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MODEL-BASED QUALITY ASSURANCE OF ONLINE BUSINESS PROCESSES

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Abstract. *Many organizations are using business process management to move their existing paper-based business processes online in order to improve the quality of provided services. Unfortunately, implementation of an online business process often neglects validating improvements the new process was supposed to realize in terms of defined business goals. It is desirable to detect any deficiencies in meeting business goals early in deployment when corrective actions can be more easily made. Typical approaches to testing an online business process treat it as a generic web application where rudimentary verification of single user behavior is tested rather than the orchestration of multiple tasks across many types of users and web services. A simple web application testing approach does not leverage the business process model to ensure consistency, completeness, and enable validation of business goals. We propose a framework for model-based quality assurance of online business processes. The framework validates business performance, describes the behavior of the business process and provides a systematic approach to quality assurance using a testing workbench with a suite of testing tools. A prototype implementation of the framework is evaluated using a hospital case study.*
Keywords: Business process management, Goal model, Service-oriented architecture, Quality assurance, Automated testing, TTCN-3

1. **Introduction.** Organizations are using Business Process Management (BPM) to move their existing paper-based business processes online in order to improve the quality of provided services and reduce operational costs. Unfortunately, implementation of an online business process often neglects validating improvements the new process was supposed to realize in terms of defined business goals. It is desirable to detect any deficiencies in meeting business goals early in deployment when corrective actions can be more easily made. However, the complexity of developing online business processes, coupled with the aggressive development schedules, often results in inadequate specification, analysis, and modeling.

Quality assurance for BPM applications is still relatively immature and there are several typical problems that are encountered in current practice. First, the requirement documents are mainly described in natural language which can cause confusion and can be subject to differing interpretations by the developers. The requirement documents

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also do not provide any performance metrics to validate or measure the outcome of the business processes with respect to defined business goals. So, when deployed we do not know if the online business process is actually performing well or not.

Another issue is that typical approaches to testing an online business process treat it as a generic single-user web application. This is insufficient since it only provides rudimentary verification of single user behavior; whereas the orchestration of tasks in parallel across many types of users and software systems can be quite complex for an online business process. Business processes are different from typical web applications in that they involve the collaboration of multiple user roles in parallel activity [1]. BPM invokes web services for parallel execution of requests supporting multiple user tasks. Collaborative testing of user interactions in parallel, involving multiple service orchestrations for multiple user tasks, is critical to online business process verification.

To address these issues, we propose a framework for model-based quality assurance of online business processes. The framework uses metrics defined in goal models to validate business performance. It uses scenario models to describe the behavior of the business process rather than relying on natural language specifications. It also provides a systematic approach to quality assurance using a testing workbench with a suite of testing tools.

This paper extends, updates, and provides more details on earlier research results presented at the conference in [2]. In this paper, we extend the background and related work (Section 2); we update the proposed model-based framework and present the implementation prototype where different tools are used (Section 3); we also present and analyze the results of a different scenario model from the conference paper, called Nurse Contact and introduce two testing tools in the test campaign: IBM BPM Testing Asset and TTCN-3 (Section 4).

The paper is organized as follows: Section 2 presents the background and related work; Section 3 presents our proposed quality assurance framework for BPM; Section 4 introduces the case study of the Lung Cancer Intake project; Section 5 presents the results and summary of experience and Section 6 presents the conclusion and future work.

2. **Background and Related Work.**

Business Process Management (BPM) provides techniques, methods and tools that support the design, development, management and analysis of online business processes [3]. Business process can be modeled using different modeling notations and modeling applications. Business Process Modeling Notation (BPMN) [4] is a graphical notation for specifying business processes for business users. BPMN helps to reduce the gap between business process modeling and software programming by allowing the mapping of the business notations to execution model languages like BPEL [5]. Business Process Intelligence (BPI) is another field that improves the selection of the business process by discovering valuable knowledge of them. BPI covers different aspect of business processes. One of the aspects proposed by Ahn et al. in [6] where a tree map visualization method based on BPI to know the mutual hierarchical relationships between business process entities.

User Requirement Notation (URN) [7] is an ITU standard for requirement elicitation, specification, evaluation and validation, with two integrated graphical modeling languages: Goal-oriented Requirement Language (GRL) and Use Case Map language (UCM). SOA is a software development paradigm that uses services to develop and deploy business applications. It is an integrated software and design approach that delivers business functions as shared and reusable services [8].

Testing and Test Control Notation version 3 (TTCN-3) is a test specification and test implementation standard created by industry and academia experts at the European

Telecommunications Standards Institute (ETSI) [9]. TTCN-3 is a scripting language that can be employed to test web applications [10] and composite applications [11].

Different goal-oriented approaches and methodologies have been followed recently that are related to our approach. In [12] a compliance technique and tool are used to validate the internal policy, ontology and business processes of an organization against the privacy requirements of its regulation. A compliance support framework is proposed in [13] that uses a production rule model to validate the software requirements for legal compliance and define new compliance requirements. In [14], researchers propose a three-step method for goal-driven analysis of business process models that aims to elicit possible improvement directions of business processes; first, a goal structure is defined for the process of interest, then goals are integrated with process warehouse and finally goal structures are used for process analysis and improvement. Researchers in [15] use Real-Time Location Service (RTLS) technology within the wifi environment to track and monitor the movement of the patients in case of emergency.

In [16], researchers argue that there is a poor correlation between outcome, generated by the clinical measures, and quality of the provided care. Using the outcome as a proxy for quality is a greater problem when the data are used for some other purposes, so they propose process measures instead for validating and accepting quality of care. In [17], an approach is used to standardize the evaluation of the process efficiency and quality using a clinical reference process model and generic KPIs. While in [18], researchers define a set of guidelines to show the correlation between the goal modeling and the business process modeling and how a goal model can be derived from a business process model.

3. **Proposed Quality Assurance Framework for BPM.**

Our proposed quality assurance framework validates the quality assurance for BPM applications at the early phases of the BPM development. We can measure the performance of the BPM web services by binding various performance metrics of a goal model at the web services workflow. This allows the developer to detect any deficiencies in meeting business goals when corrective actions can be more easily made. Also, due to the nature of the BPM testing, we introduce a testing workbench with a suite of testing tools to handle complex web services workflow such as multiple user roles and parallel activity. Our proposed framework consists of collaborative four teams, as in Figure 1. Each one of them is responsible of:

- Online business process development begins when the *Process Experts Team* creates *Requirement Models* using two modeling languages:
  a) The goal model where a *Business Goal* describes what *Stakeholder* expects to accomplish over a specific period of time. A *Business Goal* can be further decomposed into sub-goals and achieved by multiple *Tasks* with the ability to be validated by multiple performance *Metrics* (measures). A *Task* is a representation of a *Business Requirement* (Functional and Non-Functional) which can be realized as a *Scenario* represented in a *Scenario Model*.
  b) A set of *Scenario Models* to define different execution paths of the business process. A *Scenario* is a collection of *Actions* or *Use Cases* owned by different *Stakeholders*. It is executed in a certain order based on different conditions represented as *Business Rules* or constraints.
- The *Business Development Team* uses the requirement models to build the *Business Process Model*. A *Business Process Model* is a high level of the business workflow managed by different *Business Roles*. It describes the sequence of processes and sub-processes linked by *Control Flows* and controlled by *Business Decisions*, *Iterations* and *Concurrencies*. The *Business Development Team* adds *Business Artificats*

at different points of the business process path and reflects their measures to the performance *Metrics* defined in the goal model.

- At the bottom layer where the underlying services and legacy system are used to integrate the high-level business processes, the *SOA Architecture Team* is responsible for integrating services, maintaining and supporting the infrastructure of the enterprise such as Processors, VMs and Databases.
- The *QA Experts Team* uses the goal model and scenario models of the requirement model and business process model to test the business process. The Test Orchestration Workbench is composed of tools identified suitable for complete business process testing. The workbench consists of a *Test Plan* that defined the *Test Scripts* which are used to automate the execution of the *Test Cases*. It also defines a class of tools for serving testing of different business process features. The workbench supports a tool that can automatically generate test cases for unit testing of services based on the business process model, an orchestration tool that supports testing of multi-user roles collaboration in multiple service orchestration in parallel, and a performance reporting tool that can generate business process performance reports for the validation of process against business goals.
- The QA portal communicates status of the quality for BPM projects, in terms of bugs, test campaign, and performance management. It is accessible by the Process Experts, Business Development team, SOA Architecture team and QA team. The portal is composed of three elements:
  a) *Test Campaign*: it offers a platform for the planning and execution of test cases across all types of BPM testing and testing tools. It provides test reports that summarizes the test result of test runs and includes statistics related to business process testing.
  b) *Performance Reports*: they are generated based on the data written to the performance data base while the business process is taking place. They include charts and metrics that communicate how well the business process is contributing to business goals. The accuracy and usability of the reports are tested and verified correctly in the test environment as defined by the goal model, but the actual performance of the business process can only be validated when the process is deployed and being used in production.
  c) *Bug Tracking*: the quality assurance team executes business process tests to perform verification and validation of the developed business process. Any bugs identified during this testing process are logged. The bugs logged by testers are addressed by the development team. This way, the quality assurance portal serves as a communication bridge between the quality assurance and development team.

The implementation prototype of our proposed framework is presented in Figure 2. Eclipse jUCMNav [19] is a graphical editor plugin that supports URN language [7] to build requirement models (GRL+UCM). It provides a rich graphical formatting features used to improve the goal and scenario modeling. One of these features is the coloring scheme that measures and monitors the achievement degree of the business goals. IBM BPM application provides a tooling and run time capability for business processes' design, execution, monitoring and optimization. It supports BPM 2.0 language [4] to design and execute business process models. The QA suite of tools in the workbench consist of three tools used to generate test cases for unit testing of services based on the business process model, testing of multi-user roles collaboration in multiple service orchestration and a

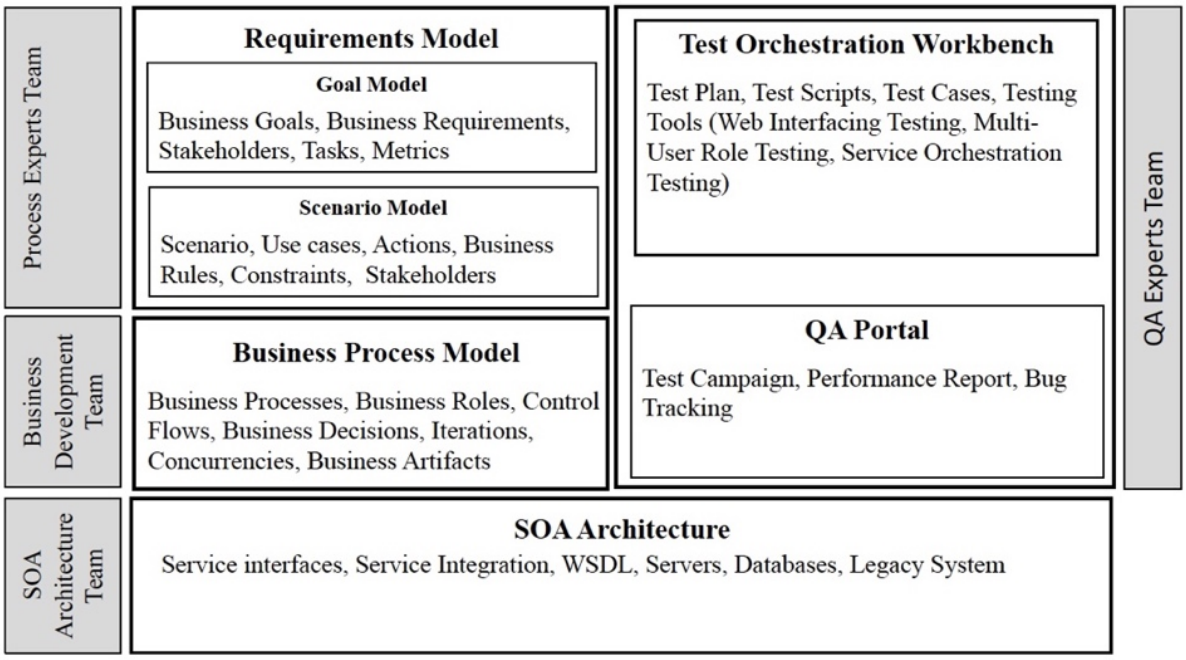

FIGURE 1. The proposed model-based quality assurance framework

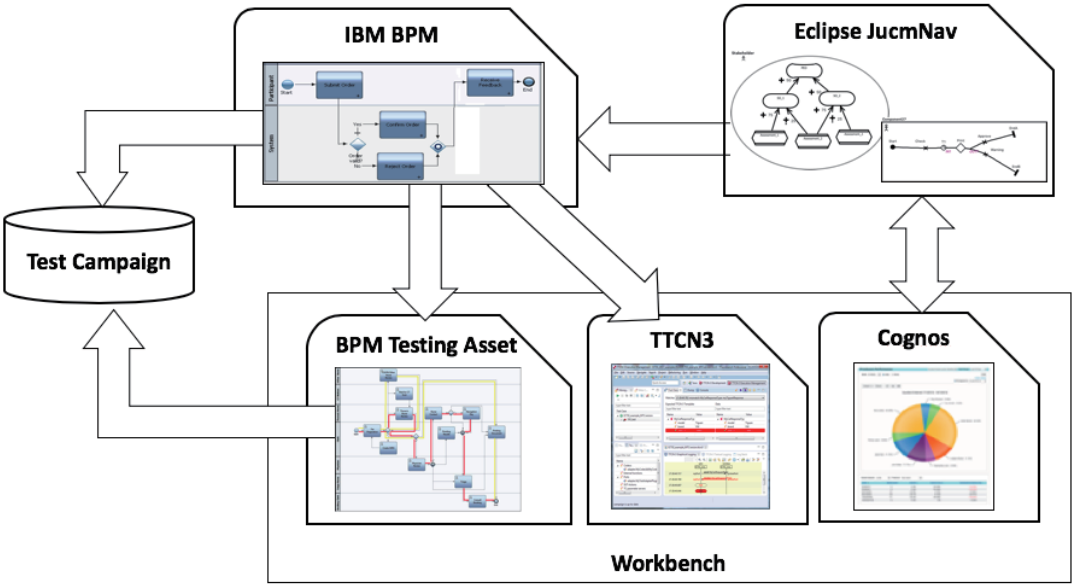

FIGURE 2. Prototype of our proposed framework

performance reporting tool that can generate business process performance reports for the validation of process against business goals.

a) IBM BPM Testing Asset: It is a model-driven test generation tool which generates a complete set of test cases for services and forms unit testing based on the business process model. The testing tool does not handle multi-role, multi-service orchestration testing.
b) TTCN-3 tool: It is an orchestration tool from Testing Tech which has been effectively used to test multi role, multi service orchestration in parallel [20]. It is extended to test web applications with several users, by leveraging its powerful Parallel Test Components (PTC) feature that allows dual structuring mechanism.

c) IBM Cognos: It is performance reporting tool which is used to generate business process performance reports. The generated reports can be analyzed and compared against the goals and metrics for performance validation.

4. **Case Study: Lung Cancer Intake.** This case study has been developed in collaboration with Ontario hospital. Our objective is to improve the performance of a *Lung Cancer Intake* process at a cancer assessment center by automating the business process and making the forms available online using our framework prototype. The requirement documents for this case study were originally defined in the form of word documents, spreadsheets and flowcharts to describe the flow and functionalities of the process services. The quality assurance of the online business process was originally planned in terms of a unit test harness and manual testing of the user interface.

4.1. **Creating requirement model.** Initially, we use the requirement documents to clearly specify the goals of automating the business process of the Lung Cancer Intake project, the performance metrics to measure the compliance of the goals and the behavior of the business process.

In our proposed approach, the requirement model is described by creating an intial goal model as in Figure 3. Our goal is to increase the "*Patient Satisfaction*" by automating the business process of "*Lung Cancer Intake*". Satisfying patients can be achieved by multiple sub-goal; one of them is reducing the overall waiting time for the Lung Cancer Intake, which will be evaluated in this paper. The workflow of the Lung Cancer Intake project contains twelve tasks, described in Section 4.2. Each one is constrained by a waiting time that contributes to the overall waiting time of the Lung Cancer Intake. So, if we manage to reduce the waiting time of any of these tasks, we will reduce the overall waiting time and we will improve the "*Patient Satisfaction*" goal.

The goal model in Figure 3 defines twelve performance metrics or Key Performance Indicator (KPI) to measure the waiting time at different stages of the Lung Cancer Intake business process. A KPI has an evaluation value that measures the current situation, which ranges between the target value (green color), threshold value (yellow color) and

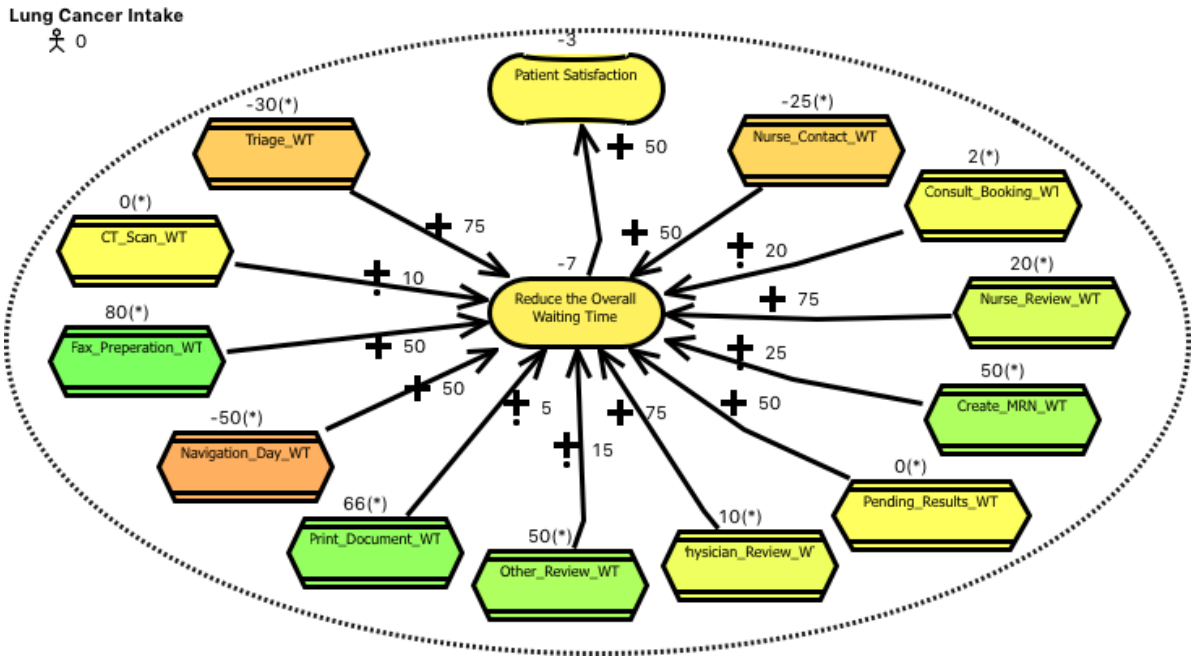

FIGURE 3. (color online) Initial goal model of the Lung Cancer Intake

worst value (red color). The contribution relationship describes how an element contributes to the other in GRL model elements. The contribution impact can be positive or negative and ranges from (−100 to +100).

As part of the requirement models, scenario models are also created, using UCM language, to describe the behavior of the project processes. Each task defined in Section 4.2 is represented as use case model that describes the process behavior. Figure 4 shows an example of *Nurse Contact scenario* from the Lung Cancer Intake project where the nurse contacts the patient to set navigation and triage dates. If the patient did not reply, a fax will be sent to the referral physician.

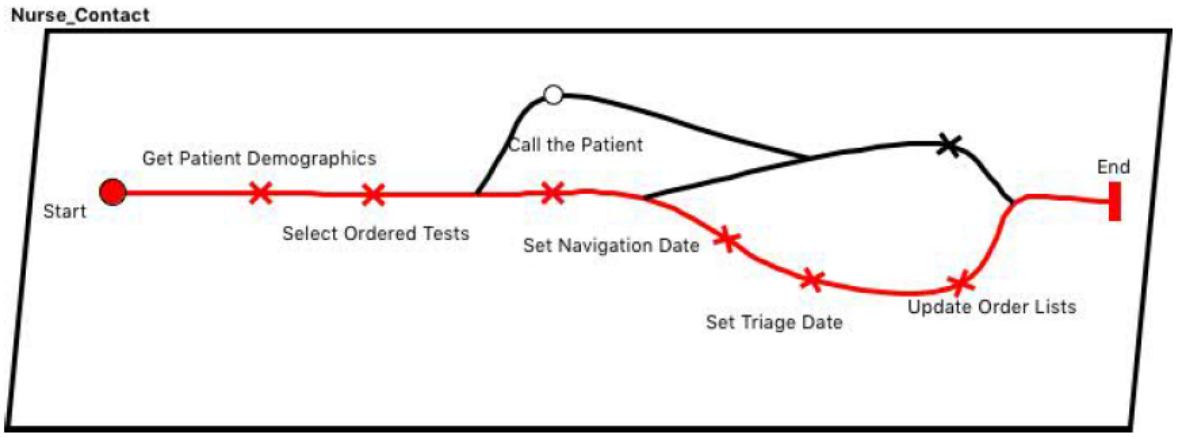

FIGURE 4. Nurse Contact scenario model

4.2. **Creating business process model.** In our case study, IBM BPM 8.5.5 tool [21] is used to model, implement, test and run the business process for Lung Cancer Intake as shown in Figure 5. The process of Lung Cancer Intake begins when a clerk receives and validates a referral fax based on the following options:

a) if it is a New Patient, he creates a new Medical Record Number (MRN);
b) if it is a Thoracic Referral, he passes it to the Thoracic Nurse Review;
c) if it is Colorectal, Prostate or Other referral, he passes it to the CR/PR/Other Nurse Review;
d) if it is a CT Scan Report, he passes it to Wait for CT Scan.

At the Physician Review process, the physician reviews the assessment and orders the needed tests (such as Biopsy, PFT, PET scan). At the Nurse Contact process, the nurse calls the patient with a maximum of three attempts to set an appointment for triage and Navigation Day (if it is needed). If the patient did not reply on the phone call, the center sends a letter to the referral physician. The Pending Result process waits for the completion of the test results, with a maximum of four days. Once the tests have been completed, it will move the patient record to test triage. On triage scheduled appointment date, the triage nurse describes the diagnosis and the urgency and sets an appointment for consult booking. Finally, the consult booking is conducted for the next available Surgeon or Respirologist based on the patient status. The print document process can be used at any time to print the referral fax and patient documents.

The *Development Team* uses the requirement models to build the business process model of the Lung Cancer Intake project. In general, most of the elements of UCM scenario models are directly mapped into the business process model. For example, use case scenarios are mapped into processes, actors are mapped into business roles, metrics are mapped into flags and business rules are mapped into decisions and concurrencies. Figure

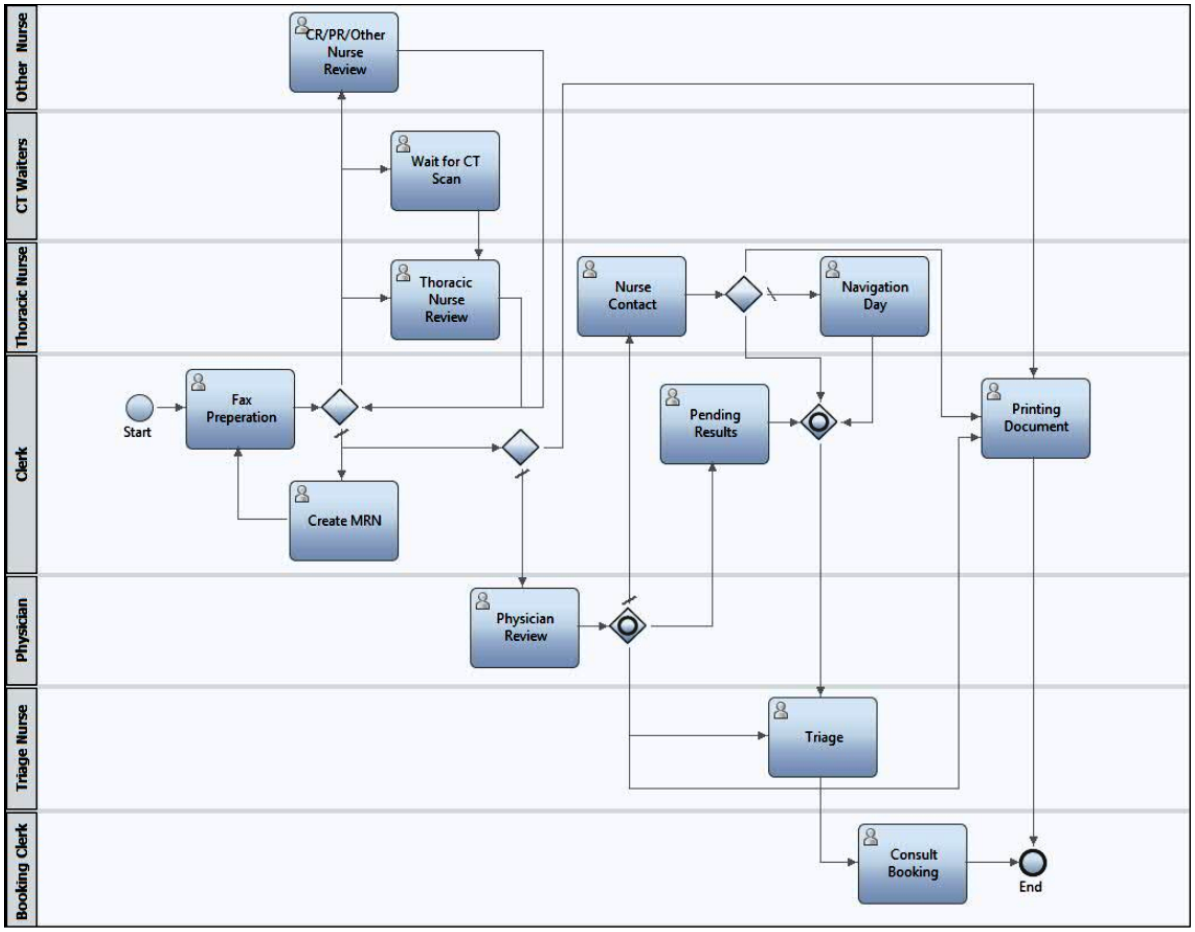

FIGURE 5. The business process of Lung Cancer Intake project

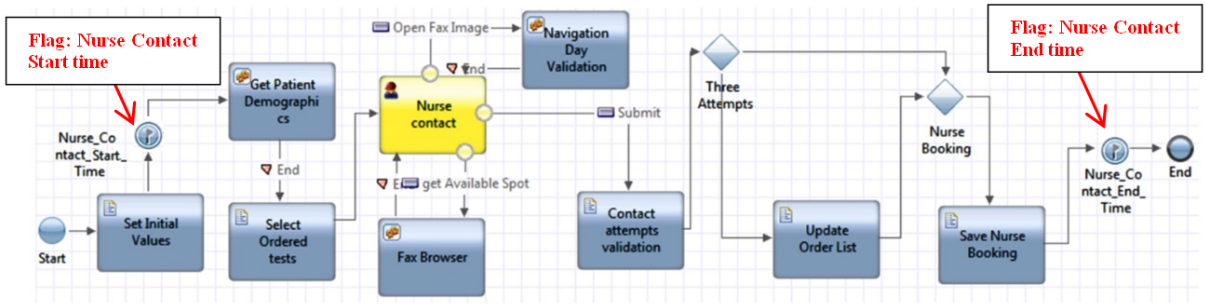

FIGURE 6. A sample of service integration models: Nurse Contact process

6 presents *Nurse Contact process*. Each process in the Lung Cancer Intake workflow is tagged with flags that capture the start and end time whenever an event is triggered. The event is usually triggered when users open or submit an online form. These flags are used to measure the performance metrics defined in the goal model. As an example, the wait time for *Nurse Contact process* is triggered when the BPM engine finishes the submission of the previous process form in the Lung Cancer Intake "*physician review*" while the ending is triggered when nurse opens the online nurse contact form as in Figure 6.

$$Nurse\_Contact\_WT = Nurse\_Contact\_Start\_time - Physicial\_Review\_End\_time$$

4.3. **Creating SAO architecture.** The *SOA Architecture Team* handles the underlying services requested by the development team. Through *Service Integration*, the underlying services are connected together to create higher-level processes.

The *SOA Architecture Team* is responsible for the supplying, maintaining and supporting the infrastructure of the enterprise such as Services, Processors, VMs and Databases. Figure 7 in [22] describes the specification of data access service with multiple of its operations. One of these operations is getPatientDemographics (Input String: MRN and Output PatientDemographics: patientDemographics, String: MRN).

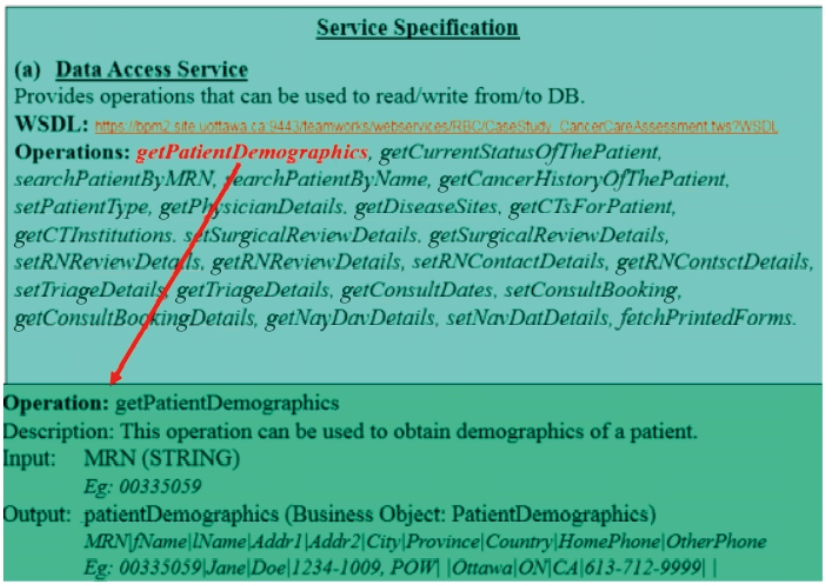

FIGURE 7. Service specification for cancer patient assessment

4.4. **Testing and verifying Lung Cancer Intake.** Within the business process development cycle, the QA team uses the testing campaign to verify that the functionalities of the product meet the business goals and ensure that the forms satisfy the expectation of the end users.

- **IBM BPM Testing Asset**

The IBM BPM Testing Asset generated test cases and covered all the services, and user-interface forms involved in the process. The tool also generated tests covering some of the user scenarios but was not really useful as it ignored timing and input values. Figure 8 illustrates a sample of two developed test cases.

a) The yellow path where a non-thoracic referral fax is received, reviewed by a nurse and then printed for filing.
b) The red path where thoracic referral fax is received, reviewed by a thoracic nurse and a physician. Next the thoracic nurse contacts the patient and sets the navigation day, followed by triage and consult booking.

- **TTCN-3**

The test scripting language TTCN-3 is model-driven testing that is used for multi-users role and multi-service orchestration testing [23]. It is based on a separation of concerns between an abstract layer and a concrete layer. The basic elements of an abstract layer consist, mainly, of three related definitions:

- data typing definition: describes structured datatypes used for defining test data (template);

- templates definition: describes the test data (stimuli) that will be reused in the test behavior;
- behavior definition: describes the action used for testing.

The following is the definitions of the login activity that would be sent by the abstract test suite and a typical template using the structured data type for a user login.

- **Performance Reporting**

The development team uses IBM Cognos to generate the performance report of the Lung Cancer Intake project. The QA team is responsible to approve the non-functional requirements of the project before transferring it into production. It uses the performance report to validate the measured performance of processes in the project with respect to the defined performance metrics in the goal model. A sample report generated for the Cancer Care Assessment process is depicted in Figure 10. This report was used to verify if the goal: Reduce wait times is successfully met.

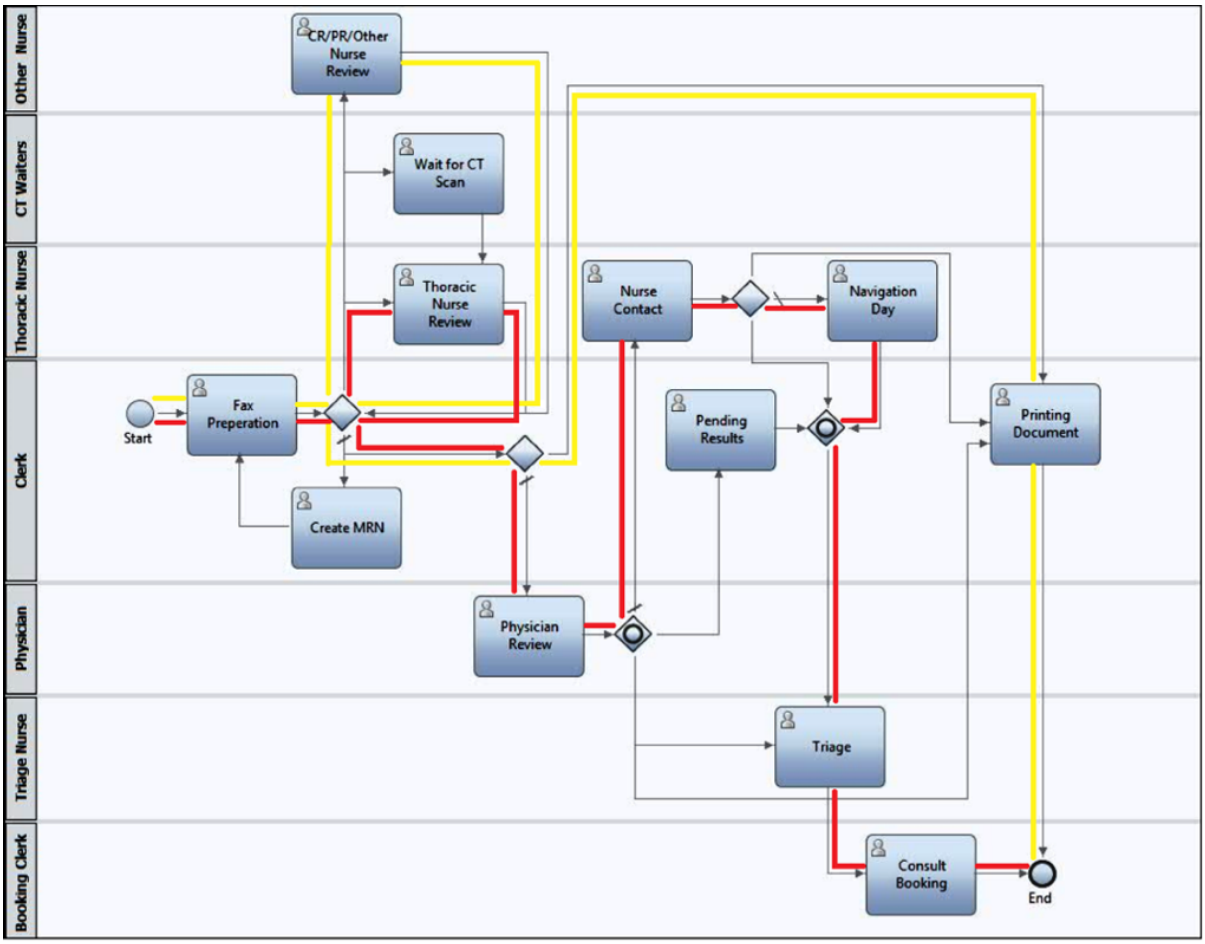

FIGURE 8. (color online) Tests generated using IBM BPM testing asset

```
type record BPMloginType { charstring userid, charstring password }
template BPMloginType admin_login_t := { userid := "bpmadmin", password := "Bpmadmin@123" }
bpmPort.send(admin_login_t);
type record TaskExecResponseType { charstring coach }
template TaskExecResponseType cac_search_mrn_exec_response_t := {coach:= "SearchMRN" };
```

FIGURE 9. A sample of TTCN-3 testing script of user login

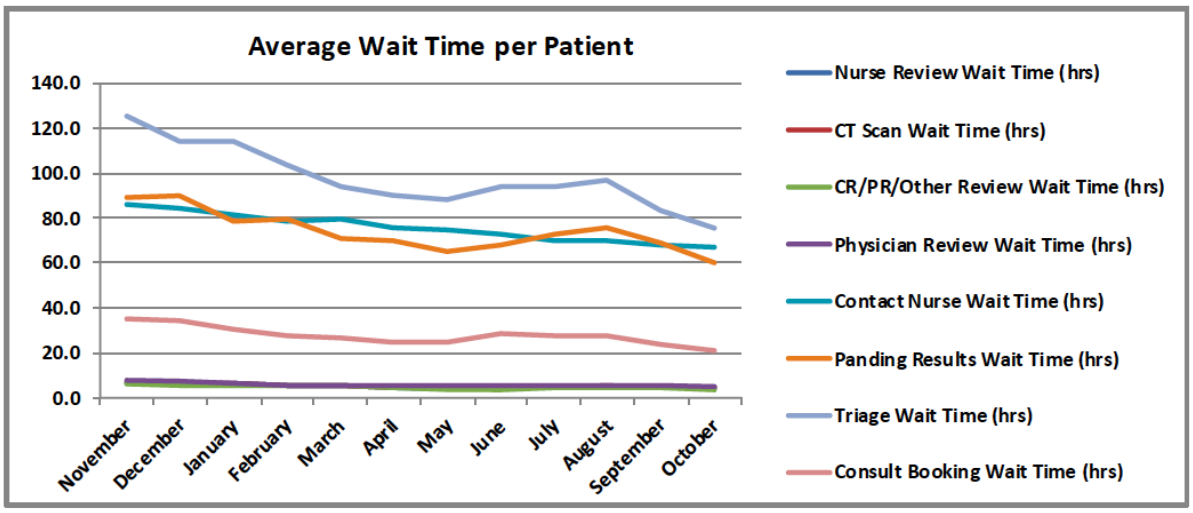

FIGURE 10. (color online) A sample of performance report for Lung Cancer Intake project

5. **Results and Summary of Experience.** The proposed framework provides a model-based approach in defining the business goals and the behaviour of the business processes. That would be useful in detecting and anticipating any deficiencies in meeting business goals at the early stages of business process development where corrective actions can be more easily made.

Figure 3 describes the initial goal model of the Lung Cancer Intake augmented with the average wait time measures. The patient satisfaction goal was below the expectation due to the long waiting times. One of the solutions of meeting the business goal and reducing the waiting time of the Lung Cancer Intake services is hiring more resources, i.e., physician, nurses, clerks. This solution, however, was unacceptable because of the high cost and it is unguaranteed. The other acceptable solution is applying several procedures and recommendations as follows:

1) Resource allocation by assigning available resources to multiple tasks;
2) Conducting trainings to the employees to improve their performance and skills;
3) Using new technologies for tracking employees and patients to reduce the idle time;
4) Applying parallel execution of processes in the business workflow where more work can be completed.

After one year of using our proposed framework, the "Average Wait Time per Patient" has been reduced between 20% and 50%. The performance report, in Figure 10, shows that the average time for Wait Time for *Nurse Contact* on November is 86.4 hours, while after one year of applying our proposed framework the Wait Time for *Nurse Contact* on October is reduced by 22.4% (67.0 hours). Figure 11 shows the patient satisfaction goal has been improved (45) after reducing the waiting time of the Lung Cancer Intake services.

The model-based framework is also used to test complex online business processes that cut across many enterprise systems interacting via the SOA and across many different roles. The BPM Testing Asset tool was the simplest and easiest to use because of the way it directly generated test scripts from the business process model. TTCN-3 was complex to set up but very powerful at providing complex multi-role, multi-service orchestration testing. Writing of tests would have been greatly improved if it could have been model-driven but would have required modeling of user scenarios as well as the business process model. Similarly, Cognos is complex to set up and use, but could also have been greatly

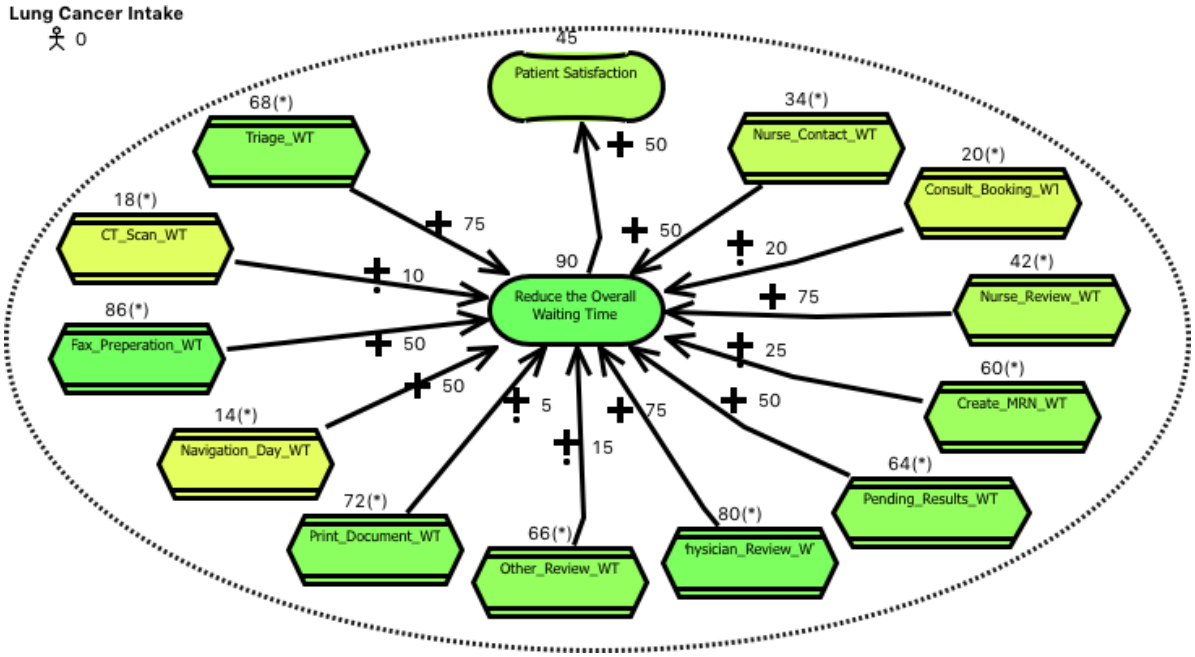

FIGURE 11. (color online) Improved goal model of the Lung Cancer Intake

improved if it could have been model-driven but would have required modeling of goals and metrics as well as the business process model.

6. **Conclusion and Future Work.** The paper proposes a requirement modeling framework for developing and providing quality assurance for online business processes that bridges the gap between a performance metrics of the goal model and the operational data model of the business processes. The goal model provides performance metrics that will measure the performance of online business processes as they are being developed to ensure that the development of online business processes quality is improving. In general, traditional approaches relegate the evaluation of business goals to the last stages of business process development. In many situations, the development process proceeds without a real measuring of business goals where metrics are computed and extracted from historical data. Scenario models are used to describe the behavior of the business process rather than relying on natural language specifications. The framework also provides quality assurance for online business processes that leverages three types of tools: model-driven unit testing for BPM services and forms, multi-role, multi-service orchestration testing; and performance reporting. We have demonstrated the success of leveraging a test workbench which offers a suite of tools: model-based test generation tool, an orchestration tool and a performance reporting tool, for quality assurance of BPM.

As future work, we are planning to use the model-driven methodology to allow the mapping between the user requirement domain and the business process domain. We demonstrate the proposed framework using a Lung Cancer Intake case study and we intend to apply it on other health case studies.

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