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PETRI NET MODEL OF ERP BUSINESS PROCESS VARIATION FOR SMALL AND MEDIUM ENTERPRISES

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ABSTRACT

In addition to various benefits to Small and Medium Enterprises (SMEs), the application of ERP system for SMEs still encounters a quite number of challenges. One of the challenges is such a great number of variations of the business needs among the SMEs. The Moreover, ERP business processes in SMEs often change due to any change in business needs and technological advancements. To cope with these challenges, it requires a development of ERP systems which is reliable to meet diverse varieties in business processes in each of its modules.

In order to analyze various models in the business processes, it calls for a business process modeling. This paper discusses about a business process modeling by means of Petri Net. The modeling emphasizes on aspects of business process analysis, i.e.: a modeling capable of verifying and analyzing the performance of business processes at present. The analysis on business process can adopt two approaches, namely Matrix Algebra and Structure Analysis.

Keywords: *Petri Net, ERP Business Process, Business Process Verification, Reachability Analysis, Web Services*

1. INTRODUCTION

Small and Medium Enterprises (SMEs) are the main business entities undertaking economic activities that contribute the most to the economic progresses in a country [1][2][3].

The contribution of SMEs to Indonesian Gross Domestic Product in year 2009 was 53.32% and in the year 2011 it increased into 56.5% [4]. SMEs have been proven to be able to stabilize the Indonesian economy in the turbulence of the global economic crisis that has been on since 2009. Besides, SMEs also employ majority workforces.

Some of the greatest challenges to SMEs in Indonesia are limited infrastructures, capital and knowledge as well as skills to exploit the available technology. Saputro addressed that there were three main problems faced by the SMEs, i.e.: lack of capital, highly competitive market and difficulties to get raw materials [5]. In addition, limited capital and lack of knowledge on information technology have caused most SMEs process their business activities manually.

It certainly requires a strategic step to cope with the above challenges. SMEs obviously need information technology supports in form of an Enterprise Resources Planning (ERP). The ERP system integrates all information and processes of a company [2]. An ERP system offers a number of benefits to SMEs, such as: (i) maintaining the control over operation activities and efficiency for business processes, (ii) integrating and synergizing SMEs business processes with other business

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entities, (iii) increasing revenues and (iv) enhancing competitive advantages in order to be able to complete in global markets [5]. Although the needs on ERP for SMEs are generally almost identical with the ERP required in large companies, there are still disdavantages, for examples: expensive software customization [1] and diversities of SME's needs on ERP.

ERP business processes in SMEs frequently change due to the changes in business needs and technological advancement. The application of ERP system encounters a lot of problems attributable to so many variations as a result of changes in business. The changes can be reviewed in terms of two points, namely: changes in needs of ERP modules and changes of business processes in a company. To elucidate this problem, it calls for a development of an ERP system which is reliable to cope with diverse variations of business processes in each of its modules.

To analyze the varieties of business process models, it requires a business process modeling. Modeling in terms of enterprise information systems generally has two major dimensions of orientations, i.e.: Design Oriented or Analysis Oriented and Information System Oriented or Business Process Oriented [3]. This paper discusses about business process modeling by means of Petri Net. The modeling stresses on aspects of business process analysis in the sense that it can be applied for verifying and analyzing the performance of business process at present.

2. SERVICE ORIENTED ARCHITECTURE OF ERP AND PETRI NET MODELLING

2.1 Architecture Model of ERP for SMEs

The architecture of ERP for SMEs showed in Figure 1. This architecture is designed to be agile and flexible to encounter any changes in business and technology. Additionally, it is built for multi-tenants purpose. Thus, the architecture must consider two elements: 1) coordination and integration, 2) the flexibility to add or modify or configure the business process of ERP. For this purpose, the proposed architecture is composed by four main components: 1) Functional domains, 2) Web service, 3) Integration layer and 4) Web client application. The first component is functional domains which function as vertical applications. These domains consist of 9 ERP modules: 1) inventory, 2) manufacturing, 3) Human Resource Management, 4) Sales, 5) Career Planning, 6) Cash Bank, 7) General Ledger, 8) Account Receivable and 9) Account Payable. Each module is independent on other modules and built based on Service-Oriented Architecture (SOA) principle. The SOA principle enables different modules to be managed in separated layers which consist of presentation layer, workflow layer, service layer and data layer [3].

Presentation layer is a layer related to user interface between user and application. The next layer, workflow layer, consists of set activities that represent business process. For example, these workflows are sales to cash, purchase to pay, make to order and make to stock. In an enterprise the workflows often change. Accordingly, it needs a Business Process Model System. In order to create a flexible business process management, this paper will discuss about Business Process Modeling and Analysis by means of Petri Net. In ERP architecture, the services are treated as web services.

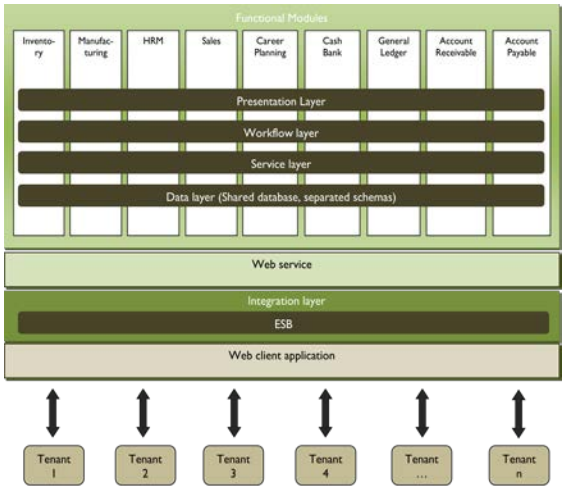

Figure 1: The Architecture Of ERP For Multi-Tenancy [3]

2.2 Web Services

In the implementation of software based on Service Oriented Architecture (SOA), a business process is treated as a service [6]. For instance: service consumer intends to communicate with service provider. The service consumer is sending service request to service provider, and the service provider sends a service response to the service consumer.

When the software of the service provider receives a service request, the request is processed by a service. The service is a clearly defined

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function and is not dependent on any condition of other services.

The software of the service consumer needs to know about how to call the service and what the expected response for the service provider. The implementation of SOA is called web services.

W3C defines web service as a software system designed to support interoperable interactions of machines through a network. The architecture of web services is showed in Figure 2. The web service has interface in machine processable formats (especially Web Service Description Language (WSDL)). Other systems interact with the web service by means of Simple Object AccessProtocol (SOAP) and usually addressed by using HTTP with Extensible Markup Languages (XML)serialization in its relation with web standards.

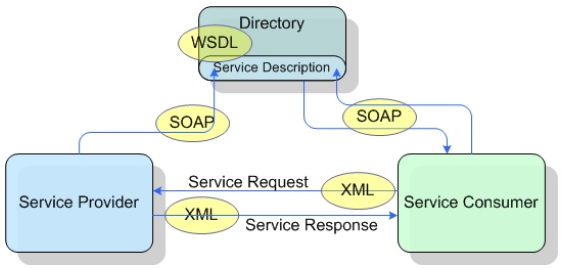

Figure 2: Web Services Architecture

2.3 Modeling Web Services with Petri Net

Petri Net is one of tools to model discrete event systems. It contains transition related events. In order that an event takes place, some conditions are to be first satisfied. Each of the information about the event and conditions is represented in a transition and a place.

The place can function as an input or output of a transition. The place as an input defines the conditions to be satisfied in order that a transition takes place. After a transition has taken place, the settings will change.

All definitions and symbolizations about Petri Net are performed following the definitions and symbolizations formulated by [7] [8].

Definition 1: (Service Net)
Service Net is a set of tuple $SN = (P, T, W, i, o, l)$, where:

- P is finite set of place.
- T is the finite set of transitions that represents the operations of services.
- $W \subseteq (P \times T) \cup (T \times P)$ is directed edge set.
- i is place input with :
- $\bullet i = \{x \in P \cup T | (x, i) \in W\} = \emptyset$
- o is place output with :
- $o \bullet = \{x \in P \cup T | (o, x) \in W\} = \emptyset$
- $l: T \rightarrow \mathcal{A} \cup \{\tau\}$ is a labeling function with $\mathcal{A}$as set of operation names and $\tau \notin \mathcal{A}$ is silent operation.

Definition 2: (Web Service) [8]
Web service is a couple of tuples
$S = (NameS, Desc, Loc, URL, CS, SN)$, where:

- $NameS$ is the name of service, having a single identifier.
- $Desc$ is a description of service provided.
- Loc is a server where a service is stored.
- URL is a name of address for calling a web service,
- CS is a set of service components. If $CS = NameS$ then S is a basic service. In addition, S is a composite service.
- $SN = (P, T, W, i, o)$ is a modeling of service net. Place i is a place as a marker of initial service S. S execution starts when a token is in place$i$and ends when a token reaches place o.

2.4 Composition of Web Services using Petri Net

The process of modeling Petri Net from composition of Web service is performed following the model formulated by Hamadi [8]. The model consists of the composition of service rules, empty web service, basic web service process, web service composition with operator sequence, web Service Composition with Alternative Operator, web Service Composition with Arbitrary Sequence Operator and web Service Composition with Iteration Operator.

The modeling of ERP business process variations in this research is performed based on the model and formulation of Sarno [9].

3. ERP BUSINESS PROSES VARIATION MODELING BY MEANS OF PETRI NET

In term of process dimension, the workflow diagram shows which tasks/processes will be executed and how the processes will take place. The workflow process modeling with Petri Net approach is designed in three ways, i.e. 1) the processes are modeled with transitions, 2) the conditions are modeled with places and 3) cases are modeled with tokens [10]. With reference to the available business process models, an equivalent Petri Net is modeled. The following is the conversion on modeling of some ERP business processes into

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Petri Net models based on four ERP business processes as the case studies.

3.1 Petri Net Model of Business Process for Purchase without Return

The business process for purchase without return in ERP for SMEs is presented in Figure 3, while the Petri Net model for this business process is presented in Figure 4.

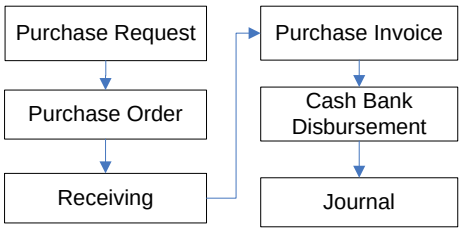

Figure 3:Business Process For Purchase Without Return

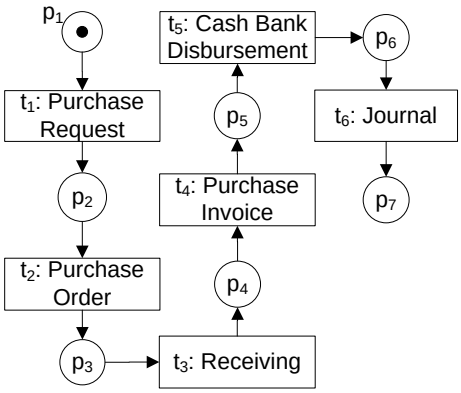

Figure 4: Petri Net Business Process Model For Purchase Without Return

The above model shows that the processes/ tasks for purchase request, purchase order, receiving, purchase invoice, cash bank disbursement and journal are modeled into transitions. While *place* p_1, p_2, ... p_7 show the conditions of status in the purchase process. Initially, the token is in p_1. This condition shows that the process of purchase request is ready to proceed. After the process of purchase request is completed, the token will move to p_2 and the process of purchase order is ready to proceed. The processes of purchase request and purchase order in this model are two processes composed sequentially.

3.2 Petri Net Model of Business Process for Purchase with Return

The business process for purchase with return is presented in Figure 5. Petri Net Modeling for the above business process is presented in Figure 6.

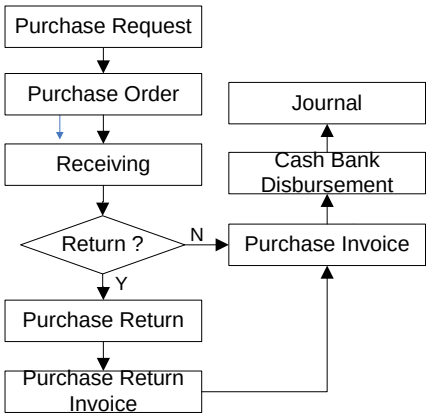

Figure 5:Business Process For Purchase With Return

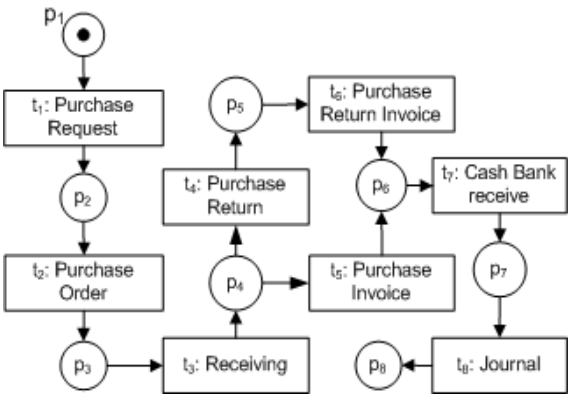

Figure 6: Petri Net Model Of Business Process For Purchase With Return

In this model there is an OR composition, i.e. in place p_4 through p_6. After the receiving process is completed, the token will be in p_4. In this condition, one of the processes of purchase return or purchase invoice can proceed.

3.3 Petri Net Model of Business Process for Sales without Return

It is identical with the previous process. The Petri Net Model of Business Process for Sales without Return is presented in Figure 7. This model contains iteration composition in processes of checking stock and making order.

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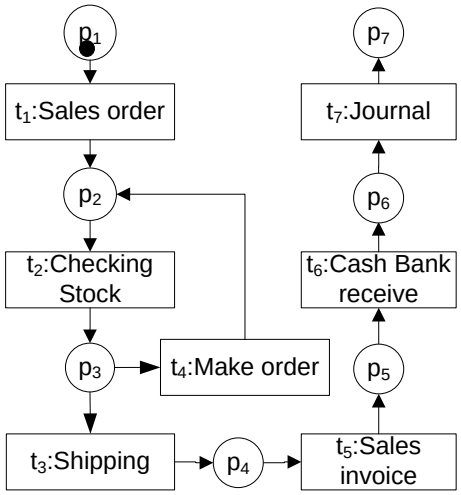

Figure 7: Petri Net Model Of Business Process For Sales Without Return

3.4 Petri Net Model of Business Process for Sales with Return

Petri Net Model of Business Process forSales with Return is presented in Figure 8. In this model there are iteration composition and OR composition. The iteration composition is in the process of checking stock and making order, while the OR composition is found in conditions of p_6 through p_8.

All of Petri net model above can only handle one query/service from one tenant. To handles many services requests from multi tenancy, it takes many value attributes in many tokens.Therefore it is necessaryto usecoloredPetri net.

4. BUSINESS PROCESS ANALYSIS USING PETRI NET

The designed Petri Net Model is a representation of behavior of an ERP business process. In order to identify the behavior of the system, it calls for a model analysis. One of the verification techniques is exploring the state space of the model and analyzing whether or not the required characters of each condition is satisfied. It can be done by means of reachability analysis approach. The reachability analysis can be applied through two approaches, i.e. matrix algebra approach and analysis with reachability graph [6].

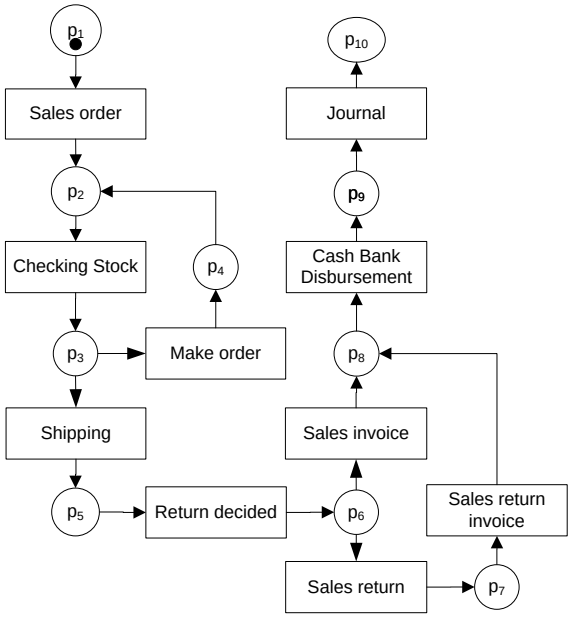

Figure 8: Petri Net Model Of Business Process For Sales With Return

4.1 Petri Net Representation in form of Matrix

To ease the analysis, the Petri Net model is represented in forms of backward incidence matrix and forward incidence matrix.

Definition 3 [8]:

The Backward incidence matrix $\boldsymbol{A_b}$ for Petri Net $(\boldsymbol{P}, \boldsymbol{T}, \boldsymbol{A}, \boldsymbol{w})$ is a matrix sized $\boldsymbol{n} \times \boldsymbol{m}$, with elements in i^{th} row, j^{th} column as $\boldsymbol{w}(\boldsymbol{pi}, \boldsymbol{tj})$. The forward incidence matrix $\boldsymbol{A_f}$ is a matrix sized $\boldsymbol{n} \times \boldsymbol{m}$, with elements in i^{th} row, j^{th} as$\boldsymbol{w}(\boldsymbol{tj}, \boldsymbol{pi})$. Matrix $\boldsymbol{A} = \boldsymbol{A_f} - \boldsymbol{A_b}$ is called incidence matrix.

The backward incidencematrix can be adopted for determining enabledtransition. Transition $t_j \in T$ in Petri Net is enabled if $x(p_i) \geq w(p_i, t_j)$, $\forall p_i \in I(t_j)$. It can be formulated as follows:

$$x \geq A_b e_j \tag{2}$$

with $x = x([p_1, \dots, p_n])$,

$A_b = w([p_1, \dots, p_n], t_j)$, and

e_j is j^{th} column vector of an identity matrix sized m. From (2), it can derive the following relations:

$$x'^{([p_1,\dots,p_n])} = x([p_1, \dots, p_n]) - w([p_1, \dots, p_n], t_j) + w(t_j, [p_1, \dots, p_n]) \tag{3}$$

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or $x' = x - A_b e_j + A_f e_j$

$x' = x + A e_j$

4.2 Incidence Business Process Matrix and Reachability Graph for Purchase without Return

Backward incidence, forward incidence, and incidence matrix of business process for Purchase without Return are as follows:

$$A_b = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 \end{matrix} \\ \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \end{matrix}$$

$$A_f = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 \end{matrix} \\ \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \end{matrix}, \text{ and}$$

$$A = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 \end{matrix} \\ \begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \end{matrix}$$

Petri Net Model has an initial state as $x_0 = (1\ 0\ 0\ 0\ 0\ 0\ 0)^T$. It shows that $x_0 \geq A_b e_j$, for j=1. Accordingly, it is only a process of purchase request(p_1)that can be fired or executed. Other processes in this condition (for $j = 2, \dots, 7$) cannot yet be executed. After the purchase request processis executed, thematrix conditionchanges intox_1 as follows:

$$x_1 = x_0 + A e_1$$

$$x_1 = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$= (0\ 1\ 0\ 0\ 0\ 0\ 0)^T$$

The condition $x_1 \geq A_b e_j$, it is satisfied for j=2, while for $j = 1,3,4,5,6,7$ it does not satisfy the condition. Consequently, purchase order is the only (p_2) processthat can be executed, and yield x_2. Other processes cannot be executed. The process will iterate until reaching a matrix of x_6 as follows:

$$x_6 = x_5 + A e_6$$

$$x_6 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} + \begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

$$= (0\ 0\ 0\ 0\ 0\ 0\ 1)^T$$

The condition $x_6 \geq A_b e_j$ does not satisfy for all values of j. It is a dead lock Petri Net condition, path to deadlock is $t_1 - t_2 - t_3 - t_4 - t_5 - t_6$. However, as all processes in the business process for purchase without return have been executed from $t_1$until t_6. This kind of Petrinet also called as safe or k-boundedwith $k = 1$. So design of business process for purchase without returnhas already satisfied the expected condition, $x_7 = (0,0,0,0,0,0,1)$.

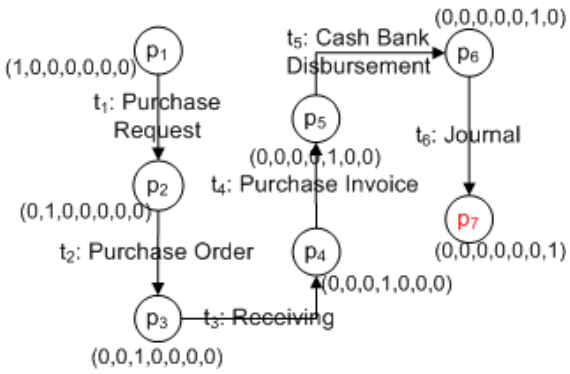

Figure 9. Reachability Graph For Purchase Without Return

Next, the Petri Net Model can derive a reachability graph for Purchase without Return as presented in Figure 9. The reachability analysis is conducted to analyize some characteristics, i.e.:

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boundedness, terminating, deadlock freedom, dead transition, liveness and home-marking. The results of the analysis show that the aforementioned characteristics are satified by the designed Petri Net model.

4.3 Incidence Business Process Matrix for Purchase With Return

Backward incidence, forward incidence, and incidence matrixes of business process for Purchase with Return are as follows:

$$A_b = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 & t_7 & t_8 \end{matrix} \\ \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4, \\ p_5 \\ p_6 \\ p_7 \\ p_8 \end{matrix}$$

$$A_f = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 & t_7 & t_8 \end{matrix} \\ \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4, \text{ and} \\ p_5 \\ p_6 \\ p_7 \\ p_8 \end{matrix}$$

$$A = \begin{array}{c} \begin{matrix} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 & t_7 & t_8 \end{matrix} \\ \begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array} \begin{matrix} p_1 \\ p_2 \\ p_3 \\ p_4, \\ p_5 \\ p_6 \\ p_7 \\ p_8 \end{matrix}$$

The initial state of condition of The Petri Net is $x_0 = (1, 0, 0, 0, 0, 0, 0)^T$. It shows that $x_0 \geq A_b e_j$, satisfied for j=1. Accordingly, p_1(purchase request) is only a process that can be fired or executed. In the mean time, other processes under this condition are not yet executable. After the process of a purchase request is executed, the matrix will change into x_1 as follows:

$$x_1 = x_0 + Ae_1$$

$$= \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$= (0\ 1\ 0\ 0\ 0\ 0\ 0\ 0)^T$$

The condition $x_1 \geq A_b e_j$, satisfied for j=2. It does not prevails so for $j = 1,3,4,5,6,7,8$. Therefore, only the process of purchase order($firing\ t_2$)that can be executed, while other processes cannot be executed. After the process of purchase orderis executed, the condition matrix changes into x_2 as follows:

$$x_2 = x_1 + Ae_2 = (0,0,1,0,0,0,0,0)^T$$

Condition $x_2 \geq A_b e_j$ satisfied just for j=3. Only process of purchase order (firing t_3)that can be executed, and x_3 obtained as follows.

$$x_3 = x_2 + Ae_3 = (0,0,0,1,0,0,0,0)^T$$

Condition $x_3 \geq A_b e_j$ satisfied just for $j = 4$ or $j = 5$. Two processes of *purchase return* (t_4)or *purchase invoice* (t_5)that can be executed. If t_4 is *firing*, the condition changes to x_4 as follows.

$$x_4 = x_3 + Ae_4 = (0,0,0,0,1,0,0,0)^T$$

From x_4, followed by firing t_6, t_7, and t_8 obtained x_7 below.

$$x_7 = (0,0,0,0,0,0,0,1)^T$$

Firing process $t_1 - t_2 - t_3 - t_4 - t_6 - t_7 - t_8$ is a sequence of execution processes of purcahse request, purchase order, receiving, purchase return, purchase return invoice, cash bank receive, dan journal.

From condition $x_3 \geq A_b e_j$, if firing process continue for $j = 5$, or firing purchase invoice(t_5), the condition changes to x_4 as follows.

$$x_4 = x_3 + Ae_5 = (0,0,0,0,0,1,0,0)^T$$

From this x_4, followed by firing t_7 and t_8 obtained x_7 below.

$$x_7 = (0,0,0,0,0,0,0,1)^T$$

Firing process $t_1 - t_2 - t_3 - t_5 - t_7 - t_8$ is a sequence of execution processes of purcahse request, purchase order, receiving, purchase invoice, cash bank receive, dan journal.

The reachability graph for purchase with returnis presented in Figure 10. The results of the analysis

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show that the Petri Net purchase with return is safe, bounded, and deadlock. The path of deadlock are $t_1 - t_2 - t_3 - t_4 - t_6 - t_7 - t_8$ and$t_1 - t_2 - t_3 - t_5 - t_7 - t_8$. Both path og deadlock begins from initial condition and ends at desired condition.

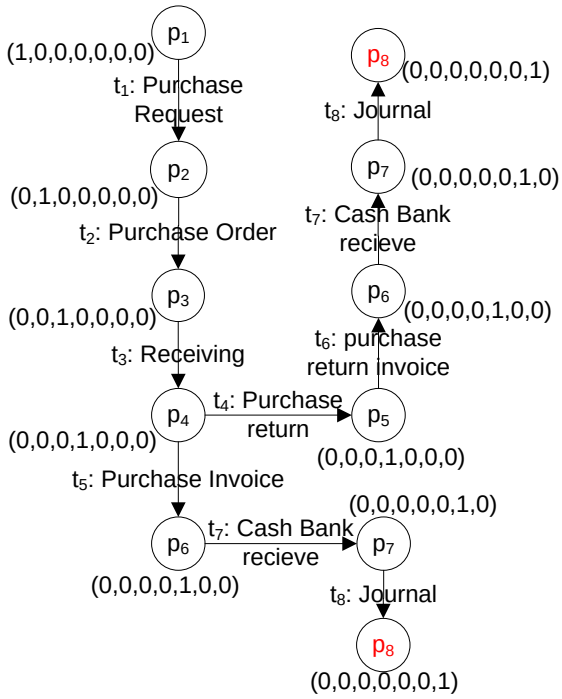

Figure 10. Reachability Graph For Sales With Return

5. CONCLUSION

This paper elaborates ERP business process modeling for SMEs with Petri Net approach. After Petri Net models are obtained, the matrix algebra and reachability graph analysis is adopted. The results of the analysis show that the designed Petri Net Model sacrifies the reaquirements for reachability which means that every business process will be executed in finite times without deadlock.

Next, the research will be focused on modeling with colored Petri Net for accomodating ERP system for multi-tenancy SMEs in form of web service composition.

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