when choosing to configure run or debug as eclipse requires.

Analysis results

The NOVA workflow tool offers a problems panel with information for workflow tool users. The result of the analysis categorizes the problems as follows:

- Descriptions, to display the error or warning description in detail
- Resources, to specify the error or warning resource in the project package
- Paths, to display the error or warning path in the process if available
- Locations, to describe the error or warning location in the process files
- Type, to describe the error or warning type (Java problem, build path)

See Figure 22.

Technical Issues

Executable model

The tool translates in principle by using the NOVA Workflow translator. It translates each of the tasks by reading the workflow model and its properties file. If a task does not have any property file, the tool will translate the flow only. The *DeVinE* model checker will do the simulation and verification after translation. NOVA Workflow User Manual 2.0[23].

Tool modeling capability

Most of the available tasks are for workflow processes tasks normally done by a human, and not to be run automatically or set to be done by a system. Variables can be declared as global or local and only in the program code.

Modeling features

Modeling feature of the NOVA tool consists of the main features of graphical editor, translator, and workflow engine. The tool contains limited features: conditions, task properties, and split join. The NOVA tool is missing the essential features of cancellation; the tool uses compensable transactions instead.

A compensable transaction is pair of programs runs together, one to do a required action and another runs the compensable action when needed; if the work is done without failure, the required action will complete its work, but if the required action failed then the compensable program will undo the previously completed non-transactional work. While when an activity in the workflow is not completed, a cancellation handles non-transactional work that not completed.

Using the compensable transaction requires more work than using the cancellation feature, especially for users with no programming background. Additionally, the tool has limited task property components, no individual transaction available, and the task property contains limited functions (name, description, author, and create property file only). NOVA Workflow User Manual 2.0 [23].

Non-Technical Issues

Language support

The NOVA workflow tool supports Java and the "Compensable Workflow Modeling Language" (CWML) languages. NOVA Workflow Overview[22].

Use in eHealth

The short demo provided by the tool source website shows the tool used to develop client application referral form healthcare workflow models, workflow for palliative care, and a browser for electronic health record. NOVA Workflow Overview [22].

Tool cost

The tool is free to download, but it is not open source software.

Available support

The tool provides the required plugin as free to download. There is also a tool user manual, two short video demos of NOVA workflow version 0.1 and version 2.0, general information, a phone number, and an email address NOVA Workflow Overview [22].

General Issues

Although the tool uses a unique language: the compensable workflow modeling language CWML, and has some workflow features, but it is not easy to use when compared with the other tools. We experienced some general issues when working with NOVA tool that we haven't experienced with the other tools (YAWL, Together, and Bonitasoft) and will express it as follows:

The tool user manual steps are not clear, especially the installation part which is missing a lot of detailed steps, including: how to get to some of the required installation files, finding the specific or exact address for some needed files, and relying on vague information for some required files. In addition, some installation files are not compatible with all computers operating systems.

The workflow engine services instructions are mostly for programmers only and the available instructions only outline how to modify the code. Even the steps in the user manual are intended for developers or for users who are familiars with eclipse SDK, not for first-time eclipse users. The graphical editor is complex and has limited features; inserting a task is a complex operation compared to other available modeling tools. NOVA Workflow User Manual 2.0 [23].

Designing testing process using the NOVA workflow tool took almost a week of work. With the other tools (YAWL, Together, and Bonita), it took no more than a day to do the same process.

Designing a process resulted in the following issues:

- With NOVA workflow tool, users do not have the control to design the splits and joins in the way that they want. The same issue arises with the transactions (branches) in which users cannot move or redirect the connection from task to task.

- Local variables should be declared in the task property class as class attributes in order to use them in the workflow.

- Users should have knowledge of eclipse when working with NOVA tool. For example, a project's name should start with small letters. A project with a name starting with a capital letter will have a problem when trying to run the project in eclipse. Changing the name later is not permissible, and a new project needs to be created from scratch.

- When creating new tasks in the editor, the tool will not create the task's property files automatically, property files needs to be created manually one by one.

- Designing the workflow requires a user with some coding knowledge. For example, all the join and split code in the design is mostly inherited abstract methods and should be created manually. There is also a need to export some files, and any change to the task property should be done by changing the code of these properties.

- To run the workflow engine, users are required to configure the project first. They then need to get "Spring and Hibernate" jar files and include them in the tool with the project files. The instructions on how to get these files are vague and intended for J2EE experts as described in the user manual[23].

- There are two versions of the NOVA workflow tool – version 0.1 and version 2.0.

We couldn't complete the work with Version 0.1 due to some missing packages and classes (entity beans classes, interface classes) and no information is available in the tool user manual or the source demo on how to get these packages, what prevent the tool engine from running successfully and complete the process design. Version 2.0 also does not run due to significant errors listed in the coming bullets.

- With version 0.1, in order to run the workflow engine, users/developers will have to write the business logic inside the business components. However, in version 2.0, users are not required to write the business logic in the J2EE code.

- The NOVA workflow tool is free to download and use but it is not an open source tool.

- The available NOVA workflow version 2.0 downloadable file is not compatible with all computer operating systems. The author's suggestion was to download eclipse separately, then transfer the *feature* and *plugin* files to the features and plugin files of eclipse. This suggestion was given after contacting the author.

- There is no substantial difference between the NOVA workflow version 2.0 and version 0.1, though version 2.0 requires adding more codes than with version 0.1.

- Running the workflow engine of NOVA workflow version 2.0 still requires configuring the tool database.

- There are significant errors with the *NOVA workflow version 2.0 eclipse file*. It is described as follows:
  - To run NOVA workflow version 2.0, the user needs to download the latest *SDK* package tool files version 21.1 for android. The NOVA workflow version 2.0 tool uses the SDK path *C:\cliresearch\tools\android-sdk-windows* to download the package tool for android in eclipse. The specified path address is not editable and cannot be reset due to the copyright of the tool. In order to be able to run the tool, we had to solve this issue by creating a path address with the same address mentioned above to let the eclipse tool work and configure the SDK manager.

- All the issues that we mentioned above will not be easy for a regular user to do or follow unless they have some coding knowledge, or worked with eclipse before.

5.1.1. Overview of Other Workflow Tools

bpmn2bpel Workflow Tool

The tool source page does not have enough information about the tool features and benefits. The plugin tool with eclipse is missing the tool context menu entry, what cause the eclipse plugin to produce errors. Searching about this tool results in following [26]:

- Not enough information for installing the tool.
- No workflow examples or screenshots.
- No user manual available.
- No support available.

The file for getting started, provided by the tool source page, specifies some of the disadvantages of the bpmn2bpel tool. It shows that the current implementation still has the following issues [27]:

- There are still some bugs with the translation of arbitrary cycles with a single entry point.
- The translation of REPEAT-WHILE patterns is still unimplemented.
- Some other problems might be present because this is the first version of the Plugin. "The current layout algorithms are not well suited to deal with highly nested models".

Apache Airavata Workflow Tool

Apache Airavata is a workflow software tool used to build science gateways, providing software modules to construct, execute, manage and monitor applications and workflows. This tool is mostly intended for developers, and most of the provided information is about code.

The download page of the tool does not provide clear information about the required files. It describes a lot of files with no instruction on how to use these files. This can be highly confusing for users [28].

The tool has not enough support available, no user manual, and the provided tutorial is not well-structured for a regular user. We couldn't find enough evidence about using the tool in a healthcare setting when searched about the tool in the available sources.

jBPM Tool Workflow Tool

Although the provided information about the tool shows that the tool has useful features and the eclipse plugin graphical editor is easy to use, but it is difficult to get to the required download files. The instructions are also unclear on how to access these files [29].

The tool uses a practical drag and drop graphical editor feature, but most of the other operations: defining process, creating a knowledge base and starting process, are to be done through modifying the XML code. JBPM User Manual [29].

Notably, the tool does not have enough support; I was not able to download some required plugin files, making it impossible to work with this tool.

Anduril Workflow Tool

This workflow framework was developed at the "Computational Systems Biology Laboratory at University of Helsinki" for the use of scientific data analysis. The tool was intended to be used by developers only; it has no graphical editor for regular users to develop a workflow. There is also not enough support available for this tool, and the overall information is missing a lot of details [30].

Kepler Workflow Tool

This tool was mostly designed to help programmers, developers, and scientists to create, execute, and share models. This tool does not have enough features to design a workflow model like the other workflow tools; the available information about this tool is vague and confusing for a regular workflow designer [31][32][31].

The graphical editor of this tool is missing a lot of the regular workflow components and features such as tasks, transitions and splits. This makes it uncomfortable for the workflow designer when working with the tool.

nexusBPM Workflow Tool

This tool is a "JBoss's jBPM" product suite. It uses eclipse and the eclipse plugin as a workflow platform. The tool's web page lacks of information, except for a download link and a screenshot.

Although the tool has a user manual, but it has not enough workflow features to develop a workflow model like the other workflow tools. This tool is considered as unreliable when comparing it with the other tools when designing a workflow [33].

Aperte Workflow Tool

This tool is web-based workflow software. The tool source provides some information about the functionality and the use of the tool, but when we used the tool to create a workflow process sample, we found following issues:

The tool interface is very basic and has no advanced components to create a powerful process, what makes it difficult to create our digital lab order process. The tool is missing some important technical features: the process analysis, process property, create variables, check validity, and problem detection. The tool does not generate code and is mostly intended for business processes developments and not for system or technical processes development [34][35].

Joget Workflow Tool

This tool comes in two editions; one is a community edition which is an open source and web based software, the other an enterprise edition which is a commercial edition. The free edition tool has some useful workflow features, but they not as flexible and powerful as the features of YAWL or Together. Additionally, some features are not as strong nor as explained in the tutorial such as when working with properties or defining variables [36].

ProcessMaker Open Source Workflow Tool

This tool comes in three editions: cloud, enterprise, and open source. Although the description of the tool feature shows some useful workflow tools, the study of the tool revealed that the tool's features are limited and not useful for designing a powerful workflow process. Some of these features are not available, and the tutorial videos and screen shots are for different editions of the software. The other main concern with this

112

tool is affecting the computer system, preventing other tools like Aperte from working properly [37].

RunaWFE Workflow Tool

This tool is open-source software based on the "JBOSS-JBPM" workflow core. Even though the tool has a user web-interface it consumes a large amount of computer memory and resources, which in turn causes the server to take a long time to launch and thus slows down the performance of other software on the computer. This ultimately makes the work progress slow and complex. The tool is also missing an analysis tool, simulation, execution engine components and features [38][39].

Yaoqiang-BPMN-Editor-2.1.21 Workflow Tool

This tool is a BPMN graphical editor for business process diagrams; the webpage of the tool does not have any information available except some screen shots and a download link. Even though the screenshots show a strong design graphical editor, but this is not enough to select the tool for designing a workflow process [40].

The tool is also missing the analysis tool and the ability to generate code in addition to other modeling capabilities such as declaring variables and setting parameters.

5.1.2. Workflow Tool Evaluations Procedure

In this section of the study we discuss how we chose to evaluate the selected 15 workflow tools. We will examine the parameters and what influenced the decision of identifying the best workflow tool among the 15 tools. To evaluate the tools, we followed a mixed

qualitative and quantitative methodology in the study, collecting qualitative data supported by quantitative data.

For the qualitative methodology we used following procedure: analyzing each tool independently, investigating all the tools' designing capabilities, exploring all the tools' features, reviewing and studying the tools. This was done by following the qualitative parameters below:

Qualitative Parameters

- Flexibility of the tool (of change, move, delete, re-design)

- Reliability of the design and analysis (to meet the goal)

- Quality (of the process, whether it was easy or difficult to read and understand the workflow, joins, tasks)

- Performance of the tool (simulation, analysis, resource needed)

- What information is available to the users (downloading, installation, user guide, examples, troubleshooting)

- Ease (of tool use and information access)

The study also included quantitative methodology to support the results gathered earlier from the qualitative methodology. This happened by providing statistical data collected from analyzing the workflow tools, the design of a workflow samples, and a list of the tools' technical features, non-technical features, designing time, and workflow components used in each design. This was all done by following the quantitative parameters below:

Quantitative Parameters

- Total cost (including user time, tool cost, support, and other sources)

- Workflow process designing time (including additional time for fixing errors)

- Types of supports available

- Number of technical and non-technical features available in the tool

The evaluation of the tools includes comparing the finally selected four tools YAWL, Together, Bonitasoft, and NOVA. When we used the workflow tools to design a workflow process, we experienced different types of errors and problems with each tool. We did not consider the number of errors the tools produce while designing a workflow process as a factor when comparing different tools.

We found that it is inaccurate to evaluate the tools and compare them based on the amount of errors and problems they produce, due to the fact that errors could be caused by the user of the tool when designing a workflow process such as selecting the wrong event or specifying unrelated parameter. Instead, we measured the ability of the tools to find and direct the user to fix the error or problem in each tool, and consider it as one of the development time factors.

Studying the tools

The work in this section includes describing and explaining the procedure of studying the selected tools. We worked with each tool independently and researched for several weeks to accumulate and collect as much as possible data on the tool, its capabilities, features; the work consists of:

- Reading about the tool's documentation and do research on the tool features, functionalities, abilities, use of the tool in healthcare or any other field, and reading the user manual.

- Applying and checking up installation process of the tool to experience any errors or difficulties.

- Getting familiar with the tool's functions and the graphical interface by using it to design some workflow samples, create variables.

- Analyzing the tool by assessing all available features in the tool, checking the ease of use when designing a process, availability of analysis and problem detection, and error fixing.

- To be fair and avoid bias when comparing and evaluating any tool, and due to the difference between tool we had to use all the tool's components proficiently to

design workflow samples, fix errors, analyze process, create parameter, until we have the same level of proficiency with all tools.

- The time for getting familiar with the tools varied, most tools needed several weeks except with the NOVA workflow tool we needed more than two months; but finally we were able to have the same level of expertise with all tools.

- We evaluated each tool based on preset criteria consists of: the information we collected from studying the tool, searching about the tool and its capability and features, and by measuring the processes designing and development time of a sample workflow process, the tool's technical and non-technical features, number of components used when designing the sample workflow process, ease of component use and fixing the errors.

An explanation about the evaluation supported with the information and data collected will follow.

Process Design and Development Time

This part of the study includes qualitative analysis of the tools and measurement parameters. This section also discusses the process design parameters and strategies of how we evaluated the tools, and what influenced our decisions.

The evaluation criteria of the tools are to set a comparison based on scoring the features of the tools. A 1 was given to the available feature, a 0 to non-available features in the tool. Then the total scores of each tool was calculated in order to compare them with other tools and to determine which tool had the most features among the rest of the workflow tools, see Table 2 and Table 3.

The work includes not only determining the features but also making sure that the features were useful when designing a new process. We will expose the results concerning the helpfulness of these features in the succeeding chapters.

We have to mention here that process designing time is different than the new digital lab order processing time. Process designing time is the time the tool takes to complete designing a workflow process, while the new digital lab order processing time is the duration time of complete digital lab order process from the time of placing lab order to the receiving of the test results.

The study included comparing the workflow process designing time by measuring the time of designing a sample workflow process using the four selected workflow tools (YAWL, Together, Bonitasoft, and NOVA) individually.

Process design and development time vary between different tools; the time depends on many factors, which are: number of workflow components used in the design, property configurations, number of parameters, variables, joins, conditions, loading time, analysis time. To measure the needed time with each tool to design a process, we created a workflow design called the *Future lab ordering* process.

The proposed process (workflow process sample) consisted of two required (start and end) tasks, and 15 other tasks: Physician assistant , Nurse practitioner order, Physician order, Using medical directive, Verbal order from the physician, Pathology order, Blood bank order, Glucometer order, Referred to lab, Phone, Verbal, CPOE, Nurse or clerk, Add on test, and New order.

The design included defining one variable of type double (order number), one date and time type variable (date time), and twelve main variables, comprised of ten variables of type string as follows: Order type, Order status, Blood type, Blood test id, Physician name, Nurse name, Patient name, Lab technician name, Physician assistant name, and Clerk name.

Measuring the Model Design Time

After defining all of the required workflow tasks and variables for the workflow process sample process, the results of the process designing time differed among the four tools.

117

With the YAWL workflow tool we needed 30 minutes to complete the design and 15 minutes to fix the errors. The design was as planned, with 15 tasks, two start and end tasks; and we needed 30 branches (flows). The number of workflow component we used in YAWL became 47 in total.

With the Together Workflow tool, we needed 60 minutes to complete the design and 15 minutes to fix the errors. The design was as planned, with 15 tasks, two start and end tasks; and we needed 40 branches. The number of workflow component we used in Together become 57 in total.

With the Bonitasoft workflow tool, we needed 40 minutes to complete the design and 15 minutes to fix the errors. The design was as planned, with 15 tasks, two start and end tasks; and we needed 41 branches. The number of workflow component we used in Bonitasoft become 58 in total.

With the NOVA workflow tool, designing the workflow was not as easy as with other tools. The NOVA workflow editor does not provide much control in terms of the direction of the branches (flows), especially when connecting two branches to one task. We had to add some extra tasks and use more branches, changing the design of the flow to get the results we needed.

For example, with NOVA workflow editor, to insert a new component (task) to the process, you need to first select the left and the right element where you want the new component to be inserted then after that you double click the new component and the editor will insert it in the position. While with other tools (YAWL, Together, and Bonitasoft) you only need to drag and drop the new task to the new position.

NOVA workflow editor doesn't allow the designer to use the transitions separately or redirect the process based on the need of the design, transitions comes already connected to a task and if you want to redirect the transition, you need to insert a new transition with a task attached to it.

With the NOVA tool, we needed 90 minutes to complete the design and 30 minutes to fix the errors. We couldn't finish the design with 15 tasks only as we planned with other tools, and some of the features are restarted and not flexible in use. We added an extra 34 tasks and we needed 60 branches to finish the design, see Table 4 for results. We needed 49 tasks and two start and end tasks. The total workflow components we used in NOVA became 111 after all, see Table 5.

Installation of the tools varied. YAWL, Together, and Bonitasoft Workflow tools were easy and fast to install, while the installation of the NOVA workflow version 0.1 was complicated, and version 2.0 was long and caused many difficulties.

The instructions on how to start a new workflow design were available in the YAWL and Bonitasoft workflow tools. However, the instructions for the Together and NOVA workflow tools on how to start a new workflow process were not clear. It was sometimes available within the text but without a specific title. The new NOVA user manual version 2.0 is missing a lot of valuable instructions on how to complete the process's configurations, guard conditions, and branches (flow) orders, making it much more difficult to complete the workflow design.

The new digital processing time is one of the important factors of choosing the right tool; the type of workflow tool plays an important role in getting the desired digital process time. Designing the process in different tools, results in getting different processing times.

We collected important data in the evaluation phase of this study; some of that data shows the difference a tool can make on the digital process time if the new digital process is designed using these tools.

The features: cancellation, identify bottleneck, automated tasks, timer event, discover infinite loop, probability of failure, plus the all features you find in Table 2, will affect the process time if used in the designing of the process.

For example, the identify bottleneck feature helps the process designer to identify the most time consuming event or task of the process and fix it; as a result, if we design a process with a tool that has this feature, we will get a less time consuming process than any other process designed with a tool doesn't have this feature. Table 2 shows the best scoring tool in these features among the other tools.

Cancellation is also one of the important features that affect the process time. A process designed with the cancellation feature can save more time compared to any other process designed without this feature. For example, by using the cancellation in the delivery process of the new digital lab order, the system can determine the order of the tasks, and cancel the other paths, see Figure 1 and Figure 6. While with any other process without cancellation, the path of the process is determined manually, which normally takes more time than the automated system.

Evaluation Summary

This study starts by selecting 15 open source workflow tools, and filtering them based on certain criteria. These include Availability of an analysis tool, tools features, support, graphical editor, execution engine, and simulation. We looked at the tool's examination results and chose four tools (YAWL, Together, Bonitasoft, and NOVA) that have the declared criteria.

We used these four selected workflow tools separately to design the *workflows process sample* and to evaluate each tool based on the outcome of the new workflow design. To evaluate the tools more intensively, we followed a mixed (qualitative and quantitative) methodology. This entailed collecting a qualitative data of the tools, supported by quantitative data of the tools.

We chose the best workflow tool based on different factors. We put the perspective of users into consideration as one of these facts. Workflow tool users prefer reliable, fast,

and controllable tools; they prefer to use the tool that provides the most designing power with the minimum time required.

Based on the information we gathered from tools examination and evaluation following the mixed qualitative and quantitative methodology, analysis and evaluation of the four selected workflow tools revealed results of the designated workflow process sample *Future lab ordering* designing outcomes.

We can recommend YAWL as the best workflow tool to design the new *digital* lab order workflow process. TWE as the second choice, Bonitasoft as the third choice and NOVA as the last tool among the four selected workflow tools.

5.2. Introduction to Current and Future Lab order Process Flows

Current process flow

The current lab process flow consists of ten main tasks: ordering, entering orders into the MT electronic health record, printing labels, receiving lab orders, collecting samples, delivering samples, processing samples, analyzing results, submitting results, and storing samples.

Tasks either contain sub-processes to reach the next task such as ordering, or split and link to multiple or single tasks like collecting samples, the design of the tasks is based on the requirements of the process, see Figure 26 and Figure 27.
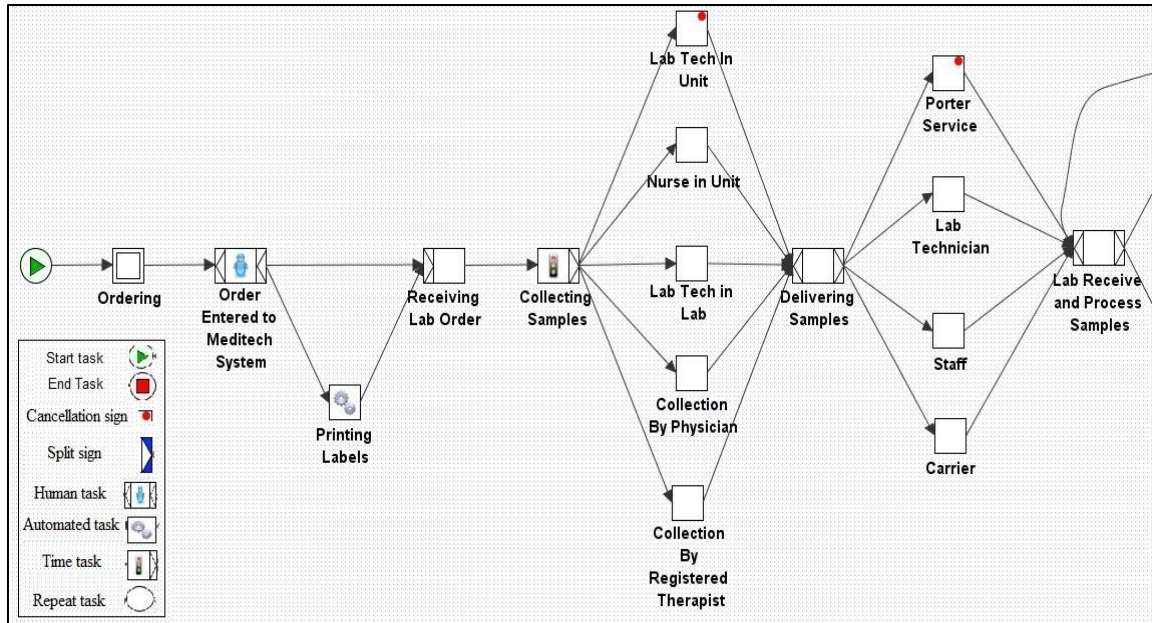
Figure 26: Current lab process designed in YAWL part 1
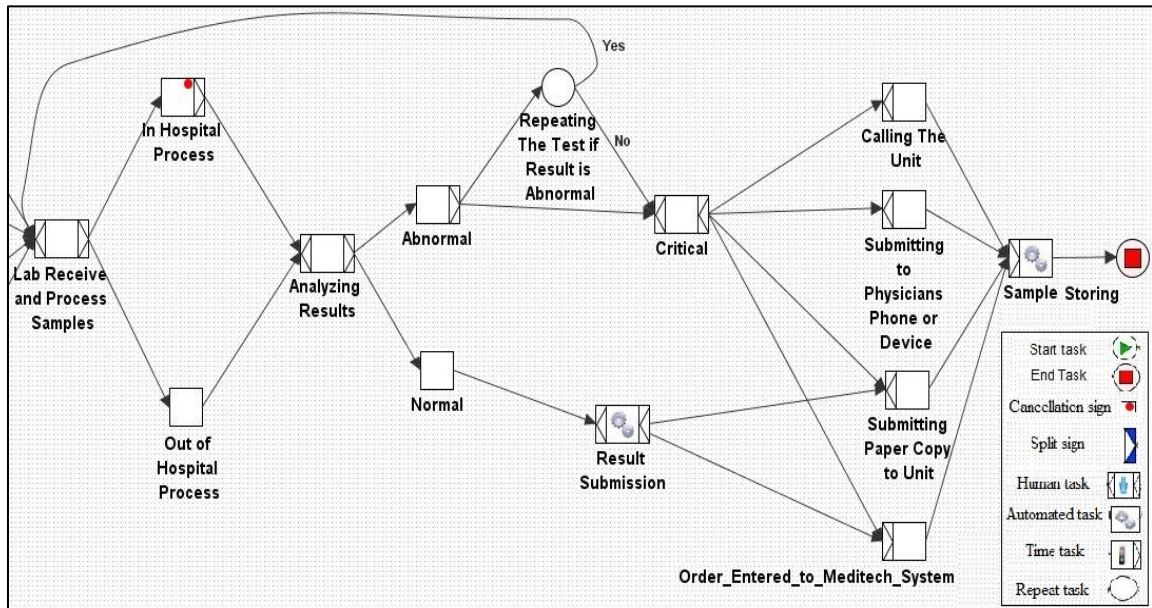
Figure 27: Current lab process designed in YAWL part 2

The following information is considered a description for the current lab order flow process diagram and the current process flow is explained as follows:

1. **Ordering.**

Lab order process starts with placing an order either by a physician, physician assistant or nurse practitioner. The main method of entering orders by a physician is a *paper-based* requisition; then a nurse or clerk will enter it into the MT electronic health record. The current process starts either by placing new order or request additional test on sample (Add on test).

The *Add on test* is a process of adding another test on a recently collected sample, the *Add on test* request will go directly to the lab and a lab technician will enter it to MT, then process the sample based on the request of the physician.

The new order process will proceed as follow:

    a. **Physician order.**

        This process consists of seven sub-processes; all these processes will lead to one of two tasks: *New order* or *Add on a test*.

            ▪ **Paper-based requisition.**
            This process is the primary method of entering an order by a physician; in the *current flow*. Physicians do not have direct access to write an electronic requisition using CPOE. Instead, physicians make a paper-based request, then a nurse or clerk will enter it into MT directly.

            ▪ **Verbal.**
            This process is typically used in units where physicians are busy and unable to write orders. For example, in the endoscopy clinic a physician could do a sample collection and verbally request another sample at the same time.

- **Phone.**

  Physicians can also place an order by calling the hospital department. A nurse or clerk can answer and enter the order details on a paper request or directly input it into MT as a new order or ad on a test order.

- **Referred to lab**

  Physicians can refer patients to the lab for a new order only. This occurs when test results take several days to be completed and need to be ready in advance when a physician sees a patient.

- **Glucometer order**

  Physicians can place a glucometer order only as a new order

- **Blood bank order**

  Physicians can place an order for a blood bank as a new order only

- **Pathology order**

  Physicians can place a pathology order as a new order or as an add on test order. Pathology orders can include cytology or histology orders.

b. **Physician assistant**

In the current process, a Physician assistant has the following options to place an order:

- **Using medical directive.**

  Physician assistant with a medical directive can use a paper request or access the MT electronic health record to begin a new lab order or pathology order

  - **Pathology order.**

    A Physician assistant can place a pathology order as a new order or add on test order. Pathology orders can include cytology or histology orders.

  - **Verbal order from the physician.**

This process is typically used in units where physicians are busy and unable to write an order. A Physician assistant would receive the order and either write a paper request or directly order it with MT.

c. **Nurse practitioner order.**

In the current process, nurses have two options when placing a lab order:

- **Using medical directive.**

  This sub-process is the only way of placing lab order process by nurse practitioner. Nurses cannot place lab orders unless they have a medical directive signed by a physician; the nurse can access the MT electronic health record and begin a new lab order or pathology order.

- **Verbal order from the physician.**

  This process is typically used in units where physicians are busy and unable to write an order like in the Endoscopy clinic. A physician could do a sample collection and verbally request for a sample at the same time.

  o **Pathology order**

    A respiratory technicians, physician assistant, or nurse in OR, Day Surgery, Radiology, Endoscopy, can place pathology (cytology & histology) orders as a new order or add on test.

The next step after *ordering* in the current process flow is explained as follows:

2. **Entering order to MT.**

   In the *current process* physicians have no access to write direct orders by using CPOE. A nurse or clerk is the one who enters a physician's order into MT.

3. **Printing labels.**

   After entering orders to MT, the system will print labels automatically either in the unit or the lab. For example, with routine orders the system prints labels in the lab so that the technicians can pick up labels and go to the destination of the collection.

4. **Receiving lab orders.**

   Receiving the orders should be performed by the person who will perform the collection. For instance, lab technicians in a unit always receive and do STAT orders.

5. **Collecting samples.**

   Collecting samples is assigned based on the order type, or the status of the patient. For example, a lab technician cannot do a PICC line collection, and a nurse cannot do a tissue collection for a dialysis patient.

   a. **Registered therapist.**

      A registered therapist is able to do the following types of collections:

      - **Specimen collection, (Pathology: Cytology & histology)**
      - **Arterial blood gas (ABG) collection.**

   b. **Physician.**

      - **Endoscopy collection.**

         A physician can do a collection of endoscopy samples in the endoscopy room.

      - **OR Collection**

         A physician can do a collection in the OR.

   c. **Nurse in the unit.**

      Nurses can do a routine sample collection in a unit for a patient with PICC line. Nurses also give glucometer orders.

      - **Endoscopy collection.**

         A nurse can do endoscopy collection based on the physician's directions in the endoscopy room

      - **Glucometer collection.**

A nurse can do a glucometer collection based on the physician's order (single collection, hourly or daily)

- **PICC line collection.**

  A nurse can carry out urine and blood collections for patients in the unit; blood collections are performed on patients with PICC line only.

- **Routine collection.**

  Nurses in some units can perform a routine collection based on the order type; but this process is mostly done by a lab technician

- **Blood bank test.**

  The process of determining the patient blood type is performed before ordering blood from the blood bank. This test is done to find out the patient's blood type.

d. **Lab technician in unit.**

Lab technicians can perform sample collections in a unit for STAT, routine, and round trip orders. This includes:

- **Routine collection.**

  The activity of performing a daily round trip to collect samples at different times of the day (7:00 am, 10:00 am, 1:00 pm).

- **Blood bank test.**

  The process of determining the patient blood type is performed before ordering blood from the blood bank. This test is done to find out the patient's blood type.

- **STAT collection.**

  This process is performed by lab technicians only, when blood test results are required urgently.

    e. **Lab technician in lab**

Lab technicians can carry out collections in the lab for patients referred by a physician or for an in advance collection for a patient with upcoming appointments.

      ▪ **Physician referrals collection.**

This process occurs once a test is referred by a physician from one of the hospitals units and not an outside clinic.

      ▪ **In advance collection.**

This process is for patients where results should be ready for the physician at the time of the appointment (primarily for oncology patients).

6. **Delivering samples.**

Delivering the samples is done in four ways:

    a. **Porter service.**

A hospital porter service personal collect the lab samples from a basket in a hospital department and deliver them to the lab, this process is the main methods of delivering samples to the lab in the current lab order process flow.

    b. **Lab technician.**

The lab technicians take the collected samples with them to the lab when they finish their round trips or routine collections.

    c. **Staff.**

A staff of a department delivers the urgent collections to the lab.

    d. **Courier**

In Humber River Hospital-Keele site, they send samples to the lab with a commercial courier services, or a taxi cab.

7. **Processing samples**

   After the lab receives samples, technicians start categorizing them based on the required test. Processing samples occurs as follows:

   a. **In hospital process.**

      Samples are normally processed in the hospital lab, except for some samples where a required instrument is not available in the lab.

      The process starts by placing the received samples in the processing instruments one by one, and then the lab instrument will process the samples and write the results into MT. Finally, the samples will proceed to be stored.

      The process in the hospital involves:

      - **Add on test**

        A physician can request to add other test on collected sample, and the lab technologist makes sure to add the new test into the system and reruns the test on the sample to get the required result.

      - **Urine process**

        A process of analyzing urine samples

      - **Blood and specimens**

        o **Manual**

           A process of analyzing blood samples manually.

        o **Automated**

           A process of analyzing blood samples by an analyzer instrument.

        o **Pathology & Micro Pathology**

           A process of analyzing pathology samples (Cytology & Histology).

b. **Out of hospital process**

> The process of sending samples that requires unavailable processing instrument, to outside the hospital for processing.

8. **Analyzing Results**

The process of analyzing some of the samples that show concerning results by categorizing them differently and process them as follows:

a. **Abnormal results**

> This process will take place if the results have abnormal expectations. The technologist analyzes samples as follows:

> - **Abnormal that meet repeat criteria**
>   - o **Repeat Process**.
>
>   Analyze the result as abnormal or critical – if it *meets or does not meet* repeat criteria. Samples that result in *meet repeat criteria* will be reprocessed again. A sample that results in *doesn't meet repeat criteria* will then proceed as *Critical*, then to result submission and sample storing.

> - **Critical**
>   - o **Calling the unit.**
>
>   In this process, the lab will call the unit and inform them directly about the result for faster action.
>   - o **Submitting to physician phone or device.**
>
>   In this process, the lab calls the physicians on their phone or device, and informs them of the results.
>   - o **Submit to MT**
>
>   All the critical results will be submitted into the MT regardless of any other method of result notification.

     b. **Normal results.**

     This process will take place if the results have normal expectations and will proceed to submitting result directly.

- **Blood bank operations**

  The process of all the blood bank activities, and contains the following three sub-processes:

       a. **Blood preparations.**

       A process of:

  - Defining the patient blood type.
  - Analyzing and preparing the blood bags by the lab.
  - Getting blood from the blood bank.

       b. **Blood supply.**

       A process of providing blood bags to the unit; a nurse or porter can obtain the samples of blood and deliver them to the units.

       c. **Analytical Instrument**

       A process of analyzing blood samples by an analyzer instrument for the purpose of the blood bank activity

9. **Submission of results.**

   The system will submit the results automatically; analyzers process the samples and submit results to:

        a. **MEDITECH (EHR)**

        Submit the result into MT in all situations.

        b. **Submitting a paper copy to units.**

        Send a paper copy to the unit's printers.

        c. **Submitting to physician phone or device.**

        Send results to the physician's devices or phones if the result is critical

        d. **Calling the unit.**

        Informing the unit by phone if the results are critical

10. **Storing Samples.**

Storing samples determined based on the samples type. For example, blood samples being stored for days while urine samples are stored for hours only.

Future lab order process

The future lab process flow will include 10 main tasks: ordering, MT electronic health record, confirmations and verifications, receiving orders, collecting samples, delivering samples, processing samples, analyzing results, submitting results, and storing samples.

Each of these tasks contains sub-processes to reach the next tasks, and can be explained as follows:

1. **Ordering.**

   The lab order process starts with placing an order either by a physician, a Physician assistant or nurse practitioner. The main method of entering orders by a physician is CPOE. The main method of entering orders by other staff is by direct entry into MT.

   - **Physician order.**

     This process consists of seven sub-processes, all of which will lead to one of two tasks: *New order or Add on a test*.

     - **Computerized Physician Order Entry (CPOE).**

       This process is the primary method of entering an order by a physician. In the current lab order flow CPOE is not fully implemented to the system, but in the future *digital* flow, physicians will have direct access to write an electronic requisition using CPOE including the lab order requisition. The system will then enter it into MT directly.

- **Verbal.**

  This process is typically used in units where physicians are busy and unable to write orders, like in the endoscopy clinic. A physician could perform a sample collection, and then verbally request another sample at the same time. The order in this case will be entered by a nurse into MT.

- **Phone.**

  Physicians can also place an order by calling the unit. A nurse or clerk can answer and enter the order details into MT as a new order or add on test order.

- **Referred to lab.**

  Physicians can refer patients to the lab for a new order only. This sub-process is preferred because sometimes test results take several days to be completed and need to be ready in advance when the physician sees the patient.

- **Glucometer order.**

  Physicians can place a glucometer order only as a new order.

- **Blood bank order**

  Physicians can place an order for blood bank only as a new order.

- **Pathology order**

  Physician can place a pathology order as a new order or add on test order. Pathology orders can include cytology or histology orders.

b. **Physician assistant**

In future processes, a Physician assistant will have the following options to place an order:

- **Using medical directive**

  Physician assistant with a medical directive can access the MT electronic health records and begin a new lab order or pathology order.

  - **Pathology order**

    A Physician assistant can place a pathology order as a new order or add on test order. Pathology orders can include cytology or histology orders.

  - **Verbal order from the physician.**

    This process is typically used in units where physicians are busy and unable to write an order. The Physician assistant will receive the order and either write a paper request or directly order it with MT.

c. **Nurse practitioner order.**

In future processes, nurses have two options when placing a lab order:

- **Using medical directive.**

  Nurses with medical directive can access the MT Electronic Health Record and begin a new lab order or pathology order.

- **Verbal order from the physician.**

  This process is typically used in units where physicians are busy and unable to write an order like in the endoscopy clinic. A physician can perform a sample collection and verbally request for a sample at the same time.

- **Pathology order**

  A nurse (in the OR, Day Surgery, Radiology, Endoscopy), respiratory technicians or a Physician assistant can place pathology (cytology & histology) orders as a new order or add on test.

MT Electronic Health Record.

Humber River Hospital uses the MT electronic health record to save and maintain patient records. In the future *digital* process flow, physicians have direct access to write lab orders using CPOE. Nurse practitioners as well have access to write orders through accessing MT directly.

After ordering, the future lab order process will continue as follows:

2. **Confirmations and Verifications.**

   This part of the process is where the confirming of sub-processes takes place. Status of the lab order will flow from MT; the status board will be updated with the information of receiving orders, collecting samples, delivering samples, processing samples and submitting results. Confirmation and verification will also consists of notifying the staff or lab of new orders, accepting orders by lab technicians or nurses.

3. **Receiving orders.**

   Receiving the orders should be performed by the person who will perform the collection. For instance, lab technicians in the unit always receive and carry out STAT orders.

4. **Collecting samples.**

   Collecting samples could be assigned based on the order type or the status of the patient. For example, a lab technician cannot perform a PICC line collection, and a nurse cannot collect a tissue from a dialysis patient.

   a. **Registered therapist.**

      A registered therapist is able to perform the following types of collections:

      ▪ **Specimen collection, (Pathology: Cytology & histology)**

      ▪ **Arterial blood gas (ABG) collection.**

   b. **Physician.**

      ▪ **Endoscopy collection.**

         A physician can carry out a collection of an endoscopy sample in the endoscopy room.

135

- **OR Collection**

  A physician can carry out a collection in the OR.

c. **Nurse in the unit.**

Nurses can perform routine sample collections in a unit for patient with PICC line; nurses also give glucometer orders.

- **Endoscopy collection.**

  Nurse can perform endoscopy collection based on the physician's direction in endoscopy room

- **Glucometer collection.**

  Nurses can perform glucometer collection based on the physician's order (single collection, hourly or daily)

- **PICC line collection.**

  Nurse can perform urine and blood collection for patients in unit. Blood collections are performed on patients with PICC line only.

- **Routine collection.**

  Nurses in some units can perform routine collections based on the order type; but this process is mostly done by a lab technician.

- **Blood bank test.**

  The process of determining the patient blood type is performed before ordering blood from the blood bank. This test is done to find out the patient's blood type.

d. **Lab technician in unit.**

Lab technicians can carry out sample collections in a unit for STAT, routine, and round trip orders, and will include:

- **Routine collection.**

  The activity of performing a daily round trip to collect samples at different times of the day (7:00 am, 10:00 am, 1:00 pm).

- **Blood bank test.**

  The process of determining the patient blood type is performed before ordering blood from the blood bank. This test is done to find out the patient's blood type.

- **STAT collection.**

  This process is performed by lab technicians only when blood tests are required urgently.

e. **Lab technician in lab**

Lab technicians can carry out collections in the lab for patients referred by a physician or for in advance collections for patients with upcoming appointments.

- **Physician referrals collection.**

  This process involves a test referred by a physician from one of the hospitals units and not an outside clinic.

- **In advance collection.**

  This process is for patients where results should be ready for the physician at the time of the appointment (primarily for oncology patients).

5. **Delivering samples.**

   Delivering the collected samples to the hospital's lab could be done in two ways:

   a. **Normal operation**

   This process will happen during the normal running operation, and will be the main methods of delivering lab order samples to the lab.

   - **Pneumatic Tube Transport or (PTT) system.**

     This delivery system will consists of a pneumatic tube network running between all of the hospital's units and labs. It uses pneumatic capsules to deliver collected samples from units to the

lab. Based on the capsule's size, this pneumatic tube system could also be used to deliver blood bags from a lab to units when needed if the pneumatic capsules are large enough to carry blood. The system could also be used by pharmacy.

b. **Breakdown operations**

This process will take place during the abnormal running operation when it is unable to use the pneumatic tube transport system for any reason. The alternative method of delivering samples during the breakdown operations could be one of the following:

- **Staff.**

  The lab technician who collects the samples or one of the unit members can deliver the samples to the lab.

- **Porter service.**

  A porter service arrangement can be used to deliver the samples to the lab.

- **AGV system**

  Automated guided vehicle (AGV) is a laser navigated vehicle that can be used to transport and deliver lab order samples to the lab.

  The method of sample delivery will be determined in the breakdown operations based on the priority of the orders.

6. **Processing the samples**

After the lab receives the samples, technicians start to place them on the pre-analyzer instrument track. The instrument will specify the samples based on the required test, and start processing the samples as follows:

a. **In hospital process.**

In future process, most samples will be processed in the hospital lab except for some samples where a required instrument is not available in

the lab. In hospital process will be done using pre and post-analytical instruments.

The process starts by placing the received samples in the pre-analytical processing instrument one by one, then the lab instrument will process the samples and write the results in MT; and finally the samples will proceed to the post-analytical instrument to be stored.

The process in hospital will include:

- **Add on test**

  A process of adding another test on a recently collected sample order where a physician can request the add on test and the lab technologist makes sure to add the new test in the system and rerun the test on the sample to get the required result.

- **Urine process**

  o **Manual**

  A process of analyzing urine samples manually.

  o **Automated**

  A process of analyzing urine samples by pre / post urine analytical instruments (this process is available in future process only).

- **Blood and specimens**

  o **Manual**

  A process of analyzing blood samples manually.

  o **Automated**

  A process of analyzing blood samples by an analyzer instrument

  o **Pathology & Micro Pathology**

  A process of analyzing pathology samples (Cytology & Histology)

b. **Out of hospital process**

The processes of sending samples require an unavailable instrument to outside the hospital for processing (in future process, less samples will be sent outside the hospital due to the availability of the new lab instrument).

7. **Analyzing Results**

Lab technologists analyze the samples and watch for cases where samples are out of the expected results and treat it as abnormal results. Some lab samples show concerning results due to abnormal patient situation and will be processed as follows

a. **Abnormal results**

This process will take place if the results have abnormal expectations. The technologist analyzes samples as follows:

- **Abnormal that meet repeat criteria**
  - **Repeat Process**.

    Analyze the result as abnormal or critical if it *meets or does not meet* repeat criteria. If the sample results in *meet repeat criteria*, it will be reprocessed again. If the samples results in *doesn't meet repeat criteria*, they will proceed as *Critical*, then to results submission and sample storing.

- **Critical**
  - **Calling the unit.**
    In this process, the lab will call the unit and inform them directly about the result for faster action.
  - **Submitting to physician phone or device.**
    In this process, the lab will call the physicians on their phone or device and inform them about the results.
  - **Submit to MT**

All the critical results will be submitted to MT regardless of any other method of results notification.

- **Normal results.**

  This process will take place if the results have normal expectations and will proceed to submitting results directly.

  o **Blood bank operations**

    The process of all the blood bank activities, including the following three sub-processes:

    - **Blood preparations.**

      A process of:

      i. Defining the patient blood type.

      ii. Analyzing and preparing the blood bags by the lab.

      iii. Getting blood from the blood bank

    - **Blood supply.**

      A process of providing blood bags to the unit. A nurse or porter can obtain the samples of blood and deliver them to the units. The AGV could be used to deliver the blood bags too, and the tube system could also be used to deliver the blood bags if pneumatic capsules are large enough to hold a blood bag.

    - **Analytical Instrument**

      A process of analyzing blood samples by an analyzer instrument for the purpose of blood bank activity.

8. **Submitting results.**

Analyzers will process the samples and submit the results to MT automatically for the following processes:

    a. Blood, Urine and Specimen collections

    b. Blood bank results

    c. Glucometer results

- **MEDITECH failure**

This process is a conditioned process of *MT failure* and consists of:

    ○ **No.**

    If MT did not fail, the process will be as follows:

        • **MEDITECH**

        Submit the results to MT in a normal process.

        • **Storing samples based on type**

        Storing samples based on type

    ○ **Yes.**

    If MT fails and is not functioning, the results should be stored in MT later when MT becomes functional. The process will be as follows:

        • **Submitting a paper copy to units.**

        Send a paper copy to the unit's printers.

        • **Submitting to physician phone or device.**

        Send results to the physician's devices or phones, if the results are critical

        • **Calling the unit.**

        Informing the unit about the by phone if the results are critical

        • **Storing samples based on the type.**

        Storing samples based on type

9. **Storing Samples.**

Storing samples is determined based on the samples type. For example, blood samples are stored for days while urine samples are stored for hours only.

Differences between the current and future lab orders

Most of the main workflow process steps in the current and future lab order workflows are the same. The future process consists of some new introduced processes, and other re-engineered key steps. Analyzing the current process helped finding the bottlenecks and deficiencies in the system, and eliminating them from the design of the new future process.

The points below will show the major differences between the two systems:

1. **Ordering**: The current process uses paper forms to place lab orders, while the future process will use CPOE.
2. **Dispatching**: Lab orders are dispatched manually in the current process, while with the future process; orders will be dispatched automatically by the system.
3. **Confirmation and Verification**: The current process has no confirmation or verification on any process, while with the future process; every process will be confirmed and verified for different purposes.
4. **Receiving the order**: In the current process, lab technicians or nurses receive orders manually by picking up printed labels, while with the future process, orders will be send through a mobile device to the receivers at their point of work.
5. **Labeling the samples**: The current system prints labels in the lab or in department when orders entered to MT, while with future process, labels will be printed at the bedside using a mobile printer; or use pre labeled tubes and eliminate the use of labels completely.
6. **Delivering the samples**: With the current process, samples are delivered manually by porters, staff, or carriers; while with the future process, samples will be delivered by using pneumatic tube system or AGV.

7. **Processing the samples**: With the current process, lab uses only analyzer instrument to process the samples, while with the future process, lab will implements new instruments and uses pre analyzers, analyzers, and post analyzers to process a sample.

8. **Submitting results**: In the current process, submitting the results contain some unnecessary steps of submitting results on a paper to the department, and no notification available when results are ready; while in the future process, the paper use will be eliminated and results will be submitted automatically to MT, and the system will notify the physician if the results are critical with confirming and updating the sample status on the status board.

6. CHAPTER SIX: CONCLUSION

This study consisted of two main parts. The first part of the study consists of examining 15 BPM tools and defining the best tool for designing the new *lab order* process flow. The chosen tool helped to design a new digital flow for Humber River Hospital's *lab order process* in a very advanced way; the new workflow tool enables the workflow process developer to control and automate the process tasks based on the need of the process flow.

The second part examined the current *paper-based* lab order process in a healthcare setting. It then went on to analyze the process information to define the major points of errors in the process, bottleneck of the process, most time consumable process tasks, and the main process points where improvement could be applied. The last point of part one was to use the selected Business Process Modeling (BPM) software tool to help in designing the new *digital-based* lab order process system.

The research collected *lab order process* data and used the qualitative methodology to analyze these data to find the critical phases in the current process and eliminate it from the new *digital* lab order process flow design.

The result of this research will have tremendous effects on eHealth and the healthcare system futures; by recommending the right tool for designing a new process system for a healthcare setting, and providing valuable data about transferring the lab order process from a *paper-based* system to a *digital-based* system.

The recommended workflow tool has unique designing features and components, allowing the tool users to manage, control, and finish a successful workflow design in sufficient time. The new *digital* lab order process flow design will save the hospital time and money, contribute to patient satisfaction, and provide more security to patient information than the old paper-based system.

6.1. Workflow Tools Evaluation Conclusion

The first part of the study is devoted to the effort of selecting the best BPML tool. To help in designing the new *digital* lab order process flow, we started by selecting 15 open source workflow tools, and filtering them based on certain criteria. This consists of availability of an analysis tool, tools features, support, graphical editor, execution engine, and simulation. We also looked at the tools examination results and chose four tools (YAWL, Together, Bonitasoft, and NOVA) that have the declared criteria.

We used these four selected workflow tools separately to design the *workflows process sample* and to evaluate each tool based on the outcome of the new workflow design. To evaluate the tools more intensively, we followed a mixed qualitative and quantitative methodology. This entailed collecting qualitative data of the tools, supported by quantitative data of the tools.

The qualitative methodology we followed to evaluate the tools included: in-depth analysis of each tool, investigating all of the tools' designing capabilities, exploring all of the tools' features, and finally reviewing and studying the tools. The study also included quantitative methodology to support the results gathered earlier from the qualitative methodology through statistical data collected from analyzing the workflow tools and the design of workflow samples. A list of the tools' technical features, non-technical features, designing time, and workflow components, were used in each design.

We chose the best workflow tool based on different factors. We put the perspective of users into consideration as one of these factors. Workflow tool users prefer reliable, fast, and controllable tools; they prefer to use the tool that provides the most designing power with the minimum time required.

Based on the information we gathered from following the mixed (qualitative and quantitative) methodology, analysis and evaluation of the four selected workflow tools displayed results of the designated workflow process sample *Future lab ordering* designing outcomes. We can recommend YAWL (Yet Another Workflow Language) as the best workflow tool to design the new *digital* lab order workflow process. The YAWL workflow tool has unique designing features and components, allowing tool users to manage, control, and finish successful workflow design in a sufficient time.

The second choice among the tools is TWE (Together Workflow Editor). Together Workflow is a powerful tool and has excellent choices in terms of workflow features. It can help workflow designers produce an effective workflow process design.

Out third choice is the Bonitasoft (Bonita Open Solution Open Source BPM): this workflow tool is easy to use and can produce workflow process in decent time. It has some significant workflow features such as message, call, and alert which can help users control the workflow of the process.

The last tool among the four selected workflow tools is the NOVA workflow tool. Although this tool uses a unique compensable workflow modeling language and has some workflow features, it is not as easy to use as the other workflow tools (YAWL, Together, and Bonitasoft).

Users could face a lot of difficulties when using the NOVA workflow tool when designing a new workflow process. Using this tool requires coding background or a user who has used eclipse before. We do not recommend using the NOVA workflow tool for design a workflow process at this time. The tool needs more powerful user interface, and need further studies to determine more areas of improvements.

The results of this research will have tremendous effects on eHealth and the future of the healthcare system; it has provided valuable data and recommends the most advantageous tool for designing a new process system workflow. Demand is increasing to switch to

using eHealth and health informatics applications and as a consequence there is increasing need for developers to have access to a reliable process modeling tool. Thus, research can be an extremely helpful tool to improve the healthcare system and facilitate the developers' efforts when designing a future healthcare process flow system.

6.2. Current Lab order Process Study Conclusion

The work in this part of the study investigates one of the essential developmental barriers to eHealth and the healthcare system. The old *paper-based* system was being used in healthcare settings, though most of the new equipment requires a new *digital* system able to comply with the new rise of technology in the healthcare.

This study explored the benefits of transferring the *paper-based* lab orders to a new fully digital lab orders. Lab orders contain significant amount of information, information related to patient safety, information related to patient privacy. By switching from paper-based to digital-based system, we would be able to save processing time, manage the flow of the orders, control the process, and secure patient information.

We collected *current lab orders* data from all process stages and found that the current lab order process orders consists of placing an order, printing labels, receiving the order, collecting the samples, delivering the samples to labs, processing the sample, analyzing results, and submitting the results, to be implemented on paper and performed as manual procedure.

The current lab order process affects numerous aspects of the healthcare system; the paper-based system uses more resources, requires more time to complete, and has a higher chance in producing errors.

The work on the current lab order process consists of four phases: phase one involves collecting information about the current lab order process, including observing the

workflow process for all the departments of the three Humber River Hospital's sites (Church site, Keele site, and Finch site), and hospital main laboratory. The work included designing an information collection form to collect interviews, data, and write *step-by-step* lab orders processes.

Phase two consisted of analyzing the collected information and creating *step-by-step* flowcharts of the current lab order workflow process followed in the hospital. A general flowchart for the lab orders role of the hospital was created for broader understanding; see Figure 4 for the current general flow chart.

In Phase three, we conducted follow-up interviews with the hospital departments' managers to confirm if the data was recorded correctly, and to verify the design of the current lab order workflow process.

Phase four involved defining the major activities and flow of the current process by drawing the current lab order process flow as a first step toward determining the correct flow for the future process, see Figure 26 and Figure 27.

The analysis of the collected data show that the current paper-based order has multiple issues; for example, lab orders taking long time to be completed, lab orders containing samples that were mislabeled, increasing the samples processing cost due to the long processing time, lack of mobility with the current order placing, and the need to improve sample-taking quality.

The current lab order process flow is performing using old paper-based methods, containing multiple issues and weak points in different areas of the process specifically laboratory, delivery and confirmation, labeling, and ordering.

The most noticeable issue in the current process is the turnaround time; turnaround time is one of the major benefits of the future digital process. We developed a turnaround table showing the difference between the current lab order process time and the future digital

149

process time. The result of the turnaround time check shows an enormous difference between the current and future process times, see Table 12.

With the current system, a complete lab order process *lifecycle* takes 135 minutes to complete, while with the new digital process, a complete lab order process *lifecycle* should take no more than 40 minutes to complete. A difference of 95 minutes between the two processes shows the benefits of the new design, see Figure 14 for more details.

6.3. Future Process Design Conclusion

The new *digital* lab order process flow design should save the healthcare organizations time and money and contribute to patient satisfaction. It should also give the healthcare staff (physicians, lab technicians, nurse, etc.) the opportunity to control and manage all of the new lab orders in more efficient way. With the new system, physicians will have the ability to order lab order by using the CPOE.

Designing the new *digital* flow system starts by: 1) defining the process tasks, 2) outlining the future process required to match the new system requirements, 3) designing the *Draft* of lab order process flow diagram, see Figure 26 and Figure 27.

We designed the final future lab order workflow process by using YAWL workflow tool, see Figure 5. One of the useful tools of YAWL is its cancelation feature: with this feature the user can specify the role of tasks and determine the order of the task based on the required order process.

For example, in the hospital breakdown operation, delivering lab order samples to the lab can be done in three ways: using Automated Guided Vehicles (AGVs), using staff, or using the porter service. By using the cancellation feature, we can determine the order of the tasks, and the order will follow the selected task and cancel the other paths, see Figure 1and Figure 6.

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APPENDIX : Forms

Interviews and Observations Questions and Answers Forms

Laboratory Interview

Project name	Lab order process flow in lab department
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Terry Calabrese / DIRECTOR, LABORATORY SERVICES
Date	Monday, June 4, 2012
Time	9:00 AM
Location	Church site/ Lab

Methods of collection

1. Unit collection
2. In unit technician collection
3. In unit nurse, RT collection
4. In lab technician collection

Methods of delivery

1. Transferred by technician to the lab
2. Sent by porters to the lab
3. Sent by taxi cab (Keele to Church)
4. Sent by pipe chute to the lab (Emergency only)

Clinic s involved

- Lab

- ER

- ICU

- Chemo

- Dialysis, Nephrology

- Outpatient (surgical, fracture, and plastics)

- Respiratory therapy

- Mental health

- Birthing (Women's and Children's), Labour and Delivery

Notes

- Labor and delivery, ICU, dialysis, chemo, and mental clinics they use (porter system, hospital carrier system, and taxi cab) to deliver the samples.

- Orders submitted to the lab should be done the day before by midnight

- There are some orders for three days in a row

- Emergency clinic in Church uses pipe chute, & Finch uses pneumatic

- Inpatient unit they use MT 6.0 order entry to order a test

- Order will be placed by physician not nurse.

- After order placed, label will be printed in the lab contain: patient name, location, DOB, test required, and a barcode generated by the system, (matching barcode with patient information will be done by system too)

- When order received, technicians will go in *two rounds 7:00 AM & 8:00 AM* to units (discharge first) to collect samples.

- Samples go to the power processor instrument to be processed, (current style involves human interaction *delay the process*).

- Instrument reads the barcode on the blood tube and will process it based on the type of test required – some tubes will be sent to a different process out of the instrument,

and the rest will go to be centrifuged and then will go to the analyzer to be processed. results will be written by the analyzer on a MT 6.0; a technologist check the results on MT and correct, add, comment, or perform some extra tests on the sample, then verify the result and release it to MT.

− Patient will be identified by name and DOB on bracelet.

− No result will be on paper

− Outpatient clinics, inpatient, surgical, fraction, and plastic; collection will be sent to the lab, other departments they do it in clinic

− No confirmations when receive of complete the tests

− All clinics perform lab orders electronically, except (cytology clinic) uses paper requisition, and technician has to inter it to the MT.

− Collection time showed in MT is the time that technicians put manually in the system. Technicians write down the collection time and then have to fine a PC station to enter it to MT, or when they deliver the samples to the lab.

− Current system calculate the time of a sample process from the time order placed in MT, while samples could take 1:30 hour to be delivered to lab, and if sample take 30 Min to be completed; the time in the system show 2 hours.

− The current instrument available, doing only: identifying of blood tubes, process tubes that

− If the analyzer shows up normal patient results, the technologist will have to perform a manual test on the sample to make sure the results are right, the technologist will check if the patient has a previous to compare with.

− Priority determined based on the letter on the right side of the label number (0566:C00045R), R ➜ means regular, current identification of the ER department is the yellow label, due to the absence of the other white labels in ER.

Suggestions for improvements

1. Technicians need hand held device (Meditech wireless phlebotomy piloted) to print labels by bedside [used by Halton healthcare] to reduce patient identification

and specimen labeling errors.

The current scenario:

- technician take printed labels and empty tubes to clinics
- tech leave labels on cart, go to patient room to collect blood
- Identify patient by the name on the bracelet
- Collect blood
- Take blood samples outside patient room where the cart is
- Take labels with patient name and place them on blood tubes

{ Error can't be noticed unless patient has previous record, so technologist can only compare results of previous and current record, otherwise for first time patients there is no record to compare with; errors will not be identified}

By implementing this device not only errors will be reduced, but also time will be managed properly, technicians will stay in floor to collect blood and if any update comes to the patient request, technicians will be notified by MT through the device, and will be possible to them to see updates on current orders and arriving of new orders.

Time of the collection will be entered directly to MT when technician print the label, and no need for manual entry to the system.

2. Need for pneumatic tube for delivery

   Technicians run between clinics collecting blood and delivering the sample to the lab at the same time, this action will waste the time (many collections waiting to be done while technicians running to the lab, technicians should stay in floors to collect blood)

3. Need an electronic board for technologists in the lab, to display:

   a. Number of samples collected, received (incase collected & not received)

   b. Number of samples in progress

   c. Number of samples completed (to determine if sample is missing).

   d. Real time turnaround to manage work in the lab, number of technicians and technologists needed.

4. Need to show correct processing time in MT

5. Need to determine better priority and clinic identification, for example by printing a colored square on the label for… etc.

6. Need for auto release / auto verification, to confirm the completion of work by technologist

7. Need for confirmation system for receiving the order and sample; and for distributing the result.

8. Blood, specimen, stool samples will be stored after work completed, urine samples will not be stored but will be kept for 4 hours only.

Laboratory Additional Questions

Project name	Lab order process flow in lab department
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Terry Calabrese / DIRECTOR, LABORATORY SERVICES
Date	Thursday, June 21, 2012
Time	11:00 AM
Location	Church site/ Lab

1) Where other test will be sent (hospital lab or which lab), and what are the types?
   - Some of the tests are too costly or the hospital doesn't have the right instruments to process it, examples (factor studies, call marker blood, and C-Reactive protein)

2) What is the current process time for a sample?

   Stat: 1 hour

   Routine: 2-3 hour

   Oncology: longer time due to the nature of the test and most oncology tests done manually.

3) For how long samples will be stored?

   Storing depends of the type of specimen, for example:

   Hematology: 3 days

   Chemistry: 7 days

   Urine: hours

4) How the processes go if one of the instruments broke?

   Follow the backup procedures (redundancy), probably another instrument will cover up, if the other down, will sent to other hospital

5) Is there any difference in the process flow of each specimen?

   General flow is same for every specimen

6) Why patients come in person to lab for test?

   Could be test for dialysis

   Or patients do the test before the appointment to be ready at the time of the appointment.

7) How many orders you process every day in the lab?

   Around 2500 total

   In Care 2000, Micro 250-300, Pathology 500

8) Do you see the lab inventory system as part of the lab process

   Inventory system doesn't break the flow of the lab round trip, but it is important to maintain the speed of the process, *shortage in supply* could cause delay.

9) Is there any automated system for ordering lab supplies when run out?

   No automated inventory system, all done manually.

Oncology Interview

Project name	Lab order process flow in lab department
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Jane Sanders / MANAGER, ONCOLOGY
Date	Thursday, June 7, 2012
Time	11:00 AM
Location	Church site/ Oncology

22. What type of samples you send to lab?

blood, urine, tissue, and fluid (lung…etc)

23. Are samples taken by nurse or lab technician?

Clinic staff, (department management prefer not to have technician perform the work, because there are not enough work for the technician and they have to sit all day waiting for work to do)

24. What are the methods of placing an order?

Paper request filled by the physician and given to the clerk to enter the information to MT

25. Who do place the orders?

Physicians or Nurse Practitioner

26. How do you receive the results?

MT

27. Where normally samples withdrawn?

Phlebotomy, patient room, or any other place where required

28. What are the methods of sample delivery?

Volunteer or nurse deliver samples to lab, (porter service rarely used, due to the slow in response and sometimes sample lost)

29. What are the methods of adding another test request to a sample?

    Physician submit a paper request and a clerk or a nurse enter the order using ad on test feature in MT

30. How long it will take to receive the results?

    4-6 hours, required to be ½ hour

31. What do you do if results not received (missing)?

    Call the lab and ask for the status

32. How do you identify the patient for sample (for sample test)?

    Tow piece of identification plus asking the patients of their names

33. How do you label samples?

    Labeling the samples will be beside the patient except the 24 hour urine collection will be labeled when patient bring the bottle.

34. Where are labels printed (or received from)?

    Labels will be printed in clinic,

35. Do you prefer to have confirmation on sample (at lab sample receiving and clinic result receiving)?

    - Yes, because when samples received by lab there will be no confirmation of receiving, samples put in fridge then it will be confirmed as received when it will be on the instrument. Samples could be lost between fridge and instrument and never found.

    - Samples always lost when sent with porter

    - Need screening to confirm receiving the sample

36. Recommendations and suggestions?

    a. Considering phlebotomy in one place close to the lab
    b. Pneumatic tube system sample delivery
    c. Now doing blood test the day before the test, to make sure results arrive

37. Any issue with the current system?

a. Need test status report

b. Porter unable to support the timely flow, and sometimes samples lost

c. Process time too long

d. Test required on labels need to be confirmed with test request

e. Date on labels represents the printing date not the test date.

Oncology additional questions

1. Is the 24 hour urine sample bottle will be labeled before or after the patient takes the bottle home?

2. How many orders you process every day?

B400 Oncology Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	B400 Oncology units
Date	Aug 15, 2012
Time	8:00 AM
Site location	Church site

Routine lab order:

- Physician order the day before or before 6:00 AM same day

- Lab tech arrived at 8:20 AM

- Labels already printed in lab/or unit

- Lab tech checks labels and leave them outside the patient room for isolation purpose (tubes will be cleaned when lab tech leaves the patient room and that could erase the labels).

165

- Collect blood and affix labels

Anew order:

- Physician write an order
- Clerk get the order and enter to MT
- Print labels in unit
- Call lab for collection, labels given to lab tech directly when they are at the unit for routine blood collection
- Lab tech collect samples and affix labels
- Lab tech deliver to lab

Glucometer:

- Physician order blood sugar test on paper only (no MT available)
- Nurse get the order from the patient chart or from the nurse sheet
- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)
- Nurse scan patient arm band or write patient information in the device
- Nurse scan the blood stripe
- Complete the test for the patient
- Write the result on a paper sheet
- Nurse place the glucometer on the loading deck, results will be sent to the lab
- Nurse could enter result shown on the device screen to the patient record in MT directly

Notes:

Lab technician has to cancel one of the orders when go back to lab; patient has passed away after placing the order.

Physician order in ER

Project name	Lab order process flow in lab department
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Laura Copeland / PHYSICIAN
Date	Thursday, June 7, 2012
Time	12:30 PM
Location	Church site/ Church: Dr. Copeland's Office

Lab order flow

Physicians in ER order a test by filling a paper request

- ⇨ Nurse or clerk to enter it to MT under their login
- ⇨ Label will be printed
- ⇨ Nurse or technician collect sample
- ⇨ Sample sent to lab through chute tube
- ⇨ Process sample
- ⇨ Report results
    - o If critical, result will be sent to physician's cell phone
    - o If normal, result will be entered to MT

Physician screen

Physician MT screen show the results of lab orders status as one of the following, depend on the status (order active, taken or received).

If order missing

Check order in MT and confirm

- Is still not received, notify the nurse to follow up

- Call the lab to find out

Suggestions and comment

- Concern about future
- CPOE takes 14 steps to place an order
- Need more specification in MT about the types of orders, prefer to have list of the available tests shows up when physician enter the test, ex. UA shows (Urine Analysis).

Add or change test

Physician fills new paper order

- Nurse enter it to MT

Questions

1. Do enter lab order under your login or the physician login?
   Nurse log in.

Emergency Department (ED) interview / Church site

Project name	Lab order process flow in Emergency department
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Mayda Timberlake / EMERGENCY SERVICES MANAGER
Date	Monday, June 11, 2012
Time	2:00 PM
Location	Church site / ED

1. What type of samples ED send to lab?
   Blood, urine, swaps, tissues (rarely happened), biopsy, specimen
2. How many orders normally placed per day?

Around 140 patients

3. Who is placing the orders?

Physician or nurse

4. How physicians placing an order?

Physician write a paper request and a clerk or a nurse enter the order to MT 6.0

5. What are the methods of adding another test request to a sample?

Physician submit a paper request and a clerk or a nurse enter the order to MT 6, using ad on test feature in MT

6. Where are labels printed (or received from)?

In clinic (4 places)

7. Do the nurse / technician confirm the information in labels with the test request?

No

8. How staff notified, there will be test needed?

Physicians give paper request to nurse or put it in the requests box

9. Who is collecting the samples (nurse or lab technician)?

    a. Nurse

    b. If difficult => call Technician

10. How do nurse / technician identify the patient for sample collection (for sample test)?

Patient name and patient hospital number on patient arm

11. Where normally samples are collected?

Bed site location, anywhere in the department

12. Where collected samples are normally labeled?

Bed site location

13. How samples delivered to the lab?

Tube chute, nurse deliver it

14. How ED receives the results?

    a. MT, with paper copy, printed in ED printers

   b. If critical, nurse will receive a phone call about the results, and lab send copy of the result to the department printer; results will be entered to MT too.

15. How long it will take to receive the results?

   Less than an hour

16. What do you do if results not received (missing)?

   a. Call the lab and ask for the status

   b. Physician can check status on their MT page

17. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

   Yes

18. Why, (related to question 15)?

   Easy to manage assessing patients when result known when to arrive

19. Any issue with the current system?

   a. Specimen labeling error

   b. Too many label printer uses too many ink cartridges

   c. No confirmation when receive samples

20. Recommendations and suggestions?

   a. Using mobile labeling machine

   b. Need receiving confirmation

   c. Need test status report

   d. Need Point-of-care testing (POCT) in every room to get result quickly.

   e. Quality control (QC) need to be done every day

Note: Emergency department uses yellow labels for labeling the tubes

Emergency Department Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Emergency Department
Date	Aug 15, 2012
Time	10:00 AM
Site location	Church site

The ED unit in Church site consists of the following subunits:

1. Triage
2. O-Zone
3. Miner treatment
4. Acute
5. Critical acute
6. CDU Clinical Decision Unit

Triage:

- o if blood work need to be done in triage;
    - Nurses will decide what type of blood work need to be done according to the medical directive they have from the physicians, they order blood work directly on MT
    - Labels will be printed in triage room label printer
    - Triage or of load nurse will collect the blood in triage room
    - Samples labeled in the same room
    - Samples sent to lab chute
    - Results will be submitted by lab to patient record in MT & a paper copy will be sent to the department printer

- If results are critical, lab will call physician or unit nurse

Glucometer:

- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)
- Nurse scan or write patient information in the device
- Nurse scan the blood stripe
- Perform the test on the patient
- Nurse enters the result directly to patient record in MT

Notes:

Nurse suggested result should flash in MT when ready.

ICU Department/Church

Project name	Lab order process flow in ICU
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Mitchell, Claudia / MANAGER CLINICAL PROGRAMS
Date	Tuesday, June 12, 2012
Time	11:00 PM
Location	Church site / ICU

1. What type of samples ICU send to lab?

   Blood, urine, and fluid

2. How many orders normally placed per day?

   Around 20 order per day

3. Who is placing the orders?

   Physician or nurse

4. How physicians placing an order?

   Physician write a paper request and a clerk or a nurse enter the order to MT 6.0

5. What are the methods of adding another test request to a sample?

   Physician submit a paper request and a clerk or a nurse enter the order to MT 6, using ad on test feature in MT

6. Where are labels printed (or received from)?

   In clinic (2 places)

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   When labels printed, check order in MT

9. Who is collecting the samples (nurse or lab technician)?

   Nurse

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Patient name and patient hospital number on patient arm bracelet

11. Where normally samples are collected?

    Bed site location

12. Where collected samples are normally labeled?

    Bed site location, after labeling nurse come and check the information on labels and compare them with patient arm bracelet

13. How samples delivered to the lab?

    Porter service, time of pickup varies and based on the availability of the porter in the department.

14. How ICU receives the results?

    a. MT

       b. If critical, nurse will receive a phone call about the results, and lab send copy of the result to the department printer; results will be entered to MT too.

15. How long it will take to receive the results?

Depend on the type of the test, normally within the normal time (no delay)

16. What do you do if results not received (missing)?

Call the lab and ask for the status

17. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

Yes

18. Why, (related to question 15)?

Make sure samples delivered

19. Any issue with the current system?

       a. Porter service

       b. Some blood band order cannot be seen in MT

       c. Some test names have been changed with the new MT

20. Recommendations and suggestions?

       a. Fix MT bugs

       b. Provide MT user guide

       c. Using reliable pneumatic tube system to deliver samples

Note: ICU department uses yellow labels for labeling the tubes

ICU department Observation/Church

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	ICU Department
Date	July 18, 2012
Time	8:45 AM
Site location	Church site

- 8: 50 AM Specimen taken by Nurse
- 9:000 AM Nurse call porter
- 9:30 AM Porter pick up the sample
- 10:15 Results come from lab

Note:

- A paper copy of the result always sent by la to ICU unit
- If test critical, the lab will call the ICU when result is ready

Outpatients interview questions/ Church

Project name	Lab order process flow in Outpatient Clinics
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Boodth,Claudette / CLINICAL PROGRAMS MANAGER
Date	Wednesday, June 13, 2012
Time	9:30 AM
Location	Church site / F- SURG PRGM ADMIN

1. What type of samples outpatient clinics send to lab?

   Blood, urine, fluid

2. How many orders normally placed per day?

   Around 60 order per day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Physician write a paper request and a clerk or a nurse enter the order to MT 6.0

5. What are the methods of adding another test request to a sample?

   Physician submit a paper request and a clerk or a nurse enter the order to MT 6, using ad on test feature in M

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   No

8. How staff notified, there will be test needed?

   When labels printed

9. Who is collecting the samples (nurse or lab technician)?

   Lab Technician

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Patient name and patient hospital number on patient face sheet

    (no arm bracelet)

11. Where normally samples are collected?

    Phlebotomy

12. Where collected samples are normally labeled?

    Phlebotomy

13. How samples delivered to the lab?

    Delivered to the lab by the same lab technician

14. How unit receives the results?

    a. MT

      b. Lab sends copy of the result to the department printer.

15. How long it will take to receive the results?

    Depend on the type of the test, normally within the normal time (no delay)

16. What do you do if results not received (missing)?

    Call the lab and ask for the status

    Check status in MT

17. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes

18. Why, (related to question 15)?

    Make sure samples delivered

19. Any issue with the current system?

      a. Porter service

      b. Some blood band order cannot be seen in MT

      c. Some test names have been changed with the new MT

20. Recommendations and suggestions?

      a. Fix MT bugs

Note: No patient arm bracelet used in fracture clinic

Outpatient Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Outpatient units / Stephaney / Resource Nurse
Date	Aug 14, 2012
Time	3:30 PM
Site location	Church site

Routine lab order:

- Physician order on paper
- Patient will be sent to lab for blood work
- Lab enter results to MT

Stat & Emergency

⇨ Physician order on paper

⇨ Clerk enter to MT

⇨ Clerk call lab collection team

⇨ Print labels in units

⇨ Collect blood and label the tubes

⇨ Send samples to lab in one of the folioing ways:

- o With collection team
- o Nurse from unit
- o Porter service

Glucometer:

- Physician order blood sugar test on paper only (no MT available)
- Nurse get the order from the patient chart or from the nurse sheet
- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)
- Nurse scan patient arm band or write patient information in the device
- Nurse scan the blood stripe
- Perform the test on the patient
- Write the result on a paper sheet
- Nurse place the glucometer on the loading deck, results will be sent to the lab
- Nurse could enter result shown on the device screen to the patient record in MT directly

Notes:

In outpatient clinic when nurse place the glucometer on the loading deck, computer sometimes doesn't recognizes the patient or takes long time to complete the process.

Outpatient Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Outpatient units / Stephaney / Resource Nurse
Date	Aug 14, 2012
Time	10:00 PM
Site location	Finch site

- 10:30 AM, Physician order on paper
- Nurse entered the order to MT
- Print labels in units
- Nurse check ID verbally (no armband used in outpatient clinics)
- RN Collect blood and label the tubes
- 10: 45 AM, Nurse toke samples to lab

Note:

- There is no Clerk in the Unit to help with entering the orders, unit dels with 100 patient /day
- Unnecessary paper copy of the results always received
- Difficulties in printing old results from MT
- CBC blood order on MT always defaulted to STAT

L & D Clinic interview

Project name	Lab order process flow in L&D Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Mary Sackeyfio / CLINICAL PRACTICE LEADER
Date	July 17, 2012
Time	12:30 PM
Location	Church site

1. What type of samples you collect at these clinics?

   CBC (blood culture), routine blood, baby blood in OR (blood gas) with delivery

2. How many orders normally placed per day?

   Depends on the number of patients they come to clinic for delivery

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper➜Nurse or clerk enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper➜Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes they double check

8. How staff notified, there will be test needed?

   Nurse to Nurse

9. Who is collecting the samples (nurse or lab technician)?

   Nurses

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Patient room

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter, Nurse (when critical)

15. How the clinics receive the results?

    MT, By fax (when critical)

16. How long it will take to receive the results?

    1-2 hours

17. What do you do if results not received (missing)?

    Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes

19. Any issue with the current system?

    -In C section only one computer in the room used by the physician and no labeling machine available there, when draw blood from the baby; baby need to be registered first, then the order and labels can be printed and places on the sample.

    -Need result quickly

    -Better timing management

    -Porter service slow

20. Recommendations and suggestions?

-Need to have mother's name on baby blood label

-On MT first page has the baby's mother name by default, second page mother name need to be entered manually, third page has no mother name; mother name need to be on the three pages by default to eliminate errors.

-When blood drawn and patient leave home, then come back within 24/h, why blood need to be drawn again?

21. Do you use blood bank service & how to order

Combine care / Nursery Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Combine care / Nursery
Date	Aug 15, 2012
Time	11:30 AM
Site location	Church site

Combine carte:

- Physician order
- Clerk enter it to MT
- Orders will be sent to lab the day before the test for lab tech to collect
- Labels printed in lab
- Next day morning lab tech come to collect blood
- Lab tech checks two patient IDs and collect samples
- Result will be submitted to MT
- If critical, a paper copy will be sent to the unit

Nursery:

- Physician order
- Clerk enter it to MT
- Labels printed in unit
- Nurse collect samples
- Porter deliver samples to lab
- Result will be submitted to MT
- If critical, a paper copy will be sent to the unit

Cardio Respiratory interview questions

Project name	Lab order process flow in Cardio Resp Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Lori Smith / CLINICAL PRACTICE LEADER
Date	July 17, 2012
Time	10:00 AM
Location	Finch site

1. What type of samples you collect at these clinics?

   Blood gas 24/7, Microbiology fluid (Biopsy)

2. How many orders normally placed per day?

   About 10 / day

3. Who is placing the orders?

   Physician, Bronchitis test (Brushing)/Respiratory Therapist (RT), Blood gas/Nurse

4. How physicians placing an order?

   Paper chart, Phone, verbal ➜Nurse or clerk enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper➔Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   For **Stat** tests ➔ nurse call to tell

   For **Routine** tests ➔ from the paper request

9. Who is collecting the samples (nurse or lab technician)?

   Nurse, RT, Phlebotomist

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    - Stat tests, get to lab quickly

    - Banc's and Fluid: the order should specify the destination of the sample in the lab

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Stat ➔ send by the clerk

    Routine ➔ sent by Porter

15. How the clinics receive the results?

    - MT

16. - MT &Fax (when critical)

- If result is up normal, it will be highlighted red

17. How long it will take to receive the results?

Stat➜ 5 min

Routine➜ 30 min-1hour

18. What do you do if results not received (missing)?

Call the lab

19. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

Yes

20. Any issue with the current system?

-Need manual, to know where to send bronchioles samples

-Porter service slow

21. Recommendations and suggestions?

-Need to have tracking system

-Mobile labelling device seems good idea

22. Do you use blood bank service & how to order

No

L & D/ Finch interview questions

Project name	Lab order process flow in L & D Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Mary Sackeyfio / Nurse Genevieve
Date	July 17, 2012
Time	1:30 PM
Location	Finch site

1. What type of samples you collect at these clinics?

   CBC (Blood Culture), Baby blood in OR (Blood gas)

2. How many orders normally placed per day?

   About 10-15 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart, Phone ➔ Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper ➔ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   Known to do, Routine, Verbal

9. Who is collecting the samples (nurse or lab technician)?

   Nurse, RT

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    Ne born baby test orders will not be saved in MT, but will be kept in medical files

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Emerge ➔ send by the nurse

Routine ➔ sent by Porter

15. How the clinics receive the results?

    - MT, Printed

16. How long it will take to receive the results?

    15-20 up to 45 Min

17. What do you do if results not received (missing)?

    Look in MT, Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, some missing

19. Any issue with the current system?

    -Porter service slow could take 1 hour to arrive

20. Recommendations and suggestions?

    Direct order by physician

21. Do you use blood bank service & how to order

    Yes

    Paper order in advance➔ MT➔ Lab will be notifies by copy of the paper order (Nurse takes the face sheet to the lab and sign in lab to pick up the blood bottles➔Nurse pick up the blood

    This operation will take about 45 min

Birthing /Finch interview questions

Project name	Lab order process flow in Birthing Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Sandra Brodie/ Special Care Nursing
Date	July 17, 2012
Time	2:30 PM
Location	Finch site

1. What type of samples you collect at these clinics?

   Blood gas, and mostly all type

2. How many orders normally placed per day?

   About 10 / day (two shifts a day)

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart ➔ Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➔ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   On care plan, or at the time

9. Who is collecting the samples (nurse or lab technician)?

   Nurse

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter

15. How the clinics receive the results?

    - MT, Printed if critical

16. How long it will take to receive the results?

    Over 1 hour

17. What do you do if results not received (missing)?

    Call the lab, re-process

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, some missing

19. Any issue with the current system?

    -Porter service slow

    - Missing sample with no confirmation

20. Recommendations and suggestions?

    Direct order by physician

21. Do you use blood bank service & how to order?

Note: Bilirubin and most stat tests will be process in Finch

Microbiology will be process in Church

Inpatients surgical interview questions

Project name	Lab order process flow in Inpatients surgical Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Cathy Brandt/ Manager, Jully / Resource Nurse
Date	July 18, 2012
Time	10:30 AM
Location	Church site

1. What type of samples you collect at these clinics?

   Blood culture, Swaps, Urine, and mostly all type

2. How many orders normally placed per day?

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart ➔Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, ➔Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   -In unit when nurse take samples

   -In lab when technician come to the unit

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   When changing shift, MT, Verbal

9. Who is collecting the samples (nurse or lab technician)?

   Lab Tech (Stat, and routine), Nurse (PICC line)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

    New bracelet has barcode now

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside (in observation, libels carried in to the room to identify the patient, then the labels carried out again to be placed on the blood sample)

14. How samples delivered to the lab?

    Porter, Clerk or Nurse

15. How the clinics receive the results?

    - MT, if critical lab will phone

16. How long it will take to receive the results?

    -Routine ➔2 hour

    -Stat ➔ ½ hour

17. What do you do if results not received (missing)?

    Check if porter pick it up, Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes

19. Any issue with the current system?

    -Turnaround time need to be shorter

    -Porter doesn't check if there is a sample in the fridge to pick up

20. Recommendations and suggestions?

    No

21. Do you use blood bank service & how to order?

Surgical department (A300 North) observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Surgical department
Date	July 18, 2012
Time	10:30 AM
Site location	Church site

- 10:45 AM Physician ordered blood test
- 10:50 AM Clerk entered the order to MT
- 11: 00 AM Clerk called the lab to send technician
- 11:15 AM Technician arrived
    - Tech went to the patient room and identify the patient by the armband
    - Tech take the labels to the room and collect the blood sample and take it with the labels outside the patient room
    - Tech initials the labels with time and date and place the labels on the blood samples
    - Sample left in the clinic to the porter to pick it up and send to lad

- 11:25 AM Nurse called porter for pickup
- 11:45 AM Porter arrive and pick up the sample
- 12:15 PM Lab submitted the result to MT

Note:

Lab technician labeled the sample with extra stat (red) label plus the (stat) on the original label

Mother & Baby, Pediatric /interview questions

Project name	Lab order process flow in Mother & Baby, Pediatric Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Mary Sackeyfio/ Manager, Joan Willis/ Clinical Practice Leader (CPL), Resource Nurse
Date	July 18, 2012
Time	10:00 PM
Location	Finch site

1. What type of samples you collect at these clinics?

   Bilirubin, Baby blood, CBC, blood culture, PKU,

2. How many orders normally placed per day?

   About 6-8 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart ➜Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➜Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

9. Who is collecting the samples (nurse or lab technician)?

   Nurse (Baby), Mother (Lab Tech)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter, Nurse sometimes

15. How the clinics receive the results?

    - MT, Sometimes for mother a paper copy will be printed

16. How long it will take to receive the results?

    1-3 hour

17. What do you do if results not received (missing)?

    Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, some missing

19. Any issue with the current system?

    -Porter service slow

    - Missing sample with no confirmation

20. Recommendations and suggestions?

    Pneumatic delivery system

21. Do you use blood bank service & how to order?

Endoscopy, Med day care/Church interview questions

Project name	Lab order process flow in Endo, Med day care Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Maryam Pourtangestani / Manager
Date	July 18, 2012
Time	10:00 AM
Location	Church site

1. What type of samples you collect at these clinics?

    All types

2. How many orders normally placed per day?

    100 / day

3. Who is placing the orders?

    Physician

4. How physicians placing an order?

    Paper chart, verbal ➔Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

    Paper, telephone order ➔Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

    In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

    No

8. How staff notified, there will be test needed?

   By physician

9. Who is collecting the samples (nurse or lab technician)?

   Physician & Nurse ➔ then Nurse enter it to the jar

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter, Nurse when stat

15. How the clinics receive the results?

    -MT

16. How long it will take to receive the results?

    Sometimes 3 days, depend on the type of test

17. What do you do if results not received (missing)?

    Call the lab, call porter, look in the department

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, some missing samples

19. Any issue with the current system?

    Porter service slow

20. Recommendations and suggestions?

    Porters should carry baskets or containers, to carry the samples

21. Do you use blood bank service & how to order?

A 300 South (Rehab & Medicine) Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	A 300 South (Rehab & Medicine)
Date	July 25, 2012
Time	10:00 AM
Site location	Church

Contact person: Candice / Clerk

- Most orders done by lab tech, except orders for patients with (PICC line)
- If there is a routine lab order, the collection will be during the lab round trip times (6AM, 10AM,1:30PM, 3:30PM)
- If order is urgent, it will be specified as STAT, the clerk enter the order and call the lab to notify them about the order; lab tech will come right away
- No notification from lab that the result is ready unless the result is abnormal, then the lab will call & send paper copy

Results:

o Regular results, takes about 2 hours from the time of entering the order to the time of receiving the results
o STAT results, takes about ½ hour
o Stat & PICC line samples will be picked up by porters
o Routine samples will be taken to lab by lab tech after doing the collection

Note:

Clerk writes OE (Order Entered) on the paper order after finishing entering the order in MT.

Observing the lab technician work

- Technician come arrive at 11:45 AM
- Collect sample
- Affix labels
- Take samples to lab

Lab tech duties

6AM – 10AM ➔ 1 technician

6AM – 2PM ➔ 2 technicians

2PM – 3PM ➔ 1 technician

Endoscopy unit Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Endoscopy unit / Nurse Valeria
Date	Aug 01 2012
Time	10:00AM
Site location	Finch site

- Collection start by a verbal order from the physician
- Nurse collect the sample and write the information on the specimen container
- Then the same nurse take the specimen container to another desk and leave it there
- Another Nurse come and enter the order information of the specimens one by one to the patients record on MT (based on the information on the container)

- Nurse print the labels, initial the labels with nurse initial and affix the labels on the containers
  - <mark>Notice now the initial on the samples' labels represents the Nurse who entered the order later in MT, while the initial should be of the Nurse who collects the labels.</mark>
- All specimens from 8AM-12PM will be placed in one basket
- Nurse or Clerk call porter to pick up the specimen
- Lab process the specimen and put the results on MT

Endoscopy unit Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Endoscopy unit
Date	Aug 14, 2012
Time	2:54 PM
Site location	Church site

Two nurses working in the clinic at the time of the observation

- Nurse review the information with patient and ask the patient to sign consent
- Nurse got labels with patient name from patient chart
- Collection start by a verbal order from the physician to nurse
- Physician collect specimen
- Nurse write the information on the specimen container and leave the container on the desk for the other nurse to affix the labels
- At this time another nurse enters the order information to patients record on MT (based on the information from physician)

- Nurse print the labels, initial the labels with nurse initial and affix the labels on the containers
  - Notice now the initial on the samples' labels represents the Nurse who entered the order later in MT, while the initial should be of the Nurse who collects the labels.
- All specimens from 8AM-12PM will be placed in one basket and sign the tracking sheet
- Nurse or Clerk call porter to pick up the specimen
- Porter pickup samples and sign the tracking sheet
- Lab receives the samples and sign the tracking sheet, then process the specimen and put the results on MT

Notes:

- Tracking sheet contain signatures of nurse, porter and lab track the samples when missing
- Swaps and specimen collection are in different pages and in order for the nurse to enter the patient information for both types, nurse has to switch between two pages on MT and login for both, this act is a time consuming for nurses.
- Always need for more than one nurse in the room.
- MT specimen collection order has no cancel button makes editing more difficult; what let the nurse to wait for the collection to be completed before entering patient information to avoid any changing in the order (in case the physician decided to collect different type of specimen).

Observing the lab technician work in PATT (Pre Operations) Department

- Lab tech paged for lab order in PATT
- Labels already printed in the phlebotomy room

- Lab tech arrives, collect samples and affix labels
- Lab tech take samples to lab

Observing the OR

- In OR, they have their own labeling machine
- Round trip (6 AM, 10AM, 1PM, 3:30PM, 6PM)
- After 6PM there will be no collection unless it's STAT & Tim Test

Kidney Care / Church interview questions

Project name	Lab order process flow in the kidney care Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Saverina Sanchez / Manager, Dorota Jamroz / Resource Nurse
Date	July 26, 2012
Time	9:00 AM
Location	Keele site

1. What type of samples you collect at these clinics?

   everything

2. How many orders normally placed per day?

   5 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Physician: telephone order, Paper chart or verbal ➔ Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Physician: telephone order, Paper chart or verbal ➔ Nurse confirm & enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   Labels or patient's chart

9. Who is collecting the samples (nurse or lab technician)?

   Nurse

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Patient chart, two ID check (H #, D.O.B), (no arm band used in this clinic)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Test room

13. Where collected samples are normally labeled?

    Test room

14. How samples delivered to the lab?

    Spin the blood➜put in ice in a specimen bag➜fridge➜Carrier

15. How the clinics receive the results?

    -MT

    - Faxed or mailed to hospital, if blood work done in lab outside the hospital

16. How long it will take to receive the results?

    Within the normal time

17. What do you do if results not received (missing)?

    Check MT

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, some missing samples

19. Any issue with the current system?

   The clinic is consists of two parts away from each other about 7 min, when blood work done in one part, it need to be carried about 7 min travel time to the other clinic to spin or complete the work.

20. Recommendations and suggestions?

   -Need lab tech to do the blood work

   -Results sent by outside labs (fax and mail), need to be entered to MT

21. Do you use blood bank service & how to order?

   Yes

   The paper work will be done; blood unit will be transferred from Church site to Keele site

Kidney Care Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Kidney Care unit / Dorota Jamroz / Resource Nurse
Date	July 26, 2012
Time	10:00 AM
Site location	Keele

- Physician: telephone order, Paper chart or verbal
- Nurse confirm & enter it to MT
- Labels printed in unit
- Nurse checks two patient IDs verbally(H #, D.O.B, or F.L Names)
- Nurse collect samples
- Spin the blood and put in ice in a specimen bag in fridge
- Call Carrier for pickup

Note:

- The clinic is consists of two parts away from each other about 7 min, when blood work done in one part, it need to be carried about 7 min travel time to the other clinic to spin or complete the work.
- Kidney care clinic will be transferred to Finch site

  State tests will be sent to church site by taxi, patient or ambulance
- There are 2 time of collection, 10:00 AM & 2:00 PM
- If patient live more than 10 KM away from the hospital, the blood work will be done in lab outside the hospital, result will be faxed or mailed to hospital.
- Result from outside labs will not be entered to MT

Mental Health /Church interview questions

Project name	Lab order process flow in Mental Health Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Jasent / Resource Nurse
Date	July 26, 2012
Time	11:00 AM
Location	Keele site

1. What type of samples you collect at these clinics?

   Blood, Urine
2. How many orders normally placed per day?

   10 / day
3. Who is placing the orders?

   Physician, phone order, Verbal
4. How physicians placing an order?

   Paper chart, verbal ➜ Nurse or Clerk enter it to MT

204

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➔ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   By communication board/ Labels will be printed the night before and will be

9. Who is collecting the samples (nurse or lab technician)?

   Nurse

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Safety check will be performed by the patient responsible nurse

    Arm band, two ID check (H #, D.O.B)], then sample collection will be done by another nurse

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Patient room

13. Where collected samples are normally labeled?

    Patient room

14. How samples delivered to the lab?

    Carrier come for pickup at (10:00 AM, 2:00 PM, 6:00 PM)

15. How the clinics receive the results?

    -MT

16. How long it will take to receive the results?

    Within the normal time, about 2 hour

17. What do you do if results not received (missing)?

    Call the lab and make sure that the lab received the samples

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    No, find it not necessary because they don't have any issue of missing samples within the last 4 years

19. Any issue with the current system?

    When placing an order in MT, labels will not be printed when order status is (to be collected), unless you change the status to (collected).

20. Recommendations and suggestions?

    On the result page in MT, regular parameter need to be beside the results

21. Do you use blood bank service & how to order?

    NO

Mental Health_ Outpatient/Church interview questions

Project name	Lab order process flow in Mental Health Outpatient Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Joan Citulski / Resource Nurse
Date	July 26, 2012
Time	1:00 PM
Location	Keele site

- Physician order lab order
- Patient do the lab order outside the hospital in private lab
- Results bill be faxed or mailed to the hospital
- Neither order nor results will be entered to MT, but it will be kept in a paper file

If patient chose to go to **Life Lab**, the result will be accessed by the hospital through a lab link system used by the lab, a password provided from the lab to the hospital to enable the hospital staff of accessing the lab patients spread sheet

- o Physician order lab order
- o Patient do the lab order outside the hospital in **Life Lab**
- o Lab process the samples and send the results to the lab database
- o Nurses & Physicians can check patients results by accessing the lab database, using the password provided

Dialysis / Nephrology clinic interview questions

Project name	Lab order process flow in Dialysis / Nephrology Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Jennifer Duteau
Date	July 26, 2012
Time	3:00 PM
Location	Church site

1. What type of samples you collect at these clinics?

   Mostly blood

2. How many orders normally placed per day?

   100 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart, verbal ➔Nurse or Clerk enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➜ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In unit

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   - Check the order sheet, Patient chart

   - Nurse check the Kardex

9. Who is collecting the samples (nurse or lab technician)?

   Nurse

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Dialysis station

13. Where collected samples are normally labeled?

    Dialysis station

14. How samples delivered to the lab?

    Porter

15. How the clinics receive the results?

    MT

16. How long it will take to receive the results?

    Long time

17. What do you do if results not received (missing)?

    Call the lab and make sure that the lab received the samples

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

Yes

19. Any issue with the current system?

-MT

-Label printer

-Porter

-Long time to get results

20. Recommendations and suggestions?

Tube system

Integrating the lab model with the computers in the unit

21. Do you use blood bank service & how to order?

Yes

- Physician order

- Nurse collect blood sample and send it to lab

- Nurse takes face sheet to blood bank

- Pick up the blood

22. Do you use Glucometer

Yes

- Physician order (Paper base)

- Nurse scan the badge and the blood stripe

- Nurse do the test

- Nurse place the glucometer on the loading deck to upload the data to the lab

- Result will be submitted to MT

Note:

Lab also does some tests on water samples from the water line

ICU Critical Care / interview questions

Project name	Lab order process flow in ICU Critical Care Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Yemi Adebayo / Manager ICU critical care, Paranjit /Nurse
Date	July 27, 2012
Time	11:00 AM
Location	Finch site

1. What type of samples you collect at these clinics?

   All types

   Regular collection time (7:00 AM, 11:00 AM, 3:00 PM)

2. How many orders normally placed per day?

   20 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart, verbal ➜ Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➜ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   Clinic & Lab

7. Do the nurse / technician confirm the information in labels with the test request?

   No, they go by the information in the label

8. How staff notified, there will be test needed?

   By chart

9. Who is collecting the samples (nurse or lab technician)?

   Nurse (if patient have PICC line), other will be done by lab tech

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside & outside the room (to be able to write the initial on the labels)

14. How samples delivered to the lab?

    Stat (Porter), Routine (Lab tech)

15. How the clinics receive the results?

    -MT

    -If up normal, the lab will call

16. How long it will take to receive the results?

    3-2 hours

17. What do you do if results not received (missing)?

    Do another test

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    No

19. Any issue with the current system?

    – Night time is hard to do collection because RT is busy

    – Nurses not trained for blood collection

    – Most night blood collection will go missing

20. Recommendations and suggestions?

    – Nurses need proper training to do blood collection

21. Do you use blood bank service & how to order?

    Yes

- Order (cross and mach)

- Lab come to check the type

- When ready, lab call or shows in MT

- Nurse or porter take the face sheet and go to lab for pick up

Note: If stat, the unit will page the lab tech (till 11:30 PM) for collection and after this time the collection will be done by the RT

ICU CCU Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	ICU-CCU
Date	July 27, 2012
Time	11:00 AM
Site location	Finch

- The unit has a satellite unit, and the satellite unit has its own label printer

- Collection will be done by lab tech unless it's PICC line

Observing lab technician work (STAT):

- Start at 11:25AM, take labels and tubes to the patient room

- Identify the patient (Bracelet, two ID)

- Collect samples

- Go outside the patient room, initial the labels and affix the labels on tubes (the technician excuse for affixing the labels outside the patient room is, there is no place inside the room where technician can write their initials on the labels)

- Samples will be left in the department for porter to pick up

- Lab technician will go to a different department

- In some cases lab technician take stat samples with them when they going back to lab after collection.

Note:

o Lab technician round trip at (6AM, 10AM, 1:30PM, 3:30PM, 8PM, 10PM)

o Lab technician has to do other duties when they go to lab

o Lab cart are not sufficient to help technicians doing the work and has no place for writing

o Lab tech suggest using pneumatic system for delivery

o It is preferred by the lab tech if there is a lab cart for every department, so lab tech don't have to take them back to lab or have to fill up the tubes

Medicine B 6CD & 6W/ interview questions

Project name	Lab order process flow in Medicine B 6CD & 6W Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Shohreh Mahdavi / Manager Medicine B 6CD & 6W , Sarbdeed / Resource nurse
Date	July 27, 2012
Time	12:00 PM
Location	Finch site

1. What type of samples you collect at these clinics?

   Urine, Blood, blood culture, tissue, fluid, spinal specimen

2. How many orders normally placed per day?

   30 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart ➜Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper ➜Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic

7. Do the nurse / technician confirm the information in labels with the test request?

   yes

8. How staff notified, there will be test needed?

   Paper request, when changing shifts

9. Who is collecting the samples (nurse or lab technician)?

   Nurse (if CVAD), otherwise collection will be done by lab tech

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter

15. How the clinics receive the results?

    -MT

    -Phone call (if critical)

16. How long it will take to receive the results?

    Stat takes ½ hour, Routine takes 2 hours

17. What do you do if results not received (missing)?

    Use add on

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes   (the current porter uses confirmation #)

19. Any issue with the current system?

20. Recommendations and suggestions?

    Need status board with color ID

21. Do you use blood bank service & how to order?

    Yes

    - Lab tech, Nurse take sample
    - Porter take face sheet to lab
    - Porter pick up the blood

Medicine F 6CD unit Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Medicine F 6CD unit
Date	July 31, 2012
Time	7:30 AM
Site location	Finch

- 7:45 Lab tech come to floor based on paged call from the department
- Lab tech take the labels from the department (because the lab tech was in a round trip when she get paged in the 4th floor)
- Lab tech confirm the information on the label with MT

- o Lab tech still struggle with placing the tubes and the equipments on a place (there is no place to put or write on the labels).
- Lab tech toke the samples & went outside the room to put the labels & write on them the initials
- Lab tech place the samples in cart
    - o Noticed that lab tech follow the proper precautions signs (Contact, Droplet, and Airborne).
    - o IV Nurse come & check the IV line for patients (not related to lab)

- Lab tech noticed that there is a duplicated order, tech has to do one of the orders & go and cancel the other order on MT
- There is no initial on the label about who places the order, it could be different or same nurse
- No need for a written order to cancel the duplicated order, the written order needed if the (physician, Nurse) want to cancel a regular order only.
- Lab tech have difficulties carrying more than one tube for patients need many samples, they don't have the proper basket or container to put in 8 tubes.

Glucometer Flow in the Medicine F 6CD unit

- Information and specification about the patient diabetes comes from Emergency Department
- Physician order blood sugar test on paper only (no MT available)
- Order could be 4 or 2 times/day (8AM, 12PM, 5PM, 10PM), or could be before eating at 6 AM
- Nurse get the order from the patient chart or from the nurse sheet
- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)
- Nurse scan or write patient information in the device

- Nurse scan the blood stripe

- Perform the test on the patient

- Nurse place the glucometer on the loading deck, results will be sent to the lab

- Nurse could enter result shown on the device screen to the patient record in MT

OR & Surgery unit/interview questions

Project name	Lab order process flow in OR & Surgery Clinics
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Judy Chadwick / Director of Surgery
Date	July 31, 2012
Time	10:00 AM
Location	Church site

1. What type of samples you collect at these clinics?

   All types

2. How many orders normally placed per day?

   150 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Verbal

5. What are the methods of adding another test request to a sample?

   Verbal

6. Where are labels printed (or received from)?

   OR room (center core)

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes, with chart, nurse, surgeon

8. How staff notified, there will be test needed?

   Verbal

9. Who is collecting the samples (nurse or lab technician)?

   Surgeon collect samples ➔ then Nurse prepare to send to lab

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Patient already identified before entering the OR

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    OR

13. Where collected samples are normally labeled?

    OR

14. How samples delivered to the lab?

    Stat ➔Porter, Nurse

    Routine➔Lab technician

15. How the clinics receive the results?

    -Normally in MT

    -If result required by surgeon➔ notification of result will be by call or verbal

16. How long it will take to receive the results?

    10 min

17. What do you do if results not received (missing)?

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, Nurse sign when they put sample in the basket for porter to pick up

19. Any issue with the current system?

20. Recommendations and suggestions?

    See results in MT right away

21. Do you use blood bank service & how to order?

Yes

- Patient do blood test in lab before surgery
- OR call the lab for blood units
- OR Porter take face sheet to lab & sign to pick up the blood units (no confirmation)
- OR Nurse check the Anesthetists

Emergency Department/ interview questions

Project name	Lab order process flow in ED Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Sonia / Clinical practice leader
Date	July 31, 2012
Time	11:00 AM
Location	Finch site

1. What type of samples you collect at these clinics?

   All types (CBC, electrolyte (majority), troponen, pregnancy, urine, blood, lever function test)

2. How many orders normally placed per day?

   400 / day

3. Who is placing the orders?

   Physician, PN

4. How physicians placing an order?

   Paper chart, verbal ➔Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➔Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In ED

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   MT, Verbal, Patient sheet

9. Who is collecting the samples (nurse or lab technician)?

   -Nurse (for most patients)

   -lab tech(for admitted only)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    -Arm band, two ID check (H #, D.O.B)

    -By chart and labels

11. Is there any difference in the process flow between different samples?

    No,

    -blood or fluid on ice, products of conception; should go directly to lab

12. Where normally samples are collected?

    Bedside, triage

13. Where collected samples are normally labeled?

    Bedside, triage

14. How samples delivered to the lab?

    -Pneumatic tube system

    -If pneumatic system malfunction, nurse or volunteer take the samples to lab

15. How the clinics receive the results?

    -MT, paper copy

    -Critical (call physician or unit)

16. How long it will take to receive the results?

    1 ½ hour

17. What do you do if results not received (missing)?

    Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes, but should not intervene with nurse work

19. Any issue with the current system?

20. Recommendations and suggestions?

    Need lab tech in ED to do blood work

    Lab need to call when blood bank have the blood ready

21. Do you use blood bank service & how to order?

    Yes

    - Physician order on paper only
    - Nurse do the test (cross & type, group & screen) and send to lab
    - Nurse order the needed blood
    - When blood ready, lab don't call but result will be on MT
    - Nurse or unit aid take face sheet when pickup blood
    - When blood arrive, two nurses should check
        1. Order
        2. Consent form
        3. Patient ID
        4. Face sheet

Note:

- When pneumatic system broke, they use basket to collect samples and then nurse, unit aid or volunteer take the samples to lab
- Pneumatic tube system samples containers are not enough and some of these containers stays open
- Containers sometimes stuck inside the tube system

– The system in easy to use and very useful.

Emergency Department unit Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	ED unit
Date	July 31, 2012 & Aug 01 2012
Time	117:30 AM & 9:00AM
Site location	Finch site

The ED unit in Finch site consists of the following subunits:

1. Triage
2. O-Zone
3. O-Zone hallway
4. Miner treatment
5. Acute
6. Sub-acute

Triage:

o If blood work need to be done in triage;

- Nurses will decide what type of blood work need to be done according to the medical directive they have from the physicians, they order blood work directly on MT
- Labels will be printed in triage room label printer
- Triage or of load nurse will collect the blood in triage phlebotomy room
- Samples labeled in the same room

- Samples sent to lab by the pneumatic tubes
- Results will be submitted by lab to patient record in MT

Glucometer Flow in triage unit

- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)
- Nurse scan or write patient information in the device
- Nurse scan the blood stripe
- Perform the test on the patient
- Nurse enters the result directly to patient record in MT
  - They don't use loading deck to download the data to lab

Minor Treatment unit

The work in this unit starts after 9:30 AM

- Triage nurse decide that the patient need to go to minor treatment (normally they don't need blood work)
- Patient walk in
- Physician check the patient
- If lab order needed, either Physician can place an order or Registered Nurse (RN) with medical directive (physician permission).
- Labels will be printed in the unit
- Samples will be collected by RN or Registered Practice Nurse (RPN)
  - RPN can collect samples but can't place an order
- Samples will be sent to lab by the pneumatic system
- Lab process the samples and submit the results to MT

O-Zone unit

- Triage nurse send the patient to O-Zone

- Patient walk in

- Physician check the patient

- If lab order needed, either Physician can place an order or Registered Nurse (RN) with medical directive (physician permission).

- Labels will be printed in O-Zone unit

    - Samples will be collected by RN or Registered Practice Nurse (RPN),

    - If O-Zone unit is full patient will wait outside in the O-Zone hallway and do samples collection in triage phlebotomy room

- Samples will be sent to lab by the pneumatic system, if malfunction, samples will be sent by nurse or volunteer to lab

- Lab process the samples and submit the results to MT after 45 min (no paper copy will be sent to the unit

Glucometer Flow in O-Zone unit

- Information and specification about the patient diabetes comes from triage

- Physician order blood sugar test

- Nurse get the order from the patient chart or from the nurse sheet

- Nurse start by scanning their badges (so the system writes the name of the person who collect the sample)

- Nurse scan or write patient information in the device

- Nurse scan the blood stripe

- Perform the test on the patient

- Nurse enter result shown on the device screen to the patient record in MT

- Nurse place the glucometer on the loading deck, results will be sent to the lab

Acute care unit

- o Usually lab order will be done in triage, if another lab order need to be done in the unit it will be as follows;
  - Physician or RN can place an order (paper chart) and place it in a basket
  - Nurse or Clerk enter the paper order to MT
  - Labels will be printed in the unit
  - Samples will be sent to lab by the pneumatic system
  - Lab process the samples and submit the results to MT

Sub-acute care unit

- o Usually lab order will be done in triage, if another lab order need to be done in the unit based on the following order;
  - Physician or RN can place an order (paper chart)
  - Nurse collect samples (bedside), and brought to front desk
  - Clerk, Nurse enter the paper order to MT
  - Labels printed in the unit (front desk), and places on tubes at the front desk location
  - Samples sent to lab by pneumatic system
  - Lab process the samples and submit the results to MT

General information about the ED unit as whole:

- o Most lab order will be done by RN or RPN; lab technicians do lab order for admitted patients only and orders need to be entered to MT by 6 AM.
- o If the result is critical, lab will call the physician, if the physician is not available, the lab then call the unit and talk to the team leader or the primary Nurse about the result
  - Most of the time, lab have hard time finding the right unit, or to be directed to the right person

o If result is not critical, the result will be submitted to MT and paper copy will be sent to the unit printer, except the O-Zone there will be no paper copy

Inpatient surgical unit / interview questions

Project name	Lab order process flow in Inpatient surgical unit
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Rose / Resource nurse
Date	Aug 01, 2012
Time	10:00 AM
Location	Finch site

1. What type of samples you collect at these clinics?

   Routine blood work, specimen

   Routine collection could be in one of these times (6 AM, 10 AM, 1:30 PM, 3:30 PM, 6PM)

2. How many orders normally placed per day?

   45 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart, verbal ➔Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper, telephone order ➔Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   Routine➔In clinic

   Stat➔In lab

7. Do the nurse / technician confirm the information in labels with the test request?

   No

8. How staff notified, there will be test needed?

   From Doctor's order

9. Who is collecting the samples (nurse or lab technician)?

   Lab tech

   Nurse (if there is a PICC line)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Outside the room

14. How samples delivered to the lab?

    Porter (stat)

    Lab tech (routine)

15. How the clinics receive the results?

    -MT, paper copy

    - Abnormal results ➔ lab call the nurse

16. How long it will take to receive the results?

    Depend

17. What do you do if results not received (missing)?

    Call the lab, look for it

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    No

19. Any issue with the current system?

20. Recommendations and suggestions?

    Porters should carry baskets or containers, to carry the samples

21. Do you use blood bank service & how to order?

    Yes

    - Physician order
    - Clerk, nurse check the MT record if there already blood collected, if not nurse do blood collection
    - Order blood on MT or by calling the lab
    - Send the face sheet with porter to lab
    - Receive the blood

B 300 Cardiology/ Respiratory interview questions

Project name	Lab order process flow in B 300 Cardiology/ Respiratory
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Kahisay / Resource nurse
Date	Aug 14, 2012
Time	12:30 PM
Location	Church site

1. What type of samples you collect at these clinics?

    Blood, Urine, Sputum

2. How many orders normally placed per day?

3. Who is placing the orders?

    Physician

4. How physicians placing an order?

   Paper chart➜Nurse enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper ➜Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   -In clinic (Routine)

   -In lab (stat)

7. Do the nurse / technician confirm the information in labels with the test request?

   Yes

8. How staff notified, there will be test needed?

   By MT

9. Who is collecting the samples (nurse or lab technician)?

   Lab tech

   Nurse (if there is a PICC line)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Bedside

14. How samples delivered to the lab?

    Porter (stat)

    Lab tech (routine)

15. How the clinics receive the results?

    -MT, paper copy

    - Abnormal results ➜ lab call the nurse

16. How long it will take to receive the results?

    3-4 hours➜ blood

    Stool ➜ 48 hours

    Urine ➜ next day

17. What do you do if results not received (missing)?

    Call the lab, look for it

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    Yes

19. Any issue with the current system?

    Porters

20. Recommendations and suggestions?

    Tube system

21. Do you use blood bank service & how to order?

    Yes

        a. Physician order
        b. Patient sign consent
        c. Order blood on MT or by calling the blood bank
        d. Nurse collect samples
        e. Send the face sheet with porter to lab for blood pick up
        f. Two nurses check the blood and do transfusion

B 300 Cardio Respiratory Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	B 300 Cardio Respiratory unit / Kahisay / Resource Nurse
Date	Aug 14, 2012
Time	12:30 AM
Site location	Church site

Stat order:

- 12:45 PM physician order stat blood test at
- 12:50 PM clerk enter the order to MT
- 12:55 PM clerk call lab for stat blood work
- 1:55 PM lab technician arrived for routine blood work & stat at the same time
- Lab tech already brought labels from lab
- Left labels outside patient room
- Collect blood and get outside patient room
- Initial, date the labels and affix them on tubes
- Lab tech toke samples to lab

PICC line collection

- physician order blood work
- clerk enter the order to MT
- print labels at the unit (labels stays at the desk for isolation reasons)
- Nurse collect blood then bring it back to desk to affix labels

Notes:

- If collection done by nurse labels normally will be printed in unit, and if the order is stat and collection will be done by lab tech then the labels will be printed in lab, but sometimes lab tech ask the staff in unit to print stat labels especially when lab tech is in round trip or to speed up the process of collection.
- Routine blood collection will be done during the round trip times (6 AM, 10 AM, 1 PM, 3:20 PM)
- Stat blood collection could be done in anytime
- There are a lot of duplicated orders
- Lab technicians have to stop the round trip sometimes and go to lab to pick up some supplies
- Lab tech do round trip collection and receive pager alerts for stats at the same time

Respiratory Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	Respiratory unit / Marg Patell / Respiratory Therapist
Date	Aug 21, 2012
Time	11:30 AM
Site location	Finch site

Pre Test:

- physician fax requisition to unit
- clerk book the appointment for patient and enter the order to MT
- print labels at the unit (labels stays at the desk for isolation reasons)

- Nurse collect blood then bring it back to desk to affix labels
- Clerk call patient two days before the test
- Patient arrive and register at P.A.T.T registration then will go to respiratory clinic
- Clerk prepare paper requisition, patient lists to Respiratory Therapist (RT)

An arterial blood gas (ABG) test

- RT check patient ID verbally
- RT perform test
- RT change test status in MT to completed
- Send samples to lab by porter, sometimes RT take samples to lab when porter delay
- RT check when results ready in MT to print copy of the results and attach to patient chart in file

Medicine, Nephrology / interview questions

Project name	Lab order process flow in Medicine, Nephrology unit
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Angila / Clerk
Date	Aug 15, 2012
Time	9:00 AM
Location	Church site

1. What type of samples you collect at these clinics?

   INR, Electrolyte, CBC, Potassium, etc…

2. How many orders normally placed per day?

233

> 30 / day

3. Who is placing the orders?

   Physician, Nurse (Sometimes for INR, Potassium)

4. How physicians placing an order?

   Paper chart ➔ Nurse confirm & enter it to MT

5. What are the methods of adding another test request to a sample?

   Paper order ➔ Nurse or clerk enter it to MT

6. Where are labels printed (or received from)?

   In clinic & lab

7. Do the nurse / technician confirm the information in labels with the test request?

   No

8. How staff notified, there will be test needed?

   Notified by clerk, check patient chart

9. Who is collecting the samples (nurse or lab technician)?

   Lab Technician, Nurse (PICC line)

10. How do nurse / technician identify the patient for sample collection (for sample test)?

    Arm band, two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

    No

12. Where normally samples are collected?

    Bedside

13. Where collected samples are normally labeled?

    Front desk (for isolation)

14. How samples delivered to the lab?

    Porter, Lab tech when they go to lab

15. How the clinics receive the results?

    -MT

    -Paper (critical)

16. How long it will take to receive the results?

    Depend on the type of test

17. What do you do if results not received (missing)?

    Call the lab

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

    No

19. Any issue with the current system?

    No

20. Recommendations and suggestions?

    Need lab abbreviation sheet (for test names)

21. Do you use blood bank service & how to order?

    Yes

    - Physician order (paper)
    - Clerk enter to MT
    - Lab call when blood ready
    - Send the face sheet with porter or clerk to lab
    - In blood bank clerk or porter confirm the info in face sheet with blood and signature sheet
    - Pick up the blood
    - Two nurses confirm and check the blood, then do the blood transfusion

B 600 Medicine / Nephrology Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	B 600 Medicine / Nephrology unit
Date	Aug 15, 2012
Time	9:30 AM
Site location	Church site

Routine lab order:

- Physician order the day before or before 6:00 AM same day
- Lab tech arrived at 9:30 AM
- Labels already printed in lab/or unit
- Lab tech checks labels and leave them outside the patient room for isolation purpose (tubes will be cleaned when lab tech leaves the patient room and that could erase the labels).
- Collect blood and affix labels

Notes:

Some of the duplicated orders are different than the other orders by one test only, for example a single order for glucose could be cancelled and entered manually at the time of the collection with other orders; the tech will put a reminder so when go back to lab can enter the test and added to the order. * An error could happened in this case

P.A.T.T interview questions

Project name	Lab order process flow in P.A.T.T unit
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Angelina Leblanc / Resource nurse
Date	Aug 15, 2012
Time	12:00 PM
Location	Church site

1. What type of samples you collect at these clinics?

   Everything

2. How many orders normally placed per day?

30 / day

3. Who is placing the orders?

   Physician

4. How physicians placing an order?

   Paper chart ➔ Nurse & enter it to MT

5. What are the methods of adding another test request to a sample?

   Add, on if possible

6. Where are labels printed (or received from)?

   In clinic or lab by lab tech only

7. Do the nurse / technician confirm the information in labels with the test request?

8. How staff notified, there will be test needed?

   pager

9. Who is collecting the samples (nurse or lab technician)?

   Lab Technician

10. How do nurse / technician identify the patient for sample collection (for sample test)?

Verbal two ID check (H #, D.O.B)

11. Is there any difference in flow between different samples?

No

12. Where normally samples are collected?

Blood work & ECG room in P.A.T.T department

13. Where collected samples are normally labeled?

Blood work & ECG room in P.A.T.T department

14. How samples delivered to the lab?

Lab tech when they go to lab

15. How the clinics receive the results?

- All results printed by the end of the day

- MT

16. How long it will take to receive the results?

within the normal time

17. What do you do if results not received (missing)?

?

18. Do you prefer to have confirmation on sample (when lab receives the samples and when clinic receives result on MT)?

No, patient will get activity sheet works as confirmation

19. Any issue with the current system?

Delay in service between 2PM-3PM (when lab tech change shifts)

20. Recommendations and suggestions?

Need lab technician work only for P.A.T.T (same as Finch site)

21. Do you use blood bank service & how to order?

Yes

- Physician order (paper)
- Clerk enter to MT

- Lab technician collect blood
- Blood will be sent to hospital when patient admitted

P.A.T.T Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	P.A.T.T
Date	Aug 15, 2012
Time	12:30 PM
Site location	Church site

- Physician order
- Clerk enter it to MT
- Labels printed in lab or unit
- Unit pages the lab tech to come to collect blood
- Lab tech checks two patient IDs verbally and collect samples in a lab and ECG room
- Initial and affix labels on tubes
- Lab tech takes samples to lab
- Result will be submitted to MT
- Clerk file the results to the patient's chart

* If urine test required, a container will be given to patient, and patient place them in a basket outside the blood work room for lab tech to pick up when arrive

P.A.T.T Observation

Project name	Lab order process flow mapping
Observer name / job title	Ammar Kamil / Project assistant
Observation place	P.A.T.T / Analisa Fortalow _ Resourse nurse
Date	Aug 21, 2012
Time	9:00 PM
Site location	Finch site

- Physician order
- Clerk enter it to MT
- Labels printed in lab or unit
- Unit pages the lab tech to come to collect blood
- Lab tech checks two patient IDs verbally and collect samples in a lab and ECG room
- Initial and affix labels on tubes
- Lab tech takes samples to lab
- Result will be submitted to MT and paper copy of the will be received
- Clerk fax the results to the surgeon's office
- Clerk file the results to the patient's chart

Note:

If different tests being requested for a patient in one order, the P.A.T.T department receives the patient test results as single pages for every type of test being requested, not as list of tests for one order in one page.

Transporting specimens / interview questions

Project name	Lab order process flow in Endo, Med day care Clinic
Interviewer name / job title	Ammar Kamil / Project assistant
Interviewee name / job title	Scott Horn
Date	July 19, 2012
Time	1:00 PM
Location	Church site

1. How do you determine the priority of a sample?

    Subject to how many calls , and the type of the order

2. How do you receive pickup request?

    Clinic call the call center ➔Call center book an appointment and display orders on the central screen

    Some departments have direct access to the booking system website

3. What are the methods of delivering a sample?

    a. Morning round trip (use basket if needed)

    b. Regular pickup

    c. Packaging the specimens is up to the department

4. Do you use confirmation?

    Porters confirm their orders internally only on the porter pager, no confirmation with units or lab

5. How many porters all together working in church and Finch sites?

    Church 18/day

    Finch 12/day

6. How many orders being processes every day?

    Church 300/day

    Finch 250/day

7. Why in your opinion most clinics complain about the delay in porter service?

      a. Too many orders to deliver

      b. Up to the management schedule

      c. First in the morning run to department takes time to be completed

      d. Some stat pickup could disturb other departments pickup

8. What are the services you provide?

   We provide service of the following:

      a. Lab order and stat specimen

      b. Medicine, pharmacy

      c. Patient pickup

      d. Solid linen

      e. Equipment

9. Any issue with the current system?

   Porter service should be determined as delivering from point A to B

10. Recommendations and suggestions?

   Need better management schedule

   Need routine work

Note: Dialysis clinic they have separate porter service.