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NETWORK RELIABILITY ANALYSIS FOR STRATEGIC PLANNING AND OPERATIONS MANAGEMENT

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ABSTRACT

A new application of network reliability is proposed to help analyze a business process performance in usual business activities. This research is to construct an easy, formal and mathematical tool to probe the health of daily-run business activities. A business activity consists of a series of value-added tasks, which are carried out by their related attenders, to meet business objectives. Traditional management behaviors include practices and skills to sustain the plan, sanction, management, and analysis of business activities. However, the assessment of activity performance remains a weak gap in analytic requirements. The approach proposed in this paper is one of the expected tools to fill the gaps in traditional management practices. The paper is to provide managers several new visions of modeling and analysis, which are not easily derived by traditional management practices. A distributor process with several scenarios to explain the approach are explored, and discussed.

1 . INTRODUCTION

The modeling and analysis of enterprise processes is a chief area in management activities [1]. Managers face more and more challenges to keep complicated as well as uncertain enterprise processes running well. An enterprise process (e.g., the order fulfillment operation, the commodity selling operation, etc.) consists of a series of value-added activities, which are carried out by their related roles, to attain the business objectives. The management tools include practices and skills such as the Zachman Framework [2], IDS-Scheer ARIS [3] and Computer Sciences Corporation's Catalyst [4] to sustain the plan, sanction, management, and analysis of business processes. Planner realized operations in terms of organization cohesion and work results, and employed various skills to control or make better the operations, containing Six Sigma [5], TQM [6], activity based costing [7]. and re-engineering [8]. However, the assessment of process performance remains a weak link in these tools. The approach presented in this paper is one of the expected tools to fill the gaps in traditional management practices. Many researches in the literature addressed the performance evaluation in business processes. Zo et al. [9] suggested an evolution skill for discovering balance in challenging goals for establishing the Pareto optimized outcomes for enterprises. Kueng [10] suggested structures in conceiving/evolving a Process Performance Measurement System (PPMS) built by experiences obtained for 2 years program with four firms. Beretta [11] suggested an accomplishment measurement tool for processes, and exert the force of consolidation, by mak- ing the processes clear to users. Vergidis et al. [12] sug gested the important skill for business process modeling in terms of their analysis and optimization abilities. Three basic sets were determined, and a range of delegate man- agement skills was categorized. Tan et al. [13] suggested techniques in active process accomplishment by means of models built under activity-based costing and activity-based management (ABC/ABM), which containing flows like cost. profit, product, resource, cash, and activity flows. Their suggested skills employ criteria such as time, cost, speed, and qualities. Huang et al. [14] introduced a mechanism in which the resource allocation optimization problem is modeled as Markov decision processes and solved using reinforcement learning, Xu [15] surveyed the state of the art in the area of enterprise systems including process management, work- flow management, enterprise application integration (EAI), service-oriented architecture (SOA), grid computing, and so on. Letia and Groza [16] developed the image logical framework, for closing the gap between the abstract norms and the concrete business processes. Barba et al. [17] pro- posed a recommendation system that assists users during process execution to optimize performance goals of the pro- cesses. Comuzzi et al. [18] proposed a framework to solve the problem of preserving the monitor-ability of processes in an

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evolving business network. However, it is not easy to determine the real current states of such processes using traditional management practices when the individual in the business process may undergo failure, incomplete failure, or be engaged by other operations. A novel approach in terms of probability to model and analyze the accomplishment of a business process is presented in this paper. The purpose of this study is not to build new management control mechanism, but to provide the manager several new visions of modeling and analysis prospects including process risk analysis, role performance inspections, critical role analysis, and so on, which are not easily derived by the traditional management practices.

Network analysis [19] recently becomes popular in many areas including software reliability [20], computing systems [21]-[23], information systems [24] and computer networks [25]. Su et al. [26] proposed an assessment proce- dure for Photovoltaic Power Integration by network reliabil- ity. Maldonado et al. [27] proposed a method to analysis the reliability of a cellular network. In enterprise management, [28] first exerted network analysis theory for evaluating the performance of an enterprise resource planning system. Their outcomes disclose more or less novel ways in management. In network study, a process comprises links and individ- uals to simulate a real-world "network." For an instance, to formulate processes is to use nodes for representing indi- viduals in the process, and their precedence connections among individuals are denoted as links: workflows move through those individuals. Generally, the individual states of processes are random in essence: they have restricted work ability and be able to malfunction. Then, a process with probabilistic individuals is referred to as a probabilistic-flow network [29]-[33]. The accomplishment of the process is called the probability of the process such that the maximal work flow is no less than the work demand d. The indication of accomplishment can be derived using minimal paths (MPs) approach [34]-[37] or minimal cuts (MCs) approach [35]. [38]. Here, paths are defined by "a set of nodes whose existence results in the connection of one source node and one sink node," and MPs are defined by "a path whose proper subset is not a path." Similarly, cuts are defined by "a set of nodes whose removal results in the disconnection of all source nodes and all sink nodes," and MCs are defined by "a cut whose proper subset is no longer a cut."

In this study, the individual's performance is integrated to calculate the overall performance of the entire process. Then, the process risk, which is the probability that the pro- cess failed to meet the business goal, can be measured. The lagged or critical roles can also be identified. These features make the proposed approach valuable and sensitive-enough in managing the complicated enterprise process under a ver- satile environment. To explain this approach, a distributor process with several scenarios is explored and demonstrated. The rest of the paper is organized as follows: Section two presents the assumptions. Section three presents the pro- cess model for an enterprise process. Section four presents the solution procedure of derivation of the accomplishment of a process. Section five presents the demonstration of a distributor process accomplishment with different scenarios. Section six gives a brief discussion on the findings of this research. Finally, section seven presents the discussion and concluding remarks.

II. NOTATIONS

We list the used notations and assumptions here.

A. NOTATIONS

s	the number of nodes
A	the set of links
B	$\{b_1, b_2, \ldots, b_s\}$ the node set
M	$(m_1, m_2, \ldots, m_s)$ where m_i is an integer for the maximum capability of b_i
G	(B, M, A) a process network
τ_i	a given distribution for b_i
z	the number of minimal paths
mp_j	the j^{th} minimal path
X	$(x_1, x_2, \ldots, x_s)$ the current state vector
Y	$(y_1, y_2, \ldots, _y s)$ the state vector
F	$(f_1, f_2, \ldots, f_z)$ the current flow vector
U_M	$\{F \mid F \text{is feasible under } M\}$
$V(X)$	$\max\{\sum_{j=1}^{z} f_j \mid F \in U_X\}$ the maximal flow function
d	the demand of work flow
t	the number of minimal vectors (MVs)
E_i	$\{X \mid X \geq X_i\}$ the set of states greater than the MV
R_d	$\Pr\{\bigcup_{i=1}^{t} E_i\}$ the performance function
$\mathbf{F}$	$\{F \mid F \in U_M \text{and satisfies demand}\}$
Ω	$\{X_F \mid F \in \mathbf{F}\}$ the set of candidates of MVs
Ω_{min}	$\{X \mid X is \text{a minimum vector in} \Omega\}$ the set of MVs for d
J	$\{j \mid X_j \notin \Omega_{min}\}$ the index set of non-MVs
I	a subset of the index set $\{1, 2, \ldots\}$

B. ASSUMPTIONS

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Assume G = (M, B, A) be a network describing the specific process, where B=\ b_{1}, b_{2} ,...,b s \ is denoted as the nodeset to model individuals in a process, the set of links in the process is used to denote the precedence connection among individuals, and a vector M = (my, m2,..., m,) is to denote the maximum capacity of individual by. Then, G satisfies the assumptions listed here.

1) The links in the network are faultless, so that they are kept out from the calculation of probability.

2) The ability of individual b, is denoted as an inte- ger RV (random variable) with values from the set (0, 1, 2,..., m), where t is the observed distribution of the current process in a fixed time period. The state 0 indicates absence or unavailability of the individual in the process.

3) The behavior of individuals (i.e., working, absent or partial functioning) are statistically independent from each other.

4) The flows in the process meet the flow-conservation law [19], and indicate that the work flow cannot be cre- ated anywhere in the process other than source nodes.

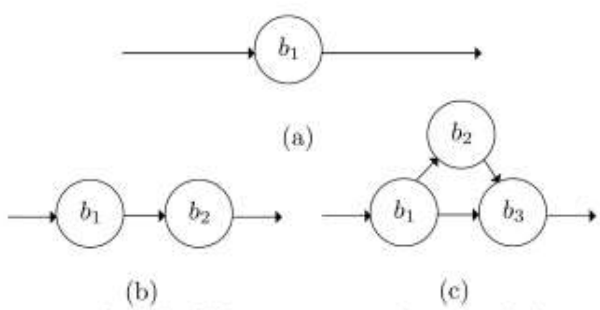

FIGURE 1. The relationship between process performance and role performance: (a) single role (b) two roles (c) three roles.

III. THE MODEL OF AN ENTERPRISE PROCESS

As in Figure 1 (a), if we only have one individual in this process, the process performance at a given state equals to the probability of the role performance in that state. If the process is as in Figure 1 (b) or (c), according to the probability principle, the process performance at a given state equals to the product of the probabilities of the roles' performance at their corresponding states. The next subsection gives the formal model.

A. THE MODEL

Let mp, mp2..... mp, be the MPs. An enterprise process can be modeled by means of two vectors: X (X1, X2, Xs) = and F (1.2...f). f is a work flow through a minimal path mp. x is a status for individual b. Then, F becomes feasible iff

$$\sum_{j=1}^{z}\{f_j|b_i \in mp_j\} \leq m_i, \text{ for } i = 1, 2, \ldots, s. \qquad (1)$$

Constraint (1) tells us that the whole work flow via b cannot be more than the largest ability for individual by. It is defined that the fitted F is denoted as Us (FF is feasible

subject to $M\}$. Likewise, F becomes feasible subject to X iff

$$\sum_{j=1}^{z}\{f_j|b_i \in mp_j\} \leq x_i, \text{ for } i = 1, 2, \ldots, s. \qquad (2)$$

For clearness, let $U_X = \{F|F \text{ is feasible subject to } X\}$. The maximal function of work flow subject to X is described as

$$V(X) \equiv \max\{\sum_{j=1}^{z} f_j|F \in U_X\}. \qquad (3)$$

B. ACCOMPLISHMENT DERIVATION

Specified d is a demand to stand for the required work flow,the accomplishment R_{d} is defined as the probability of thelargest flow not less than d. To obtain R_{d} , we have R_{d} beequal to Pr \ X|V(X)>= d\ . One finds beneficial for findingthe minimal vector (MV) from X| V(X) >= d . A vector X issaid to be minimal for d iff (i) V(X)> d and (ii) V(Y) < d ,for any other vector Y such that Y < X , in which Y < X iffy_{j} <= x_{j} , forall j , and Y < X if and only if Y < X where y_{j} <xy for some j. Say we have X_{1}, X_{2} ,...,X 1 , MVs for d. Lettilde E 1 =\ X| X >= X_{l} \ . Ra can be equivalently calculated via thewell-known inclusion-exclusion principle.

$$\begin{aligned} R_d &= \Pr\{\bigcup_{i=1}^{t} E_i\} \\ &= \sum_{k=1}^{t}(-1)^{k-1} \sum_{I \subset \{1,2,\ldots,t\}, |I|=k} \Pr\{\bigcap_{i \in I} E_i\}, \qquad (4) \end{aligned}$$

where $\Pr\{\bigcap_{i \in I} E_i\} = \prod_{i=1}^{s} \sum_{l=\max\{x_{ii}|\forall i \in I\}}^{m_i} \tau_j(l)$.

C SEARCHING FOR ALL MVS FOR d

The 1 ^ (st) step is to discover F from U_{M} so that the flow on Fis equal d. We describe it as follows:

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$$\sum_{j=1}^{z} f_j = d. \quad (5)$$

Given $\mathbf{F}$ equals $\{F|F \in U_M$ fulfill constraint (5)$\}$. If X is an MV for d, then there is an $F \in \mathbf{F}$ such that

$$x_i = \sum_{j=1}^{z} \{f_j | b_i \in mp_j\} \quad \text{for} \quad i = 1, 2, \ldots, s. \quad (6)$$

This is a necessary condition for an MV. To explain this, consider an X is an MV for d, an F exists and $F \in \mathbf{F}$. Assume $\sum_{j=1}^{z}\{f_j|b_i \in mp_j\} \leq x_i$ for all i. Think that a k exists so that x_k is greater than $\sum_{j=1}^{z}\{f_j|b_k \in mp_j\}$. Let $(x_1, x_2, \ldots, x_{k-1}, x_k - 1, x_{k+1}, \ldots, x_s) = Y = (y_1, y_2, \ldots, y_{k-1}, y_k, y_{k+1}, \ldots, y_s)$. Therefore, $X > Y$. Because $\sum_{j=1}^{z}\{f_j|b_i \in mp_j\} \leq y_i$ for all i,$F \in U_Y$ and $V(Y) \geq d$, this controverts the fact X be an MV for d. Therefore, x_i is equal to $\sum_{j=1}^{z}\{f_j|b_i \in mp_j\}, \forall i$.

Taken into account that F belongs to $\mathbf{F}$, $X_F = (x_1, x_2, \ldots, x_s)$ can be created through equation (6). Then, Ω equals $X_F|F \in \mathbf{F}$. Allow $\Omega_{min} = \{X|X \text{ is MV } \in \Omega\}$. We obtain Ω_{min} the set of MVs for d.

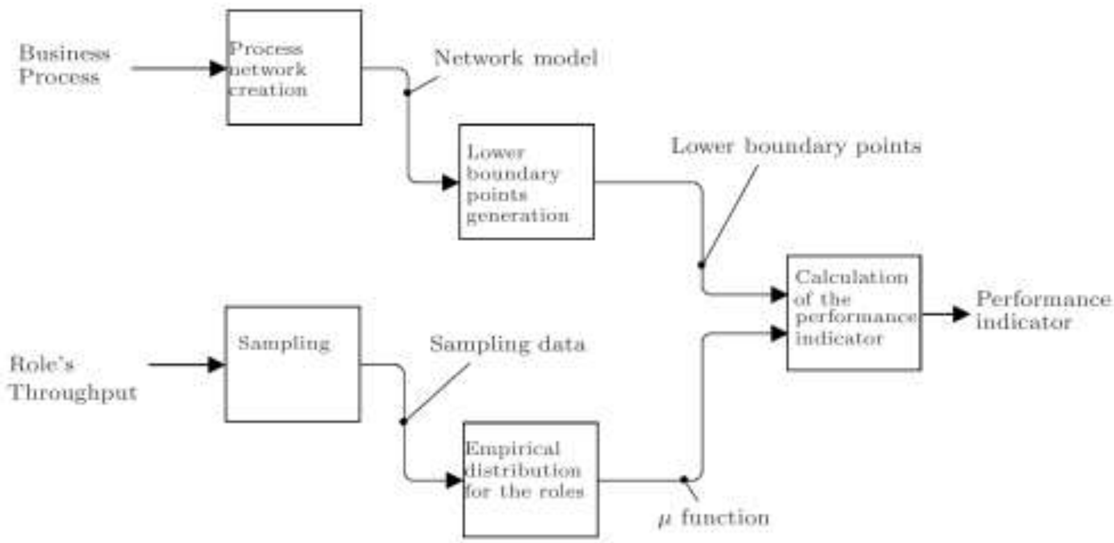

FIGURE 2. Application procedure.

IV. APPLICATION PROCEDURE

Figure 2 presents the application procedure for the proposedapproach. Firstly, the process model is generated. MVs forthe process are searched by the proposed algorithm. In themeantime, the empirical distributions for each individual inthe process are sampled in a time frame. Finally, the accom-plishment R_{d} is derived to indicate the whole process accom-plished in that time frame (See subsection III-B).

A. THE PROPOSED APPROACH

Creating all MPs for a network is NP-complete [39]. There-fore, we follow [40] - [43] , and suppose that all MPs have beenpre-computed and focus our topic on how to probe the healthof a current enterprise process. The question of efficientlysearching for all MPs in a network can be found in [37], [44],[45]. The following algorithm searches for all MVs in G for d

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Algorithm: Creating all MVs for d.

1) Find the feasible flow vector $F = (f_1, f_2, \ldots, f_z)$ satis fying both ability and demand constraints.
   a) for $0 \le f_j \le \min\{m_i | bi \in mp_j\}$ do
   b) in case f_j meets $\sum_{j=1}^{z} f_j = d$ and $\sum_{j=1}^{z}\{f_j | b_i \in mp_j\} \le m_i$
      we have $\mathbf{F} = \mathbf{F} \cup \{F\}$.
      end for.
2) Create Ω. // Create candidates.
   a) regards $F \in \mathbf{F}$ do
   b) x_i equals $\sum_{j=1}^{z}\{f_j | b_i \in mp_j\}$, for all i.
   c) U_X equals $U_X \cup \{X_F\}$.
      end for.
   d) for $X \in U_X$ do
   e) if $X \notin \Omega$, then $\Omega = \Omega \cup \{X\}$.
      end for. //Remove the redundant vectors.
3) Search for Ω_{min}. Specify J equals $\{j | X_j \notin \Omega_{min}\}$.
   a) for $i \notin J, 1 \le i \le |\Omega|$ do
   b) for $j \notin J, i \le j \le |\Omega|$ do
   c) if $X_j \le X_i$, then J equals $J \cup \{i\}$ and go to Step 3a
      else if $X_j > X_i$, then $J = J \cup \{j\}$.
      end for.
   d) $\Omega_{min} = \Omega_{min} \cup \{X_i\}$.
      endfor. //where $|\Omega|$ denotes the number of e ments in Ω.
   e) Return Ω_{min}.

According to MPs, F under equation (1) and (5) is list into set $\mathbf{F}$ in Step 1. The candidate vectors in Ω can obtained in Step 2 by $\mathbf{F}$ with equation (6). In Step 3, Ω_{min} is obtained by the pairwise comparisons.

Creating Ω_{min} requires $\binom{z+d-1}{z-1}$ computation. In summa the total computation time is $O(\binom{z+d-1}{z-1}^2)$ for the worst cas

V. AN ILLUSTRATIVE EXAMPLE FOR AN ENTERPRISEPROCESS

The company in this example is a Taiwan's detergent dis-tributor in Taiwan. The company offers various detergents toconsumers lived in the east of Taiwan. The business processis started from an inquiry entered to the teller, who decidesthe next step of the entry to one of the sales representatives,where the salesman creates orders for the entry. The createdorder should be completed by either the salesman himselfor a transporter. At last, the completed entry is finalizedby an accountant after received the money. The examplein Figure 3 gives the considered network of the case. Theorder constitutes the workflow in the network and satisfiesthe law of conservation of process. Each path of the workflowis an MP in the network. Everyone has processing power(random variables) and may be part of the function. Theprobabilistic behavior of each person can be observed andsolved by the distribution of experience over a period oftime. The process begins from by, and then, the work flowbe delivered through either b_{2} or b_{3} to b_{4} or bs, and finally.all work flow will be stopped at bs. The accomplishment ofthe process will be modeled by the proposed approach. Theexpected output is four items per three hours in this example.We have (4. 2. 2. 2, 4) as an expected output for each indi-vidual. For illustration purposes, we present three scenariosto explain the modeling and analysis applications for the proposed approach.

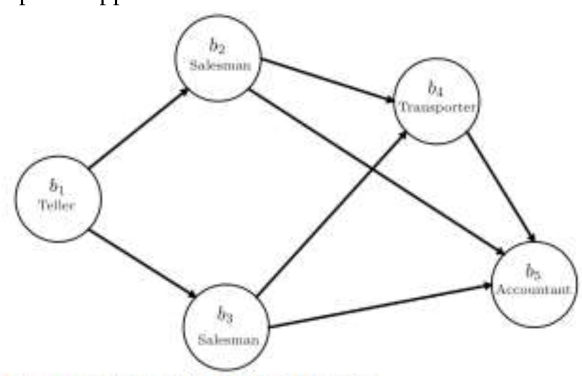

FIGURE 3. Network of the distributor process.

TABLE 1. Throughput of five individuals for one month.

The individuals	Number of items per three hours						
	0	1	2	3	4	5	6
b_1	1^a	1	3	5	30	3	1
b_2	1	20	16	6	1	0	0
b_3	1	10	20	10	2	1	0
b_4	7	14	16	5	2	0	0
b_5	0	2	4	35	2	1	0

[a] Number of incidences.

TABLE 2. Observed distributions for scenario one.

Dist. Fun.	Number of items per three hours						
	0	1	2	3	4	5	6
τ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
τ_2	0.0227	0.4545	0.3636	0.1364	0.0227	0.0000	0.0000
τ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
τ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
τ_5	0.0000	0.0455	0.0909	0.7955	0.0455	0.0227	0.0000

SCENARIO 1-IDENTIFYING THE LAGGED INDIVIDUALS

We can do the historical observation for the individuals in the process. So, we have the results of observation in Table 1 for all individuals after a period of time. The empirical distributions of such observation can be derived as in Table 2

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A total of four MPs are identified: $mp_1 = \{b_1, b_2, b_4,$ $mp_2 = \{b_1, b_2, b_5\}$, $mp_3 = \{b_1, b_3, b_4, b_5\}$, mp_4 $\{b_1, b_3, b_5\}$. All MVs are generated in the following step

Step 1)Searching for all feasible vector $F = (f_1, f_2, \ldots, f_4)$.

a) for f_j for $0 \le f_j \le 6, 1 \le j \le 4$ do

b) if f_j satisfies the following equations $f_1 + f_2 + f$ $f_4 \le 6, f_1 + f_2 \le 6, f_3 + f_4 \le 6, f_1 + f_3 \le$ $f_1 + f_2 + f_3 + f_4 = 4$, then $\mathbf{F} = \mathbf{F} \cup \{F\}$.

end for.

The result is $\mathbf{F} = \{(0, 0, 0, 4), (0, 0, 1, 3)$ $(0, 0, 2, 2), \ldots, (4, 0, 0, 0)\}$.

Step 2)Create $\Omega = \{X_F | F \in \mathbf{F}\}$.

a) for F is $(0, 0, 0, 4)$ in $\mathbf{F}$ do

b) $x_2 = f_1 + f_2, x_4 = f_1 + f_3, x_1 = f_1 + f_2 + f_3 +$ $x_3 = f_3 + f_4, x_5 = f_1 + f_2 + f_3 + f_4$.

c) $U_X = U_X \cup \{X_F = (4, 0, 4, 0, 4)\}$.

⋮

d) for $X = (4, 0, 4, 0, 4)$ in U_X do

e) in case X not belongs to Ω, then set Ω to equal $\{X = (4, 0, 4, 0, 4)\}$.

⋮

TABLE 3. Empirical distributions for scenario one after retraining b_5.

Distr. Func.	Number of items per three hours						
	0	1	2	3	4	5	6
τ_1	0.0227	0.0227	0.0682	0.1136	[illegible]	0.0682	0.0227
τ_2	0.0227	[illegible]	0.3636	0.1364	0.0227	0.0000	0.0000
τ_3	0.0227	0.2273	[illegible]	0.2273	0.0455	0.0227	0.0000
τ_4	0.1591	0.3182	[illegible]	0.1136	0.0455	0.0000	0.0000
τ_5	0.0000	0.0227	0.0682	0.0909	[illegible]	0.0455	0.0227

TABLE 4. New distributions for scenario two after retraining b_2.

Distr. Func.	Number of items per three hours						
	0	1	2	3	4	5	6
τ_1	0.0227	0.0227	0.0682	0.1136	[illegible]	0.0682	0.0227
τ_2	0.0227	0.0455	[illegible]	0.3636	0.0455	0.0227	0.0000
τ_3	0.0227	0.2273	[illegible]	0.2273	0.0455	0.0227	0.0000
τ_4	0.1591	0.3182	[illegible]	0.1136	0.0455	0.0000	0.0000
τ_5	0.0000	0.0455	[illegible]	[illegible]	0.0455	0.0227	0.0000

At the step tail: $\Omega = \{X_1 = (4, 0, 4, 0, 4), X_2 = (4, 0, 4, 1, 4), \ldots, X_{25} = (4, 4, 0, 4, 4)\}$.

Step 3)Searching for $\Omega_{min} = \{X | X \text{ is least in } \Omega\}$.

a) i equals 1,

b) j equals 2,

c) Since $X_2 = (4, 0, 4, 1, 4) \le X_1 = (4, 0, 4, 0, 4)$ is false and $X_2 = (4, 0, 4, 1, 4) > X_1 = (4, 0, 4, 0, 4)$ becomes true, then J equals $J \cup \{2\}$. // expanding J.

⋮

We have $\Omega_{min} = \{X_1 = (4, 0, 4, 0, 4), X_6 = (4, 1, 3, 0, 4), X_{10} = (4, 2, 2, 0, 4), X_{13} = (4, 3, 1, 0, 4), X_{15} = (4, 4, 0, 0, 4)\}$.

Eventually, the accomplishment R_4 can be derived by means of five MVs. Given $E_1 = \{X | X \ge X_1\}$, $E_2 = \{X | X \ge X_6\}$, $E_3 = \{X | X \ge X_{10}\}$, $E_4 = \{X | X \ge X_{13}\}$ and $E_5 = \{X | X \ge X_{15}\}$. By Equation (4), we get $R_4 = \Pr(\cup_{i=1}^{5} E_i)$. Employing the inclusion-exclusion principle to calculate, we have

$$R_4 = \Pr(\cup_{i=1}^{5} E_i) = \sum_{h=1}^{5} (-1)^{h-1} \sum_{I \subset \{1,2,\ldots,5\}, |I|=h} \Pr(\cap_{i \in I} E_i) = 0.0296808$$

In this scenario, R_{4} is 0.0296808, which indicates a verylow probability (or possible performance) to achieve thedemand of four. Table 2 shows that b_{2} and b_{5} are laggedby comparing with the expected output vector. Let b_{5} beretrained to improve their skill. We obtain the new empiricaldistributions as shown in Table 3. b_{5} is now at the expectedoutput, i.e., 4 tasks per three hours. The entire process per-formance is recalculated and increased to 0.357043. We sawthat the process performance has been effectively improved.

B. SCENARIO 2-ANALYZING CRITICAL ROLES

If b_{2} is retrained instead of b_{5} Table 4 presents the newdistributions. The accomplishment of the process is recalculated as 0.0427591, which indicates that it is not effectivelyimproved. However, b_{2} is over-performance by comparingwith his standard throughput, i.e., two deliveries perthreehours. This fact reflects that b_{5} is more critical than b_{2} . Thesame analysis can be applied to the other roles in the process.Table 5 gives the results. In there, both b_{1} and b_{s} are critical,and the others are not.

TABLE 5. Critical individual analysis for scenario two.

Roles	b_1	b_2	b_3	b_4	b_5
Critical ?	Yes	No	No	No	Yes

TABLE 6. Empirical distributions for scenario three.

Distr. Func.	Number of items per three hours						
	0	1	2	3	4	5	6
τ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
τ_2	0.0227	0.0455	0.5000	0.3636	0.0455	0.0227	0.0000
τ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
τ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
τ_5	0.0000	0.0227	0.0682	0.0909	0.7500	0.0455	0.0227

TABLE 7. Empirical distributions for scenario three after enlarging both salesman's abilities.

Distr. Func.	Number of items per three hours						
	0	1	2	3	4	5	6
τ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
τ_2	0.0000	0.0000	0.0227	0.0455	0.6818	0.2045	0.0455
τ_3	0.0000	0.0000	0.0227	0.0455	0.7045	0.1818	0.0455
τ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
τ_5	0.0000	0.0227	0.0682	0.0909	0.7500	0.0455	0.0227

C. SCENARIO 3-ANALYZING PROCESS RISKS

This process performance can be used to measure the risk (or possible failure) of an enterprise process, which is the probability that the process failed to meet the business goal. It equals to 1 minus Rd. For example, the empirical distributions for all individuals in fare conditions are pre- sented in Table 6. The process performance is calculated and equals to 0.514339. The risk of the enterprise process is 1-0.514339=0.485661, which is a very high risk. That is, the business process may have 48.6% probability under per- formance in that month. The following improvement strategy can be made: Both salesman's standard abilities are enlarged to four deliveries per three hours. Then, after sampling. the new empirical distributions for all roles are as depicted in Table 7.

The process performance is now 0.632223 and the risk of the process has dropped to 0.367777. By analyzing process risks, the manager of the business process may take actions to reduce the risks to do the preventive management activities.

VI. DISCUSSIONS

Based on the above illustrative examples, we can realize the important indication and potential power of the new manage ment tools brought to us.

A. THE PRECISION MANAGEMENT BECOME POSSIBLE

Since the network reliability can reflect the slight variation of flow in the process, any changes in the system activities can be monitored. Thus, this feature gives the process manager the ability of precision management of process.

B. THE OBJECTIVE PERFORMANCE EVALUATION FOR HETEROGENEOUS JOB CONTENTS IN A PROCESS

In traditional performance evaluation, to do a fair assess- ment of heterogeneous job contents is very difficult. How- ever, the theory of network reliability can give the possi- bility of fair assessment for heterogeneous job contents by two point of views: the process importance, and the process contribution.

C THE OBJECTIVE BONUS DISTRIBUTION FOR HETEROGENEOUS JOB CONTENTS IN A PROCESS

In traditional bonus distribution, to do a fair distribution is very difficult. However, the theory of network reliability can give the possibility of fair distribution for heterogeneous job contents just by performance reports.

VII. CONCLUSION

New applications of network reliability to model and analyze the accomplishment of a process is proposed by integrating each individual's accomplishment. Several interesting analy- ses are performed by means of this approach. For instances, one wants to know how to measure the process risk, the prob- ability that the process failed to meet the business goal, and what is the suggestion to reduce the risk. This study demon- strates the identification of lagged individuals in the process, and discovers the critical individual in the process. All these features are not easily derived by the traditional management tools. These features make the proposed method valuable to connect the weak link in the traditional management tools. The proposed approach is not to replace the traditional man- agement tools, but to enhance the capability of the traditional tools to include the performance evaluation mechanism.

The proposed approach presents new tools to assist man- agement in enterprise activities. A timely and precisely adaptation of process activities turns into possible than ever. Future studies are urged on the application of multi- commodity, cyclic process, or integrating the traditional management tools such as Petri-net, Markov chain to solve more complicated applications, because they are very common in real-world applications.

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