A Probe for Organizational Dynamics

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Abstract. This paper proposes a novel approach to explore the influence of different working groups in a connected organization. A connected organization is a corporation with working groups/departments connected with flow of business processes. A business process often comprises a series of value-added activities, which are performed by their relevant roles to achieve the common business goal. Traditional ways of exploration are mostly based on questionnaire surveys. However, such explorations neglect the nature influence of organization structure, which may be the important factors in organizational dynamics. This paper explains how to explore the influence of different working groups in a connected organization by the engineering perspectives. An example is presented for the explanation of the proposed approach.

Keywords: organizational dynamics, business flow, performance, network reliability, minimal path.

1. INTRODUCTION

Department influence has received much attention in the literature and popular press. For example, Verhoef and Leeflang (2009) explained the influence of the marketing department within firm. Their results showed that the accountability and innovativeness of the marketing department represent two major drivers of its influence. Galang and Ferris (1997) explored the influence of human resource (HR) department via power, politics, and social constructionism. Wright *et al*. (2003) explored the impact of HR practices on the performance of business units, and revealed that both organizational commitment and HR practices are significantly related to operational measures of performance, as well as operating expenses and pre-tax profits. Brass (1985) investigated the interaction patterns and influence of men and women in an organization, and got the results that individuals' positions in workflow and interaction networks relate strongly to measures of influence. Brass (1984) also examined the relationships between structural positions and influence at the individual level of analysis, and got the results provide support for a structural perspective on intraorganizational influence. Verhoef *et al*. (2011) explored that the marketing department influence contributes to business performance indirectly through its positive relationship with market orientation and directly through its positive direct relationship with business performance. Till now, most of the above approaches are based on questionnaire surveys. However, such explorations neglect the nature influence of organization structure (Mintzberg, 1979), which may be the important factors in organizational dynamics.

This paper explains how to explore the influence of different working groups/departments in a connected organization by the engineering perspectives, and proposes a novel approach in terms of network analysis to explore the influence of different working groups in a connected organization. A connected organization is a corporation with working groups/departments connected with flow of business processes. A business process often comprises a series of value-added activities, which are performed by their relevant roles to achieve the common business goal.

Network analysis (Ford and Fulkerson, 1962) has recently received considerable interest in many areas. Examples of these areas are the software reliability (Dai et al., 2005), the computing systems (Dai and Levitin, 2006; Cruz and Liu, 2012; Lin and Yeng, 2013), the information systems (Chen and Lin, 2009) and the computer networks (Lin and Yeh, 2011). For the area of business process modelling, Chen and Lin (2008) have first applied network analysis theory in the performance evaluation of an enterprise resource planning system. Their results reveal some new directions in business process modelling and analysis. In network analysis, the network consists of edges and nodes to model a real life "network". For example, modelling a business process is to express the roles in the process as nodes, and the process precedence relationships between roles/groups as links. Then, work flows are moving between these roles/groups. Obviously, the influence between different groups/departments is strongly correlated in an organization due to the work flow connection, and varies from the shapes of the organization structure. In practice, the states of the roles are stochastic in nature. They have limited work capacity and may fail. Such a network with stochastic nodes is named stochastic-flow network (Wollmer, 1968; Chan et al., 1997; Hsieh and Lin, 2003; Chen and Lin, 2010; Lin and Yeh, 2012). The network influence (or reliability) is the probability that the maximal work flow of the network is no less than the demand *d*. Such influence can be calculated by means of minimal paths (MPs) (Colbourn, 1987; Shen, 1995; Yeh, 2002; Chen, 2011) or minimal cuts (MCs) (Shen, 1995; Yeh, 2006). A path is a set of nodes whose existence results in the connection of one source node and one sink node. A MP is a path whose proper subset is not a path. A cut is a set of nodes whose removal results in the disconnection of all source nodes and all sink nodes. A MC is a cut whose proper subset is no longer a cut.

This paper discusses the group influence in an organization by the engineering perspectives without considering the social perspectives. This may be helpful in the design of an organization structure. The remainder of the work is described as follows: The types of organization structure are discussed in Section 2. Section 3 describes the process network model of an organization. A solution procedure to evaluate the influence is proposed subsequently in Section 4. Then, the calculation and analysis of an example are illustrated in Section 5. Section 6 draws the conclusion and discussions of the paper.

2. TYPES OF ORGANIZATIONAL STRUCTURE

Figure 1 gives the typical structures of an organization, where (a) is the most commonly hierarchical structure, (b) is a popularly serial-cascaded structure, and (c) is a network-shaped structure.

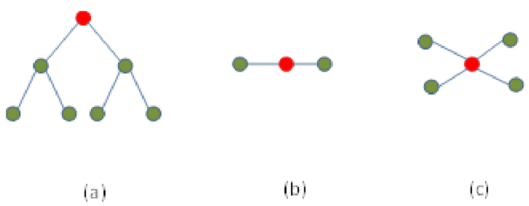

Figure 1: The typical organizational structures.

A hierarchical organization is commonly existed in the government bureaucracy or some of the private companies. Then, the administrative role (in red) is the bottle-neck in such business flow. A serial-cascaded structure is popular in small business companies or some of the service providers. Then, anyone in the business flow may be the bottle-neck when failed in its function. A network-shaped structure is often existed in a company whose business flow is complicated. Then, the bottle-neck is not easily detected and mostly drifting time by time. In such cases, the traditional qualitative methods are difficult to detect the right department of bottle-neck. However, the proposed approach can be used to probe such influence of a department in a business flow time by time in terms of network analysis.

3. PROCESS NETWORK MODEL

To explain the proposed approach, we describe the organization in terms of network model. For example, modelling a business process is to express the roles in the process as nodes, and the process precedence relationships between roles/groups as links. Then, work flows are moving between these roles/groups.

3.1 Assumptions

Let $G = (B, A, M)$ be a process network where $B = \{b_i \mid 1 \le i \le s\}$ is the set of nodes representing the roles in the process, A is the set of links representing the process precedence relationships between roles, and $M = (m_1, m_2, ..., m_s)$ is a vector with m_i (an integer) being the maximum work capacity of b_i. Such a G is assumed to satisfy the following assumptions.

(1) The capacity of b_i is an integer-valued random variable which takes values from the set $\{0, 1, 2, ..., m_i\}$ according to an empirical distribution function μ_i, which can be obtained by a statistical observation in a time frame. Note that the capacity 0 often means a failure or unavailability of this node.

(2) The links are perfect. That is, they are excluded from the influence calculation.

(3) Flow in G satisfies the flow-conservation law (Ford and Fulkerson, 1962). This assumption means that the work flow started from the source node should be passed to the succeeding nodes and ends at the sink node.

(4) The states of roles (i.e., working, failure or partial failure) are independent from each other.

3.2 The Model

Let $mp_1, mp_2, ..., mp_z$ be the MPs. Thus, the process network model can be described in terms of two vectors: the state vector $X = (x_1, x_2, ..., x_s)$ and the flow vector $F = (f_1, f_2, ..., f_z)$, where x_i denotes the current state of b_i and f_j denotes the current flow on mp_j. Then, such a vector F is feasible iff

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

Constraint (1) describes that the total work flow through b_i cannot exceed the maximal capacity of b_i. We denote such set of F as $U_M = \{F|F$ is feasible under $M\}$. Similarly, F is feasible under $X = (x_1, x_2, ..., x_s)$ iff

$$\sum_{j=1}^{z}\{f_j \mid b_i \in mp_j\} \le x_i \quad \text{, for } i = 1, 2, \ldots, s. \tag{2}$$

For clarity, let $U_X = \{F|F$ is feasible under $X\}$. The maximal work flow under X is defined as

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

3.3 Influence Evaluation

Given a demand d to represent the standard level of work flow, the group/department influence R_d is defined as the probability that the maximal flow is not less than d, i.e., $R_d \equiv \Pr\{X|V(X) \ge d\}$. This means that if the throughputs of a whole group/department are in high probability to meet its business goal, the group/department is considered to have high influence upon the business goal in the company. To calculate R_d, it is advantageously to find the minimal capacity vector in $\{X|V(X) \ge d\}$. A minimal capacity vector X is said to be a lower boundary point (LBP) for d iff (i) $V(X) \ge d$ and (ii) $V(Y) < d$, for any other vector Y such that $Y < X$, in which $Y \le X$ iff $y_j \le x_j$, for $j = 1, 2, ..., s$ and $Y < X$ iff $Y \le X$ and $y_j < x_j$, for at least one j. Suppose there are totally t LBPs for d: $X_1, X_2, ..., X_t$, and $E_i = \{X|X \ge X_i\}$, the probability R_d can be equivalently calculated via the well-known inclusion-exclusion principle.

$$\begin{aligned} R_d &= \Pr\{\bigcup_{i=1}^{t} E_i\} \\ &= \sum_{k=1}^{t}(-1)^{k-1} \sum_{I \subset \{1,2,\ldots,t\}, |I|=k} \Pr\{\bigcap_{i \in I} E_i\} \end{aligned} \quad , \tag{3}$$

where $\Pr\{\bigcap_{i \in I} E_i\} = \prod_{j=1}^{s} \sum_{l=\max\{x_{ij} | \forall i \in I\}}^{m_j} \mu_j(l)$.

4. SOLUTION PROCEDURE

Figure 2 denotes the solution procedure for the evaluation. At first, the network model for the process is created. The LBPs for the network are generated by the algorithm stated in Subsection 4.1. Meanwhile, the empirical distributions for every role in the process are sampled in a time frame. Then, the influence R_d is calculated to indicate the overall process influence at that time frame.

4.1 Algorithm

Searching for all MPs in a network is NP-complete (Ball, 1986). Therefore, we take the same way as the work of Xue (1985) and Lin (2007a, b, c), and suppose that all MPs have been pre-computed and focus our topic on how to probe the states of a current business process. A recent achievement about how to efficiently search for all MPs in a general flow network can be found in the works (Chen *et al*., 2010; Chen, 2011; Chen and Lin, 2012). The following algorithm searches for all LBPs in G for d:

Algorithm 1: Search for all lower boundary points in G for d.

Step 1. Find the feasible flow vector $F = (f_1, f_2, ..., f_z)$ satisfying both capacity and demand constraints.

i. **enumerate** f_j for $1 \le j \le z$, $0 \le f_j \le \min\{m_i \mid b_i \in mp_j\}$ do

ii. **if** f_j satisfies the following constraints

$\sum_{j=1}^{z}\{f_j \mid b_i \in mp_j\} \le m_i$ and $\sum_{j=1}^{z} f_j = d$, for $1 \le i \le s$, **then** $\mathbf{F} = \mathbf{F} \cup \{F\}$.

end enumerate.

Step 2. Generate the set $\Omega = \{X_F \mid F \in \mathbf{F}\}$.

i. **for** F in $\mathbf{F}$ **do**

ii. $x_i = \sum_{j=1}^{z}\{f_j \mid b_i \in mp_j\}$, for $i = 1, 2, ..., s$.

iii. $U_X = U_X \cup \{X_F\}$. // where $X_F = (x_1, x_2, ..., x_s)$ may have duplicates.

end for.

iv. **for** X in U_X **do** //Remove the redundant vectors.

v. **if** $X \notin \Omega$, **then** $\Omega = \Omega \cup \{X\}$.

end for.

Step 3. Find the set $\Omega_{min} = \{X|X$ is a minimum vector in $\Omega\}$. Let $J = \{j|X_j \notin \Omega_{min}\}$.

i. **for** $i \notin J$ and $1 \le i \le |\Omega|$ **do** //where $|\Omega|$ denotes the number of elements in Ω.

ii. **for** $j \notin J$ and $i < j \le |\Omega|$ **do**

iii. **if** $X_j \le X_i$, **then** $J = J \cup \{i\}$ and go to Step 3i.

else if $X_j > X_i$, **then** $J = J \cup \{j\}$.

end for.

iv. $\Omega_{min} = \Omega_{min} \cup \{X_i\}$.

end for.

Step 1 indicates that according to the MPs, the feasible F under Constraint (1) and (4) is enumerated into set $\mathbf{F}$. Then, the candidate vector set Ω for LBPs can be derived from $\mathbf{F}$ under Equation (5) at Step 2. Finally, the set, Ω_{min}, of LBPs is filtered out by the pairwise comparisons at Step 3.

The pairwise comparisons were required for generating Ω_{min} from $\binom{z+d-1}{z-1}$ solutions. This took $O(\binom{z+d-1}{z-1}^2)$ time to generate Ω_{min}. In short, the total computation time required was $O(\binom{z+d-1}{z-1}^2)$ in the worst case.

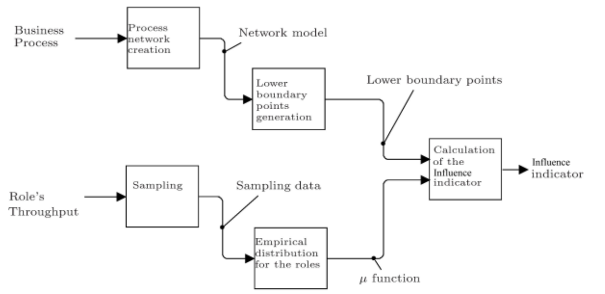

Figure 2: The solution procedure.

5. AN EXAMPLE

The company in this example is a distributor of a well-known detergent provider in Taiwan. The company sells many kinds of detergents to the east-Taiwan market. This process is initiated with a product inquiry from a customer to the teller in this company, who sends the confirmed inquiry to one of the sales representatives to create orders for the inquiry. Then, the order is fulfilled by either the representatives themselves or another transporter. Finally, the order is closed by the accountant. Figure 3 shows the corresponding process network. The orders constitute the work flow in the process network, and satisfy the flow-conservation law. Each path of work flow is an MP in the process network. Each node has capacity, which acts as a random variable, and may fail. The stochastic behavior of each node can be observed by the empirical distribution for a period of time. When the process starts, b_1 will initiate the work flow and sends it via either b_2 or b_3 to b_4 or b_5, and b_4 sends it to b_5. Finally, b_5 ends the process. Therefore, the influence of such process network can be analyzed by the network reliability theory. The standard throughput level is 4 deliveries per 3 hours for the entire process, and (4, 2, 2, 2, 4) is a standard throughput vector for each role respectively. Three scenarios with the corresponding action strategies for influence are explored in the following subsections.

5.1 Scenario 1 – Identifying Bottle-Neck Roles

Table 1 gives the results of sampling of the throughputs for all 5 roles during a month. The corresponding empirical distributions are shown in Table 2. There are 4 MPs found: $mp_1 = \{b_1, b_2, b_4, b_5\}$, $mp_2 = \{b_1, b_2, b_5\}$, $mp_3 = \{b_1, b_3, b_4, b_5\}$, $mp_4 = \{b_1, b_3, b_5\}$. All LBPs for 4 are generated step-by-step as follows:

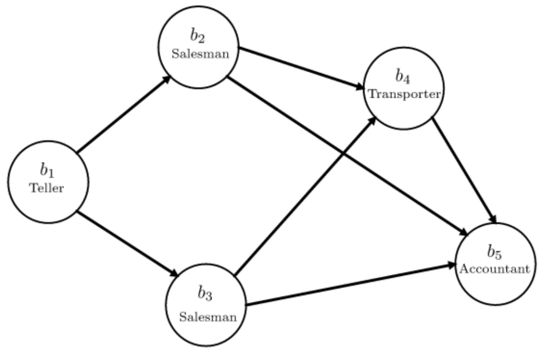

Figure 3: The network of the distributor process in the example company.

Table 1: The throughputs of 5 roles sampled during a month.

	The number of deliveries per 3 hours						
The roles	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] The number of occurrence.

Table 2: The empirical distributions for the scenario one.

	The number of deliveries per 3 hours						
Distr. Func.	0	1	2	3	4	5	6
μ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
μ_2	0.0227	0.4545	0.3636	0.1364	0.0227	0.0000	0.0000
μ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
μ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
μ_5	0.0000	0.0455	0.0909	0.7955	0.0455	0.0227	0.0000

Step 1. Find the feasible vector $F = (f_1, f_2, \cdots, f_4)$ satisfying both capacity and demand constraints.

i. **enumerate** f_j for $0 \le f_j \le 6$, $1 \le j \le 4$ **do**

ii. **if** f_j satisfies the following equations

$f_1 + f_2 + f_3 + f_4 \le 6$, $f_1 + f_2 \le 6$, $f_3 + f_4 \le 6$, $f_1 + f_3 \le 6$, $f_1 + f_2 + f_3 + f_4 = 4$, then $\mathbf{F} = \mathbf{F} \cup \{F\}$.

end enumerate.

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

Step 2. Generate the set $\Omega = \{X_F \mid F \in \mathbf{F}\}$.

i. **for** $F = (0, 0, 0, 4)$ in $\mathbf{F}$ **do**

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

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

...

iv. **for** $X = (4, 0, 4, 0, 4)$ in U_X **do**

v. **if** $X \notin \Omega$, **then** $\Omega = \Omega \cup \{X = (4, 0, 4, 0, 4)\}$.

...

At the end of the loop: $\Omega = \{X_1 = (4, 0, 4, 0, 4), X_2 = (4, 0, 4, 1, 4), \cdots, X_{25} = (4, 4, 0, 4,$

4)}.

Step 3. Find the set Ω_{min} = {X|X is a minimum vector in Ω}.

i. $i = 1$,

ii. $j = 2$,

iii. Because $X_2 = (4, 0, 4, 1, 4) \leq X_1 = (4, 0, 4, 0, 4)$ is false and $X_2 = (4, 0, 4, 1, 4) > X_1 = (4, 0, 4, 0, 4)$ is true, **then** $J = J \cup \{2\}$.

...

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

Finally, the probability R_4 can be calculated in terms of 5 LBPs. Let $E_1 = \{X|X \geq X_1\}$, $E_2 = \{X|X \geq X_6\}$, $E_3 = \{X|X \geq X_{10}\}$, $E_4 = \{X|X \geq X_{13}\}$ and $E_5 = \{X|X \geq X_{15}\}$. By Equation (3), we get $R_4 = \Pr\{\bigcup_{i=1}^{5} E_i\}$. Then, by applying the inclusion-exclusion rule,

$$R_4 = \Pr\{\bigcup_{i=1}^{5} E_i\}$$

$$= \sum_{k=1}^{5} (-1)^{k-1} \sum_{I \subset \{1,2,\ldots,5\}, |I|=k} \Pr\{\bigcap_{i \in I} E_i\}$$

$$= 0.0296808$$

If b_2 is retrained instead of b_5, the new empirical distributions are in Table 3. The process influence is recalculated as 0.0427591, which is not increased much. However, b_2 is over-influenced by comparing with his standard throughput, 2 deliveries per three hours. This fact reflects that b_5 is more bottle-necked than b_2. The same analysis can be applied to the other roles in the process. The results are listed in Table 4. In this table, b_1 and b_5 are bottle-neck, and the others are not.

Table 3: The empirical distributions for the scenario one after retraining b_2 instead.

Distr. Func.	The number of deliveries per 3 hours 0	1	2	3	4	5	6
μ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
μ_2	0.0227	0.0455	0.5000	0.3636	0.0455	0.0227	0.0000
μ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
μ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
μ_5	0.0000	0.0455	0.0909	0.7955	0.0455	0.0227	0.0000

Table 4. The bottle-neck role analysis for the scenario one.

Roles	b_1	b_2	b_3	b_4	b_5
Bottle-neck ?	Yes	No	No	No	Yes

5.2 Scenario 2 – Identifying the Lagged Roles

In Table 2, R_4 is 0.0296808, a very low probability to achieve the demand of 4. In Table 2, one can identify that two roles, b_2 and b_5, are lagged when compared with the standard throughput vector. Let b_5 be retrained to improve his skill. We get the new empirical distributions as shown in Table 5. b_5 is now at the standard throughput, 4 deliveries per three hours. The process influence is recalculated and increased to 0.357043. The process influence has been increased effectively.

Table 5: The empirical distributions for the scenario two after retraining b_5.

Distr. Func.	The number of deliveries per 3 hours 0	1	2	3	4	5	6
μ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
μ_2	0.0227	0.4545	0.3636	0.1364	0.0227	0.0000	0.0000
μ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
μ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
μ_5	0.0000	0.0227	0.0682	0.0909	0.7500	0.0455	0.0227

5.3 Scenario 3 –Analyzing Process Risks

This process influence can be used to measure the risk of a business process, which is the probability that the process failed to meet the business goal. It equals to 1 minus R_d. For example, the empirical distributions for all roles in normal condition are shown in Table 6. The process influence is calculated and equals to 0.514339. The risk of the business process is 1- 0.514339 = 0.485661, a very high risk found. That is, the business process might have 48.5% probability under-influence in that month. An action strategy can be made by that both salesmen's standard capacities are enlarged to 4 deliveries per three hours. Then, after sampling, the new empirical distributions for all roles are denoted in Table 7. The process influence is now changed to 0.632223. The risk of the process has dropped effectively to 0.367777.

Table 6: The empirical distributions for the scenario three.

Distr. Func.	The number of deliveries per 3 hours 0	1	2	3	4	5	6
μ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
μ_2	0.0227	0.0455	0.5000	0.3636	0.0455	0.0227	0.0000
μ_3	0.0227	0.2273	0.4545	0.2273	0.0455	0.0227	0.0000
μ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.0000	0.0000
μ_5	0.0000	0.0227	0.0682	0.0909	0.7500	0.0455	0.0227

Table 7. The empirical distributions for the scenario three after enlarging both salesmen's capacities.

Distr. Func.	The number of deliveries per 3 hours 0	1	2	3	4	5	6
μ_1	0.0227	0.0227	0.0682	0.1136	0.6818	0.0682	0.0227
μ_2	0.0000	0.0000	0.0227	0.0455	0.6818	0.2045	0.0455
μ_3	0.0000	0.0000	0.0227	0.0455	0.7045	0.1818	0.0455
μ_4	0.1591	0.3182	0.3636	0.1136	0.0455	0.000	0.0000
μ_5	0.0000	0.0227	0.0682	0.0909	0.7500	0.0455	0.0227

6. CONCLUSION AND DISCUSSIONS

This article proposes a novel approach to explore the influence of different working groups in a connected organization.

In general, the proposed approach provides a new probe tool to assist the managers in supervising organizational activities. The real-time and precise inspection of organizational activities becomes possible. Future researches are encouraged on investigating multi-commodity organization. Such kind of process networks is common in our real life networks.

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