Linked Warning Criterion on Ontology-Based Key Performance Indicators

Hanif Affandi Hartanto
Directorate of Data Integration and Information System
Institut Pertanian Bogor
Bogor, Indonesia
hanf_aff@apps.ipb.ac.id

Riyanarto Sarno
Informatics Department
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
riyanarto@if.its.ac.id

Nurul Fajrin Ariyani
Informatics Department
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
nurulfajrin@ if.its.ac.id

***Abstract*—Business process metamodel is a representation of knowledge on business processes. Balanced scorecard ontology (BSCO) is a conceptual representation of the balanced scorecard, so it can be integrated in semantics. However, the balanced scorecard ontology unable to measure fraud criterion when a business process has been executed. This research propose a model Warning Criterion Ontology (WCO) to detect wrong pattern and wrong resource in the organization. In this study, Key Performance Indicator (KPI) has been performed to cascades quality assurance office from the universities in Indonesia. The KPI method for "Percentage of Compliance in running well Standard Operating Procedure (SOP)" has been proposed in this research. By using KPI, warning activity measurement could be measured in organization with linked WCO, business process metamodel, BSCO and Petri net ontology.**

Keywords—balanced scorecard ontology; key performance indicator; ontology; warning criterion ontology

I. INTRODUCTION

The business process involves activities carried out in a coordinated manner and run by people to achieve the goals/objectives of business [1]. A process remains a top priority in conducting business setting, but some aspects of the process that still has its own challenges in implementing it [2]. On average, a company lost 7 percent of its gross revenue each year. There are 20 percent of people in the company never commit fraud, 60 percent of them rely on the opportunities to commit fraud, and the remaining 20 percent actually commit fraud [3]. Based on the research [4] wrong pattern and wrong resource is a fraud criterion.

Nunes [5] has proposed a model to creation, manipulation and reuse information contextually related to the activities of business process. Then, Mattos [6] improved that research by propose three-layer metamodel, they are context metamodel layer, business process metamodel layer, and domain metamodel layer. The research aims to represent a concept or knowledge of the context of business process. Petri net can be used to describe a business process, with representing petri net using ontologies can provide semantic description of petri net concepts and their relationships [7].

Balanced Scorecard (BSC) is a tool in the field of management to manage business strategies, measuring the performance of the company, communicate the vision, mission, strategies and objectives to stakeholders. In the measurement of performance, the BSC uses four perspectives: financial, customer, business process, learning and growth. The previous studies have proposed a model of balanced scorecard based on ontology (BSCO) [8].

However, the balanced scorecard ontology unable to measure fraud criterion when a business process has been executed. This research proposes a model Warning Criterion Ontology (WCO) to detect the wrong pattern and wrong resource in the organization. The KPI method for "Percentage of Compliance in running well Standard Operating Procedure (SOP)" has been proposed in this research. By using KPI, warning activity measurement could be measured in organization with linked WCO, business process metamodel, BSCO and Petri net ontology.

II. LITERATURE

A. Petri Net Ontology

Petri net can be used to describe a particular business process. Petri net is a specific type of chart that contains several types of objects, namely the place, transition, arc and tokens. Zhang Fu [7] has modeled in the form of a Petri net ontology, by translating some of the key features of a Petri net into classes, properties and axioms of OWL DL.

B. Business Process Metamodel

Mattos [6] has proposed a layer to specifically define concepts of context and their relationships. Thus, to express the element of a business model modifying by Nunes [5], excluding the class Context and establishing new relationships between the two layers. Moreover, the formalism presented to improves the original ontology by making all of the relevant concepts related to context explicit in a separate model (context metamodel layer) and highlighting in the second layer a business process metamodel. This metamodel should be taken as a basis for building the process models, which is needed to identify and monitor.

C. *Balanced Scorecard Ontology*

The Balanced Scorecard (BSC) [9] can be identified as the organization's drivers toward its objectives and make them converge toward them, defining the relations among the goals of performance from four perspectives of the organization. Kaplan and Norton described the BSC as a framework of action to translate the vision of an organization in its strategy, lending attention to the requests of shareholders, clients, and internal requests, that in a joint way describe the strategy of an organization, and how this strategy can be achieved. In the measurement of performance, the BSC uses four perspectives: financial, customer, business process, learning and growth.

The previous studies have proposed a model of balanced scorecard based on ontology (BSCO). BSCO is a representation of elements, relationships, vocabulary and semantics of the essential subjects in the balanced scorecard domain [8]. BSCO is structured into several levels of decomposition with increasing depth and complexity. The first level of decomposition of ontology contains the four perspectives, which are the products and services firm offers, the relationship it maintains with its customers, the infrastructure necessary in order to provide this and finally, the financial aspects, which are the expression of business success or failure. An ontological model built around the balanced scorecard domain, allows us to achieve a conceptualization of the business process, aligned with the strategy of an organization, to be captured, represented, disseminated and processed by the resource at a company.

III. REPRESENTATION OF WARNING CRITERION

In this paper, we propose a warning criterion base on ontology. In this section, we present Warning Criterion Ontology (WCO) master with two component, i.e. enterprise ontology and specification (viewpoint). Enterprise ontology for WCO-Master includes five domains: performance management, business process, petri net, organizational and warning criterion. Figure. 1 depicts the WCO-Master enterprise ontology.

A. *Semantic Integration*

Semantic technologies [10, 11] offer a new way to integrate data and applications. Before making the maps, a model (or an ontology [12]) of a given business domain is defined. The model is expressed in a knowledge representation language and contains business concepts, relationships and a set of rules. This representation of the knowledge enables the creation of structured information collections and rules of inference to facilitate the automated reasoning.

In this research, business rule class on business process metamodel will link with standard operating procedure (SOP) class on WCO. Where the representation of the SOP is derived from petri net. Then activity class on business process metamodel will link with key performance indicator (KPI) class on BSCO. Legal activities in this model are divided into key activity and normal activity. The key activity of the business process will be mapped into one of the key performance indicators.

B. *Warning Criterion Ontology (WCO)*

At model Warning Criterion Ontology (WCO) with OWL

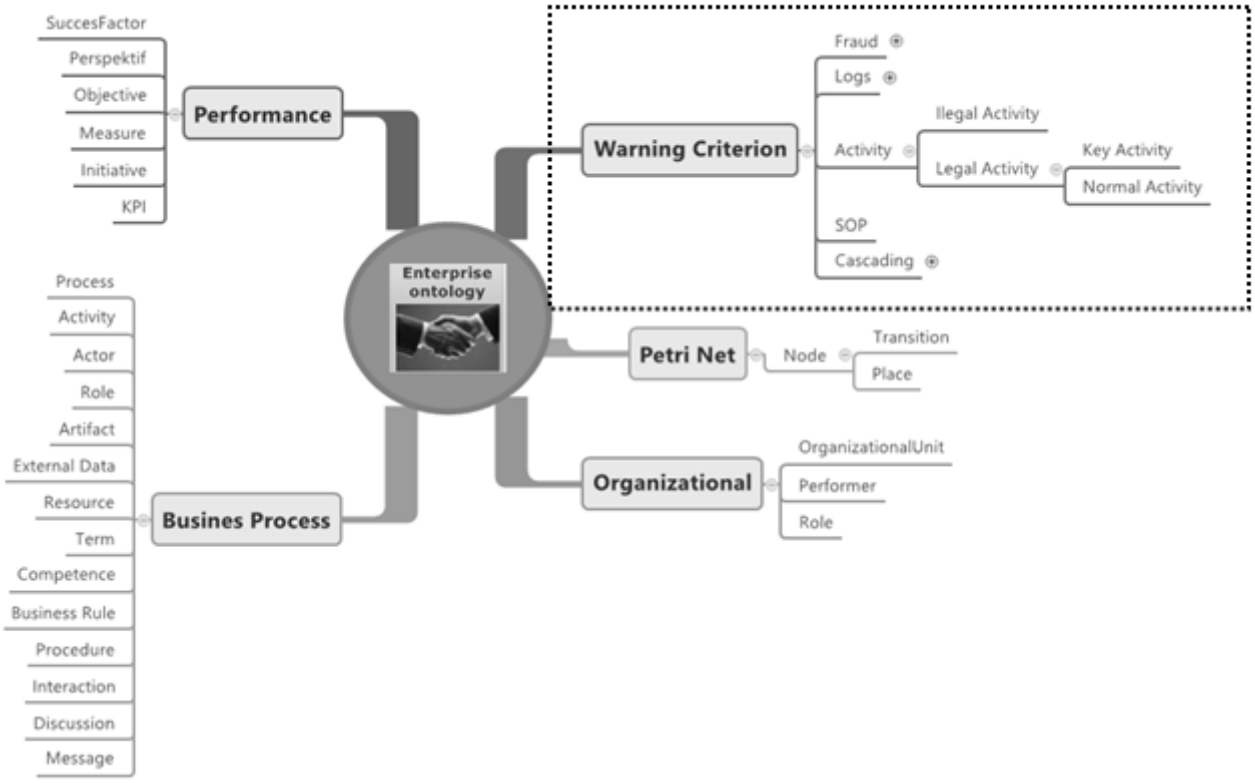

Fig. 1. WCO-Master Enterprise Ontology.

DL ontologies, i.e., we translate some key features from the component of WCO into classes, properties and axioms of OWL DL ontologies. Figure. 2 shows a model of WCO. The main classes and attributes are described in Table I.

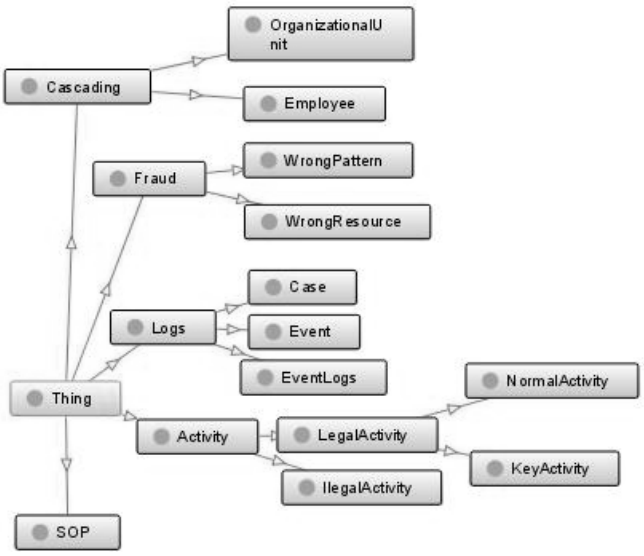

Fig. 2. Model of WCO.

TABLE I. WARNING CRITERION CLASSES AND ATTRIBUTES

Class	Description and attributes
Cascading	Representing cascading on balanced scorecard. Attributes: name, description.
Fraud	Representing for criteria fraud. Attributes: name, description.
Logs	Logs is a super class for all element on event logs. Attributes: description
Activity	Set of actions aimed at reaching one or more objectives that consumes and produces and requires actors to execute it. This class linked with activity from business process. Attributes: name, description, action, expected goal, achieved goal.
SOP	Representing standards operational procedure. Attributes: relation with transition.

Let WCO = (S, E, F, A, C) be warning criterion ontology. The OWL DL ontology $O = \phi(WCO) = (ID_0, Axiom_0)$ can be defined by transformation function ϕ as follows:

1) The OWL DL identifier set ID_0 of $\phi(WCO)$ contains following elements:
   - Each SOP symbol $s_i \in S$ is mapped into a class identifier $\phi(s_i) \in CID_0$;
   - Each event logs on Logs symbol $e_i \in E$ is mapped into a class identifier $\phi(e_i) \in CID_0$;
   - Each key activity on Activity symbol $ak_i \in A$ is mapped into a class identifier $\phi(ak_i) \in CID_0$;
   - Each employee on cascading symbol $ce_i \in C$ is mapped into a class identifier $\phi(ce_i) \in CID_0$;
   - Each organizational unit on cascading symbol $cu_i \in C$ is mapped into a class identifier $\phi(cu_i) \in CID_0$;
   - Each warning activity on Activity symbol $wa_i \in A$ is mapped into a property identifier $\phi(wa_i) \in PID_0$;
   - Each wrong pattern from a fraud $f_{wp} \in F$ is mapped into an individual identifier $\phi(f_{wp}) \in IID_0$;
   - Each wrong resource from a fraud $f_{wr} \in F$ is mapped into an individual identifier $\phi(f_{wr}) \in IID_0$;
   - A class identifier $\phi(CSOP) \in CID_0$ denotes all the SOP in WCO;
   - A class identifier $\phi(CEventLogs) \in CID_0$ denotes all the Event Logs in WCO;
   - A class identifier $\phi(CKeyActivity) \in CID_0$ denotes all the Key Activity in WCO;
   - A class identifier $\phi(CEmployee) \in CID_0$ denotes all the Employee in WCO;
   - A class identifier $\phi(CUnit) \in CID_0$ denotes all the Unit in WCO;
   - A property identifier $\phi(wa) \in PID_0$ denotes all the warning activity in WCO;
   - A individual identifier $\phi(f_{wp}) \in IID_0$ denotes all the fraud criteria wrong pattern in WCO;
   - A individual identifier $\phi(f_{wr}) \in IID_0$ denotes all the fraud criteria wrong resource in WCO;
   - A class identifier owl:Thing $\in CID_0$ is used to denote all elements in warning criterion ontology WCO, and another class identifier owl:Nothing $\in CID_0$ denotes empty sets;

2) The OWL DL axiom set $Axiom_0$ of $\phi(WCO)$ contains following elements:
   - Warning activity in WCO means that its input is an event logs and output is a warning activity in class perspective (BSCO). Then creating the property axioms:
     ObjectProperty (ϕ(wa) domain (Class perspective on BSCO) range (ϕ(CKeyActivity)));
   - Fraud criteria in WCO mean that its input is event logs and output is a status wrong pattern or wrong resource, and thus it is necessary to define the domain and range of the corresponding individual identifiers $\phi(f_{wp})$ and $\phi(f_{wr})$. Then creating the property axioms:
     DataProperty ($\phi(f_{wp})$ domain (ϕ(CEventLogs)) range (boolean));
     DataProperty ($\phi(f_{wr})$ domain (ϕ(CEventLogs)) range (boolean));

Rule for warning criterion ontology, can see below:

1) Rule for wrong pattern:
   EventLogs(?e1), EventLogs(?e2), BusinessRule(?b1), BusinessRule(?b2), hasActivity(?b1, ?a1), hasActivity(?b2, ?a2),

hasActivity(?e1, ?a1), hasActivity(?e2, ?a3), hasNextBusinessRule(?b1, ?b2), hasNextEventLogs(?e1, ?e2), hasNameActivity(?a2, ?na2), hasNameActivity(?a3, ?na3), notEqual(?na2, ?na3) → hasWrongPatternSequence(?e1, true), hasWrongPatternSequence(?e2, true);

2) Rule for wrong resource:
EventLogs(?e), BusinessRule(?b), hasActivity(?b, ?a), hasActivity(?e, ?a), originator(?b, ?o1), originator(?e, ?o2), hasName(?o1, ?no1), hasName(?o2, ?no2), notEqual(?no1, ?no2) → hasWrongResource(?e, true);

3) Rule for linked perspective with activity:
BusinessProcess(?b), BusinessProcessObjective(?o), BusinessProcessSucessFactor(?s), KPI(?k), Activity(?a), contains(?b, ?o), measures(?a, ?k), measures(?k, ?s), measures(?s, ?o) → linkedPerspective(?a, ?b)

4) Rule for warning activity:
EventLogs(?e), BusinessProcess(?b), Activity(?a), hasActivity(?e, ?a), linkedPerspective(?a, ?b), hasWrongResource(?e, ?f), equal(?f, true) → warningActivity(?b, ?a)

IV. EXPERIMENT AND RESULT

In this paper, an accreditation assistance program was investigating as an experiment for linked activity with KPI. Figure. 3 shows a Standard Operating Procedure of accreditation assistance program [13]. In which the university has implemented a balanced scorecard approach to assessing the performance of the university. In this case, we used key performance indicators from the university in Indonesia [14]. In 2011 Quality assurance office at the university have 11 KPI. Then we proposed KPI for controlling KPI at Quality assurance office about "Percentage of unit academic and non-academic services certified by ISO 9001: 2008". This KPI is "Percentage of compliance in running well SOP (The percentage of fraud criteria at SOP)". KPI of Quality assurance office are described in Table II.

TABLE II. KEY PERFORMANCE INDICATOR OF QUALITY ASSURANCE OFFICE [14]

Key Performance Indicator
The number of department has been accreditation/international equity (accumulative) (Facilitation Program in the process of accreditation/international equity)
The percentage of students who graduate on time (SPMI implemented/assessment SPMI)
Percentage of S1 student with GPA> 3 annually (SPMI implemented/assessment SPMI)
The average level of student satisfaction on the quality of academic activities (department assessed SPMI)
Lecturer percentage with EPBM> 3 (Student participation in accreditation forms filling EPBM)
Percentage of S0 department which is accredited by BAN- PT (Facilitation Program in the accreditation process BAN-PT)
Percentage of S1 department which is accredited by BAN- PT (Facilitation Program in the accreditation process BAN-PT)
Percentage of S2 department which is accredited by BAN- PT (Facilitation Program in the accreditation process BAN-PT)
Percentage of S3 department which is accredited by BAN- PT (Facilitation Program in the accreditation process BAN-PT)
Percentage of unit academic and non-academic services certified by ISO 9001: 2008 (Facilitation ISO certification through socialization, training and mentoring)
Number of laboratory that obtain ISO 17025 certification and Knapps (Facilitation ISO certification through socialization, training and mentoring)
Percentage of compliance in running well SOP (The percentage of fraud criteria at SOP)

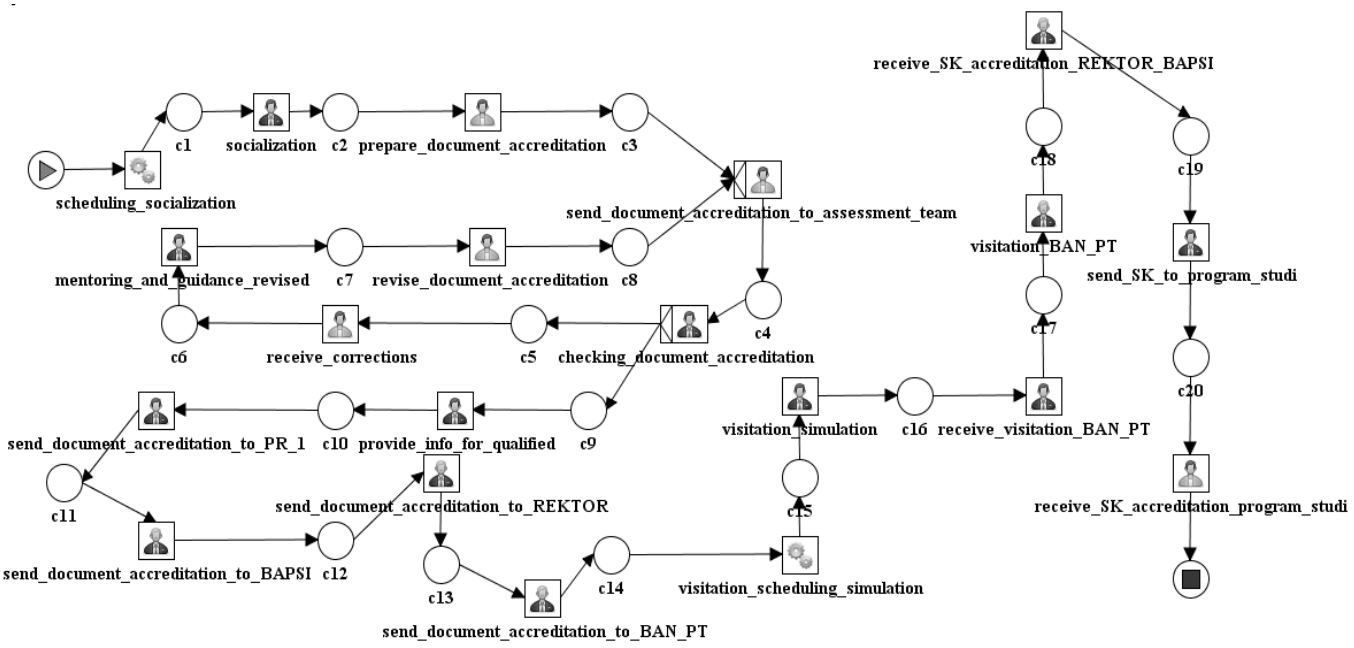

Fig. 3. Standard Operating Procedure (SOP) of accreditation assistance program [13].

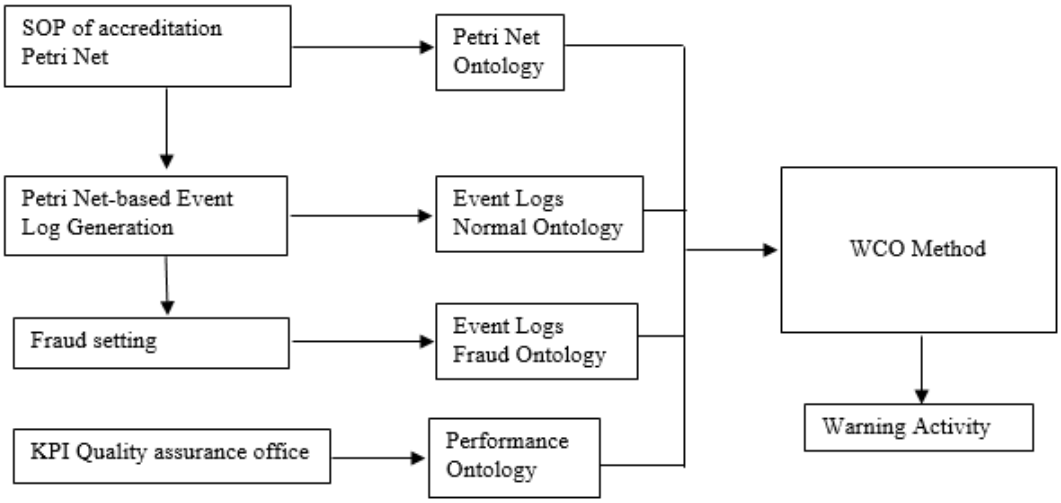

Fig. 4. Flowchart evaluation of WCO

A. *Experiment*

In this research, we use three step for evaluation our method. The steps are: a) define dataset, b) converted into the format of OWL, c) detect warning activity. Figure. 4 shows a flowchart evaluation of WCO.

1) *SOP of accreditation Petri Net.*
In this research, we used tools Workflow Petri Net Designer (WoPeD). WoPeD stands for Workflow Petri Net Designer and is open-source [15]. The underlying file format complies to standard PNML, allowing models created by WoPeD to be exchanged with other PNML-aware tools [16]. Then PNML format is converted into the format of OWL with Petri Net Ontology structure.

2) *Petri Net-based Event Log Generation.*
In this research, we used event logs from the generator plugin log in ProM [18]. We use two simulations at event log generation option, that is: random path generation and complete generation. At random path generation, we get 2000 cases, when complete generation we get 3 cases. Figure. 5 shows the results of the random path generation.

Fig. 5. The results of the random path generation.

The results of the random path generation, we separate it into event logs normal based on the results of a complete generation. We set 100 cases for event logs normal. The result from event logs generation complies to standard XES. Then event logs normal converted into the format of OWL.

3) *Fraud Setting.*
Event log fraud is the results generated are not contained in the case from three complete generation. We set 50 cases for event logs fraud. Where 20 cases is a case where the originator has misplaced and 30 cases is a case where there was a wrong pattern sequence. Then event logs fraud converted into the format of OWL.

This simulation has been implemented with protégé with the reasoned pellet. The results of the simulation showed that are activities that were detected as a warning in perspective BSCO. Figure. 6 shows simulation in the class perspective balanced scorecard.

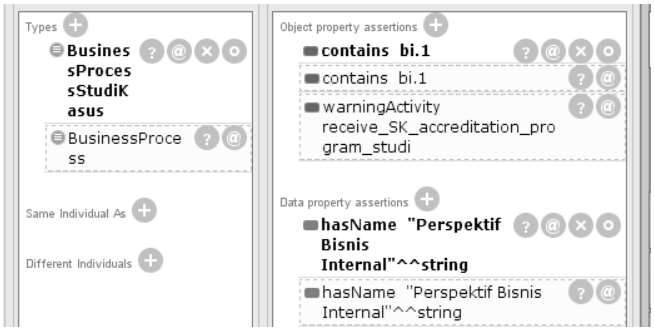

Fig. 6. Simulation in class perspective balanced scorecard.

B. *Result*

In this research, our model can detect wrong pattern sequence and wrong resource misplaced. But our model can't detect pattern split. The result for detection warning activity can show in Table III.

TABLE III. RESULT FOR DETECTION WARNING ACTIVITY

KPI	Activity		Wrong pattern		Originator has misplaced
	name	type	sequence	split	
Compliance in running well SOP of accreditation assistance program	scheduling_socialization	Normal Activity	5	-	0
	socialization	Normal Activity	5	-	0
	prepare_document_accreditation	Key Activity	0	-	0
	send_document_accreditation_to_assesment_team	Key Activity	-	0	2
	checking_document_accreditation	Key Activity	-	0	2
	receive_corrections	Key Activity	0	-	2
	mentoring_and_guidance_revised	Key Activity	0	-	2
	revise_document_accreditation	Key Activity	5	-	2
	provide_info_for_qualified	Key Activity	0	-	0
	send_document_accreditation_to_PR_1	Key Activity	0	-	2
	send_document_accreditation_to_BAPSI	Key Activity	2	-	2
	send_document_accreditation_to_REKTOR	Key Activity	2	-	1
	send_document_accreditation_to_BAN_PT	Key Activity	2	-	0
	visitation_scheduling_simulation	Normal Activity	0	-	0
	visitation_simulation	Normal Activity	0	-	0
	receive_visitation_BAN_PT	Key Activity	2	-	0
	visitation_BAN_PT	Key Activity	0	-	0
	receive_SK_accreditation_REKTOR_BAPSI	Normal Activity	2	-	0
	send_SK_to_program_studi	Normal Activity	0	-	0
	receive_SK_accreditation_program_studi	Normal Activity	5	-	5

V. CONCLUSION

In this paper, we proposed an ontology approach for representing of warning criterion on key performance indicator. This model is used to measure warning activity in an organization business process that has been executed. By linked warning criterion into performance indicators so that management can be more responsive to activity indicated as the wrong pattern and wrong resource that affect the performance of the company. Our method only detects originator has misplaced and wrong pattern sequence.

In the future, we will repair rule for the wrong pattern for pattern split, then we will add other fraud criteria such as skip activity, throughput time, wrong decision and wrong duty. Then it will be implemented into the plugin ProM for fraud detection at a key activity of the business process.

REFERENCES

[1] M. Weske, "Business Process Management: Concepts, Languages, Architectures", 1st ed, Springer, 2007.

[2] Gartner Group, Meeting the Challenge: The 2009 CIO Agenda. EXP Premier Report January 2009, Inc.,Stamford, Connecticut, 2009.

[3] Peter D. Goldmann, "Anti-Fraud Risk and Control Workbook", 2009.

[4] Huda, S., Sarno, R., Ahmad, T., Santoso, H,A., "Identification of Process-based Fraud Patterns in Credit Application", Information and Communication Technology (ICoICT), 2014 2nd International Conference, pp. 84-89, 2014.

[5] V.T. Nunes, F.M. Santoro, M.R.B. Borges, "Context in Knowledge Intensive Collaborative Work", in 10th International Conference on CSCW in Design, vol. 2, pp. 793-798, 2006.

[6] T. d. C. Mattos, F. M. Santoro, K. Revoredo and V. T. Nunes, "A Formal Representation for Context-aware Business Processes", Computers in Industry, vol. 65, pp. 1193-1214, 2014.

[7] Fu Zhang, Z. M. Ma, Slobodan Ribarić, "Representation of Petri Net with OWL DL Ontology", in 8th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), vol. 3, pp. 1396-1400, 2011.

[8] R. F. N. Hernandez, A. P. Soltero, G. S. Schmitz and M. B. Valenzuela, "An Ontological Model to Support the Implementation of Balanced Scorecard in the Organizations", in Proceedings of the 10th World Multiconference on Systemics, Cybernetics and Informatics (WMSCI 2006), Orlando Florida, 2006.

[9] Kaplan R. S. and D. P Norton, "The Strategy Focused Organization – How balanced scorecard companies thrive in the new business environment". Harvard Business School Press, Boston, Massachusetts, USA, 2001.

[10] Noy, N. "Semantic Integration: a Survey of Ontology-Based Approaches", ACM SIGMOD Record, Vol. 33 No. 4, pp. 65-70, 2004.

[11] Uschold, M. and M. Gruninger, "Ontologies and semantics for seamless connectivity", ACM SIGMOD Record, Vol. 33 No. 4, pp. 58-64, 2004.

[12] Gruninger, M. and J. Lee, "Ontology applications and design: Introduction", Communications of the ACM, Vol. 45 No. 2, pp. 39-41, 2002.

[13] Badan Penjaminan Mutu, Manual Prosedur Standar Operasional Prosedur Penataan Proses Akademik UNUD-BPMU-05.01.10, Universitas Udayana, 2010 Available at: http://www.fkp.unud.ac.id/wp-content/uploads/2013/09/SOP-Penataan-Proses-Akademik-Akreditasi-PS-Baru-Ijin-Operasional.pdf (accessed May 2015).

[14] Sistem Manajemen Kinerja IPB, Available at: https://simaker.ipb.ac.id (accessed May 2015).

[15] W. M. P. van der Aalst, K M. van Hee: "Workflow Management: Models, Methods, and Systems", MIT Press 2002.

[16] Freytag, T. Sänger, M., "WoPeD - An Educational Tool for Workflow Nets", Proceedings of the BPM Demo Sessions, Eindhoven, pp. 31-35, 2014.

[17] Vanden Broucke, S., De Weerdt, J., Vanthienen, J., Baesens, B. (2012). "An Improved Process Event Log Artificial Negative Event Generator", FEB Research Report KBI_1216, pp. 1-17, Leuven (Belgium): KU Leuven – Faculty of Economics and Business.