A Simulation Analysis for Renovation of the Hierarchical Structure

Michiya Morita and Nobuhide Tanaka
Gakushuin University, Faculty of Economics
1-5-1 Mejiro, Toshima-ku, Tokyo 171, Japan

ABSTRACT

The hierarchical structure of pyramidal shape which is adopted by most of relatively large organizations is now the target of renovation to raise the capability of adaptation in changing environments. The objective of this study is to obtain relevant insights for redesigning the structure. A simulation analysis is tried to investigate information processing properties that determine to a great extent the effectiveness of the organization. Several derivatives of the hierarchical structure, which are realistically likely candidates from which appropriate choices would be made, are the targets of the analysis. A set of implications will be provided as the results of the analysis.

Introduction

The hierarchical structure of pyramidal shape, including its derivatives, is the most common type of information networks. The structure is considered as a typical one of mal-adaptation to rapidly changing environments. The structure, however, that are actually adopted even after a lengthy analysis, are modified versions rather than completely different ones. For example, simplification of upper management, diminishing the number of tires of management levels, adding or deleting authority and responsibility, etc.. As long as the organization consists of many people with different values and expectations of it, we are hardly able to escape from the hierarchical structure.

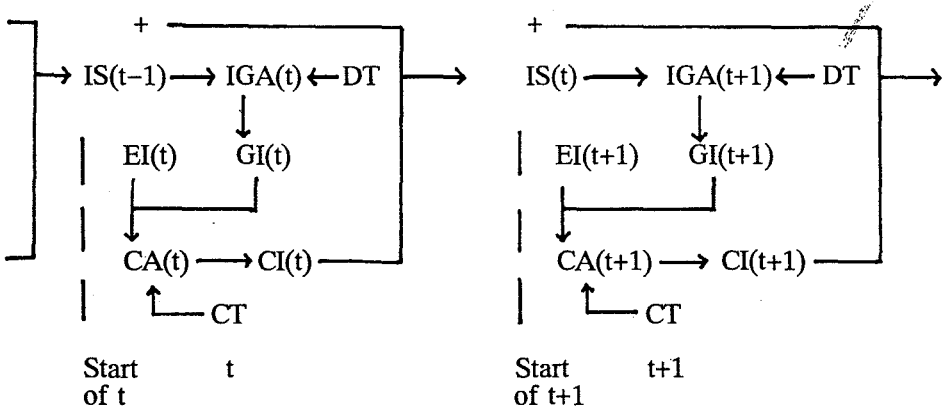
The objective of this research are to inquire into properties of the hierarchical structure including its derivatives in terms of information processing in order to obtain meaningful implications for renovation of the organizational structure. The effectiveness of the organization to survive and grow continuously must be a function of numerous factors. We pay attention to the information processing aspect which is one of the most important basic processes, based on which most of actual and effective actions are created and executed. The aspects of information processing we are interested in are the creation of ideas and the implementation of them. Both aspects are indispensable and also complementary for the organization to achieve its effectiveness. Activities that underlie the aspects are communication and formation of information stock at individual level. The communication activity contributes to exchanges of information among members, augmentation of information stock and promotion of mutual understanding.

The formation of information stock can be expected to provide with good chance of creation of good ideas given member's ability and time. The mutual understanding among members can give birth to common threads and strengthen the centripetal force that is needed for implementation of ideas. We assume the effectiveness performance of the

organization is the product of the performance of creating good ideas and decisions and the performance of attaining the centripetal force. Information processing properties that are brought about by structural factors attached to each structural type determine the effectiveness performance of the organization by way of their effects on the aspects.

The information processing in the model

The basic process of information processing activities in the model consists of communication and information generation as shown in Fig.1. The communication activity is to share members' information stocks that exist in the form of internal and external information storages each of which is exclusively available to the member as its owner with each other through communication channels formally set among the members. The information generation activity of each member is to create new information from his own information stock that is formed by the summation of his information stock at previous period, newly acquired information through channels outside of formal ones and communicated information as the result of the communication activity at previous period.



Note: IS:Information Stock, IGA:Information Generation Activity, DT:Time for Information Generation, EI:Exogenous Information, GI:Generated Information, CA:Communication Activity, CI:Communicated Information, CT :Time for Communication

Fig 1. The Basic Process of Information Processing in the Model

(1) Communication process

Total time for the information processing, which is defined as H in an unit interval of the simulation is divided into two parts, the time for information generation and the time for communication. Letting AT a portion of time usable for communication, CT=H× AT and DT=H−CT. Henceforth we assume a term of i's "neighbor" means a member with whom member i has a formal communication channel. We introduce a rule for determination of the actual communication time between i and j, CT(i,j). It says that CT(i,j) = min [ACT(i,j) , ACT(j,i)]. ACT(i,j) is the available time member i can use for communication with member j. ACT(i,j) is determined by the number of neighbors of

member i as in (1) below.

$$ACT(i,j)=H\times AT(1/N_i) \qquad (1)$$

N_i is the number of member i's neighbors. Therefore if the number of member i's neighbors is larger than member j's, then member j can't use his total communication time H×AT completely. The time unused is turned into the information generation time.

Each member exchanges his newly generated and exogenously obtained information at t−1 with his neighbors at t. As the result of it, the total information stock of member i at t is calculated by the following formula.

$$IS_i(t)=IS_i(t-1)+\sum_{j\in NS_i} B_{ij}\,GI_j(t-1)+\sum_{j\in NS_i} B_{ij}\,EI_j(t-1) \qquad (2)$$

where B_{ij} = rCT(i,j) for i≠ j and B_{ij} =1 for i=j.

IS_i (t)	: information stock of member i at t
GI_j (t)	: generated information of member j at t
EI_j (t)	: exogenously obtained information of member j at t
B_{ij}	: effective transfer coefficient
r	: communication loss factor
CT(i,j)	: actually used communication time between members i and j
NS_i	: set of neighbors of member i

(2) Performance functions

We define the two sub−performances, creativity of ideas or decisions and centripetal force. The total performance of effectiveness is the product of the two performances.

[Performance of creativity]

This performance measures the degree of organizational potentiality of bearing creative ideas or decisions. We assume that it is an aggregate of members' ones.Each member's potentiality is assumed to be defined as follows.

$$dX_i/dDT = mX_i(kIS_i(t)^h - X_i), \quad X_i = 0 \text{ if } DT = 0 \qquad (3)$$

where,

X_i	: member i's potentiality measure
DT	: decision time for generating ideas
m	: factor of learning (constant over simulation period)
h	: information stock elasticity of upper bound of potentiality
k	: upper bound of Xi when upper bound is independent of the information stock. The total creativity potentiality of the organization is defined as follows.

$$QP = aX_1^{b1}X_2^{b2}X_3^{b3}\cdots\cdots X_n^{bn} \qquad (4)$$

where,

QP	: creativity potential performance
bi	: member i's elasticity of total potentiality. Here 1=b1+b2+. . . +bn
a	: total potentiality if total potentiality is independent of members' ones

[Performance of centripetal force]

This measurement means how much members are ready to cooperate each other to implement the ideas generated and adopted. In other words it is the degree of concentration of the organization to implement the organizationally adopted ideas. This

is a function of the degree of communication which can be measured by how much members can communicate with other members. Then it's formulated as follows.

$$CP = dY_1^{u1}Y_2^{u2}Y_3^{u3} \cdots\cdots Y_n^{un} \qquad (5)$$

where,

CP : centripetal force performance
Y_i : amount of information obtained through communication of member i at t
ui : member i's elasticity of centripetal force. Here 1=u1+u2+. . . +un
d : total centripetal force if centripetal force is independent of members' communication

[Total performance]

This is the product of QP and CP, and is shown below.

$$TP = gQP^{v1}CP^{v2} \qquad (6)$$

where, v1+v2=1 and,

TP : total performance of the organization, that is, effectiveness
v1 : creativity potential performance elasticity of organizational performance
v2 : centripetal force performance elasticity of organizational performance
g : total performance determined only by uncontrollable environmental factors

(3) Information generation process

Each member generates new information based on his or her information stock at t−1. The amount of information generated by member i, GI i , is defined as follows.

$$GI_i(t) = L / [1 + (L-1)\exp(-wIS(t))] - 1 \qquad (7)$$

(7) is the solution of the differential equation of the form of;

$$dGI_i(t)/dIS_i(t) = wGI_i(t)[L - GI_i(t)] \qquad (8)$$

where, $GI_i(t) = 0$ if $IS_i(t) = 0$, and,

L : upper limit of the amount of information to be generated (constant)
w : efficiency coefficient of generating information (constant)

The analysis

The structures picked up are shown in Fig.2., all of which can be considered as a family of the hierarchical structure and also are likely ones in the real world. The number of members is 15.

The analysis consists of the following three cases.

Case 1: V1=V2=0.5. All bi and ui are uniformly equal

Case 2: V1=0.25 and V2=0.75. All bi and ui are uniformly equal

Case 3: V1=0.75 and V2=0.25. All bi and ui are uniformly equal

Case 4: V1=V2=0.50. All bi are uniformly equal. ui is 0.2 for top, their total is 0.595 for the middle management and all are equal for them and the total is 0.21 for the lowest and all are uniformly equal for them.

Case 1 is the standard case and case 2 and 3 include the intention to change environmental conditions. Case 4 is designed to make a sensitivity analysis on the role of management in achieving the centripetal force. There must be more interesting cases including the feedback mechanism of changing controllable variables such as CT or DT according the effectiveness performance achieved that is to analyses the properties of the

structures with more dynamic or behavioral responses. All of these are left to be tried in the near future. The results of the analysis cases are summarized in Table 1 to 3.

Summary of the results

Table 1. shows the performances according to AT. The standard structure is superior to the others when the environment is stable (smaller V1) and the time communicable decreases (smaller AT). The gap of the size of information stock between the maximum and the minimum holders. It means that the total information stock becomes larger than those of the others. Taller structures makes it possible for the lowest members to open the channels with their bosses (the second middle) while the first middle communicates with the top.

The two sub-performances behave differently according to the structures. The creativity performance is generally raised in the flatter organizations as expected while the centripetal force performance is lower. The most extreme one is the star structure. The flatter structures show the better performance of QP. On the contrary CP is generally poor. The horizontal channels (the H.Channels structure) have the same effect as shortening the height, but the degree of the effect is moderate.

Changing the elasticities of the upper management members upward has the favorable effect to the flatter structures. This result is easily expected if considering the properties of the structures above mentioned.

The actual communication time ratio in the organization(Communica. TS) does not increase in proportion to the increase of the available communication time (AT). Especially those of the flatter structures respond rather slowly. It means that the middle is too busy to respond to communication partners' enlarged communication opportunities due to the abundance of formal channels.

Summary results we have obtained from this analysis are as follows.

(1) Middle management is most informational.

Middle management tends to form the largest information stock in the hierarchical structure except the star structure with no middle management. Their information stocks are larger than that of top management and the less the number of them, the more the gap. This happens because they intermediate communication and cope with many communication partners. The more they are responsible for communication through formal channels set organizationally, the more the amount of information attained. Therefore as the communication time increases, the gap expands and middle managers become more influential.

The gap of the information stock size between the middle and others increases as the middle management decreases in the number and the structure turns into a simple and less tiers one. If the middle managers are put on the load of communication between them like the structure of H.Channels, it only makes them too busy to form the information stock and promote the centripetal force in the organization. It is behind the standard one without horizontal channels.

(2) Top management comes short of its assumed informative position.

Top management's power in terms of the information stock changes depending on the degree of communication within the organization. If it increases, the power of the top management declines to be behind the lowest level, except the star structure. If the middle management increases its power, the top tends to lose the power in contrast. Therefore the conditions that increase the power of the middle management will reduce the power of the top management. The decrease of communication time and also the reduction of the number of the middle managers bring about the erosion of the power of the top management. Cutting the middle managers is most effective to give a rise to the strengthening of the top management like the star structure.

(3) The performance depends on environmental conditions.

The organizational performance generally depends on the environmental condition determining the degree of effectiveness of the two sub-performances, the degree of creativity of decisions and the magnitude of centripetal force. As the environment becomes more changeable and creative decisions are more effective, the structure which strengthens the former performance will attain better performance,

It depends on how much each structure allocates time into communication and decision-making and also how much each allocated time contributes to the sub-performances. The communication time contributes to the quality performance by way of forming the information stock and also to the centripetal performance by way of the amount of information communicated. The decision time increases the quality performance by way of the deepness of analysis and consideration. Marginal effects of the times on the performances subject to the constraint of the total time which is the summation of the communication time and the decision time are critical factors to make the comparative evaluation of the structures.

The structures with less and simple middle management tend to reduce the communication time provided that the same communication ratio is given. It implies that under the structures the middle management has more communication partners and the communication time available for each member except the middle managers shortens. Therefore if the decision time is more effective to improvement of the creativity of decisions and the environment also imposes decision problems that requires higher creativity, the structures can show better performance as in our results. The middle slim structures(3H3M and 3H2M) and the star structure improve their performances enormously because they raise the quality of decisions under the environment of changes.

(4) The degree of effectiveness of members on the performances changes the organizational performance.

If the degree of contribution of each member to the sub-performances, the creativity and the centripetal force, differs, the organizational performance can be variable and the ranking of the structures in terms of the performance may change. For example, if the upper management including the top raises its share of contribution to the centripetal force performance as usual, the structures with less and simple middle management show much improvement to be superior to the standard structure regardless of the environmental condition because under them the middle management's information stock becomes larger than the standard structure.

Conclusions

As environmental conditions of the firm or organization become turmoil and require more responsive attitudes, they start to improve or change their traditional structures. The structure that is always under the pressure of reformation is a so-called pyramidal or hierarchical one. It is a symbol of dulness. Though the trend is toward the abandonment of the structure, we could not escape from them completely. As long as we need a system of cooperation to achieve a significant or big goal and concentrate their cooperative efforts on the accomplishment, a kind of hierarchy is indispensable to maintain the order desirable. In most of cases our reformation efforts will remain in the neighborhood of the traditional hierarchical structure.

We tend to talk about the reformation in terms of flatness or tallness, the number of channels permitted between members, the degree of responsibility and freedom of decision-makings, etc.. But we need to add the concept of rightness of persons designated as management. In a actual world, perhaps this is a more important factor than the structure itself. Therefore they think about it before the structural reformation. In effects we should differentiate the effectiveness of the structure into two parts, a part to be determined by the structure itself and a part possible to be realized by the personal ability. Ideal reformation turns to improvement of both parts. But first of all we need to check the properties of the structures and then make the right staffing.

In addition to the staffing, we should also take the environmental conditions into account. The properties of the structure may bring about different performances, depending on the environmental conditions which require different capabilities. Therefore in sum we have to take the two aspects into account, that is, the potential properties as the results of the interaction between the environmental conditions and the properties defined by the physical structure, and the right staffing amplifying or complementing the potential properties, in order to reconstruct the organization.

The prescriptions we have obtained are as follows, assuming we have the standard structure with 4 tiers and 5 middle managers.

(1) If the environment turns to require more creative or better quality of decisions for adaptation, we could rely on the middle-less and flatter structures. If we put more right persons on middle management, the effect could be magnified. Especially the star structure will need to have the brightest person who can exert himself for leadership, in order to avoid the problem of weaker centripetal force of the organization.

(2) Top management should be able enough to cover the poor information feedback. He tends to be isolated from communication in the hierarchical structure of multi-echelons. Therefore the person who can cover the weakness by himself with the brightest mind or can motivate effectively his men toward the goal of the organization with minimum face-to-face communication.

(3) If you want to strengthen the centripetal force of the organization in the structures with less and simple but powerful middle management, the information exchange like meeting is desirable. Increasing communication channels for a member strengthens his

position with others being fixed because only his information stock increases while actual communication time of his communication partners decreases. Then decreasing the number of middle management and flattening means the dramatic increase of importance of middle management's position in the organization accompanying an impediment to the centripetal force. The meeting type communication where relevant members can get together at a time, can use time more effectively for communication.

(4) Informal communication channels are expected to be more effective than increasing formal channels. The increase of formal channels tends to make relevant members busier due to the automatic increase of formal reporting duties. Then the actual communicable time decreases for the unoccupied members who are excluded when a channel opens. Informal channels among the unoccupied members may promote communication as needed. It could be especially effective among the members at the same level. For example the star structure is the case. But the informal channels may distort the inherent properties that give the reason to adopt the structure due to the information promulgation.

(5) If the tasks the organization achieves are relatively mutually isolated and can be assigned to each member exclusively, or can be implemented in more decentralized ways, the centripetal force could be minimum. Then the flatter and middle-less structures could be promising alternatives.

Our analysis has been done under the dynamic framework of formation of the information stock and communication over time,which assumes the rules of them fixed.In the real world,however,most of organizations try to renovate or improve their performances by changing first of all their existing staffing and rules rather than structures.They try to make maximum use of their existing structures because of the difficulty to change structures.Therefore the analysis under the condition of the maximum use of structures is meaningful and desirable. The real evaluation of structural properties should reflect such a possibility of gradual improvement. It means that our analysis should be done introducing the self corrective feedback mechanism into the model. It will put the real dynamical character on the analysis. This will be one of the most highest priorities.

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Case / Indexes		Standard	3H3M	3H2M	Star	H. Channels
AT=0.3[1]	QP[2]	94.1	100.0*	97.4	88.8	93.1
	CP[3]	25.1	14.4	8.8	3.7	20.9
V1=0.25[4]	TQ[5]	51.6	34.5	23.8	12.2	45.0
V1=0.50	TQ	71.8	56.1	43.3	27.1	65.3
V1=0.75	TQ	100.0**	90.9	78.9	59.5	94.7
AT=0.5	QP	44.0	69.5	81.6	81.8	46.8
	CP	31.7	18.1	10.9	4.6	26.4
V1=0.25	TQ	50.9	37.5	26.7	14.1	45.0
V1=0.50	TQ	55.2	52.4	44.2	29.1	51.9
V1=0.75	TQ	59.9	73.4	73.0	60.2	59.9
AT=0.7	QP	13.7	35.0	51.1	67.3	16.2
	CP	29.7	16.6	9.8	4.0	24.5
V1=0.25	TQ	36.1	29.2	21.8	11.9	32.7
V1=0.50	TQ	29.8	34.8	33.1	24.2	29.5
V1=0.75	TQ	24.5	41.4	50.0	49.2	26.5

Note: (1)Ratio of maximum time for communication to total available time,%, (2) Quality or creativity of decisions,(3)Magnitude of centripetal force,(4)Elasticity of creativity of decisions,(5)Organizational performance

* : All values of QP and CP are normalized with its maximum being 100.0

** : All values of TQ are normalized with its maximum being 100.0

Table 1. The results of the case with members' equal elasticity

Case / Items	Standard	3H3M	3H2M	Star	H. Channels
AT=0.3/Total IS[1]	100.0	94.2	90.0	84.8	98.1
Maximum IS[2]	88.6	89.4	89.1	88.4	88.0
Minimum IS[3]	76.2	72.5	70.4	67.7	74.1
Communica. TS[4]	59.3	56.0	54.0	52.0	58.3
AT=0.5/Total IS	99.7	96.6	92.6	86.6	97.8
Maximum IS	90.2	95.4	96.7	96.0	87.8
Minimum IS	100.0	96.1	93.7	89.6	97.8
Communica. TS	65.6	60.0	56.6	53.3	64.0
AT=0.7/ Total IS	87.7	91.7	90.3	85.7	86.3
Maximum IS	81.1	94.7	99.3	100.0	76.0
Minimum IS	81.6	85.1	90.6	88.2	81.9
Communica. TS	71.6	64.0	59.3	54.6	70.0
Power Ranking[5]	0.3[6] 0.7	0.3 0.7	0.3 0.7	0.3 0.7	0.3 0.7
Top	93 , 78	91 , 69	83 , 70	100 , 100	90 , 88
Upper Middle	98 , 77	// //	// //	// //	99 , 82
Middle	100 , 100	100 , 100	100 , 100	// //	100 , 100
Lowest	85 , 85	81 , 74	79 , 70	76 , 76	84 , 91

Note: (1)Total information stock, (2)Information stock of the maximum holder, (3)Information stock of the minimum holder, All figures of (1)-(3) are % and are normalized with the maximum of each corresponding IS being 100.0,(4)Ratio of actual time used for communication to total time,%,(5)Ranking of each management level in terms of IS with the maximum holder's IS being 100,(6)AT being 0.3 and AT being 0.7

Table 2. The results of the information stock size and communication time

Case	Index	Standard	3H3M	3H2M	Star	H. Channels
	QP	52.1	82.4	96.7	100.0	55.5
	CP	51.0	51.9	41.8	8.4	44.0
	Total IS	100.0	96.9	92.8	86.8	98.0
	Maximum IS	86.6	98.6	100.0	99.2	90.7
	Minimum IS	79.3	76.3	74.3	71.1	77.6
V1=0.25	TQ	65.4	74.3	65.7	20.0	59.6
V1=0.50	TQ	65.7	83.4	81.0	37.0	63.1
V1=0.70	TQ	66.1	93.6	100.0	68.9	66.8

Table 3. The results of performances with different elasticities

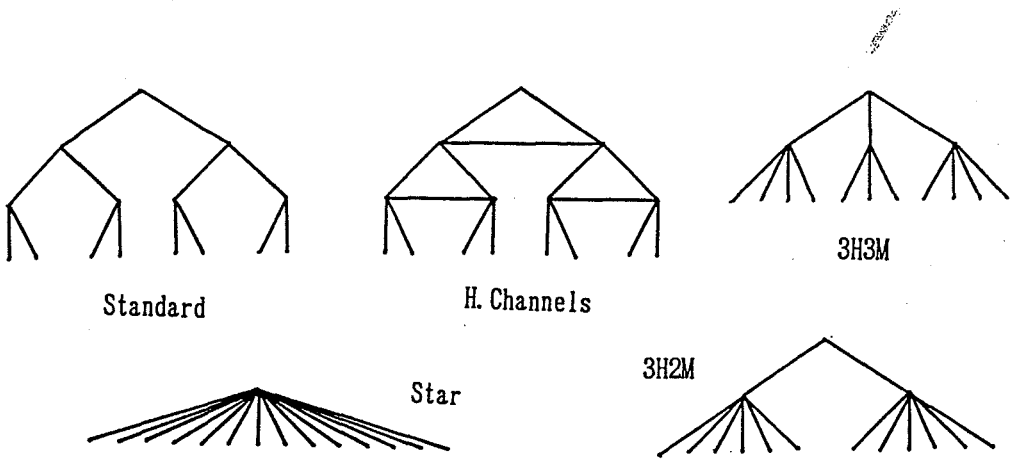

Fig. 2. The structures to be analyzed