ORGANIZATIONAL RESPONSE: TRADE-OFFS AMONG OPPORTUNITIES FOR REVIEW, COST, AND PERFORMANCE

Zhiang Lin
H. John Heinz III School of Public Policy and Management
zh1h@andrew.cmu.edu

Kathleen Carley
Department of Social and Decision Sciences
kathleen.carley@centro.soar.cs.cmu.edu

Carnegie Mellon University
Pittsburgh, PA 15213

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INTRODUCTION

Organizations constantly face a dynamic environment where time constraint, external stress, and internal stress all require organizations to respond both quickly and accurately in order to survive (Aldrich 1979; Perrow 1984; Scott 1987). Though the common knowledge is that more complex organizations are more costly, there are debates over whether complexity/redundancy in organizational design would provide organizations with more opportunities to review decisions and whether more opportunities by organizations to review decisions would lead to higher performance. In this paper, we examine the issue: given a set of intelligent agents, how can we design a cost-effective high performance organization. We examine the relationships among organizational cost, opportunities for review, and organizational performance as discussed in the organizational literature by using computational techniques.

Organizational performance can be severely affected by time pressure (Lin and Carley forthcoming; Means et al. 1992). Organizations must respond quickly if they are to have adequate time to review supporting decisions before making a final decision. Because of the merit of more and fast responses, most organizational researchers have advocated frequent and active responses by organizations (La Porte and Consolini 1991; Pauchant et al. 1990). However, there are several factors that can affect the number of opportunities for review by organizations. One factor is the training. Often, organizations form standard operating procedures in the hope that those programmed procedures will create more opportunities for review (March and Simon 1958).

Another factor is structures within organizations. To generate more opportunities for review, organizations have to reduce the layers of bureaucracy. In fact, the need for fast response has made organizations become leaner and rigid when faced with stressful situations, even though the merit of such lean and rigid structures has not been adequately shown (Hermann 1963; Staw, Sandelands, and Dutton 1981). Within organizational theory there is a debate as to what organizational designs best enhance the efficiency and so the organizational performance. Mackenzie (1978) suggests that pure hierarchical structures reduce redundancy and increase efficiency and therefore, presumably, can respond in a more timely fashion. In contrast, Carley (1991) and others (La Porte and Consolini 1988) suggest that some complex forms such as desegregated structures can learn faster and respond more quickly.

In addition, organizational theorists argue that organizations should have a complex design (Krackhardt and Stern 1988) or loosely coupled design (La Porte and Consolini 1991; Thompson 1967) or redundant design to maintain high performance (Roberts 1989, 1990; Rochlin 1989). They point out that with a tightly coupled structure, organizations are extremely fragile to the disruption of information. In contrast, others claim that hierarchies may exhibit lower performance due to information loss through the process of condensation as it goes up the hierarchies (Jablin et al. 1986) or inability to absorb uncertainty and interruption under stress (March and Simon 1958; Simon 1962). Studies also show that some simple organizations, such as teams can outperform many complex organizations, such as hierarchies and matrices (Carley 1992).

However, such complex and presumably reliable designs are often very costly. The basis for this cost includes the number of communication links, the time spent on the communication, the degree of information processing, and the number of information processors (Carley 1991; Lin forthcoming; Malone 1986). In addition to the concern of cost, researchers have not been able to show that those complex organizations will always respond accurately. In fact, organizations may well end up being very costly but ineffective in responding to organizational problems. Resource constraints and a concern with cost have forced organizational practitioners to ask: is the cost of complexity worthwhile?

So, to reiterate the research issue: how should organizations composed of intelligent agents be designed so that they can not only respond quickly but accurately at a low cost? With few exceptions (Baligh, Burton, and Obel 1990), researchers in organizations have often focused on one or two aspects among organizational design, cost, and opportunities for review, and their effects on organizational performance. When looking at organizational literature, we can find numerous propositions with some being vague or contradictory to another (Lin and Carley 1992). For example, even though centralized hierarchy has been favored by some as better performers (Roberts 1990), the voices for more complex forms such as matrices can also be heard frequently (Davis and Lawrence 1977; Krackhardt and Stern 1988). This phenomenon is largely due to the fact that there

is a lack of systematicity in the research of organizational performance (Lin and Carley 1992). It is our intention in this paper to systematically examine the relationships among opportunities for review, cost, and organizational performance with different designs and facing different task environments, under situations where stresses are considered. We wish to examine whether there is a trade-off among those factors, and the impact of such a trade-off. We are particularly interested in the following propositions.

Proposition 1: Organizations with more opportunities for review tend to have a better performance than organizations with fewer opportunities for review (La Porte and Consolini 1991; Pauchant et al. 1990).

Proposition 2a: Complex and thus more costly organizations tend to have a better performance than simple and thus less costly organizations (Krackhardt and Stern 1988; Roberts 1989, 1990; Rochlin 1989; Thompson 1967).

Proposition 2b: Simple and thus less costly organizations tend to have a better performance than complex and thus more costly organizations (Carley 1992; Jablin et al 1986; Mackenzie 1978).

We will address the research issue and examine those propositions by using computational techniques. In the remaining of the paper, we will first briefly describe the DYCORP framework developed by Lin and Carley (1993), and the methods we will use to address our research issue. Then, we will analyze the results generated from DYCORP to find the relationships among opportunities for review, cost and organizational performance. Finally, we will discuss the implication of the findings, limitations of the research, and future directions.

FRAMEWORK DESCRIPTION

Stylized Radar Task

The DYCORP framework examines the performance of organizations faced with a limited choice task in which organizations make decision choices regarding the state of a moving aircraft from limited alternatives according to information they have through organizational communication processes. The organization, to solve the problem, must make a decision, before the aircraft reaches the "red zone" as to whether the organization "thinks" the observed aircraft is friendly, neutral, or hostile. The red zone is defined as being the point at which either the aircraft enters the danger zone or the point at which the a time limit set by the organization has been met, whichever occurs first. After the problem is "over" (i.e., the aircraft has hit the red zone) the organization's final decision is recorded as its decision. A new problem (i.e., aircraft) occurs.

In the organizational decision making process, no one individual has access to all information needed to make the decision. Further, the task does not require consensus, rather, for a particular alternative to be chosen, it is sufficient that the CEO or a majority of the people in the organization choose that alternative. Because each agent of the organization can only see directly or indirectly part of the nine parameters, the final organizational decision can only be reached through communication and coordination among members of the organization. Which analyst reads what information depends on the resource access structure. How members of the organization communicate depends on the organizational structure. What style of decision each agent uses depends on the type of training he or she receives. The distribution of possible problems (in this framework aircraft) constitutes the task environment. The organizational operation can be disrupted due to sub-optimal operating conditions (or internal stress). Organizations are also frequently faced with hostile task environment or external stress, which would have severe consequences to the organization if not handled properly (see Lin and Carley 1992 for details). In this paper, our focus is not on internal or external stress, rather, we focus on time stress as will be discussed later.

In the DYCORP framework, the organization can track the aircraft and can make a series of decisions about the state of the aircraft. The number of decisions made by the organizations for each problem is recorded by the framework, though the organization only reports one decision for each problem. Though some of the characteristics of the aircraft may change during the flight, the true state of the aircraft cannot change and is defined relative to the characteristic of the aircraft at the starting state.

Since this is a dynamic task, the amount of time pressure faced by the organization will vary. Time pressure in DYCORP is represented by the number of time units the organization has to make the decision as will be described further later. The lower the number of time units the faster the organization must make its decision, the greater the time pressure.

In this paper, each agent in the organization has a proactive agent style in which they tend to engage in organizational decision making process whenever possible. Each agent asks for information, reads information if there is information, makes a decision based on the information, then passes up the decision. This process repeats until time expires. Time expires when the aircraft enters the red zone. Each agent's process (except the top-level manager's) can be interrupted when he or she receives a request from a superior for a decision. The agent will respond to the request by passing up a decision based on whether there is a previously made decision (when the agent has not previously made a decision the agent continues with the current action). There are minor differences among the top-level manager, middle-level managers, and analysts. The top-level manager cannot be interrupted (since there is no superior), and an analyst can not ask for information (since there is no subordinate), while a middle-level manager can be interrupted as well as ask for information. Further, the top-level manager has the power to decide which decision will be used as the final organizational decision.

Independent Variables

In DYCORP, the independent variables are the aspects of organizational design. Organizational design used in this

paper is characterized using three design variables — organizational structure, resource access structure, and organizational procedures (herein limited to procedures for providing training, feedback, communicating recommendations, and combining these to create an organizational decision). The complexity of organization is often associated with organizational structure and resource access structure. The complexity of organization has also been measured by organizational cost, that is, the summation of pieces of information being processed and reported and communication linkages (Carley 1991). By considering those design variables DYCORP effectively combines structural theory, resource dependency theory, institutional theory, and social theory in a single framework. DYCORP focuses on these elements as they were previously shown to epitomize particular types of organizational response, to correspond to forms observable in real world organizations, and to have captured attention in the literature (Carley 1992; Lin and Carley 1992).

Organizational Structure

Five organizational structures can be examined in DYCORP: team with voting, team with a manager, hierarchy, matrix_1, and matrix_2. Each structure consists of nine analysts. In addition, some structures employ middle and/or top-level managers (Figure 1).

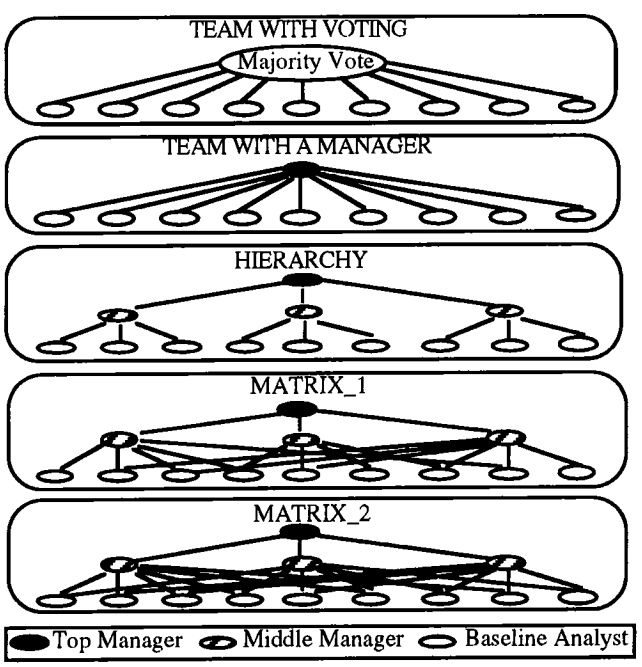

Figure 1: Stylized Organizational Structures

Resource Access Structure

The resource access structure determines the distribution of raw (unfiltered) information to analysts in the organization. In DYCORP, what this means is that the resource access structure determines which analyst has access to which type of radar or surveillance equipment. Each type of equipment allows that analyst to garner information on a particular (or a particular set of) characteristics. Using DYCORP the researcher can examine six resource access structures. They are: segregated_1, segregated_2, overlapped_1, overlapped_2, blocked, and distributed (Figure 2).

Organizational Decision Making Procedures due to Training

Experientially Trained Procedure

In the experiential condition, the agents have historical information on which they base their recommendation. This is often studied in the learning theory literature. The experientially trained agents are fully trained agents in the sense that they have previously encountered all possible aircraft and have received feedback on each aircraft. Agents proceed as though they are following a historical dominance rule. That is, the agent after having classified an aircraft will make the decision that has been the historically dominant (most often correct in the past). The experientially trained agents follow their decision procedure but they no longer alter their memory. Thus, their expectations remain fixed.

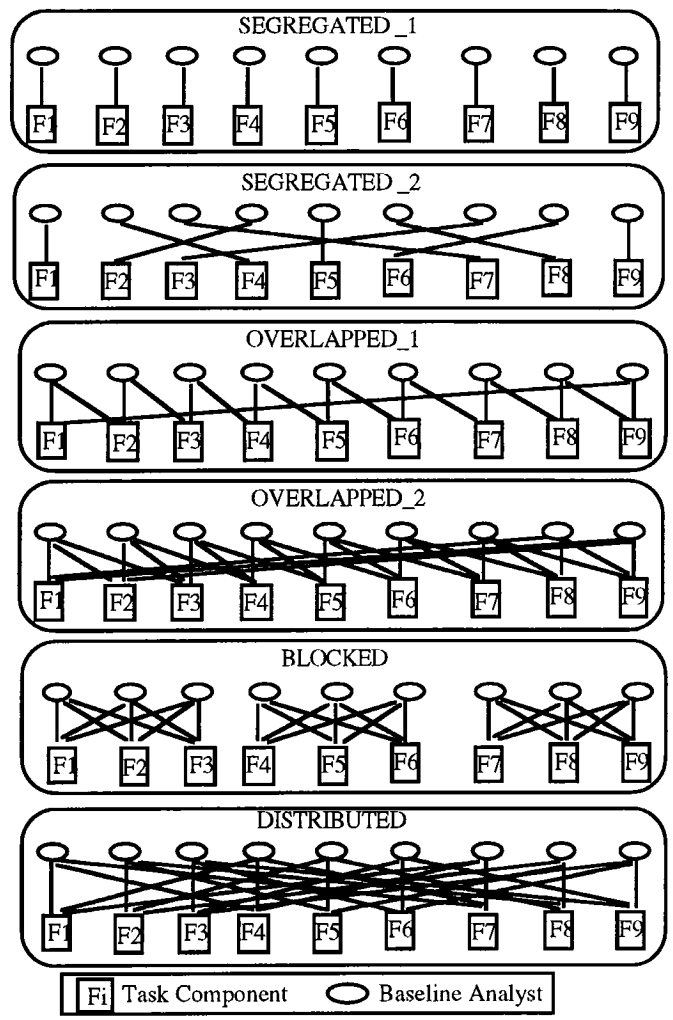

Figure 2: Resource Access Structures

Operationally Trained Procedure

In the operational condition, the agents have standard operating procedures (SOPs) on which they base their recommendation. This is often mentioned in organization theory, particularly in military settings. Agents are

considered fully trained as they have perfect knowledge of the SOP and employ it without error.

In this paper, our focus is on post-training performance of the organization.

Control Variables

In this paper, the control variables we examine include task environment and time stress. We examine these control variables because, organizational survival, to a large extent, depends on how the organization adjusts to the task environment, and how the organization mitigates stress. Unlike the independent variables discussed previously, the control variables cannot be manipulated by the organization (Lin and Carley forthcoming).

Task Environment

The aircraft of course really exists, and is therefore "truly" friendly (1), neutral (2), or hostile (3). The organization is not omniscient and the true state of the world is not known a priori. Rather it must be determined by the organization by examining the radar characteristics of the aircraft. Based on the literature, two types of manipulations of the task environment were built into DYCORP. These are: the extent to which the task is decomposable (Simon 1962; Roberts 1990) and the extent to which it is concentrated (Aldrich 1979; Hannan and Freeman 1977).

A task environment is decomposable if there are no complex interactions among components that need to be understood in order to solve a problem. In contrast, when the task is non-decomposable then the pieces of information do not contribute equally to the final decision, and portions of the information interact to determine the true nature of the aircraft. A task environment is concentrated if the possible outcomes are not equally likely. In a concentrated environment this inequality of outcome biases perception. Concentrated environments, or niches, are quite common. In a dispersed environment approximately one third of the 19683 aircraft (6568) are hostile and one third of the aircraft are friendly. This environment can be thought of as an uncertain environment because the chances of all three outcomes are almost identical.

This classification involves first combining the values of all nine characteristics and then categorizing the aircraft (based on the combined value) as either friendly, neutral, or hostile. Based on these two manipulations, four different "realities" or environmental situations can be examined in DYCORP: concentrated decomposable, dispersed decomposable, concentrated non-decomposable, and dispersed non-decomposable.

Time Stress (Time Pressure)

Recall that the organization must make a decision before the aircraft reaches the red zone. The longer it takes the aircraft to reach the red zone the less the time pressure. Within DYCORP the researcher can examine three levels of time pressure: low, medium, and high. A low time pressure ($\geq$ 41 time units) puts little or no time constraint on the organizations. In this case, the organizational decision making process is least affected by time. A high time pressure ($\leq$ 20) puts great pressure on an organization to quickly respond and so constrains the organization's decision making process. A moderate time pressure ($\geq$ 21 and $\leq$ 40) places some constraint on the decision process. As DYCORP is a dynamic model, interactions among agents are affected by the time pressure. Time pressure can affect whether agents communicate, how they communicate, and which decision procedure they choose.

Dependent Variables

In this paper, we examine three dependent variables: opportunities for review, cost, and organizational performance. These three dependent variables are important because based on them, we can address the research issue in this paper.

Opportunities for review

The number of opportunities for review is measured as the number of decisions generated in the process of reaching the final organizational decision for the problem. It can be expressed in the following equation:

$$O_r = f(O_s, R_s, T_p, T_s) \quad (1)$$

where O_r is the opportunities for review, O_s is the organizational structure, R_s is the resource access structure, T_p is the trained decision making procedure, and T_s is the time stress.

Organizational Cost

The measure for organizational cost as created by Carley (1991) is shown as follows:

$$O_c = I_c + C_c \quad (2)$$

where O_c is the organizational cost, I_c is the information processing cost, which can be thought of as total number of pieces of information being processed by the organization, C_c is the communication cost, which can be thought of as total number of communication links installed in the organization. With vulnerability cost being discarded, Malone's cost measure (Malone 1986) is the same as Carley's cost measure. The organizational cost measured for all the organizational forms examined in this paper is listed in Table 1.

Table 1: Measure of Organizational Cost

Resource Access Structure	Organizational Structure				
	Team with Voting	Team with a Manager	Hierarchy	Matrix 1	Matrix 2
Segregated 1	18	37	46	64	73
Segregated 2	18	37	46	64	73
Overlapped 1	27	46	55	73	82
Overlapped 2	36	55	64	82	91
Blocked	36	55	64	82	91
Distributed	36	55	64	82	91

Organizational Performance

In DYCORP, the accuracy of organizational responses, or organizational performance, is defined as the percentage of correct decisions made by the organization given a set of problems presented to the organization. DYCORP records the performance of organization under various conditions examined in this paper. Such relationship can be expressed by the following equation:

$$P_r = f(O_s, R_s, T_p, T_e, T_s) \quad (3)$$

where P_r is the organizational performance, O_s is the organizational structure, R_s is the resource access structure, T_p is the type of trained decision making procedure, T_e is the task environment, and T_s is the time stress.

SIMULATION EXPERIMENT

The DYCORP framework is written in UNIX C and is currently stored on an HP workstation. Using DYCORP, we systematically vary each of the following independent variables: organizational structures (5 types), resource access structures (6 types), training scenarios (2 types). These independent variables determine the variables of interest to this study, opportunities for review decisions and the cost of making a decision. We control for task environments (4 types), and time units assigned (1 to 60 units). Through the simulation experiment, we examine the impact of opportunities for review and cost on organizational performance and their interrelationships.

RESULTS AND ANALYSIS

Overall Analysis

As discussed previously, there are debated propositions on the effect of opportunities for review and cost on organizational performance. In this paper, we examine those propositions using stepwise regression with the entry level and stay level set to 0.5 in SYSTAT (Macintosh version). The results are listed in Table 2.

As noted before, it is generally argued that organizations with more opportunities for review will tend to make better decisions and so exhibit higher performance than those organizations with fewer opportunities for review (Proposition 1). In contrast, to this expectation, we find that on average when across all conditions examined, the fewer opportunities for review the better the organization's performance. This suggests that overall, increased opportunities by an organization to review decisions do not increase organizational accuracy. There are several reasons for this. First, there is a training effect. Operationally trained agents do not benefit from review opportunities as they always take the most recent decision, with no consideration for previous experience. In this case, increased information loss over time serves to decrease accuracy. Experientially trained agents can integrate their decisions over time and so do not suffer from temporal information loss. However, experientially trained agents, are resistant in the face of new and contradictory information. Experientially trained agents, lock onto a decision and have difficulty changing it as new information is acquired. In this case, decreased information usage over time serves to decrease accuracy. Second this result controls for different levels of time pressure.

Table 2: A Regression Analysis for Trade-Offs

Variable	Coefficient
CONSTANT	107.305***
OPPORTUNITIES_FOR_REVIEW	-11.844***
ORGANIZATIONAL_COST	-0.667***
TIME_PRESSURE	-26.255***
TYPE_OF_TRAINING	-2.689
OPPORTUNITIES_FOR_REVIEW * TIME_PRESSURE	5.434***
OPPORTUNITIES_FOR_REVIEW * ORGANIZATIONAL_COST	0.096***
OPPORTUNITIES_FOR_REVIEW * TASK_ENVIRONMENT	0.443***
ORGANIZATIONAL_COST * TIME_PRESSURE	0.188***
OPPORTUNITIES_FOR_REVIEW * ORGANIZATIONAL_COST * TYPE_OF_TRAINING	0.047***
ORGANIZATIONAL_COST * TYPE_OF_TRAINING * TASK_ENVIRONMENT	-0.011
R^2	0.552

Note: In TYPE_ OF_TRAINING, 1 is for experientially trained organizations and 0 is for operationally trained organizations. TASK_ENVIRONMENT is in the order from simple to complex. n=720, *** p<0.001, ** p<0.01, * p<0.05

In fact, we find a positive interaction effect for opportunities for review and time pressure on performance. This suggests that when time pressure is high, the more opportunities the organization has to review its decisions the higher the organization's performance. This result suggests that the advantage of more opportunities for review can only be shown when the organization is tightly constrained by time pressure. This is also consistent with the findings from Lin and Carley (forthcoming) in which they found that the amount of information available does not necessary categorize a better decision. This supports Proposition 1 under high and medium level of time pressure. In other words, there is a short run effect — when the organization has little time to respond, any review is better than none. In the long run, as the time pressure decreases, opportunities for review increase, and the impact of information loss, and unused information increases.

There is also a positive interaction effect of opportunities for review and task environment. This suggests that when faced with complex task environment, more opportunities for review help organizational performance. This suggests that when organizations have to deal with complex problems, more opportunities for review will make sure that organizations can off-set the time loss incurred by the need to process complex information, thus helping them get better decisions. This supports

Proposition 1 under more complex task environments such as concentrated non-decomposable and dispersed non-decomposable ones.

Let us now consider the impact of cost. As we noted, the literature is somewhat ambiguous on the impact of cost. Some suggest that more costly organizational structures will fair better (Proposition 2a), while others opt for the less costly structures (Proposition 2b). Our results indicate that overall cost has a negative impact on organizational performance. That is, the higher the organizational cost the lower the organizational performance. Essentially, more costly organizations have more communication. This increase in communication both decreases the speed with which the organization can respond and increases the extent of information distortion, loss, and uncertainty absorption. In addition, more costly organizations have greater redundancy in access to information and resources. This redundancy also decreases the speed with which the organization can respond. These factors lower the performance of costly organizations. This result is consistent with Lin and Carley's finding (1992) that whether a more complex (and thus presumably a more costly) design is beneficial to organizational performance depends on the nature of the task environment.

There are other factors that can make costly organizations better performers. We find a positive interaction between cost and time pressure on organizational performance. This suggests that costly organizations that are also under more severe time pressure exhibit higher performance, which supports Proposition 2a. The rationale behind this finding can be that under time pressure, more complex organizations can often generate more information in the process of decision making, thus increasing the chance of a better assessment of information than simpler organizations when time constraint is severe and information is most valuable.

In addition, we find not only a positive two-way interaction effect between the opportunities to review decisions, cost on organizational performance, but also a positive three-way interaction among opportunities to review decisions, cost, and type of training on organizational performance. This suggests that for experientially trained, costly organizations, with more opportunities for review their decisions exhibit higher performance and that experientially trained agents will be biased toward their first decision. However, in a costly organization, it will take longer to make that decision in the first place. Since the environment is dynamic, the first decision will therefore be closer to the "correct final position" in the environment. In this case, having any opportunities for review will slightly overcome the bias (as it did under high time pressure).

DISCUSSION AND CONCLUSION

In this paper, we have focused on the relationship among opportunities for review, cost, and organizational performance. We have systematically examined some of the most debated trade-offs in the study of organizations. The analyses of the trade-off among cost, opportunities for review, and organizational performance show that more opportunities for review do not necessary help organizations make more accurate decisions except when organizations are under tight time constraints or are faced with complex task environments. More complex, and therefore, more costly organizations often do not make more accurate decisions. Our analyses suggest whether a complex or a simple organizational design can benefit organizational performance depends on other important factors such as type of task environment, level of time pressure, and type of training as well and that organizations should spend scarce resources on mitigating the adverse impact of time pressure and task environment rather than on more complex organizational designs.

There are also limitations in this study. First, when we examine opportunities for review by organizations, we only look at the number of intermediate decisions made by the top-level manager. We do not count all the intermediate decisions made by other members of the organization. In the future research, it may be interesting to see the impact of the total sum of all the members' intermediate decisions on the organizational performance. Second, when we consider organizational cost, we only consider organizational structure and resource access structure, but not the decision making procedure due to training. In the future research, we wish to consider cost from other perspectives.

There are many important policy implications that can be drawn from this study. First, our results point out that organizations should be careful not to spend too many resources on designing more complex and so costly organizations. Whether a complex design is beneficial to organizational performance depends on other important factors such as type of task environment, level of time pressure, and type of training. Second, our results support the notion that opportunities for review and quantity of information do not necessarily characterize organizational performance (Feldman and March 1981). Organizations should counter the adverse impact of task environment and time pressure first. Third, our results advocate a systematic examination of organizational performance, by explicitly listing the specific conditions for each relationship to exist. This goes beyond studies by traditional contingency theorists.

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