AUTOMATIC RESTRUCTURING OF THE C2 STRUCTURE AND PERFORMANCE

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Abstract

Organizations often alter their organizational design, specifically their C2 structure, in response to their performance. For example, when an organization is doing well it may expand and take on new personnel. In contrast, downsizing may occur when an organization's performance is compromised. At issue, however, is whether such restructuring actually improves the organization's performance. This question is addressed using a computational model of organizational behavior. A series of simulations in which the organization's rate of response to changes in its' performance, and the likelihood of moving different personnel are altered. It is found that the slower the rate of change the higher the organization's performance due to greater opportunities for learning on the part of individuals. Further, strategies for change involving either staff or executive succession tend to result in better organizational performance than a strategy requiring change in middle management.

1. Introduction

Organizational theorists have long suggested that, although their is no one right organizational design overall, there are right designs for specific environments. Organizations who match their structure to their environment will exhibit better performance than those who do not [Thompson, 1967]. Further, over time organizations will evolve those structures best suited to their environments [Hannan and Freeman, 1977]. However, the form of that structure is an empirical question. On the one hand, theorists have argued that organizations when faced with decrease in their performance will shift to a more rigid and centralized structure [Staw, Sanderlands, and Dutton, 1981]. On the other hand, a volatile environment may be the source of the decrease in performance. And, theorists have argued that if the environment is volatile then the organization should maintain a highly flexible structure, one that can be rapidly adjusted as the environment changes [Thompson, 1967; Mintzberg, 1979]. At issue then, is whether organizations that adapt over time to changes in performance can evolve a structure highly suited to that environment. A secondary issue is whether the evolved structure will be a rigid or flexible structure.

In this paper, I examine whether organizations that automatically restructure in response to changes in their performance evolve a structure that is better suited to their environment. Using a computational model of organizational behavior a series of simulations are run in which the rate of response to changes in performance, and

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organizational performance increases does organizational performance improve or degrade. Second, what strategy for altering the organization's structure leads to better performance and more or less rigid structures. These strategies vary in terms of whether the organization is most likely to make personnel changes at the top, middle or bottom of the organizational ladder.

2. Organizational Structure

The aspect of organizational design of concern herein is structure. Structure is the number of personnel and the command/information linkages between them. Illustrative structures are the team with manager and the simple hierarchy. In the team with manager structure, communication links are predominantly lateral. There is a commander or supervisor who is responsible for making final decisions. In the hierarchy structure, communication is predominantly vertical, going between organizational levels. There is no overlap in the chains of command in this structure.

Herein the organization's structure is allowed to evolve over time by moving personnel into or out of slots and adding or dropping connections. Thus a large number of structures are possible. Rather than list all possible structures, the constraints on these structures will be listed.

All organizational structures must fit within the following constraints. There can be a maximum of three levels — top (or executive), middle, and bottom (or staff). Information flows from bottom to top, Only agents at the bottom can access information on the aspects of the problem. Agents at the bottom or top can only access the recommendations of the individuals one level down. At each level there can be a maximum of nine agents.

2.1 Organizational Performance

The organization faces a sequence of 18,500 problems. These problems are drawn randomly with replacement from the set of possible problems. For each problem the organization makes a decision. This decision is then compared with the "right" decision. Performance is measured as the percentage of problems seen for which the organization made the correct decision.

3. Restructuring

For the first 500 of these 18,500 problems the organization is in training. That is, during these first 500 no restructuring occurs. All agents start building a set of memories.

The remaining problems are divided up into a set of observation windows. A window is 100 problems long. At the end of each window performance since the last window is calculated. If performance has dropped or increased by a value greater than x then restructuring may occur. The x is a value between 0 and 100 representing the number of percentage points needed for a noticeable difference. In this paper, five values of x are examined 0, 1, 5 and 10. Given that a noticeable drop or increase in performance has occurred, whether an agent is moved in/hired or moved out/fired and whom depends on the restructuring strategy. If there is a change in the number of agents then no change in the organizational structure is made for another 500 problems. Thus, with 18,500 problems the maximum possible number of changes in the organizational structure is 30.

Three restructuring strategies are examined: executive change, mid-level management change, and staff change. Restructuring strategies are defined by setting the probability that change will occur at that level given that a noticeable difference has occurred. The three strategies mentioned correspond to the following distribution of probabilities:

	top	mid	bottom
executive change	.6	.3	.1
mid-level change	.2	.5	.3
staff change	.2	.3	.5

In all cases, if performance has dropped noticeably then an agent is likely to be moved out/fired. In all cases, if performance has increased noticeably then an agent is likely to be moved in/hired. If an agent is to be moved out then at the chosen level the agent moved out is that which is exhibiting the lowest performance. If an agent is to be moved in then at the chosen level the agent who is moved in is given as its task one of the agents or pieces of information currently reporting to or analyzed by the best performing agent at that level. These procedures result in organizations maintaining there best performers. If the level of noticeable difference is set to zero then if the change in performance is zero the organization is as likely to hire as to fire.

4. Other Model Features

4.1 Task

The task used is the stylized radar task, also referred to as the pattern matching and limited choice task A version of this task was previously used by Carley and Lin (1994). In detection terms, the task is to determine for each problem, whether that problem represents a friendly, neutral, or hostile aircraft on the basis of nine aspects. Each aspect, such as speed, can take on a low, medium, or high value. Since a problem is characterized by nine aspects each of which can take on three values there are a total of 19683 unique problems. For a particular problem the "right" decision is defined as follows: First find the product of the values for all nine aspects. This results in a value between nine and 3^9. If this value is less than 109 then the correct decision is defined to be one. If this value is greater than 432 then the correct decision is defined to be three. In all other cases the correct decision is defined to be two.

The relationship of the values for all aspects to the right decision is initially unknown by all agents in the organization and must be learned over time.

4.2 Agents

All agents are experientially trained. That is, each agent makes his or her decision on the basis of what information the agent has learned in the past. Each agent has a partial memory of the patterns of incoming information and correct decisions that he or she has seen in the past. This memory is partial in that the agent only remembers the information learned initially (first 500 problems) and most recently (last 200 problems). Further, the agent remembers only frequencies and not specific events.

Each agent sees between zero and nine pieces of information. How many pieces of information are seen depends on the organizational structure. The number of pieces of information known is equal to the number of aspects of the problem to which the agent has direct access (bottom level) or the number of other agents who report to him or her (top or middle level). The number of patterns of incoming information seen by an agent in 3^N where N us the number of pieces of information seen by the agent. The larger N the longer it takes the individual to learn.

4.3 Organizational Decision

Who makes the organizational decision depends on the structure. If there is only one agent at the top then that agent's decision is the organization's decision. If there are multiple agents at the top then the organizational decision is the majority consensus of these agents. If there are no agents at the top then the organizational decision is made at the middle level. In this case, if there is only one agent in the middle then that agent's decision is the organization's decision. If

there are multiple agents in the middle then the organizational decision is the majority consensus of these agents. If there are no agents at either the top or the middle then the decision passes to the bottom level (the analysts). If there is no clear majority then decision of an agent who is not in the minority is randomly chosen to be the organization's decision.

4.4 Initial Conditions

Initially all organizations are simple hierarchies with nine at the bottom, three in the middle, and one at the top. Each agent at the bottom reports to only one mid-level agent. Each mid-level agent has exactly three subordinates. Each agent at the bottom initially gathers information on only one aspect of the overall problem (this is known as a segregated resource access structure, Carley and Lin, forthcoming). All agents begin knowing nothing and build up their patterns over time. Agents when they have no information to go on, make their decisions by guessing. Given this initial configuration, no agent in the organization, at least initially, has enough information to make the decision completely unassisted.

4.5 Veridicality

Computational models similar to the one used herein have been shown to provide a reasonably accurate portrayal of the relationship between organizational design and performance [Carley, 1992; Carley and Lin, forthcoming]. In particular, Carley and Lin [1994] demonstrated a strong fit between a , static version of this model and the restructuring behavior of 69 organizations faced with crises.

5. Simulation Experiment

Using this computational model a series of organizations were simulated. These organizations varied in the strategy used for moving agents in to and out of the organization (three strategies). These organizations also varied in the level of noticeable difference that they required before they would respond to the environment (four levels). This led to 12 different organizations. Each organization was simulated 20 times for 18500 problems. In addition an organization in which there were no changes in personnel was simulated 80 times.

6. Impact of Rate of Response

The rate of response to the environment increases as the level at which an organization responds to variations in its performance decreases. To begin with, if the organization did not respond at all its performance was 60.34. Any response, regardless of strategy or level of noticeable difference responded to resulted in lower average and final performance. In addition, we see that as the level of noticeable difference to which the organization responds increases the number of agents hired and fired decreases (see Table 1).

Table 1: Average Number of Moves In and Out by Level of Noticeable Difference

In Difference	exec	mid	staff
0	11.87	3.07	1.10
1	10.87	3.78	1.15
5	9.20	2.73	1.08
10	4.93	1.23	0.43
Out Difference	**exec**	**mid**	**staff**
0	8.90	2.90	2.55
1	7.72	3.03	2.72
5	6.17	2.28	2.08
10	3.05	1.05	1.18

N per cell is 60

The higher the difference the less likely it is to occur. Agents at the top and in the middle are more likely to be hired or moved into the organization than fired or moved out; whereas, agents at the bottom are more likely to be moved out

than in. This difference is basically due to a combination of two factors: the fact that all organizations began initially as hierarchies that were heavier at the bottom (more staff than mid-level or executive personnel) and the constraint that there could be a maximum of nine agents at any level. Given these two constraints, initially, organizations who want to move in staff can't as all positions are filled.

Even though the number of moves in or out increases as the level of difference responded to decreases the ratio of hires to fires actually decreases. In Figure 1, it can be seen that as the level of noticeable difference increases so does the ratio of moves in to moves out. This is because the slower the organization responds the more it learns. Thus on average its performance improves over time.

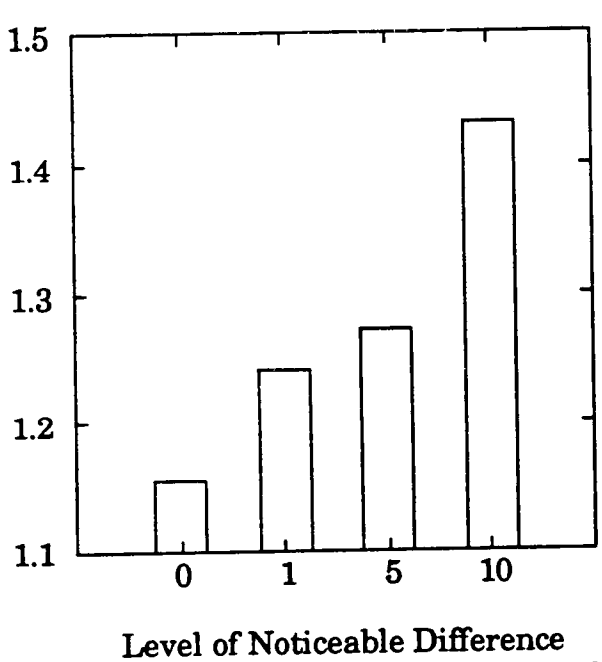

Figure 1. Impact of Level of Noticeable Difference on Change

A result of all this change is that the organizational structures tend to grow (see Table 2). Interestingly, a slower rate of response (higher level of noticeable difference) results in a slightly less top-heavy organization.

Table 2: Average Number of Agents in Final Structure by Noticeable Difference

Difference	exec	mid	staff
0	3.33	3.17	7.55
1	3.52	3.60	7.73
5	3.20	3.38	8.00
10	2.77	3.15	8.25

N per cell is 60

One aspect of flexibility is the ability to respond rapidly to the environment. Organizations which respond to smaller variations in performance are in this sense more flexible. As can be seen in Figure 2, such flexibility is not beneficial to the organization. That is performance increases the slower the rate of response (the higher the level of the noticeable difference).

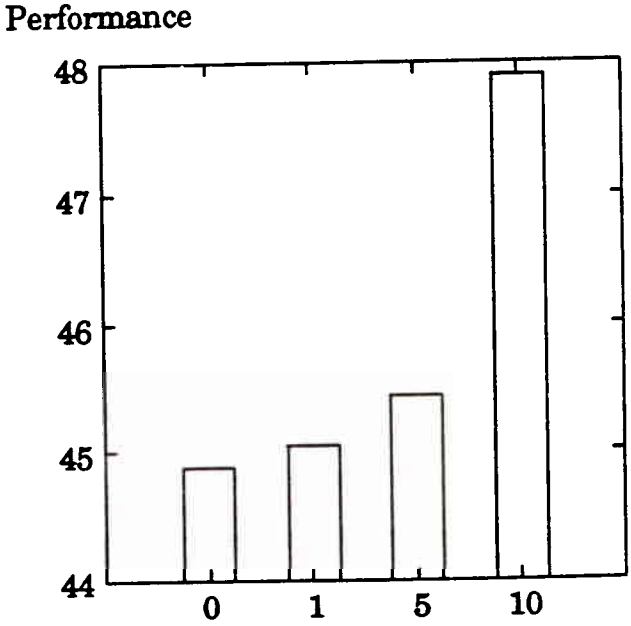

Figure 2. Impact of Level of Noticeable Difference on Performance

7. Impact of Strategy

The three strategies differ in whether there is a stronger tendency toward

executive, mid-level, or staff succession. Regardless of which strategy is followed the highest number of changes occurs at the executive level and the fewest at the staff level. For personnel moving into the organization this is a reflection of the fact that in the initial organization the number of agents decreases as one goes up the ladder. However, for personnel moving out of the organization, when a strategy of predominant staff change the lowest level of change occurs at the mid-level.

Table 3: Average Number of Moves In and Out by Strategy

In Strategy	exec	mid	staff
executive	10.93	2.45	0.16
mid-level	8.46	3.61	0.96
staff	8.26	2.05	1.93
Out Strategy	**exec**	**mid**	**staff**
executive	8.11	1.99	0.65
mid-level	5.50	3.05	2.08
staff	5.76	1.91	3.68

N per cell is 80

Regardless of the strategy. there are on average more hires than fires. Moreover, as the location of predominant change in the strategy moves up the corporate ladder the ratio of agents moving in to those moving out increases (see Figure 3). A strategy of executive session results in, basically, larger organizations. The larger size, however, is mainly in the lower rungs of the organizational level (see Table 4)

Table 4: Average Number of Agents in Final Structure by Strategy

Difference	exec	mid	staff
executive	3.23	3.45	8.51
mid-level	3.15	3.43	7.89
staff	3.24	3.10	7.25

N per cell is 80

Another aspect of flexibility is the ability to alter the organizational structure. This statement has many interpretations. One interpretation is that organizations that change more personnel are more flexible. As we previously saw, as the threshold for a noticeable difference decreases the number of personnel changes increases an performance drops.

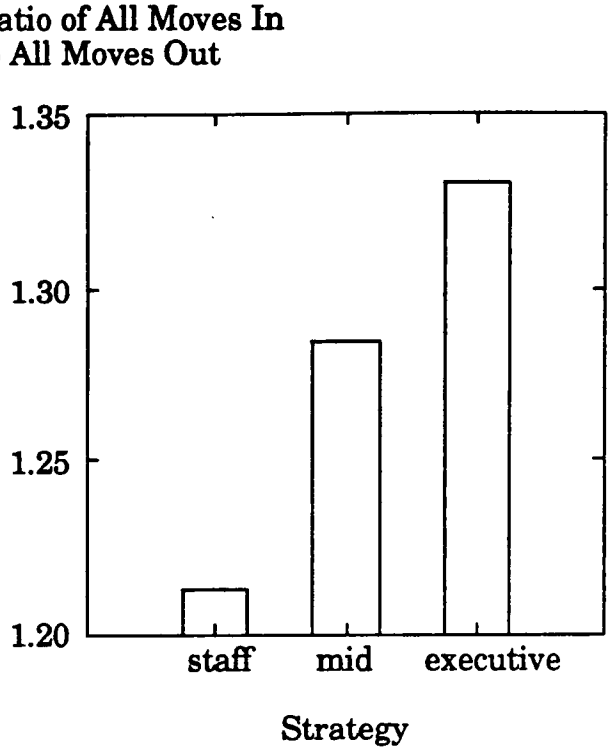

Figure 3. Impact of Strategy on Change

Another interpretation is that, organizations which are willing to change their upper levels might be considered more flexible. Here it is important to consider the strategy and flexibility should increases as we move from the staff to the mid-level to the executive change strategy. As can be seen in Figure 4, performance does not necessarily increase with increased flexibility. Although performance is high when an executive change strategy is used it is higher when a staff change strategy is used. The reason for this is simple. All organizations begin as bottom heavy. Initially they cannot move in new analysts. Since performance for all organizations is on average increasing all organizations would rather move

personnel in than out. However, when a staff change strategy is used that movement should occur at the staff level, but it cannot. Consequently, under a staff change strategy organizations are slightly more likely to remain unaltered. This lack of change results in better individual learning and consequently better organizational performance.

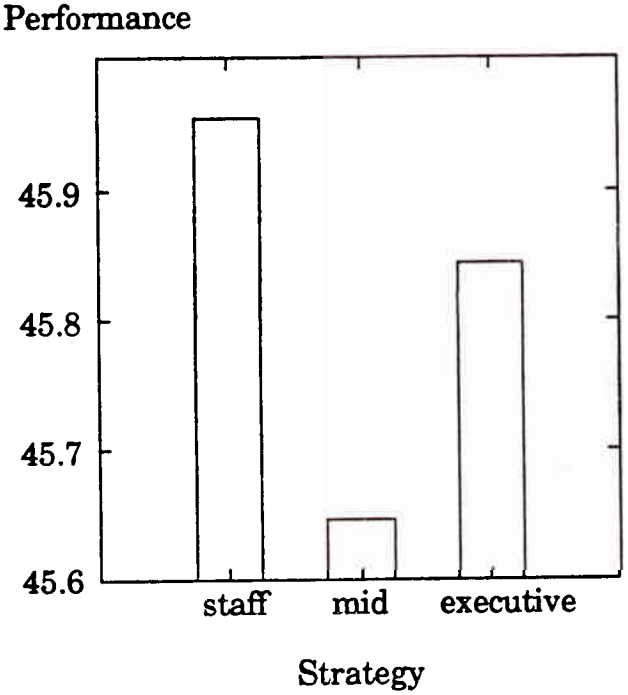

Figure 4. Impact of Strategy on Performance

8. Evolved Structures

As individuals move in to and out of organizations the structure changes. Thus far we have talked about conditions that lead to better or worse performance. Now let us consider what structures actually evolve. There are a huge number of possible structures, thus simply enumerating how many of each evolve provides little information. Rather we can characterize the common organizational form that evolves. For example, on average all final structures have 3 executives, 3 agents in the middle, and 8 staff members. But what are the connections between these?

To determine the connections between agents and the common structural form that emerges we use the central graph procedure [Banks and Carley, 1994]. Given a set of graphs (binary matrices) this procedure locates the central graph, that graph such that each connection in it occurs in 50% or more of the individual level graphs.

The central graph was calculated for each type of organization given those 20 structures that emerged at the end of the 18500 problems. These are shown in Figure 5. There are several things to notice.

First, all of the central graphs are smaller than one might expect given just the average number of agents at each level. In other words, although the average structure has more agents there is little agreement as to how to use the additional agents (one or two at the top level, one or two at the mid level, and two to eight at the bottom level). However, there is a "core" structure that is common. It is these core structures that appear in Figure 5. Most core structures are hierarchical regardless of the level of noticeable difference or the strategy used for change. This suggests that hierarchical forms are robust in the face of change.

Second, most of the evolved structures have a "small" middle. That is, there are few mid-level managers and those that remain in the organization tend to evolve to having a larger cache of subordinates. This suggests that organizations may be able to improve their performance by maintaining a small mid level.

Third, given that the organization is responding to the environment (and not just randomly as when the level of noticeable difference is 0) the slower the response the larger the common structure. In this case, the slower rate of evolution has the side effect that the emergent structures are more similar.

9. Conclusion

In this paper, the impact of automatically restructuring the organization's structure on its performance is explored. It is found that the smaller the change in the organization's performance to which the organization responds the lower the

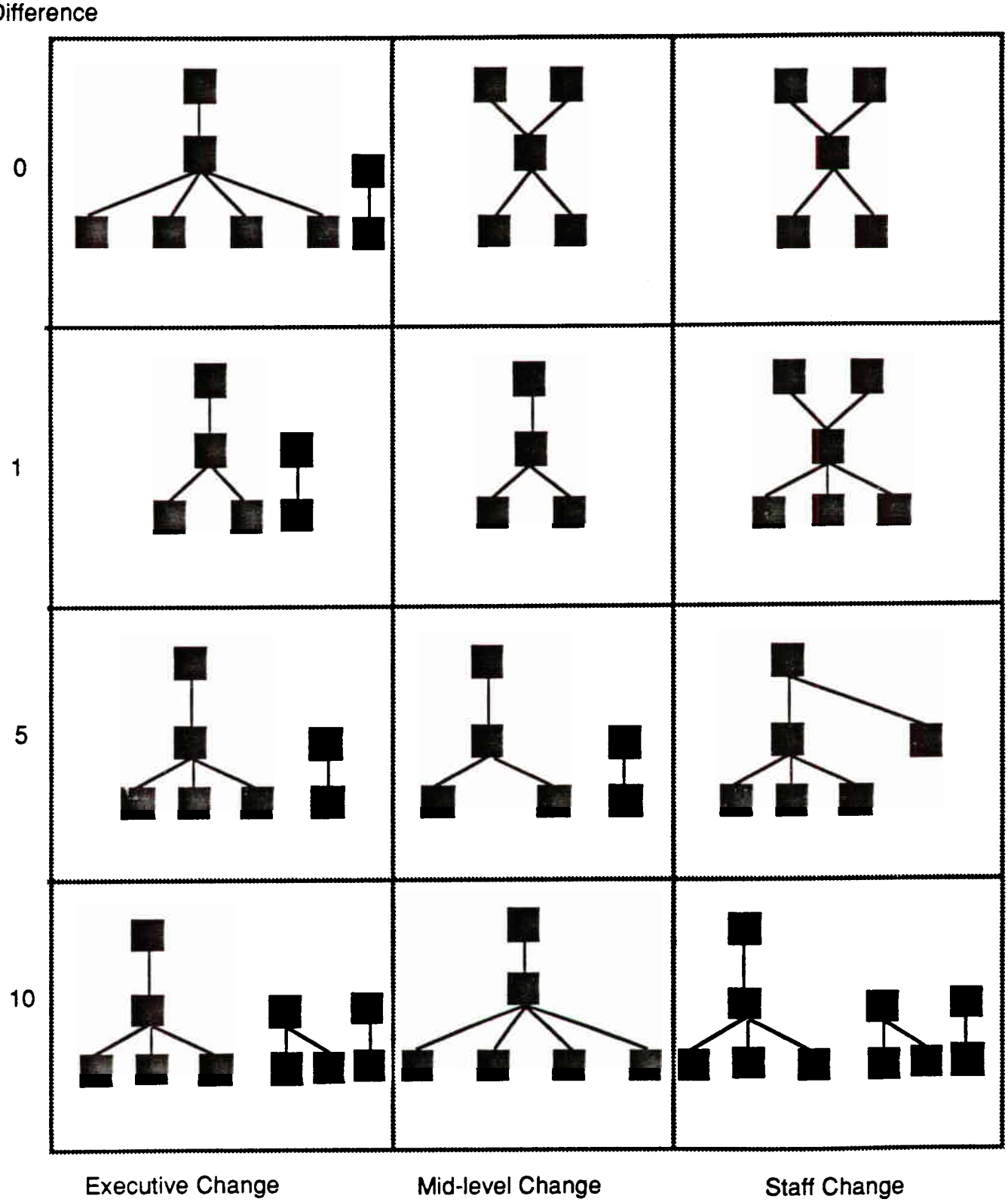

Figure 5. Organizational Structures that Evolve After 18000 Problems.

organization's performance. Further, strategies for change involving either staff or executive succession tend to result in better organizational performance than a strategy requiring change in middle management. Flexibility, in these two senses, does not improve performance. It is also found that the structure that evolves tends to have multiple executives and one of those executives tends to coordinate a lean division.

Methodologically, two issues are raised. First, examining organizational change over time requires having a model not only of the organization but also of the processes in the organization that admit change. To this end, the model used herein allows the researcher to examine the impact of a variety of processes. Second, in order to determine what structures evolve it is necessary to have a technique for locating common emergent structures. In this paper, a procedure based on the central graph technique was used. The central graph procedure is designed for networks with labeled nodes. In this case, the nodes are not labeled but they do fall into categories. Thus the central graph procedure was adjusted by first reordering agents at each level according to presence and then locating the central graph. While this increases the likelihood of finding the central graph, there are still misalignments in the nodes that need to be overcome. Future work should explore how best to locate common structures given a set of graphs with categorical or "colored" nodes.

Theoretically, this research demonstrates that organizational strategies for change can have profound and to an extent non-intuitive impacts on organizational performance. We saw that fine tuning, in the sense of altering the organizational structure in response to minor shifts in performance tends to limit organizational performance. Further we saw that succession among staff resulted in organizational downsizing at the staff level and upsizing at the executive level. In fact, regardless of the strategy employed we find an increase in organizational size and an increase in agent-to-agent links. It is interesting to note that in empirical studies of organizations often respond to stress by increasing the number of links among agents [La Porte and Consolini, 1991; Krackhardt and Stern, 1988]. And we saw a greater impact due to the rate at which the organization responded than the strategy it employed. Future work might consider alternate strategies.

These finding should be viewed as illustrative. That is, to generate these results each organization was only simulated 20 times. A full Monte Carlo analysis would have required on the order of 100 resimulations. Second, with respect to each strategy whether slight variations in the strategies would alter the results is unknown. Future research should examine these issues.

The importance of this study lies not so much in the specific findings as in pointing the way to examine the issue of organizational evolution. Using the model and approach outlined herein other evolutionary issues can be examined. For example, one could examine whether responding after fewer decision cycles affects performance differently than responding to smaller differences in performance. Or one could examine the impact of downsizing occurring more frequently than upsizing. This approach does show that these issues are at least approachable with a process based model. And, this approach demonstrates that automatic restructuring does not guarantee better

performance and in fact, doing nothing may result in better overall performance.

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