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ORIGINAL ARTICLE

Towards a compliance requirement management for SMSEs: a model and architecture

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Abstract Today's business entities face an ever-growing number of laws and regulations due to recent high profile business scandals and failures. Small and medium scale enterprises (SMSE) in developing countries do not have an efficient compliance checking mechanism to make their business processes compliant with these regulatory standards. This checking mechanism is needed to give the enterprises full assurance of complete adherence to regulatory standards, bodies, or Service Level Agreements. Therefore, a structured and efficient compliance management model is needed to aid SMSE in launching their businesses safely and to ensure business processes fit into the classical regulatory standards. This paper presents a business rules compliance checking model and architecture for SMSEs in developing countries to verify and monitor their business process models at design time and at run time. It involves a systematic compliance requirements classification and analysis that employs a goal based requirement engineering approach prior to design time verification. It also introduces the idea and demonstration of network analysis for runtime business processes monitoring. The business process model will be verified at design time using a Simple PROMELA Interpreter model checker through Linear Temporal Logic rules. The approaches were tested on a financial

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institution in Nigeria, a developing nation in Africa at the time of this research. In order to ensure that the choice of the requirements analysis approach was efficient, a number of standard metrics for evaluating requirements engineering techniques were used and promising results were obtained. We also carried out a comparative analysis of the proposed approach in this paper with the approaches of previous research papers. This approach proved to be effective in terms of clarity, simplicity, flexibility and expressiveness while reducing incomplete adherence of business processes and enhancing the correctness of the business process.

Keywords Business process · Compliance management · Compliance · SMSEs · Requirements

1 Introduction

Every business is set up with the goal of making profit and expanding the scope of its service delivery, yet various activities must be put in place to achieve this goal. These activities are expected to be carried out in such a way and manner that comply with the standards guiding the business operations in the domain concerned. This will allow for flexibility in operation and interoperability with similar business organizations.

Flexibly reacting to requirement changes coming from these laws, regulations and internal guidelines becomes a necessity to business process management. Compliance refers to the entirety of all measures that need to be taken into consideration in order to adhere to laws, regulations, standards and guidelines within the company (Daniel et al. 2009). Developing nations like Nigeria are yet to have a compliance checking system in many of the SMSE business domains that will ensure full compliance to requirements for efficient business operations. In 2012, financial organizations had to pay exponentially increasing fines caused by their failure to show full compliance with anti-money laundering directives. Executives and analysts of various sectors of industry identified compliance and regulation as the top business risk (Ernst and Young 2010; Ly et al. 2012).

Previous research analyzes compliance requirements collectively without separating them into data flow constraints, control flow constraints, temporal constraints and resource allocation. These requirements are also verified at design-time and runtime using formal methods like declarative compliance request language, description logics, semantic languages, model checking and ontology. These approaches have proved to be very helpful, yet limited in terms of simplicity, expressiveness and clarity. This paper is focused on an improved conceptual model and architecture to effectively check the compliance of Business Processes.

In this paper, we present a compliance requirement management model and architecture to enhance the effectiveness of business operations among SMSEs. This was carried out in a real life case study of a Microfinance bank in Nigeria using rules from four regulations: Central Bank of Nigeria (CBN) Revised Regulatory and Supervisory Guideline for Microfinance Bank (MFB) in Nigeria (CBN 2012), CBN

Anti-Money Laundering/Combating Financing of Terrorism (AML/CFT) (CBN 2009), CBN Prudential Guideline for Deposit Money Banks in Nigeria (CBN 2010), Banks and other financial Institution Acts. This domain was chosen due to its great relevance to the economic status of any nation. Examples from CBN Privacy Rule case study are used throughout this paper. This paper is organized as follows: Sect. 2 describes related research works, methods and limitation of research works that have been previously carried out in the area of business process compliance. The global research methodology for this work is discussed in Sect. 3 which includes the model and the architecture. A description of the proposed compliance management architecture is given in Sect. 4. An explanation of the main task performed at each phase of the proposed compliance management system is given in Sect. 5. Section 6 provides a discussion of the findings of this work. The conclusion of the work is given in Sect. 7.

2 Related work

Today's business entities face an ever-growing number of laws and regulations due to recent high profile business scandals and failures. The laws and regulations require organizations to audit their business processes, and ensure that compliance requirements set forth in laws and regulations are adhered to (Elgammal et al. 2014).

Papazoglou (2011) introduces a declarative Compliance Request Language (CRL) for specifying compliance requirements. He further examines sets of compliance patterns to support the definition of these requirements. The approach did not efficiently analyze all of the compliance requirement classifications because the data flow and temporal constraints of the business process (BP) compliance were not verified. Pham and Thanh (2015) propose an ontology based approach for modeling and integrating BP and business rules. They integrated a colored Petri Nets based ontology using Business Process (BP) ontology and an ontology to check compliance and consistency. The system checked only for the compliance of processed data in the data flow leaving out the aspects of resource Management and control flow.

Cabanillas et al. (2015) introduce a Resource Allocation Language which is a graphical notation for assigning human resources to BP activities visually. They defined it semantically by mapping this notation to a language that was formally defined in description logics. This approach neglected the data flow and control flow of the process cycle.

Turetken et al. (2011) introduce a comprehensive compliance management framework with Focus mainly on design-time compliance management as the first step towards preventive lifetime compliance support. They employ a Compliance Request Language which is formally grounded on temporal logic and enables abstract pattern based specification of compliance requirements. However, the approach neglected the data or information aspect of the BP.

Elgammal and Turetken (2015) propose a compliance management framework which was semantically enabled using ontology. The framework addressed the entire business process compliance lifecycle but could not offer an efficient compliance requirement analysis; i.e., requirements having two or more constraints could not be separated out but were only partially considered in the framework. The framework was centered on the compliance repository in comparison to other segments of the compliance management. Turetken et al. (2011) introduce a compliance conceptual model which captured and managed the compliance requirements and relate them to business processes in a transparent and verifiable manner. The compliance management approach was able to effectively address the data flow requirements of the BP compliance. This approach centered on the analysis and refinement, and a concept of the compliance which did not deal with the timing requirements of the BP.

Becker et al. (2011) propose a semantic approach using a Semantic Business Process Management Language (SBPML) to model and analyze the BP compliance through the use of business rules and building block patterns in the financial domain. This approach allowed the updating of compliance requirements with new rules but did not implement the timing related Business Compliance rules.

These research works analyzed the compliance requirements collectively which resulted in conservative output of the analysis. In all of the aforementioned related works, timing constraints were frequently left out and most of the compliance management frameworks were designed for the web. These lacks are addressed in this work and we consider conventional business organizations specifically SMSEs so as to efficiently aid their operations.

3 Proposed compliance management model and architecture

The management of business process compliance commences with the understanding of the business domain (finance, manufacturing, education, information, etc.) where an enterprise is operating. The knowledge of the business domain enables the compliance expert to know which compliance documents are required. The proposed compliance model shown in Fig. 1 consists of six phases: (1) the pre-analysis phase, (2) the analysis phase, (3) business process model design, (4) design time verification of BP model, (5) runtime verification of BP model and (6) offline monitoring. The architecture that implements the model is shown in Fig. 2. The compliance documents contain compliance requirements which pass through a pre-analysis stage followed by the analysis stage. The business process is a structured form of the various operations intended to be carried out by the enterprise from the beginning to the end and they are modeled using standard tools like the SPIN model checker. This model necessitates transformation into a format that facilitates formal checking applied at design-time verification. The design-time verification is a preventive phase of the compliance management (Papazoglou 2011). The run-time verification is a detective phase considering workability of the process where SMSE time is assigned to each task in the process and checked against the compliance time. The offline monitoring phase checks for requirements that have not been dealt with at design time and run time manually. These are requirements that relate to security concerns such as encryption and decryption of data in the business process. The pre-analysis phase adopts a goal based requirement analysis approach. Goal

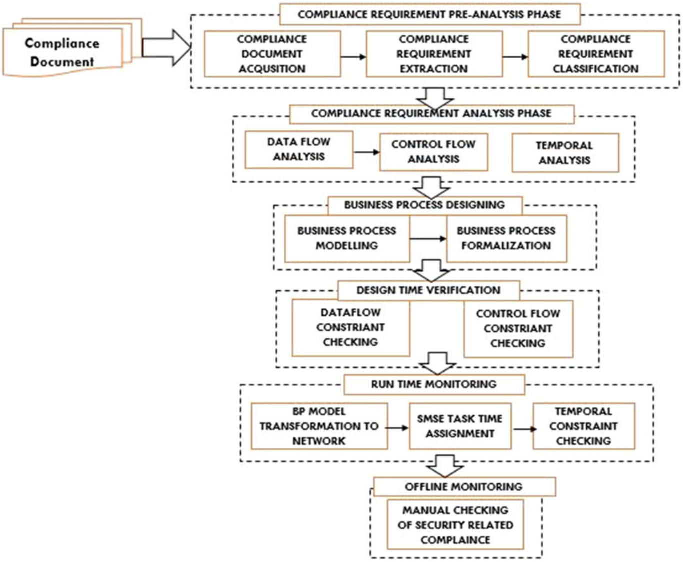


Fig. 1 Proposed business process compliance checking conceptual model

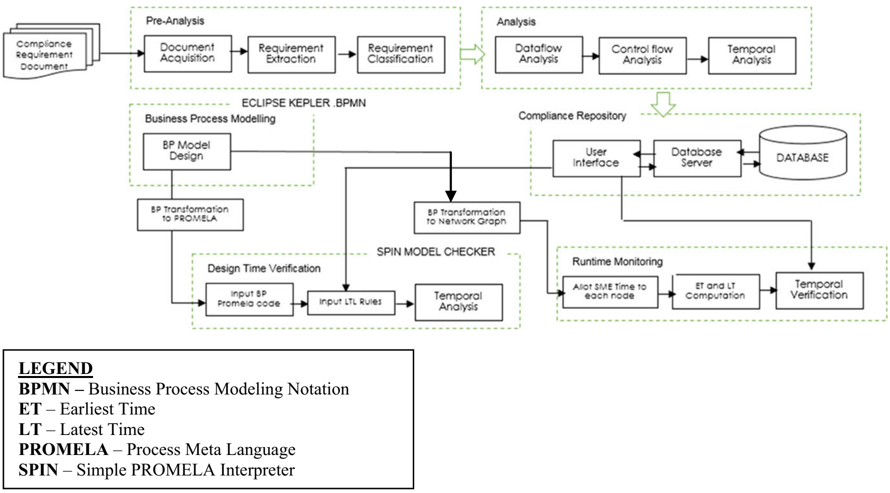


Fig. 2 Proposed business process compliance checking architecture

Based Requirement Attributes consist of the following terms defined within the context of the compliance requirements (Anton 1996):

> *Goals* are objectives defined by regulatory bodies that are required to be accomplished by the business enterprise. They capture the purpose for the existence of the requirement.

Type is a kind of goal that a particular requirement belongs to. It could be an achievement that needs to be fulfilled by a target or maintenance that needs to be checked if the target's action is true.
Description is an explicit statement of a requirement as extracted from the compliance document.
Actions are activities represented as verbs required to be performed by individuals or systems in a particular business process.
Agents are individuals or systems required to carry out an action or set of actions.
Stakeholders are targets that a requirement is meant for or be carried out upon.
Obstacles are negations or oppositions to a goal or action.
Scenario is an instance when the action is required to be carried out in relation to the goal.
Precondition is an action that precedes the word "before" or follows the word "after" in a requirement.
Post condition is an action that precedes the word "after" or follows the word "before" in a requirement.

4 Main tasks of the proposed compliance checking architecture

4.1 Compliance requirement pre-analysis phase

This phase encompasses acquisition of regulatory documents and extraction of compliance requirements aiding in efficient requirement classification into data flow, control flow and temporal constraints as seen in the model in Fig. 1.

4.1.1 Compliance document acquisition

Compliance documents are soft copied (e.g., .html, .doc, .pdf) or hard copied documents obtained from regulatory bodies such as standards, guidelines, policies or Service Level Agreement (SLAs). These are made available to enterprises in specific business domains to study, analyze, and to ensure adherence. These documents can be acquired on request (via e-mail, postal letter) to the concerned body or downloaded online from the regulatory bodies' website(s) if made available. SLA guidelines are obtained after reaching agreement for some service. Each compliance document is titled by the name of the regulatory bodies followed by type (whether it is an act, policy, guideline or standard).

4.1.2 Compliance requirement extraction

After the acquisition of the document(s), the requirements contained in the document(s) need to be extracted. The extraction phase checks for sections, functions, roles, conditions, targets, orders, acts, objects (Breaux and Anton 2007) and temporal requirements. These are needed to aid the next phase of the pre-analysis stage. For example, CBN (AML/CFT) regulatory document statements can

Table 1 The description of the proposed extraction tags

Tags	Name	Function
[$s]	Section and sub-sections	Identifies the sections and sub-sections of requirements in the document
[$r]	Roles	Takes note of actors in a particular requirement statement
[$c]	Condition	Comprises of words such as when, if and its relations
[$t]	Target	Locates the individuals that the requirement is relating to
[$o]	Order	Locates words that describe order of performance or execution such as before, after, during, at and its relations
[$a]	Act	Locates verbs that show expectation of action that is expected to be performed
[$ob]	Object	Locates the data or information required in the compliance document
[$tm]	Time	Locates in a requirement statement time durations of duties as shown in the statement

A sample output of the requirements extraction stage using the tags is shown in the statements below

[$s|] 2.6 ESTABLISHING IDENTITY

[$s|] 2.6.1 Private Individuals

[$s|] 2.6.1.1.1. The following information is to be

[**$r|**] established and independently

[**$a|**] validated for all

[**$t|**] private individuals whose identities need to be

[**$a|**] verified

[$ob|] The true full name(s) used; and

[$ob|] The permanent home address; including landmarks and postcode where available

be extracted using the following formulated tags (see Table 1). Tags are proposed in this study for each of the attributes of the goal based requirements analysis approach in order to aid the effectiveness of the goal based approach. These tags are inserted manually into the compliance document at this phase.

This phase of the work helps remove irrelevant statements in the compliance documents as well as locate the source of each requirement and thereby aiding traceability of the compliance requirements.

4.1.3 Compliance requirement classification

The compliance expert classifies these extracted requirements into dataflow, control flow and temporal categories. The dataflow requirements have to do with access to certain information or movement from one point of the business process to another. Control flow requirements are based on the order which activities should take in the business process, what action is expected and who is allowed to carry out the action. The temporal requirements have to do with those statements that include duration that an activity or set of activities requires. We employed a goal based requirement analysis approach explicitly explained in (Anton 1996). This approach has attributes related to the tags considered in the previous stage. This approach was selected based on the fact that every requirement can be considered as a goal expected to be accomplished or fulfilled. The action attribute in this approach was extended into action and role. The existence of an object tag ($ob) in a requirement statement was used to categorize a requirement as a data flow constraint which centers on the use of certain objects in achieving an action showing that some information must be acted upon or pass through some activities in the business process. Requirements having role tag ($r), action tag ($a), and/or order tag ($o) present in them were classified into control flow. The role tag is represented as an agent in a goal based requirement analysis. Actions that precede a "before" order tag are considered as preconditions while following actions are considered as post conditions. The stakeholders in the goal based requirement analysis approach applied here are the targets that each requirement is centered on; i.e., the words tagged with the $t in the extraction phase. The $tm tag determines the choice of temporal compliance requirements. A single requirement could be categorized into multiple constraints classes. This Classification stage of the compliance requirement helps segment the various requirements into their constraints types to facilitate an efficient compliance checking and maximal adherence to compliance requirements.

Examples of the goal based analysis approach applied to two compliance requirements are shown in Tables 2, 3 and 4:

[$s|]	**1.7.1**
[**Agent**|]	Financial Institutions are required to
[**$a**|]	verify the
[**$ob**|]	identity of the
[**$t**|]	customer,
[**$t**|]	beneficial owner and
[**$t**|]	occasional customers
[**$tm**|]	before or
[**$tm**|]	during the course of
[**$a**|]	establishing a business relationship or
[**$a**|]	conducting transaction for them
[$s| 3.7	Basic information on

Table 2 Compliance requirements' achievement goals, agents, stakeholders, obstacles and scenarios

Achievement goals	Agent	Stakeholders	Goal obstacles	Scenarios
G1: verify identity before transaction	Financial institution	Customer, beneficial customer, occasional customer	Customer identity not or not well verified	Customer does not have a valid identity document Customer stands in for another person
G2: ensure completion of loan application form before disbursement	Bank	Concerned bank officials, loan borrower	Loan approval not completed before disbursement	Borrower did not attach full requirement document Submission of loan application form with incomplete details

Table 3 Goal schema model for G1

Goal	Verify identity before transaction
Type	Achievement
Description	Financial institutions are required to verify the identity of the customer, beneficial owner and occasional customers before or during the course of establishing a business relationship or conducting transaction for them
Action	Verify, establish, conduct
Object	Identity
Agent	Financial institution
Stakeholders	Customer, beneficial customer, occasional customer
Obstacles	Customer identity not/not well verified
Scenarios	1. Customer does not have a valid identity document
	2. Customer stands in for another person
Precondition	Verify the identity
Postcondition	Establish business relationship or conduct transaction

Table 4 Goal schema model for G2

Goal	Ensure completion of loan application form before disbursement
Type	Achievement
Description	Financial institutions are required to verify the identity of the customer, beneficial owner and occasional customers before or during the course of establishing a business relationship or conducting transaction for them
Action	Verify, establish, conduct
Object	Loan application form
Agent	Bank
Stakeholders	Bank official, borrower
Obstacles	1. Loan application form not completed
	2. Required documents not available
Scenarios	1. The borrower submits loan application form with incomplete details
	2. Required documents not attached
Precondition	Loan application form completed
Postcondition	Loan approved and exposure grated

[$t|]	Borrowers
[Agent|]	Bank shall not
[$a|]	approve and/or
[$a|]	provide any exposure (including
[$a|]	renewal enhancement and
[$a|]	rescheduling/restructuring)
[$o|]	until and
[$c|]	unless the
[$ob|]	Loan Application Form designed by bank is completed

4.2 Compliance requirements analysis phase

This phase addresses analysis of the classified requirements. This analysis phase retrieves the source where the requirement was extracted from, description of the requirement, formal representation of the rule in LTL and risk implication of any violation.

4.2.1 Dataflow constraints analysis

The compliance requirements that are classified as dataflow are analyzed by tracing their sources (the regulatory body, compliance document title, section or sub-section), likely risk in failing to meet this requirement and converting the requirements description into rules (e.g. LTL, Computational Temporal Logic (CTL), Metric Computational Logic (MTL), etc.). LTL rules are considered in this paper. The purpose of utilizing the LTL rule is because of its prominent usage in prior research and it is the accepted input format to check for compliance in the SPIN model checker at the design-time verification phase of the framework.

4.2.1.1 Dataflow constraints analysis algorithm The data flow analysis algorithm takes the pre analysis output in terms of the requirements that have been classified as data flow constraints. The number (N) of data flow requirements go through the extraction of the source for traceability, description and risk. Table 5 shows a descriptive algorithm of this process.

The analysis of data flow requirements helps provide full details on each requirement such as the source and description which helps address traceability. The algorithm carried out manually returns the sources of requirements with the same context and represents them as one record which helps reduce redundancy. Analyzing requirements using this approach facilitates easy and maximal checking of data flow constraints in a business process. An extracted output of the algorithm can be seen in Table 6.

4.2.2 Control flow constraints analysis

The compliance requirements that were classified as control flow are analyzed by tracing their sources; i.e., the regulatory body, compliance document title, section or sub-section, and description. The rules are represented and likely risks are noted.

4.2.2.1 Control flow constraints analysis algorithm The control flow analysis algorithm takes the pre-analysis of requirements classified as control flow constraints. The number (N) of control flow requirements go through the extraction of the source for traceability, description and risk. Table 7 shows a descriptive algorithm of this process.

The analysis of control flow requirements gives detailed requirements information such as the source and description which helps to address traceability. The algorithm was implemented manually. The algorithm has the ability to identify the

Table 5 Algorithm for dataflow constraints analysis

```
Input: Classified Dataflow Requirements (CDR)
Output: Sources (S), Description (Des), Dataflow rules (DR), and Risks (R).
Process:
 1:  get CDR
 2:  structure and classify requirements by source
 3:  for i <---- 1 to N of CDR
 4:          describe requirement Des_i
 5:          identify rules, DR_i
 6:          identify risk, R_i
 7:          identify source S_i
 8:      for j <---- i+1 to N
 9:          if DR_i = DR_j
10:              print S_j only
11:          end if
12:      end for
13:          return i, S_i, Des_i, DR_i, R_i
14:  end for
```

Table 6 Extract from dataflow analysis

S/N	Source	Description	LTL rules	Risk
1	CBN (AML/CFT) maintenance of record of transaction **1.14.1**	All transaction details must be recorded	[] (Send_Transaction_details_to_DB)	Legal penalty

sources of one or two requirements with the same context and represent them as one. Hence, Lines 8–12 help take care of requirement redundancy as well and provide easy and efficient control flow compliance checking in business processes. Table 8 shows an extract from the control flow requirements analysis carried out on a CBN regulation.

4.2.3 Temporal constraints analysis

The compliance requirements that were classified as temporal constraints are analyzed by tracing their sources; i.e., the regulatory body, compliance document title, section or sub-section, and description. The analysis of timing related compliance requirements helps address traceability issues because it shows sources of the temporal constraints and description of each requirement. This enables compliance experts to carry out efficient timing related compliance checking on business processes of the enterprises. In the case of temporal constraints we are not utilizing LTL instead we make use of network analysis for the runtime verification.

The temporal analysis algorithm takes the output of pre-analysis of requirements classified as timing constraints. The number (N) of temporal requirements goes

Table 7 Algorithm for constraints control flow analysis

Input: Classified Control flow Requirements (CCR) Output: Sources (S), Description (Des), Control flow rules (CR), and Risks (R).
Process: 1: get CCR 2: structure and classify requirements by source 3: for i <---- 1 to N of CCR 4:   describe requirement Des_i 5:   identify rules, CR_i 6:   identify risk, R_i 7:   identify source S_i 8:   for j <---- i+1 to N 9:   if $CR_i = CR_j$ 10:   print S_j only 11:   end if 12:   end for 13: return i, S_i, Des_i, CR_i, R_i 14: end for

through the extraction of the source for traceability, description and risk. Table 9 shows a descriptive algorithm of this process.

The analysis of temporal requirements from Table 9 gives detailed information such as the source and temporal based description which helps address traceability. The algorithm returns the sources of temporal requirements with the same context and represents them on one row as shown in lines 8–12 of the algorithm. This helps address redundancy and provides an easy and efficient temporal compliance checking of the business processes. Table 10 shows an extract from the analysis of temporal requirement from a CBN regulation.

4.3 Business process modeling

The operations carried out in the banking industry are modeled in this phase. Five major business processes of the microfinance bank case study: (1) Account Opening process, (2) Cash Withdrawal process, (3) Cash Deposit, (4) Cheque Clearing process, and (5) Loan Request. Here, we designed the business process on the Eclipse kepler environment with BPMN2.0 (Business Process Modeling Notation) from the Object Management Group (OMG 2011) plugin. The design forms of the BP models are in .bpmn. Thereafter the business process models were transformed into PROMELA using a software application designed in Wenzhong (2012) made available on request and well explained in Solaimon et al. (2015).

The business process samples designed in the eclipse environment are shown in Figs. 3 and 6 below. The models are choreography-like models showing individual tasks with the participants involved in the processes. Table 6 shows the Cash Deposit business process modeled in an eclipse environment. The process commences with the request deposit slip which is done by the customer from the customer care agent at the microfinance bank. The customer may have the account number to pay into or may not. If the customer knows the account number, he/she fills the deposit form but if not, he/she requests the account number from the

Table 8 Extract from control flow constraints analysis

S/N	Source	Description	LTL rules	Risk
1	CBN (AML/CFT) timing of verification **1.7.1**	Verify identity of the customer, beneficial owner and occasional customer before establishing business relationship	[] ((Verify_Customer_Type) ^ (Verify_Beneficial_Owner)) → (Allow_Tansaction)	Likely money laundering occurrence

Table 9 Algorithm for temporal constraints analysis

```
Input: Classified Temporal Requirements (CTR)
Output: Sources (S), Description (Des), Timing constarints (TC), and Risks (R).
Process:
    get CTR
    structure and classify requirements by source
    for i <---- 1 to N of CTR
            describe requirement Des_i
            identify timing constraints, TC_i
            identify risk, R_i
            identify source S_i
        for j <---- i+1 to N
                if TC_i = TC_j
                    print S_j only
                end if
        end for
    return i, S_i, Des_i, TC_i, R_i
    end for
```

Table 10 Extract from temporal analysis

S/N	Source	Description	Timing rules	Risk
1	CBN (revised guideline for financial institution)	Application of granting overdraft to customer is done in 24 h	Overdraft_Grant_Duration <= 24 h	Legal penalty

customer care unit. The customer then submits the deposit form and cash to be paid at the cash counter to the Cashier. The Cashier confirms the information provided. If the information supplied is not valid, the process is terminated; otherwise, the cashier confirms the cash, writes the amount on the deposit form and signs and stamps the transaction. The transaction is then posted and notification sent to the account beneficiary.

The Loan Request business process model in Fig. 4 begins with the loan request form task which is initiated by the customer or new customer. The customer care unit finds out if the customer is an existing or intending customer. If the customer is not an existing customer, he/she will need to go through the open account process. If he/she is an existing customer, the customer care verifies the identity documents of the customer. The customer then seeks advice from the credit unit department. This is to make the customer know what terms are involved in the business process. The income of the customer is determined and the possibility of paying back the loan is considered. The customer can choose to terminate the process or proceed by going further to obtain the loan form. The customer fills the form and submits it to the customer care unit. The submitted form is moved to the credit unit where it is analyzed and recommendation is made. The form is then taken to the internal audit unit where the form is verified. If the customer makes a request for a loan of N

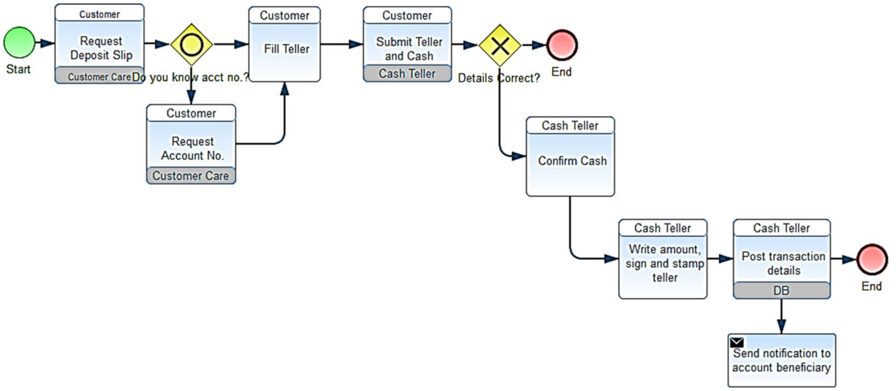


Fig. 3 A cash deposit business process model of the SMSE

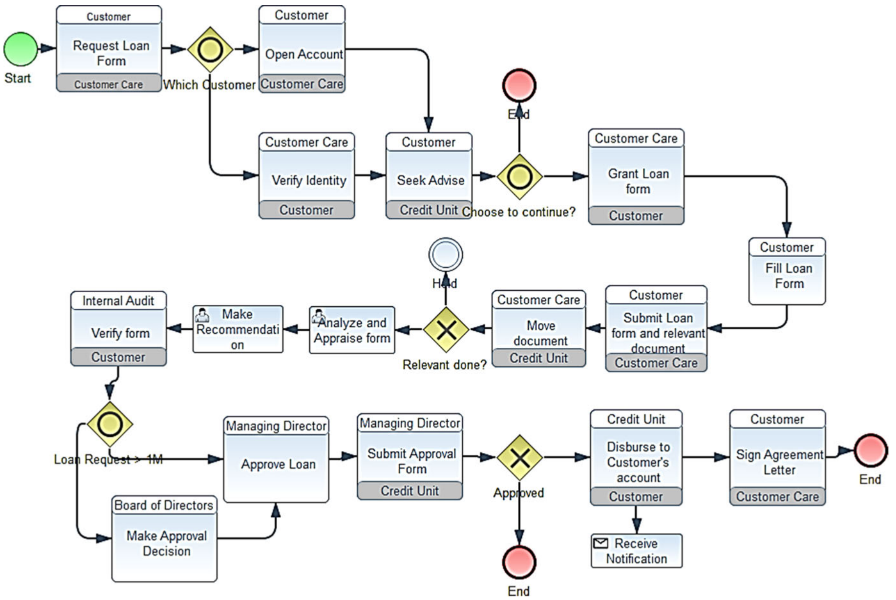


Fig. 4 Loan request business process model of the SMSE

100,000 or more, the final decision will need be made by the Board of Directors. In such a case, the customer may need to wait until after the next meeting of the Board. If the request is less than N 100,000, the Managing director makes the decision which is made known to the credit unit. If the loan is approved at this level, the loan is disbursed to the customer's account who signs an agreement letter at first withdrawal. If the loan is disapproved, the process is terminated.

4.4 Business process model transformation

The business processes modeled at the previous sub-phase are transformed into a PROMELA set of code for use in the next phase for verification at design time. This set of codes and formal rules obtained from the compliance requirement analysis phase are used for checking constraints using a particular tool that will be discussed in the next phase. The tool (BPMN2PROMELA Verifier) explained in Wenzhong (2012) is a very helpful tool in the translation of.bpmn to generate a set of xml codes to PROMELA to enhance the verification process. The tool interface is shown in Fig. 5 below.

4.5 Design time verification

The BP definition involves specifying process models using Business Process Modeling Notation (BPMN). Notwithstanding, BPMN specifications are not grounded on a formal model, but need to be transformed into a formal representation to enable automated verification against formally specified compliance rules (Cabanillas et al. 2015). The verification of BP specifications at design-time will involve automatically checking the formal BP specifications against formal compliance rules with the use of the SPIN model checker. SPIN takes a Process Meta Language (PROMELA) code as input which captures the behavior of the BPMN specification; as well as a set of LTL rules by capturing compliance requirements that are relevant to the business process. SPIN gives a yes–no answer as output to indicate whether LTL rules are being violated or have been satisfied; "yes" means rules have been satisfied and "no" mean they are being violated. The requirements focused in this phase are the dataflow and control flow requirements. If a violation is detected, the root-cause analysis of the violations needs to be carried out as proposed in Wenzhong (2012). Guidelines are then provided to the user as remedies for how compliance deviations can be resolved. A re-mapping and re-verification are then carried out on the BP specifications. This is an iterative process that takes place until all violations are resolved and the BP model produced is compliant. Table 11 shows an algorithm of how this phase of the compliance management is carried out.

One of the inputs into this algorithm is the PROMELA codes obtained from the translation of the XML codes generated from the BPMN using a tool developed in (Solaiman et al. 2015). The other inputs are N number of control flow LTL rules and M number of data flow LTL rules. These will be input one after the other by the compliance expert to verify if such rules are being obeyed in the model or not. A YES reply means that it adheres while a NO means the rule is not present in the model.

4.6 Runtime compliance monitoring

The Business Process is a collection of networked tasks having duration assigned to each individual task. The proposed technique applies Network Analysis, which is an operations research technique complementary to formal approaches used in

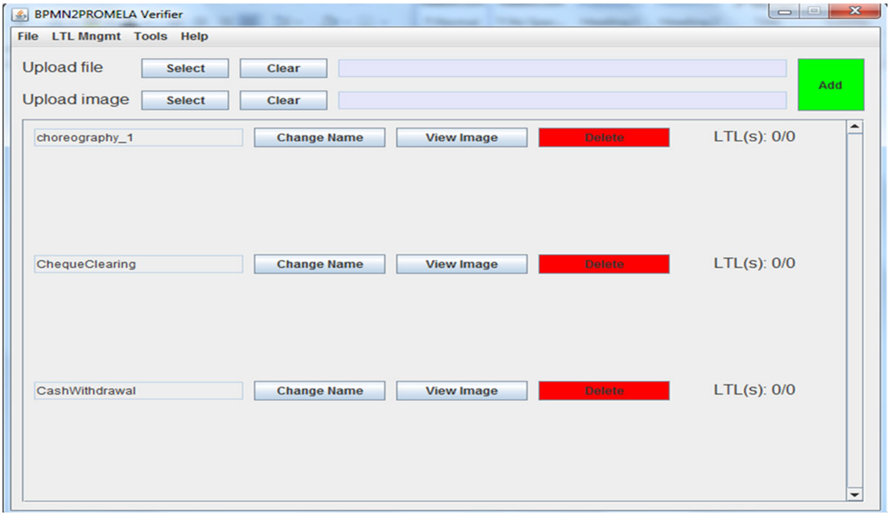


Fig. 5 BPMN2PROMELA Verifier application

Table 11 Design time verification algorithm

```
INPUT: BP model PROMELA Code (BPC), Control flow LTL rules (Ci), Data flow LTL rules (Dj)
OUTPUT: compliance requirements adherence indicators (YES OR NO)
Process:
    input BPC into SPIN
    for i <---- 1 to N of Control flow rules
        input Ci into SPIN
    end for
    for j <---- 1 to M of Data flow rules
        input Dj into SPIN
    end for
    verify BPC against all compliance requirements.
    for k <----- 1 to M+N of all Ci and Dj
        if BPC includes Ci or Dj
            print YES
        end if
        else
            print NO
        end else
    end for
    return adherence indicators.
```

Elgammal et al. (2014) and Cabanillas et al. (2015). The analysis is centered on adherence to the timing constraints which cannot be determined at design-time (Barnawi et al. 2015). The order in which the task is carried out is resolved at design-time, which makes it easier for the monitoring of the business process at runtime.

4.6.1 Network analysis

A network (or graph) is defined by two set of symbols (nodes and edges) (Winston et al. 2003) as seen in Fig. 6. Nodes are points or vertices of the network. Edges consist of an ordered pair of vertices and represent a possible direction of motion that may occur between vertices. Representing a problem as a graph provides a useful perspective that makes the problem much simpler. Networks are applicable to various research areas such as social science, biology, computing and business enterprise. Network representation can provide an appropriate tool for solving classes of problems (Adeleke et al. 2011). Network theory provides a set of techniques for analyzing structure in a system using a graph theoretical representation. Network analysis is the breaking down of a complex project's data into its component parts (activities, events, duration, etc.) and plotting them to show their inter dependencies and interrelationship.

Definition 4.6.1.1: Graph, G Gis an ordered triple G = (V, E, F) where V is a set of nodes, points or vertices. E is a set, whose elements are known as edges or lines, and f is a function which maps each element E to an unordered pair of vertices, V.

Definition 4.6.1.2: Vertex, V Avertex is a basic element drawn as a node or a dot. The vertex set of a graph, G, is usually denoted by V(G), or V.

Definition 4.6.1.3: Edge, E Aset of two elements drawn as a line connecting two vertices, are called end vertices and endpoints. The edge set of G is usually denoted by E (G) or E.

Definition 4.6.1.4: Connectivity Agraph is connected if one can get from one node to any other by following a sequence of edges.

Network Analysis encompasses certain specific techniques that are utilized in the management, planning and control of certain projects or processes. It serves often as a tool for the management of networks and for breaking down of processes into components comprising individual activities which are being recorded on the network diagram. It helps in giving knowledge about events taking place at each critical point of the network. Since business processes are temporal in nature, the mode of managing them differs from job shop related type of scheduling (Adeleke

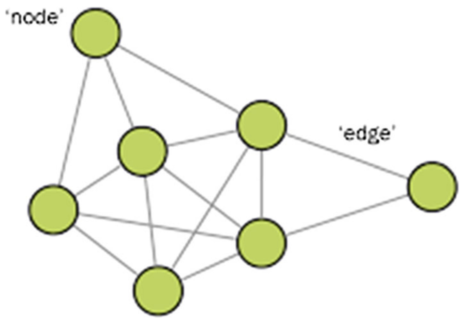


Fig. 6 A simple network (Winston et al. 2003)

et al. 2011). Business processes consist of tasks with definite start and finish points, which necessitate business operations completion within permissible cost and time constraints specified by policies or regulations. Business processes can be typically separated into the following two aspects:

Separate activities These are kind of activities where individual activities have their associated time of completion from the commencement to completion.

Precedence relationships These control the order in which events in a business process take place.

There are two major techniques used in carrying out network analysis: Program Evaluation and Review Technique (PERT) and Critical Path Management (CPM). PERT is able to cope with uncertainty in the completion time of activities while CPM, which is the approach adopted in this paper, emphasizes the trade-off between the cost of executing a project and the overall time of completion. CPM is advantageous in that it decreases the time of completion which might lead to less spending. Network Analysis enables us to take a systematic quantitative structural approach to the problem of temporal related compliance management of industrial BPs through to final completion in the delivery of services to customers. Also, since CPM has a graphical representation, it makes it easy to understand and use by individuals with minimal technical background.

4.6.1.1 Linear programming formulation To ensure the formulation, we assume that a network exists having a path to be determined between two nodes (a and b) where n is the total number of network nodes. Another assumption is that a single branch connects a node i to another node j not considering flows moving in the opposite direction. Therefore, the set $x_{i,j}$ can be found to:

$$minimize \sum_{i=1}^{n}\sum_{j=1}^{n} d_{i,j}x_{i,j}$$

subject to

$$\sum_{k=2}^{n} x_{i,k} = 1$$

$$\sum_{k=1}^{n-1} x_{k,n} = 1$$

$$\sum_{i=1}^{n} x_{i,k} - \sum_{j=1}^{n-1} x_{k,j} = 0 \; for \; k = 2, \ldots, n-1$$

$$x_{i,k} = 0,\ 1 \; for \; all \; i,\ j$$

$$where \; d_{i,j} = \; distance \; from \; node \; i \; to \; node \; j$$

$$x_{i,j} = \begin{cases} 1 & \textit{if the branch from node i to j is connected} \\ 0 & \textit{otherwise} \end{cases}$$

4.6.1.2 Critical path composition The composition of the critical path derives the path that could be taken from start to finish. The CPM is used to make a choice of the path with the shortest time of completion. It is determined by four things: forward pass through the network, backward pass through the network, float time computation, and critical path determination.

Definition 4.6.1.2.1: Forward pass through the network or earliest time (ET) The earliest completion of event i is computed as:

$$ET_j = \max\left[ET_i + d_{i,j}\right] \quad \textit{for all i j}$$

where i = 1, 2,…n indicates the preceding event of the n activities that terminates at j. ET_i is the earliest occurrence time of event i so that when i = 1, ET = 0.

Definition 4.6.1.2.2: Backward pass through the network or latest time (LT) The pass determines the latest occurrence time for each event. This is given by;

$$LT_{i,j} = \min\left[LT_j - d_{i,j}\right] \quad \textit{for all } i,\ j$$

where i = 1, 2,…, n indicates the successor events of the n activities.

Definition 4.6.1.2.3: Determination of float time, critical time and critical path Float time is the delay from the ET of an activity without disturbance of the critical activities that follow. It can be represented as;

$$F_{ij} = LT_{ij} - ET_{ij}$$

The float time for event i is the difference between the earliest and latest occurrence time for the activity. All activities having float time of zero make up the critical path.

4.6.2 The network analysis approach

The verified business processes at design time are transformed into a network (nodes and vertices). Here, the allotted time by the SMSE is input to each task represented as nodes in the network. The Earliest Time (ET) and Latest Time (LT) are computed and represented on the network. Any task with special compliance time will be checked against the temporal constraints which is the major interest at this phase. This implies that only business processes which have consideration in the temporal analysis are monitored at this phase. This is achieved via querying the compliance repository with the name of the business process. Figure 7 shows a network representation of the Loan Request Business Process model.

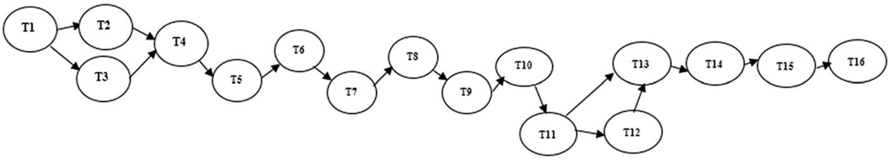


Fig. 7 Network representation of loan request business process

Table 12 Runtime monitoring algorithm

```
INPUT: Design time verified BP model (DTB), Compliance Requirements Time (CRT)
OUTPUT: adherence indicators (yes or no)
Process:
          Step 1:   get DTB
          Step 2:   transform DTB into nodes and vertices manually.
          Step 3:   allocate assigned activity time by SME to each node.
          Step 4:   for i <----1 to N of nodes,
          Step 5:        compute ET_j = max(ET_i + t_ij),
                         where i is the starting node number of all activities ending at
                         node j
                         t_ij is the time for activity i ----> j
          Step 6:   end for
          Step 7:   for j <---- N to 1 of nodes,
          Step 8:        compute LT_i = min (LT_i - t_ij),
                          where j is the ending node number of all activities starting at
                          node i
                          t_ij is the time for activity i ----> j
          Step 9:   end for
          Step 10:  for i <----1 to N of nodes,
          Step 11:      for j <----1 to N of nodes,
          Step 12:          if ET_j <= LT_i, <= CRT_j ,  where i = j,
          Step 13:                constraint adhered, print YES
          Step 14:          end if
          Step 15:          else
          Step 16:                constraint violated, print NO
          Step 17:          end else
          Step 18:      end for
          Step 19:  end for.
          Step 20:  return adherence indicators
```

4.6.2.1 Algorithm for the run time verification The algorithm presented in Table 12 at this phase gets the N number of temporal requirements and verified design time verification BP model as the input. For N times standing for N nodes representing each activity, the earliest time is computed forward and latest time backward. The earliest time, latest time and compliance timing are compared for any task concerned in the network. It is expected that the earliest or latest time is not greater than the compliance timing required. The outcome of the temporal compliance checking carried out on the Loan Request business process network represented in Fig. 7 can be seen in Table 13 while the analysis of the cash deposit business process network of Fig. 8 can be seen in Table 14.

4.6.2.2 A network representation of the business process model The business process model looks like a connection of activities via various links from one end to the other. This understanding brought about the idea of network analysis. An analysis cannot be carried out on the network until it has been represented. This transformation aids the computation of the required parameters (ET and LT) which are required at this phase. We use here the loan request business process model in

Table 13 Network analysis of loan request business process

S/N	TASK	SME TIME	ET	LT	CT
T1	Request loan form	<1 h	<1 h	<1 h	
T2	Open account	<2 h	<3 h	<3 h 10 min	
T3	Verify identity	<30 min	<1 h 30 min	<1 h 30 min	
T4	Seek advise	<40 min	<2 h 10 min	<2 h 10 min	
T5	Grant loan form	<30 min	<2 h 40 min	<2 h 40 min	
T6	Fill loan form	<1 h	<3 h 40 min	<3 h 40 min	
T7	Submit loan form and relevant documents	<2 h	<5 h 40 min	<5 h 40 min	<7 days
T8	Move documents	<1 h	<6 h 40 min	<6 h 40 min	
T9	Analyze and appraise form	<2 h	<8 h 40 min	<8 h 40 min	
T10	Make recommendation	<1 h	<9 h 40 min	<9 h 40 min	
T11	Verify form	<1 h	<10 h 40mis	<10 h 40mis	
T12	Make approval decision	<20 days	<20 days 10 h 40 min	<20 days 11 h 40 min	<1 month
T13	Approve loan	<1 h	<11 h 40 min	<11 h 40 min	
T14	Submit approval form	<1 h	<12 h 40 min	<12 h 40 min	
T15	Disburse loan to customer's account	<1 h	<13 h 40 min	<13 h 40 min	
T16	Sign agreement letter	<1 h	<14 h 40 min	<14 h 40 min	<1 month 24 h

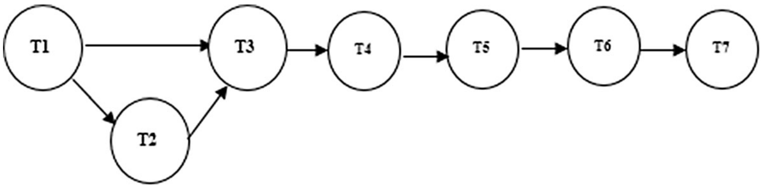


Fig. 8 Network representation of cash deposit business process

Fig. 3 to demonstrate the network analysis approach introduced in this work. The first task (Request Loan Form) in the Loan Request BP model is represented as node T1 in the network representation shown in Fig. 7. There are 16 tasks in the BP model which translate to 16 different nodes in Fig. 7.

The transformation of the cash deposit business process model shown in Table 6 can be seen in Fig. 8 comprising seven tasks. The first task (request deposit slip) in the BP model is represented as node T1 in the network representation in Fig. 8.

4.6.2.3 Temporal constraint checking The checking of the temporal constraints identified in the analysis phase is carried out here making use of the algorithm presented in Table 12. An output of this process is shown in Tables 13 and 14; Table 13 verifying the Loan Request Business Process while Table 14 the Cash

Table 14 Network analysis of cash deposit business process

S/N	TASK	SME TIME	ET	LT	CT
T1	Request deposit slip	<20 min	<20 min	<20 min	
T2	Request account number	<20 min	<40 min	<15 min	
T3	Fill teller	<15 min	<35 min	<35 min	
T4	Submit teller and cash	<30 min	<1 h 5 min	<1 h 5 min	
T5	Confirm cash	<15 min	<1 h 20 min	<1 h 20 min	
T6	Write amount, write and stamp teller	<15 min	<1 h 35 min	<1 h 35 min	
T7	Post transaction details	<1 h	<2 h 35 min	<2 h 35 min	<5 h

deposit business process. The approach is expressive as each task that necessitates checking is being compared with the network analysis method employed.

Table 13 above shows the allotted SMSE time required by the organization for each task to be carried out, the Earliest Time (ET) that each task would have been completed, and the Latest Time (LT) in the loan request business process of the SMSE. Not all the tasks are considered at the temporal analysis phase of the compliance management, but only the task(s) that necessitates comparison of the Compliance Time (CT) with the ET and LT. From the table, it can be deduced that Task 7 (T7) which is expected to take place in less than 5 days will be taking place in less than 5 h 40 min which is far less than the compliance period required. Task 12 (T12) which has to do with the decision making of the Board of Directors on the loan request which has an Internal Policy of not being more than 1 month will be taking place in less than 20 days 11 h 40 min which is less than the Compliance Time. This implies that the loan Request business process of the SME is compliant to the three temporal requirements of the compliance requirements.

Table 14 shows the allotted time required for each task of the business process, computation of ET and computation of LT. The row of T7 which has the total Earliest and Latest Time which is less than 2 h 35 min is far less than the compliance timing of 5 h. This implies that the Cash Deposit Business Process of the SME is compliant. This technique is simpler, efficient, and more expressive than the existing formal approaches (Barnawi et al. 2015; Elgammal et al. 2014; Cabanillas et al. 2015) that require formal knowledge on the side of the user.

4.7 Offline compliance analysis and monitoring

The offline compliance analysis monitoring is carried out after the design time and run time execution and verification have been performed. This looks at the compliance constraints such as data security and data encryption and decryption which could not be dealt with at design and run time. This analysis and monitoring is performed manually by the business process compliance experts by utilizing the available facts from the design and run-time report. The algorithm is described in Table 15.

Table 15 Offline compliance monitoring algorithm

INPUT: run time verified BP model, all compliance requirement documents
OUTPUT: offline verified BP model
PROCESS
1: get verified run time BP model
2: physically check unverified compliance requirements (data encryption, and decryption) where necessary manually
3: if any violation is discovered, go to step 4, else go to step 5
4: modify BP model, go to step 2
5: end Process

4.8 Compliance repository

The Compliance Repository (see Fig. 9) is a database that keeps record of the Compliance Requirements that are being satisfied in the business process, the regulatory bodies and standards as well as the rules employed. This is built through a software environment developed through integrating software tools (Turetken et al. 2011). The Business Process Compliance Requirement Management (BPCRM) System will be a web-based application used to store, define and manage the compliance requirements and other factors in a compliance repository. The user interface enables the user to input the outcome of the various compliance requirement analyses into the database. Here, the business process(es) concerned with the requirement is also stored with their requirements. This is made possible through a database server that enables connection between the web application and the database. In order to make access to requirement properties such as rules and descriptions easy, data can be queried from the database using the business process and constraint type as the string for querying. For instance, if the compliance expert intends to access the control flow compliance requirements of the account opening business process, he selects the account opening business process and control flow as the constraint type after which he clicks on the search button. The selected record(s) are then fetched as a table as well as the number of records. The proposed tool was implemented with Hypertext Preprocessor (PHP) as the scripting language and mysql as the database server which is a component of the Windows Apache Mysql PHP (WAMP) server software for the compliance repository. This will aid the reusability of the compliance requirements and rules for future use and access. Figure 9 shows the diagrammatic representation of the Business Process Compliance Repository Architecture and Fig. 10 shows its user interface for uploading new requirement details. Figure 11 shows the user interface for querying the compliance repository. The outputs include the source of the compliance requirement, the description of the compliance requirement, the type of compliance requirements, the business process the requirement is attached to, the LTL rule equivalent of the requirement and the risk of violating the rule.

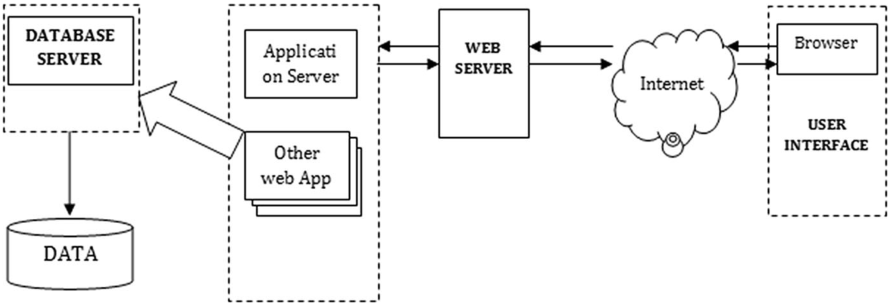


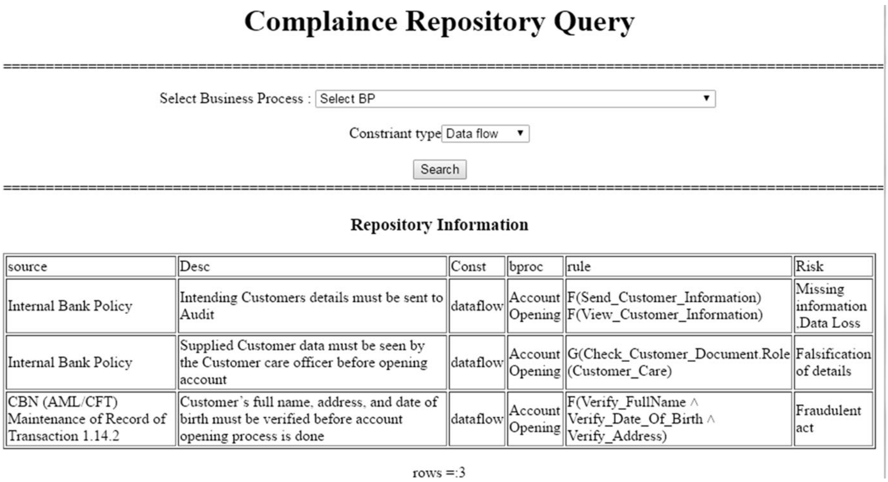
Fig. 9 Architecture of the business process compliance repository

Fig. 10 Extract of the user interface of the compliance repository for updating new records

5 Evaluation and comparison of the proposed approach with existing proposals

Considering how crucial the subject of business process compliance management is, we evaluate the newly introduced mechanism for requirements extraction and classification into their various categories. We also compare our proposal with existing proposals that explored compliance requirement analysis and runtime monitoring of BPs. This is aimed at evaluating the approaches for capability, efficiency and future prospects of their application. The comparison is based on important parameters discussed in this paper as well as some attributes required of approaches for efficiently analyzing and verifying business processes at runtime.

In this paper, we have basically proposed two approaches to maximally manage business process compliance by enhancing the architecture proposed in Papazoglou (2011) through compliance requirement classification using the idea of goal based



source	Desc	Const	bproc	rule	Risk
Internal Bank Policy	Intending Customers details must be sent to Audit	dataflow	Account Opening	F(Send_Customer_Information) F(View_Customer_Information)	Missing information .Data Loss
Internal Bank Policy	Supplied Customer data must be seen by the Customer care officer before opening account	dataflow	Account Opening	G(Check_Customer_Document.Role (Customer_Care)	Falsification of details
CBN (AML/CFT) Maintenance of Record of Transaction 1.14.2	Customer's full name, address, and date of birth must be verified before account opening process is done	dataflow	Account Opening	F(Verify_FullName ∧ Verify_Date_Of_Birth ∧ Verify_Address)	Fraudulent act

Fig. 11 The query page of the compliance repository

requirement analysis. We also proposed an approach to verifying timing constraints in business processes using network analysis. A comparative evaluation of our approaches with that of other works can be seen in Tables 16 and 17. The comparisons were based on the performance coverage of the approaches with respect to business process compliance management. In Table 16 the first row shows the parameters on which we base our comparison and the subsequent rows indicate the extent to which each of the runtime monitoring approaches were able to address the parameters. In Table 17 the first row shows the parameters on which we base our comparison and the subsequent rows indicate the extent to which each of the proposals were able to take care of the parameters.

5.1 Evaluation of compliance requirements classification approach

To ensure that the choice of the requirements and their classification approach was efficient and effective, an understanding and definition of the following metrics are essential.

5.1.1 The "uniqueness" metric

This metric checks whether the requirements used in checking business process compliance are different from each other in terms of their meaning. Some requirements are likely to be synonymous, leading to a re-check of the same constraints. Also, two different compliance documents could pose the same requirements in different contexts. Iqbal and Khan (2012) recommended that if the evaluation of requirements based on this metric is less than 95% (0.95), then it indicates the requirements are ambiguous. This metric is used to measure the uniqueness of the requirements obtained after the classification and analysis stages of the compliance management framework.

Table 16 Comparison of runtime monitoring approaches with the current proposal

Authors	Diagrammatic description of approach	Textual description of approach in terms of formal method uses	Flexibility	Expressivity of the approach	Background required	Tool support required
Elgammal et al. (2014)	Not expressed	Explicitly expressed	Not flexible	Average	Highly required	Yes
Morales (2014)	Explicitly expressed	Not explicitly expressed	Not flexible	Average	Highly required	Yes
Koetter et al. (2014)	Explicitly expressed	Not explicitly expressed	Flexible	High	Partially required	Yes
Barnawi et al. (2015)	Explicitly expressed	Explicitly expressed	Flexible	High	Highly required	Yes
Proposed framework	Explicitly expressed	Explicitly expressed	Flexible	High	Minimal	No

Table 17 Comparison of compliance requirement analysis approaches with the current proposal

Authors	Addresses dataflow requirement	Addresses control flow requirements	Addresses requirements
Pham and Thanh (2015)	Yes	No	No
Cabanillas et al. (2015)	Yes	No	No
Elgammal et al. (2014)	Yes	No	Yes
Turetken et al. (2011)	Yes	Yes	No
Papazoglou (2011)	Yes	Yes	No
Becker et al. (2011)	Yes	Yes	No
Proposed framework	Yes	Yes	Yes

$$U_i = \frac{R_i}{R_t} * 100 \tag{4}$$

where R_i = Requirements with distinct explanation, R_t = Total number of requirements.

5.1.2 The "correctness" metric

This metric measures the percentage of requirements that are valid, indicating how well we have done in the choice of requirements for verifying compliance of the business processes. According to Iqbal and Khan (2012), if the result is less than 80%, then it is assumed that the correctness cannot be verified; whereas, a result greater than 80% is acceptable

$$C_i = \frac{R_c}{R_t} * 100 \tag{5}$$

where R_c = Requirements having the same interpretation, R_t = Total number of requirements.

5.1.3 The "traced" metric

The result of this metric is the percentage of requirements traced throughout the business process compliance management process. The analyzed requirements which could be traced easily to a source document were measured with the total number of requirements used for the process. Let R_{tr} be the requirements traced while R_t be the total requirements, then the traceability rate of the compliance management process is:

$$T_i = \frac{R_{tr}}{R_t} * 100 \tag{6}$$

where R_{tr} = Requirements traced, R_t = Total number of requirements.

5.2 Result analysis

Compliance requirements for five different business processes were evaluated using the metrics. Table 18 summarizes results of the evaluation carried out on the compliance requirements employed in our implementation.

Table 18 shows that the dataflow constraints made up of a total of 9 requirements had an average measure of 0.96 based on the fact that all the requirements had distinct meaning, with a uniqueness of 1.00 and a correctness of 1.00, but only 0.89 of the requirements could be traced to their root sources in their regulatory guideline and sections. The control flow constraints made of a total of 30 requirements have an average requirement measure of 0.88 computed from their 0.90 uniqueness, 0.97 correctness and 0.77 traceability. The temporal constraints made up of a total of 6 requirements had a uniqueness of 1.00, correctness of 1.00 and 0.83 traceability which makes up an average measure of 0.94. It can also be deduced that the requirements considered are 0.97 unique, 0.99 correct and 0.83 traceable. This implies that they are acceptable and not ambiguous according to Iqbal and Khan (2012). A representation of this result can be seen in Fig. 12.

Table 18 Results of effectiveness of compliance requirement classification and analysis technique

Parameter/constraint type	U_i	C_i	T_i	Average measure
Dataflow	1.00	1.00	0.89	0.96
Control flow	0.90	0.97	0.77	0.88
Temporal	1.00	1.00	0.83	0.94
Average	0.97	0.99	0.83	

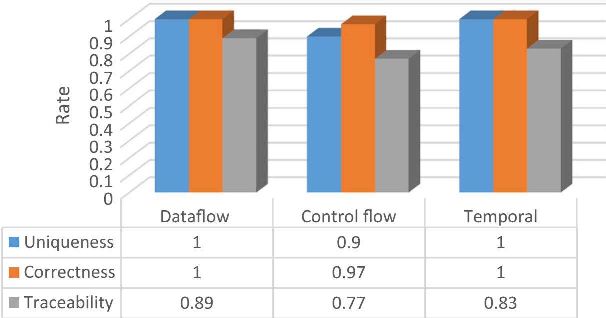


Fig. 12 Chart showing the evaluation result of the compliance requirements' classification and analysis

6 Discussion

The approaches employed in analyzing compliance requirements of business processes should be well structured and efficient in making business enterprises adhere maximally to regulatory rules and standards. This can be achieved by identifying and analyzing as many requirements as necessary through the classification of these requirements.

The comparisons in Tables 16 and 17 support the conclusion that the proposed approaches address SMSE needs more effectively than previous efforts. The past approaches have not been able to fully extract all constraints from a single requirement which has led to incompleteness of constraints checked and verified in subsequent phases of the compliance management process. A single requirement extracted from a compliance document can have in it two or three of the constraints types which if collectively analyzed can lead to the neglect of one or two of the constraints.

Various approaches employed in the verification of timing constraints at runtime required in-depth background knowledge before they could be applied due to their formal foundation despite being tool supported. There was also the challenge of identifying parts of the business process model that were not compliant with their requirements by the enterprise from prior approaches. The results of prior research only give the compliance expert a compliant or violation report without clearly making them identify the task in the business process that had faulted its requirement. The proposed framework will not just detect violations but also aid correction to violations.

7 Conclusion

This paper presents a compliance checking model and architecture with effective approaches at the pre-analysis, analysis and runtime monitoring phases for SMSE. The introduction of tags and the concept of a goal based requirement analysis applied in the study helped in carrying out an easy and distinct classification of compliance requirements before analyzing them. Several research efforts carried out on the management of compliance on businesses have singly analyzed the requirements which did not aid the effectiveness and efficiency of the design time and runtime verification phases of the management framework. Compliance requirement analysis is the bedrock upon which design time and runtime verifications depend on which is being introduced and used in this research work. It can hereby be deduced that compliance requirements extraction and classification are vital stages for efficient business process compliance checking. This paper also presented an approach (network analysis) to the temporal constraints checking of the business process at runtime which was found to be more expressive, clear and easier to comprehend by enterprises at any level (large, medium or small). The formal approach utilized by previous research work required a foundational knowledge of the principles before they can be understood which might take a longer time. The approach introduced in this paper will aid the detection of adherence and non-adherence of business processes to temporal constraints. This will further aid these enterprises to detect any aspects of the BP that need to be modified. The framework was employed in the microfinance banking system, specifically UNAAB Microfinance bank in Nigeria using relevant compliance requirements by the CBN, NDIC and Internal policies. The presented approaches form a strong motivation for SMSE who may want to adopt cloud computing since it gives room for efficient management of SMSE business process compliance to regulatory standards.

Part of our future work is automation of the proposed network analysis and integration of the main phases of the model into a software tool that can be used by the SMSE. We also aim to carry out further evaluation on the framework by utilizing it on other case studies in order to fully assess its usefulness in the industry. Also, we intend to design a compliance management framework that can be used on the cloud platform to help ascertain the adherence of cloud customers to the standards in the cloud.

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