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Effects-Based Designing Organizational Processes: Methodology and Applications

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Effects-Based Designing Organizational Processes: Methodology and Applications

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Abstract Designing organizational processes is to select best course of action (COA) to accomplish organizational mission, which is under organizational resources capability constraints. In this paper, a new methodology is advanced to obtain an optimal strategy of organizational processes, which is based on organizational resource capability and desired effects. We define the basic conceptions that include statements of organizational environment and organizational resource capability, actions, events and effects, on which dynamic Bayesian network (DBN) and Markov chain are employed to represent the evolving of organization with its environments.

An example of joint landing campaigns is analyzed in our paper, and the new methodology is applied to design optimal strategy for a military organization to accomplish its missions. The optimal COA, obtained from our new methodology under diverse campaigns conditions, are given and analyzed. Results from the simulation of the COA show that our approach to solve optimal strategy of organizational processes accord with traits of general landing campaign.

Keywords Strategy of Organizational Process, EBO, DBN, Influence Graph

1. Introduction

Contingency theorists argue that a proper organizational design is critical to superior organizational performance [1][2][3]. Setting up efficient strategy of organizational processes is one of the keys to a successful organizational design. And studying works on this problems interest lots of scholars who advanced various methodologies and theories from respectively fields, which includes Course of Action (CoA) in military field, strategy oriented goals in fields of artificial intelligence, and organizational processes designing in fields of organization science, etc.

In military field, CoA and Effect Based Operation (EBO) are a pairs of twinborn sister. And they build the front of research on military theory and technology [4]. EBO is not a new conception and idea. Excellent commander always devote his attentions to the CoA taken to force enemy to reason and action as his expectations. Since gulf war, EBO is accepted as a thinking way in the course of military planning, executing and evaluating by military persons. EBO links CoA with intelligent scheme and analysis in battlefields, which decreases the uncertainness of CoA planning[5][6].

In field of artificial intelligent, classic behaviors selecting, oriented goal, includes making plan and schedule of actions. Plan of actions is also strategy of CoA. Schedule is a scheme of resource assigned to put plans of actions into practice. Plan and schedule could be dividable theoretically. In reality, however, the two kinds of behavior are always integrated and inseparable. For instance, there exist two problems that must be considered for manufacture of enterprise, one is working procedure of manufacture, and the other is effect-cost of the working procedure. There exist same reasons for us to deal with military problems. Not only should we select strategy of

CoA to complete military missions, but we should availability and utilization of equipments or military platforms. Theories of Decision Theoretic Planning (DTP) and Markov Decision Processes (MDP) are employed to settle these problems in the field of artificial intelligent [8][9]. Traditional problem of DTP is how to build sequence of actions to achieve goals. And methodology of MDP is considered best appropriate to solve problems of DTP, which is conformed by most of researcher on DTP.

In essence, constructing strategy of organizational process is how to optimize CoA, completing its missions efficiently, on the conditions of organizational resource. Compared with problems of behavior oriented goal or course in artificial intelligent, optimizing strategy of organizational process is more complex and involve new specialty, which includes conjunction of resource, sequence of actions, uncertain of external environment and randomicity of environment evolving.

Methodologies of optimizing strategy of organizational process, based on modeling organizational environment and process, is advanced in this paper, which combines ideas of EBO in field of military with theory of MDP in field of artificial intelligent.

2. Statements of Problem

A successful campaign, of which plans of combat are the most important works, required to be designed elaborately by lots of staffs. Generally, there exist various uncertain factors and possible selections and different constraint for staffs to make a plan. As the following campaign scene (figure.1), there exist two goals (G1 and G2) to be achieved, for which lots of critical targets marked with red color need to be captured. To complete mission, available actions are selected under resource capability and confronted with uncertain events from enemy's actions.

For an organized force, we give resource capability of force as table I. In order to make best plan to achieve goal of campaign with expected effects, we should optimize strategy of CoAs under force resource capability.

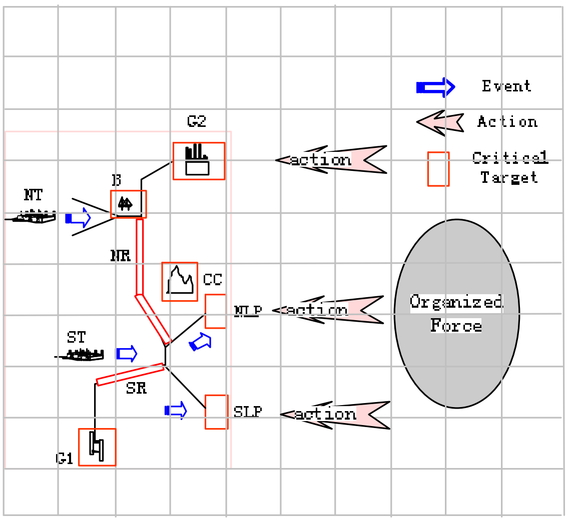


Figure.1 Mission Environment Scene of Campaign

Table I Description of Resource Capability of Force

Resource of Force	Function Capability							
	fc1	*fc2*	*fc3*	*fc4*	*fc5*	*fc6*	*fc7*	*fc8*
p1	10	10	1	0	9	5	0	0
p2	1	4	10	0	4	3	0	0
p3	10	10	1	0	9	5	0	0
p4	0	0	0	2	0	0	5	0
p5	1	0	0	10	2	2	1	0
p6	5	0	0	0	0	0	0	0
p7	3	4	0	0	6	10	1	0
p8	1	3	0	0	10	8	1	0
p9	1	3	0	0	10	8	1	0
p10	1	3	0	0	10	8	1	0
p11	6	1	0	0	1	1	0	0
p12	6	1	0	0	1	1	0	0
p13	6	1	0	0	1	1	0	0
p14	0	0	0	6	6	0	1	10
p15	0	0	0	0	0	0	10	0
p16	0	0	0	0	0	0	0	6
p17	0	0	0	0	0	0	0	6
p18	1	0	0	10	2	2	1	0
p19	1	0	0	10	2	2	1	0
p20	1	0	0	10	2	2	1	0

3. Modeling Evolution of Organizational Processes based on Environment States

3.1 Basic Conceptions

Capability State of Organizational Resource (S_{Or}). S_{Or} descript state of function capability of organizational platform resource. S_{Or} is the constraint of generating actions, which comprises local restriction (Or_l) and global restriction (Or_g). Local restriction, also called as instantaneous restriction, restrict available actions on some phase of CoA. For reusable resource, Or_l refer to constraint of resource function capability. Replenishment of resource is not taken into account in this paper.

Action (*a*). Action is related to function of platform resource. One or more functions executed simultaneously compose actions. Single function execution is called as basic action. Action expends function capability and time. So it can be presented by a dualistic composite: $a=<f, d>$, *f* is the functions to execute *a, and d is* the duration of *a.* Available actions set $A=\{a_0, a_1, a_2, \cdots, a_m\}, m=|A|$ depends on combat principles and knowledge of military experts. Actions induce effects and affect transitions of environment state in battlefields. If action $a_i \in A$ is taken in some environment state $S_{En}(t_k)$, $P_k\{a_i=1\}=1$;otherwise, $P_k\{a_i=1\}=0$.

Strategy of Course (?). ? is the sequence of actions that change environment state to reach expectation states. ? could be denoted by ? = <*p* (t_0), *p* (t_1)… *p* (t_e)>, thereinto, t_i $(0\leqq i\leqq e)$ is the phase of CoA and *p* (t_i) is the set of basic actions in phase t_i. *p* (t_i) *could be written by* *p* (t_i)=$\{a_1,a_2,\cdots,a_n\}$. So *p* expends function capability of organizational platforms and time as action. We denote the function capability and time expended by p respectively as $F(p)$ and $D(p)$. p is the direct cause that induce transition of environment state.

Event (*ev*). Event is uncontrollable factor out of organization. In battlefields, uncontrollable events usually refer to actions taken by enemy according to changing environment. So arising events always ties up environment state. Event produces an affect on effects of actions. Denote possible event set as $EV=\{ev_0, ev_1,\cdots, ev_w\}(w=|EV|)$, and $P\{ev_1=1\}=p_1$ means event probability of ev_1 is p_1. In some phase of environment evolving, parts of events could arise. Denote these events as $EV(t_k)=\{p_k\{ev_1=1\}, p_k\{ev_2=1\},\cdots, p_k\{ev_h=1\}\}$, h is the total number of events in phase t_k. In figure.1, events include those arrows marked with blue color.

Situation of Battlefields (S_{En}). S_{En} characterize environments of battlefield and is states of instantaneous environment. Generally, we focus only on some critical targets (CT) to present battlefields, and these targets are the key site that both sides strive for to change situation of battlefield and called center of gravity for whole battlefield. So we descript environment state with all CTs in battlefield, and endow each CT with two states: 0 and 1. 0 denotes CT controlled by enemy and 1 denotes CT captured by us. Denote environment state of t_k phase as $S_{En}(t_k)$, then

$S_{En}(t_k)=<Sct_1(t_k), Sct_2(t_k),\cdots, Sct_h(t_k)>$, $Sct_1(t_k)$ present the state of ct_1 in t_k phase.

Transition of Situation (Tr_{en}). T is state transition of environment, which is influenced by controllable actions and uncontrollable events. Transition of environment could result in two different outcomes: one is in favor of reach anticipant environment state, the other is not. And the anticipant state in the environment evolving is final situation of battlefields for planning to strive for. To optimize strategy of CoA, Generating CoA is in the light of the anticipant final state, which is called "attractable state". "Attractable state" should be the drawing power of transition of environment. We denote attractable state as $S_{En}(t_e)$, and its states set as A_{En}, then if exist $S'_{En}(t_e)\in A_{En}$, the CoA that induce $S'_{En}(t_e)$ is one of the optional CoA.

Effect (*ef*). Effect is the additional results from CoA. For example, ending of a combat operation could have achieved goals, but at the same time, it could bring on damnification of combat platform, casualty of persons or political effect. For a plan of actions, we always set lots of anticipant effects, denoted by $E=\{ef_1, ef_2,\cdots, ef_g\}$. We expect complete mission efficiently (ef_1) and decrease loss (ef_2) of force resource.

3.2 Evolution of Organizational Processes based on Environment States

The motivation of organizational operation is that control and transfer its environment into anticipant states. But environment always influence its operations and hold up its changing efficiently. Behaviors, changing organizational environment purposefully, could be controlled by organizational capability and called as "controllable action", which is favorable factors for organization evolving. The uncontrollable factor, counteract changing organization, is damper and call as "event". So the evolving of organizational processes based on environment could be illuminated as Figure.2. The evolving involves controllable action, uncontrollable event and environment.

As an intelligent whole, organization always manages to complete its missions efficiently by optimal strategy of actions. With the ideas of EBO and MDP and DTP, we model evolving of organizational process based on environment, from which strategy of organizational process could be generated. And the generation of strategy should follow some basic principles and processes, which consists of the following part:

(1) Available actions in any phase originate from function capability of organizational resource;

(2) Controllable actions induce transition of environment state with events, and the course of transition with actions, final goals achieved, produces choice strategy of CoA;

(3) Optimizing strategy is to choose best strategy that achieved goals and expectation effects from the set of choice CoA, with which uncontrollable events and actions are related to expectation effects.

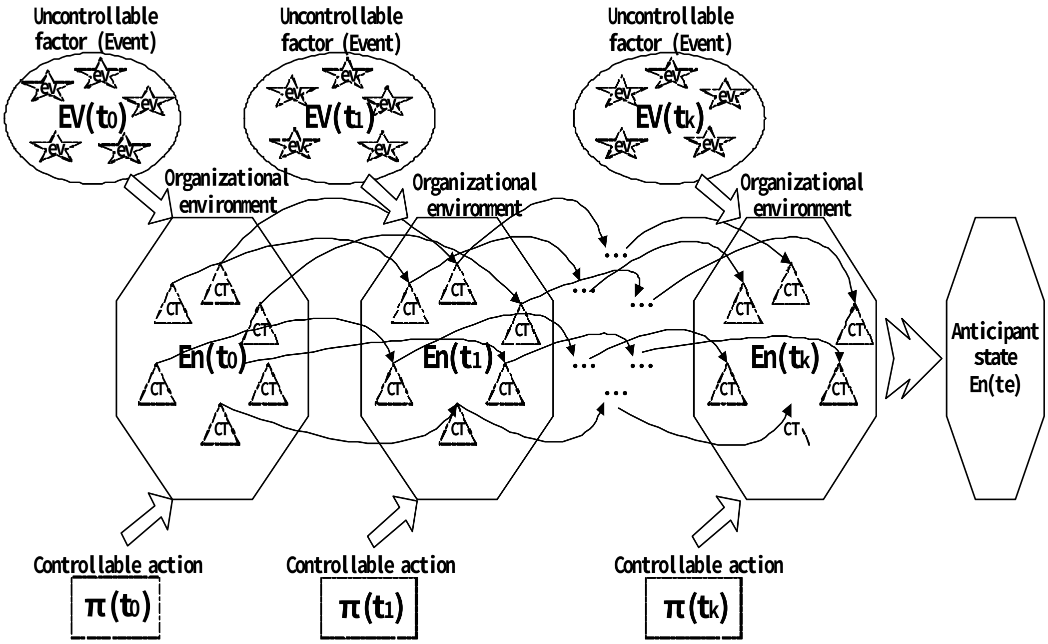


Figure.2 Evolving of Environment State Controlled by Strategy and Event

So CoA is composes of multi-phase actions, called phase action set (PAS). And each PAS is given under current function capability state of platform resource and is intended to control and change current environment state so that final goals and expectation effects are achieved. Because of probability event, transition of environment and achieving effects is uncertain and always difficult to be controlled as expectation. We need to evaluate impacts on actions from probability event in the course of environment evolving, and select the best strategy that reached attracted state of environment transition and induced optimal effect in the end of CoA.

Evolving of organizational process (EOP) is the transition of PAS, which is varied with changing environment state. EOP is intended to facilitate transition of environment state to anticipant final state. Incidental factors of EOP include probability event, actions, function capability state of organizational resource and environment state. It is not all EOP that could achieve final goals, that is, bring environment into attract states. And all EOP that transfer environment into attract states is the set of choice strategies.

There exist the following relationships among action, event, organization and environment in the course of EOP.

(1) Actions and events together build transition of environment state in any phase;
(2) Selections of actions depend on specify environment, that is, chosen actions is necessary for current environment;
(3) Availability of action lie on current state of function capability of organizational resource;
(4) Arising of probability event rest with environment;
(5) Transition of environment, driven by actions and events, is various, and only od the course of environment evolving reach attract states, the CoA from it is choice.

Above relationships are the foundation of modeling EOP and optimizing strategy of CoA.

Based on basic definitions and laws of EoP, we can write the relationships among environment state S_{En}, Capability State of Organization Or and uncontrollable events EV (shown by Fig.2) as the following formula:

$$\begin{cases} S_{En}(t_k+1)=\Gamma_{En}(S_{En}(t_k),p(t_k),EV'(t_k)) \\ Or(t_k+1)=\Gamma_{Or}(Or(t_k),p(t_k),EV'(t_k)) \\ p(t_k)=y(S_{En}(t_k),Or(t_k)) \\ EV'(t_k)=f(S_{En}(t_k),Or(t_k)) \end{cases} \quad (1)$$

Where Γ_{En} and Γ_{Or} present transition of environment state and function capability of organization respectively in some phase, which depend on current state, PAS and events EV'. That is, current states, PAS and EV' together make next states of environment and Or. y and f are functions of PAS, EV', S_{En} and *Or*.

3.3 Generating Strategies of Organizational Processes

Transitions of environment depend on actions and events, and actions root from function capability of organizational resource. Execution of action expends function capability, and also changes state of organization. So evolving of environment is also based on state of organization, which include function capability and time state.

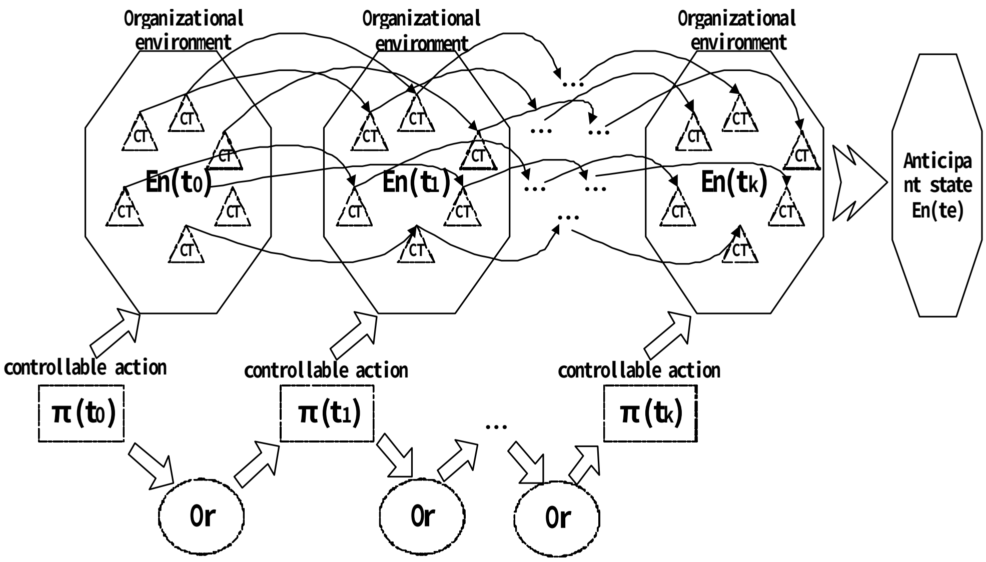


Fig.3 Generating Strategies of Organizational Process

A CoA is unsuccessful when all resource of organization is exhausted and final goals are not achieved. Given function capability and time state of organization, there could exist series of CoA to form strategies of organizational process. So generating strategies of organizational process can be illuminated as fig.3.

We denote these CoA with Θ , then obtaining of Θ can be expressed as the follow mathematics formula:

$$\Theta = \{\Pi \mid Tr(S_{En}(t_0), \Pi, S_{En}(t_e))\}$$
$$st \quad \begin{cases} S_{En}(t_e) \in A_{EN} \\ F(\Pi) \le R(Or_g) \\ D(\Pi) \le D(Or) \end{cases} \qquad (2)$$

where $Tr(S_{En}(t_0), \Pi, S_{En}(t_e))$ denotes the course of transition of environment state from initial state $S_{En}(t_0)$ to terminate state $S_{En}(t_e)$($S_{En}(t_e) \in A_{EN}$) by execution of Π. *D(?)* is time requirements of Π. During the transition, requirement of function capability *F(?)* for Π is not more than global restriction Or_g of organizational state, and requirement of function capability $R(p(t_k))$ for PAS $p(t_k)$ is not more than local restriction Or_l.

Based on formula (2), we can further give basic conditions for generating strategies of organizational process as following:

(1) Completing organizational mission, that is, transferring initial environment state into anticipant final state;

(2) Requirements of CoA are under capability state of organization, which includes Or_l and Or_g;

(3) Each PAS of CoA follows a function relation between specify environment state and optional CoAs set.

So formula (2) can be further written as:

$$\Theta = \{\Pi \mid Tr(S_{En}(t_0), \Pi, S_{En}(t_e))\}$$
$$st \quad \begin{cases} S_{En}(t_e) \in A_{EN} \\ r(p(t_k)) \le R(Or_l), d(p(t_k)) \le D(Or_l) \\ F(\Pi) \le R(Or_g), D(\Pi) \le D(Or_g) \\ \Phi_k = y'(S_{En}(t_k)) \\ p(t_k + 1) \in \Phi_k \end{cases} \qquad (3)$$

Where

$$D(\Pi) = \sum_{i=0}^{q} D(p_i) = \sum_{i=0}^{q} \max\{a_0(t_i), a_1(t_i), \cdots, a_n(t_i)\}, (n = |p|, q = t_e - 1)$$

$$R(\Pi) = \sum_{i=0}^{q} r(p(t_i)), (q = t_e - 1)$$

$$r(p) = \sum_{i=0}^{|p|} r(a_i), (a_i \in p)$$

$$d(p) = \max\{d(a_0), d(a_1), \cdots, d(a_n)\} (n = |p|, a_i \in p)$$

Generation of organizational process builds optional CoAs with corresponding transitions of environment state and organizational capability state, on which we can evaluate and compare effects of strategies and optimize it if we can construct qualitative relations among actions, events and effects. Analyzing of generating CoA bounds searching space of optimal strategy.

Denoted optimal strategy as $\Pi^* = < p'(t_0), p'(t_1), p'(t_2), \cdots, p'(t_e - 1) >$, then optimizing strategy can be written as:

$$\Pi* = \arg\max_{\Pi \in \Theta} P_e\{E \mid Tr'(\Pi)\} \quad (4)$$

Where $P_e\{E \mid Tr'(\Pi)\}$ present achieved probability of anticipant effects. **Π (** $\Pi \in \Theta$) is optional CoA, and exists $Tr' \in Tr$. So formula (4) means that the CoA to obtain best effect probability is the optimal strategy.

Formula (3) and (4) build mathematic expressions to generate CoA and optimal strategy. How to solve optimal strategy? In order to settle this question, we need to construct qualitative relations among basic actions and events and effects.

4. Optimization Strategy of Organizational Processes based on Effects

4.1 BN of Actions, Events and Effects

BN, also known as causal or probabilistic networks, are formalisms for representing uncertainty according to the axioms of probability theory. As a graphical model with strong mathematical background, it has grown enormously over the last two decades. There is a large set of theoretical concepts, results and software tools for model construction and computation, such as Microsoft's MSBNX and Matlab Toolbox, etc.

BN is directed acyclic graph consisting of a set of nodes and a set of directed edges. Each node describes a random variable, and each directed edge describes the relationship between two variables. For the given sets of variables X, Y and Z, if there have $P(z|x, y) = P(z|x)$ for any $x \in X$, $y \in Y$, $z \in Z$, variable *Z* and *Y* are considered independent.

Given a set of nodes $V = \{v_1, v_2, \cdots, v_n\}$, one can compute the joint probability of variables in the Bayesian network by

$$P\{v_1, v_2, \cdots, v_n\} = \prod_{i=1}^{n} P(v_i \mid p(v_i)) \quad (5)$$

where $p(v_i)$ is the set of the parent nodes of v_i. This equation is derived based on the chain rule of probability and conditional independence. That is, given the state of a node's parents, all the ancestors are conditionally independent of the node.

In the section above, relationships among actions, event, and effect and environment state have been illuminated. That how to establish qualitative consequence among these factors is primary works to evaluate a CoA. Generally, a complex CoA would involve lots of actions, events and anticipant effects. Herein, we cite the conception "indirect influence" [11] to assort and nail down these mutual relations, on which we construct static BN based on action-event-effect (as figure.4).

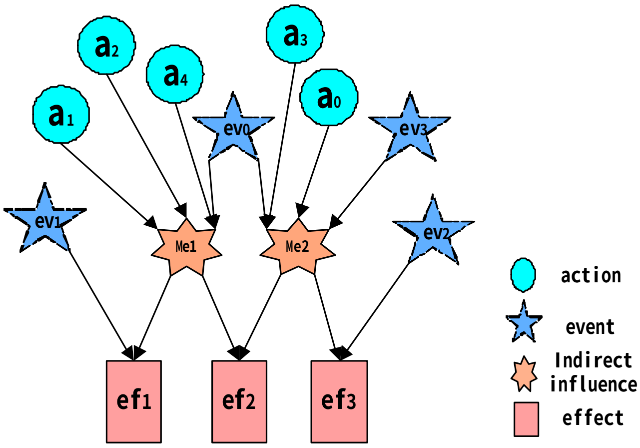


Figure.4 static BN based on action-event-effect

In Fig.4 nodes in the set $V = \{a, ev, Me, ef\}$ denote action, event, intermediate influence and effect respectively. The set of directed edges, $E = \{(a, Me), (ev, Me), (ev, ef), (Me, ef)\}$, describe the causal relationship among these variable. Let $G = (V, E, P)$ denote the static Bayesian network, where P is a probability mass function of nodes. $P(v_i)$ expresses the probability of node v_i ($v_i \in V$).

Based on the principle of conditional independence, the probability of achieving the effect ef_i in Fig.4 is given by

$$p\{ef_i\} = \prod_{j=1}^{|j\ (ef_i)|} p(u \mid j\ (u)), ef_i \in E, u \in j\ (ef_i) \tag{6}$$

Where j *(?)* is the set of the parent nodes.

Thus the joint probability of achieving the desired effect E can be computed via

$$P\{E\} = P\{ef_1 \Lambda ef_2 \Lambda \cdots \Lambda ef_g\} = \prod_{i=1}^{g} p\{ef_i\} \tag{7}$$

4.2 DBN based on Environment Evolving

A major drawback of the standard theory of BNs is that there is no natural mechanism for representing time; it only describes the static causal relationship. In above sections, we build model of synchronous evolving among environment state, function capability state of organizational resource and organizational process. In this evolution process, actions and events vary with environment states, therefore standard BN cannot describe the process effectively.

Because the uncertain causal relationship network among action, event and effect varies with the evolution of process, we construct DBN based on the evolution of environment states in order to evaluate the variation of desired effect induced by evolution process. Fig.5 shows that DBNs of action, event and effect vary with environment evolution, and the dashed edges portray the correlation and effect among nodes during the dynamic evolution process. The DBN, showed in Fig.5, is a simple description for the evolution process. DBN can be decomposed as a sequence of static BNs with certain connections. The initial static BN determines the correlation among all basic actions and events. At each time slice, since the environment state is certain, the current environment state decide the event interference and the selection of current actions. That is, the certain environment state makes certain the BN at that time slice.

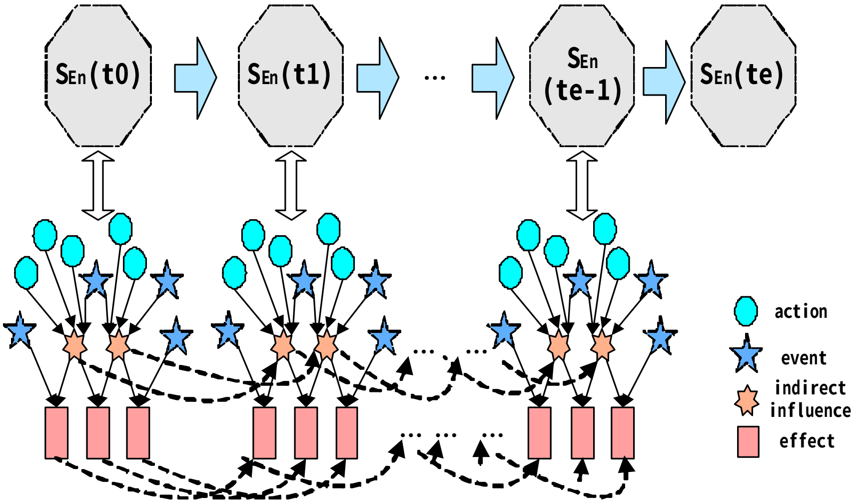


Figure.5 DBN based Environment Evolving

In Fig.5, the dashed edges show the temporal links of the "intermediate influence" and effects between neighboring time slices. At time slice t_k, the static BN $G(t_k)$ is different from the static BN $G=(V,E,P)$, which is showed in Fig.4. $G(t_k)(k \neq 0)$ contains part of "intermediate influence" and effects nodes in $G(t_k-1)$, and only the initial BN $G(t_0)$ satisfies $G=(V,E,P)$.

At time slice t_k, the graph $G(t_k)$ is affected by the evolutional results of graph $G(t_k-1)$. Let the set of desired effects $E'=\{ef_1(t_k-1), ef_2(t_k-1), \cdots, ef_g(t_k-1)\}(g=|E|)$ be the evolutional results of graph $G(t_k-1)$, and $\{Me_1(t_k-1), Me_2(t_k-1), \cdots, Me_h(t_k-1)\}(h=|M|)$ be the set of intermediate influence. The static BN $G(t_k)$ can be formulated as follows:

$$\begin{cases} G(t_k)=(V_k, E_k, P_k) \\ V_k=\{a_k, ev_k, Me_k, ef_k, Me_{k-1}, ef_{k-1}\} \\ E_k=\{(a_k, Me_k), (ev_k, Me_k), (ev_k, ef_k), \\ \quad (Me_k, ef_k), (Me_{k-1}, Me_k), (ef_{k-1}, ef_k)\} \end{cases} \tag{8}$$

Fig.6 shows the static BN at some certain time slice. In the evolution of environment, the occurrence of events and the employ of actions will vary with the environment state. Therefore, the set of leaf nodes in DBN is variational. At the environment state $S_{En}(t_k)$, for any nodes $v_i \in V_k=\{a_k, ev_k, Me_k, ef_k, Me_{k-1}, ef_{k-1}\}$, $P_k\{v_i=1\}=p$ denotes the probability of node v_i being activated at time slice t_k, and $P_k\{v_i=0\}=1-p$ denotes the probability of node v_i being not activated. In initial state of environment evolving, $v_i \in V_0 = \{a, ev, Me, ef\}$. And $P_k\{v_i = 1\}$, $P_k\{v_i = 0\}$ denote the probability of action or event to be enabled and not enable respectively. Thereout, we build the uncertain description of node in any time slice $G(t_k)$ for DBN, on which we can analyze and compare achieved probability of expectation effects from different environment evolving.

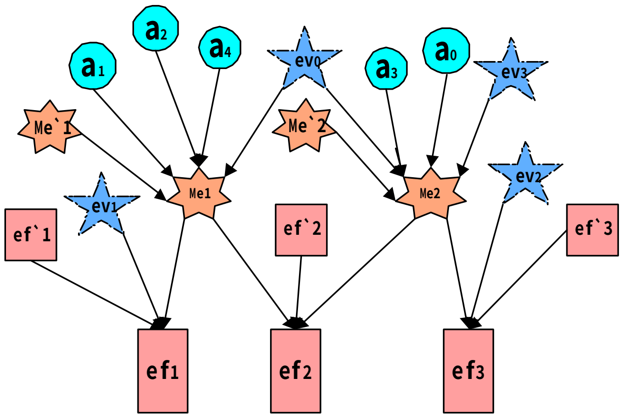


Figure.6 Static BN in Some Phase of Environment Evolving

Conceptually, the problem is to achieve the desired effects with the maximum possible probability at specified times. The mathematical formulation of the strategy optimization of organizational processes is as follows:

$$\begin{aligned} \Pi^* &= \arg\max_{\Pi \in \Theta} P_e\{E \mid Tr'(\Pi)\} \\ &= \arg\max_{\Pi \in \Theta} P_e\{ef_1 \Lambda ef_2 \Lambda \cdots \Lambda ef_g \mid Tr'(\Pi)\} \\ &= \arg\max_{\Pi \in \Theta} \left(\prod_{i=1}^{g} p_e\{ef_i(t_e) \mid Tr'(\Pi)\} \right) \end{aligned} \tag{9}$$

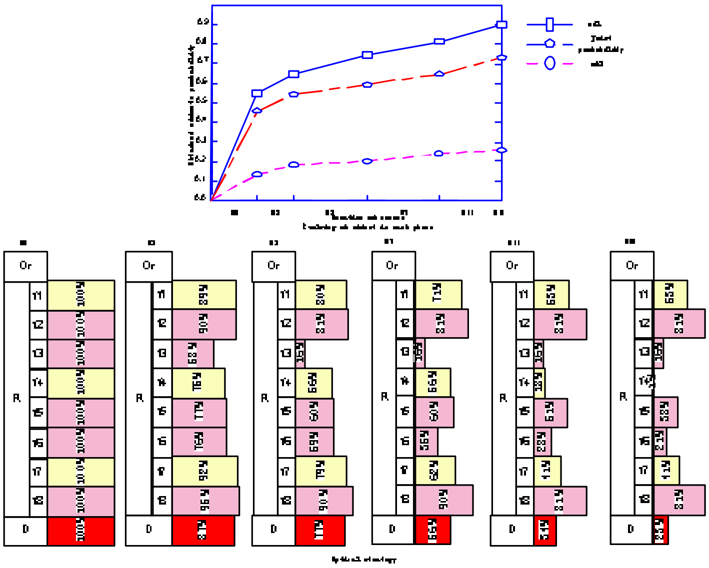
Where $p_e\{ef_i(t_e)\}$ is the joint probability to achieve the desired effect by strategy Π and Π^* is the optimal strategy.

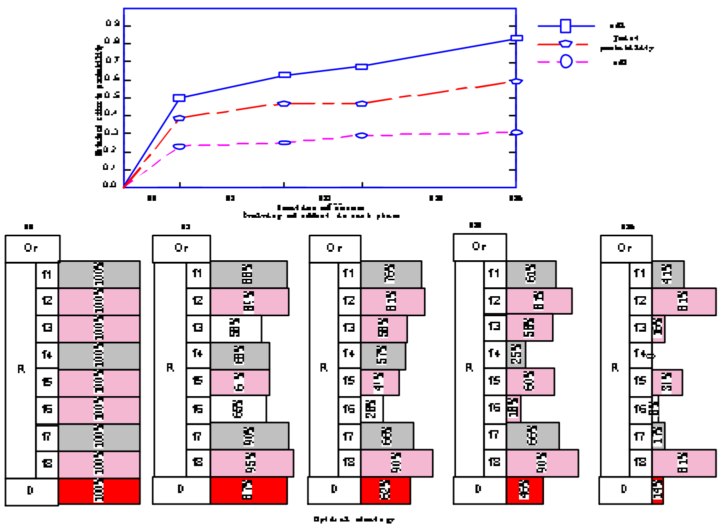
5. Analyzing of Results from Case

For our case, the parameters of function capabilities for organizational resource are shown in Table 1. Fig.7(a) shows the evolution processes of organizational state (function capability of platform resource), effects and optimal strategy.

From the curve of evolution process of effects, showed in Fig.7(a), it is obvious that the steps $S_0 \rightarrow S_2$ and $S_2 \rightarrow S_3$ are the key steps in the battle. The successes of these two steps make to achieve the mission with a probability of 60%. These two steps also bring the most loss of resource. From the evolving of organizational capability state with strategy of CoA, we can know the two phase exhausted plenty of function capability. In this case, the two step $S_0 \rightarrow S_2$ and $S_2 \rightarrow S_3$ are the right foremost two wave attacks. This accord with traits of general landing campaign.

When we reduce the platforms (p_8, p_9, p_{20}) in the case of the time limit being not changed, the evolution of function capabilities, effects and optimal strategy are showed in Fig.7(b). The reduction of the platforms induced the degradation of the effect of the initial step, and also postponed the completion time of mission. From the evolving of organizational capability state, we can know capability of function *fc4* has been exhausted in the end of the campaign.





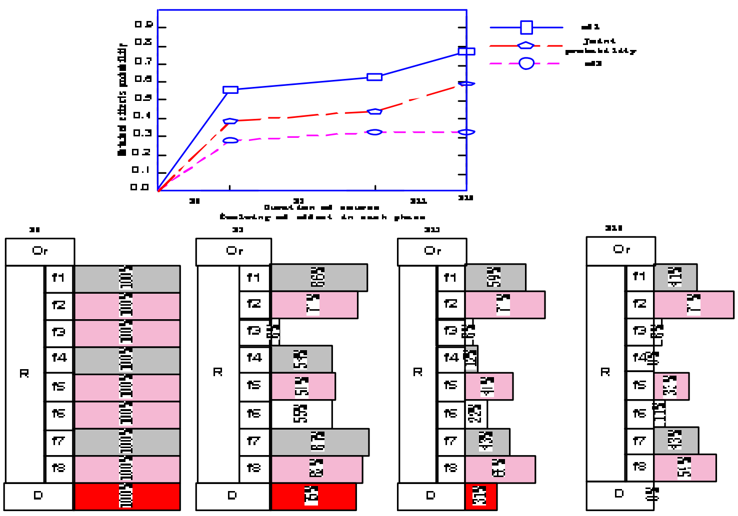


Figure.7 (c)

Figure.7 Optimal Strategy of CoA under Different Function Capability State of Organization

Fig.7(c) illuminates optimal strategy and evolving function capability of organization under time limit being 48.

From above analyzing, we can draw a conclusion that more function capability of organizational resource is devoted into foremost phase of campaign. Compared with other phase of campaign, utility of function capability and achieving effect in foremost phase take are the most important part to whole campaign. In the case of time reduced, the strategy from Fig.7 (b) is more economic than the other two strategies in force employed, which illuminate centralized force attacking is the optimal strategy under limited resource. Fig.7(c) shows disperse attacking ways is optimal strategy of CoA if there is limited time and enough organizational capability, but it induce more loss than the other two strategies in force. From the three cases, we also know that capability of *fc4* function is the bottleneck of the landing campaign. In campaign planning, we should reinforce *fc4* function capability of force to get victory of campaign.

6. Questions and Discussions

This paper introduced a method to optimize action strategies base on effects. Expert knowledge is need during the construction of BN. On the other hand, we only considered the probability value of event in different battlefield situation, but in fact, the uncertainty of the occurrence of some events is a probability mass function in some situation. For this case, the optimization strategy should be computed from Monte Carlo runs. The description of battlefield situation and resource capabilities state, the influencing graph of action, event and effect, and also the search of process evolution should be more investigated in the future study.

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