

ON THE THEORY OF DIVISIONAL STRUCTURES: SOME ASPECTS OF CENTRALIZATION AND DECENTRALIZATION OF CONTROL AND DECISION MAKING*

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The organization structure of the firm has been the subject of diverse research approaches. The purpose of this paper is to provide a framework for integrating the various views and analyzing the various factors that affect centralization and decentralization. After a historical review of some milestones in organization research, a definition of decentralization which is based on the overall objectives of the firm is provided. The notions of hierarchical and mutual interaction structures are examined and contrasted with the notion of decentralization. Finally, the determinants of divisionalization are analyzed, and the suggestion is made that a study of the covariance matrix of subunit performance will guide us to the areas that need attention for possible reorganization.

I. Introduction

As the size of firms increases managers become increasingly preoccupied with problems of organization. More recently this preoccupation has been accentuated by the advent of computers and the realization that a new era in management practices may be dawning. To some, this new era foretells "recentralization" of business organizations.

While there is no argument that we are in the midst of an evolutionary process, with or without the computer, the direction we are heading, as far as organization structures are concerned, is not so clear cut in the general case, and cannot be described simply in one word. Besides, a lot of confusion exists on what we mean when we use the terms "centralization" and "decentralization."

The purpose of this paper is threefold. It will first of all present a short historical review of the centralization-decentralization research, then suggest a definitional framework and finally analyze the factors that favor centralization and decentralization. Hopefully, businessmen and students of organizations, by applying the framework and tools of analysis that we will provide, will be able to determine the impact on particular organization structures of any changes that may occur in the environment within which their firms operate. In any event there is a real need for an integration of the diverse views on the subject of centralization and decentralization, and the development of a theory which can

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help us derive operationally meaningful propositions. It is toward these ends that this paper is aimed.

II. Historical Review

Over the years many professional disciplines dealt with problems of organization. Up until recently, however, most of these investigations were only descriptive and often in terms of the vague notions of "unity of command," "span of control," "responsibility" and "authority." Today we find that this type of approach is not satisfactory, because it does not provide operationally meaningful propositions and tools for analysis.

The earliest attempts toward an "analytical" approach to the design of organization structures were made by accountants. The objective of their efforts, however, was limited to the control of behavior for fraud detection and hopefully fraud prevention. In order to prevent duplicity and make the assessment of responsibility possible, the accountant of the early days designed a structure of non-overlapping subentities, and an ingenious system of checks and balances that compartmentalized authority. Under such a system, if not circumvented of course, fraud could be perpetrated only by means of a conspiracy by two or more people.

The accounting approach in its pure form is not satisfactory either, because it presupposes a deterministic world of inviolable pre-established interrelationships among the various factors of production, the parts of an organization, and the organizational goals. Consequently, the traditional accounting approach is incompatible with notions that in certain cases we consider vital for successful business operations, such as participative goal setting, group decision making and the exercise of initiative, and so it tends to discourage innovation. Without wishing to underestimate the influence of personal managerial philosophy, business characteristics, and in general environmental and even irrational determinants of organization structures, one could say that even today a significant number of business organizations reflect for the most part requirements of accountability. It is for this reason that we often hear the adage that "authority must accompany responsibility."

Following, in terms of chronology, the accounting stage or organizational development, psychologists, sociologists and human relations experts, excited by the results of the research conducted at the Hawthorne Works of the Western Electric Company, began investigating the many aspects of motivation in an industrial setting and the relationships between organizational structures and employee morale and behavior. In particular, among the topics studied by the aforementioned researchers were the adaptation of group members to the various facets of pressure, the resolution of conflict, the emergence of leadership and organization, the communicational patterns among group members and the relationships between task characteristics, information flow, group structure and performance.

The results of the research that we have just mentioned, are often very inter-

esting and also provide useful insights. They cannot, however, be applied to issues of centralization and decentralization of total business entities, because:

- (a) the investigations often focus primarily on special subactivities of the firm,¹
- (b) the inferences drawn from the results obtained are not usually tested for statistical significance. Consequently, the conclusions are mostly in the realm of hypothesis and are not readily amenable to generalizations, and
- (c) a great number of these experiments are of problem-solving nature. Often the problem-solving situations studied do not require that the group members undergo extensive learning experience, which in the process will undoubtedly create a hierarchy of knowledge and influence the design of organization structures.

In business practice, the simplicity of the microcosm of *independent* problem-solving activities is usually absent. For the accomplishment of complex objectives there is often a necessity for mutual interaction of subactivities, each of which in turn realizes extensive economies of scale through specialization. Consequently, by concentrating on relatively simple and often programmable tasks, one cannot claim that the results so obtained can be automatically extended to complex tasks.

Research in organizational matters of general applicability has not been completely neglected. Some of the most distinguished researchers in the area of human relations have studied these issues and made significant contributions to the literature. The results of their studies, which are mostly based on extensive personal experience and philosophy, are usually characterized by suggestions for "more decentralized and participative decision making," and for substitution of inner control and motivation for "punitive accounting control" [1], [7], [12, pp. 33-49].

In addition to providing a new general frame of reference, the research in human relations has pointed out some dynamic interrelationships between aspirations, motivation, initiative, individual satisfaction and productivity, which had been completely neglected before. Effectively it has shifted the focus from a theory of antagonism and incompatibility of interest between management and workers, to one of cooperative behavior and mutual benefit, and thus opened horizons for research that are literally inexhaustible. But the problems involved in designing efficient business organizations are for the most part still with us, and the human relations approach does not offer us much help. For in the aggregate it neglects many *economic* aspects of total structure design and it is not analytical, while at the micro level it focuses too much on individual welfare. No one can honestly claim that the firm should be a "charitable" organization nor that it should be expected to shoulder responsibility for all the problems of

¹ One of the most favorite subjects for study of social psychologists and sociologists is the scientific research laboratory. Here we have a situation where the overall objective may exist in the substantive terms but it is often undefinable in terms of prior operational plans and subplans, thus allowing task independence.

the society. Yet one is often left with this feeling when reading the literature in the field of human relations.²

Traditionally, theoretical economists have not concerned themselves with issues relating to the organizational structure of the firm. By viewing the size of the firm as small enough to be directed by the entrepreneur, and within a purely competitive setting at least as far as the input factors of production are concerned, they found no need for delving in issues of organizational structures and internal controls. The behavior of the factors of production within such setting is optimal, because it is governed by impersonal market interactions. Little by little, however, economists have been moving away from the entrepreneurial model of the firm with unidirectional and uniform goals and have begun dealing with organizational problems [4], [5], [14].

It must be noted that once we abandon the entrepreneurial notion of the firm and relax the assumptions regarding the existence of free market information for optimizing behavior, we are faced with a vast array of issues that demand resolution. We must analyze the factors that favor centralization and decentralization, find substitutes for market prices whenever the latter are absent, find ways to set goals and guarantee goal consistency within an organization, determine the economics of information that is necessary for motivating efficient behavior, and analyze the patterns of interaction—human as well as knowledge—within a group. Some of these issues have attracted considerable attention lately [2], [10], [11], [19, Ch. 4], [20, Ch. II, IV, VI], but unfortunately most efforts focused on isolated problems which were not viewed within the context of the total organization. As a result, little progress has been made toward a cohesive theory of divisionalization.

One notable exception to the above criticism is the work of Herbert A. Simon [9], [17] which following the pattern set by Barnard [3] gave impetus toward a more analytical approach to the relationships between organization structures and the decision-making process in its totality. Even in this case, however, rather undue emphasis is given to the behavioral determinants of organizations at the expense of the economic.

III. Definitional Framework

The notion of centralization and decentralization can be classified among the terms whose meaning on the surface appears to be self-evident and common knowledge, yet very few of the users ever attempt to precisely define. The reasons for this imprecision are not necessarily related to carelessness, but rather to the difficulty and complexity of the issues involved.

Most writers on subjects related to organizational structures, accept Simon's definition of centralization and decentralization. In his study of the "Controllers' Department," Simon stated that:

An administrative organization is centralized to the extent that decisions are

² The role of the business sector in a free enterprise economy will receive increasing attention in the future as new ways of exploiting economies of size become available.

made at relatively high levels in organization; decentralized to the extent that discretion and authority to make important decisions are delegated by top management to lower levels of executive authority [18, p. 1].

This is admittedly a neat statement which is not likely to draw any strong objections but it is not as simple as it may appear to be. Indeed, the notion of centralization and decentralization is quite complex and if put to a test it will not stand the rigor of clarity either. One has to define first of all what is "high" and what is "low" level of "authority" in organizations composed of multiple tiers, and also explain what determines the number of tiers. These questions are important for definitional as well as comparative purposes. Furthermore, to the extent that decisions are continuously made at all levels within organizations, one must introduce a scale for distinguishing between the various types of decisions.

It appears to us, that in order to impart a meaningful empirical content to the notion of centralization and decentralization, one has to interpret these terms relatively to the overall objectives of the firm. In effect this is the approach taken by the students of functionalization and the so-called "federal decentralization," although often only implicitly and in very general and vague terms [6, Ch. 11, 17], [15, pp. 680-682], [17, pp. 190-192]. Once such an approach is followed, it soon becomes clear that the unqualified use of these terms for the description of empirical findings is rather meaningless.

We will say that a unit is decentralized absolutely, always of course within the overall objectives of the total organization,³ if and only if its index of overall objectives is qualitatively identical to those of its parent. Furthermore, if more than one such unit exists within an organization, the latter must not realize any economies or diseconomies of scale in the intensity of pursuit of these objectives. The latter qualification is necessary because otherwise the decentralized subunits, if more than one exists, will not be absolutely independent of each other in their efforts to maximize the overall objective of the firm. In our case absolute decentralization and absolute independence are synonymous within the organizational context. If we denote with $V = v(\sum_{i=1}^n C_{f_i}(\alpha_i))$ the value that the firm derives from the successful pursuit of its n objectives, then given k subentities our arguments imply that:

$$V = v(\sum_{j=1}^k \sum_{i=1}^n C_{i:f_j}(\alpha_i)) = \sum_{j=1}^k v_j(\sum_{i=1}^n C_{i:f_j}(\alpha_i))$$

Qualifications such as the one mentioned above, however, are not serious or in any way limiting in empirical research, because absolutely decentralized subunits within an organization are non-existent. It is only for a frame of reference and a point of departure that we need the definition. If we look at functioning organizations, we will notice that these appear to have one or more "independent" objectives. The latter are assigned to one or more subentities before they are translated and reassigned. Such an arrangement is partial decentralization, be-

³ Given that no organization in the whole world is absolutely independent and autonomous, we must define first of all the context within which a unit is viewed. In business structures, the highest context that we will consider is the firm as an administrative entity.

cause the freedom of each subactivity is limited in its choice of objectives and often in the degree of pursuit of such objectives.

At this point it may be necessary to digress for a moment and make a few comments concerning our use of the notion of independence of multiple objectives. It is necessary for our purpose to deal with multiple objectives, because of the various translations of objectives that take place at the various levels in the organizational structure of the firm. Whether there is such a thing as an array of *purely independent* overall substantive objectives of the firm, is very debatable. However, by means of translations (mappings) one can develop for subentities multi-dimensional objective vectors, whose components appear, *at that particular organizational level*, to be absolutely independent. The process of translation results in the gradual reduction of the amount of value judgment a subunit is allowed to exercise, and also gives rise to hierarchical structures and *external* subunit interdependencies.

In general a *hierarchy* is an ordinal ranking on the basis of some rules of supremacy. Although the number of tiers from top to a particular subentity within an organization may serve as a measure of cardinality, the latter cannot help us in deciding how centralized or decentralized a subunit is.

From our discussion so far three definitional conclusions emerge.

1. That the notions of centralization and decentralization are relative and not universal. Consequently we cannot make unqualified general statements as to whether a company or a subunit is decentralized or centralized. Only in comparative (relative) terms can we express an opinion, after applying as a criterion of measurement the number of translations and the dimension of such translations of the overall substantive objectives. For example, given any two organizational structures with at least two hierarchical tiers, which are governed by the same task and human characteristics, then the greater the number of hierarchical levels the greater will be the *diffusion of authority* within the organization. *Nothing can be said, however, about the degree of centralization or decentralization at any level unless an analysis is made of the relationship between overall objectives and subunit subobjectives.*

2. That hierarchical structures although related to the general issue of centralization and decentralization do not necessarily prejudice its nature or form.⁴ Any organization which is short of the utopian absolute decentralization must be hierarchical because it necessitates a translation of the overall objectives into subobjectives.⁵ In fact, if we were to view the process toward relatively more and

⁴ Simon in his *The New Science of Management Decision*, op. cit., p. 44, states that: "Hierarchy always implies intrinsically some measure of decentralization." While the latter statement is true, so is its complement and opposite, that hierarchy implies *some* measure of centralization. As we have previously mentioned *centralization and decentralization are relative terms, and not absolutes.*

⁵ Later we will show that entities which are absolutely decentralized and are also paper thin, are only *decentralized in their external relations. Internally*, these organizations are *highly centralized in their totality.* That is one reason why we made the statement that hierarchical structures do not necessarily prejudice the nature or form of centralization and decentralization. Under conditions of *partial decentralization*, hierarchies are necessary.

more decentralization as occurring in a semblance of a continuum, but with only rational graduations of objective coefficients, the organizational structure may be looked upon as becoming more and more hierarchical up to the point it is composed of an infinity (denumerable) of hierarchical layers, only to collapse to one layer upon reaching absolute decentralization. Such a collapse occurs because then the objectives of the various layers become indistinguishable and the superstructure appears to be unnecessary as we approach the absolute limit.⁶

We must stress here that the preceding paragraph refers to the external structural relationships between subunits. In other words we are viewing the unit, however defined, as an entity and study its position vis-a-vis other units in the hierarchy especially the units in higher tiers. The units of lower tiers may be viewed for convenience as embedded in or internal to the subunit.

3. That another dimension of relativity must be introduced to distinguish relationships that emanate "from within" versus "from without" a unit. To the extent that we are dealing with embedded structures that are quite complex even in their smallest subdivision, we must make the proposed classification in order to distinguish between inter- and intra-subunit organizational problems. For example, if a subunit is part of a hierarchy, this does not perforce imply that it should be also hierarchically organized internally.

The above discussion of inter- versus intra-subunit relationships brings us to the definition of *equalitarian* or *mutual interaction* structures. *The latter terms are applicable purely within an organizational subentity and to the whole array of subunit objectives and tasks.* An equalitarian structure is defined as one where superior-subordinate roles are absent, and where decisions are made through the mutual and equal interaction of all the members within the unit. Such a structure is by definition nonhierarchical.⁷

A question may now arise, however, as to whether an equalitarian structure is centralized or decentralized. "From without," that is to say looking at the relationship between the equalitarian unit and any other (higher) units in the or-

However, let us stress again, that there is no connection here between the necessary condition and the final form, or degree of partial decentralization.

⁶ As the reader may remember, we specified that in order to establish the degree of relative decentralization of any two subunits within a firm, we must compare their index of objectives to that of the firm. The unit whose objectives are a closer representation (image) of those of the firm, is then judged to be relatively more decentralized. Given that for absolute decentralization we require linearity, then we have a system by means of which we can introduce between any subunit and the top as many hierarchical layers we wish, with each one becoming a better and better image of the firm. Or alternatively we can view each subunit, through changes of objectives, becoming more and more decentralized by going through the denumerable number of steps that we have already mentioned. In the end all subunits will be separated by infinitesimal differences not worthy of the superstructure. This process is similar to the one we follow in order to count all the rational numbers between any two of them.

⁷ This does not necessarily imply that the knowledge of the members of an equalitarian unit cannot be specialized and ranked in a hierarchical fashion given a specific task. It only implies that the task cannot be accomplished unless all members of a subunit mutually interact on an equal basis. The hierarchy of knowledge usually is temporary, and shifting depending on the characteristics of the particular task on hand.

ganization, one has to examine the relationship between the substantive objectives of these units and apply the definition as we previously explained. Internally, however, to the extent that there is no further translation of objectives and no hierarchical or lateral diffusion of decision making, the equalitarian unit must be considered as highly centralized. As in the case of hierarchical structures and their relation to the decentralization issue we have here what may appear to be a paradox.⁸ In the extreme absolute decentralization results in independent unicellular structures that are non-hierarchical, completely decentralized "from without," and highly centralized "from within," although the power within the structure is horizontally and equally shared. There is no contradiction, of course, in this, because *the centralization of power "from within" rests with the totality in a democratic manner.*

Finally a few words on the difference between centralization and decentralization of control versus decision making. Although control and decision making are not mutually exclusive and often interdependent, these two processes and activities are not identical. Control refers to the function by means of which observations are collected and the resultant information is transmitted for adapting or changing behavior and instigating remedial action. Decision making on the other hand goes beyond control in that it includes also future planning and the assessment of the future consequences of present decisions. In this sense, control is grounded in present or past operations, and it is a combination of communication and of those aspects of decision making that refer to adaptive behavior. Whether the decision-making aspects of this feedback-control process are performed automatically by the system, through man-machine interaction or through purely human initiation, is rather immaterial. What is important is the fact that some type of decision making follows the information communicated by the control system.

The definition of control, as given above, is concerned with the allocation of resources within a given activity vector, and presupposes the existence of an objective or objectives. As a result, the type of information that is transmitted and the criteria which determine the desirability of behavior changes and remedial actions, are a function of the goals and tasks of the activity. The decisions that are generated by the control process are thus limited in scope, nature and durability, by *policy decisions that are more often determining than determined by the characteristics of the control system.* Furthermore, while the decisions motivated by control processes have their origins in the past, a major classification of decision making, as we have already pointed out, refers to future planning, control-system design, and determination of objectives and activity vectors.

We can now summarize the preceding discussion by saying that other things equal, mere control decentralization ranks lower in terms of significance than

⁸ In stating our definitional conclusion No. 2 we pointed out that as we proceed toward more and more decentralization the hierarchical levels approach denumerable infinity, only to disappear when we reach absolute decentralization. Now we see that in the end this process results in structures that are self-sufficient in their simplest form but *highly centralized from within in their totality.*

decision-making decentralized, and is included in the latter (but of course not the other way around).⁹ The objective vector of a decision-decentralized unit is usually in substantive terms, thus leaving room for the exercise of a great degree of value judgment in the process of its *translation* into operational objectives, a process that often affects the fringes of subunit interdependence. In contrast control-decentralization delegates to a subunit the function of ascertaining that a given activity vector is realized.

IV. Determinants and Characteristics of Divisionalization

We have thus far developed the expositional setting for analyzing the factors affecting centralization and decentralization of control and decision making. In the process, we have reviewed the literature, commented on the results of previous organizational research in terms of contributions, validity, and shortcomings, and then embarked on establishing the analytical definitional foundation on which we will now build.

In discussing the determinants of organizational structures, we will be viewing the various factors as affecting the internal structure of—"from within"—the particular unit. Since structures are embedded, this approach will somewhat facilitate and simplify the conceptual part of our discussion. As we have already stressed the terms centralization and decentralization are relative and not universal, and this qualification will be implied but not stated every time these notions are used.

Some Determinants of Centralized Structures

Among the factors that favor centralized structures we have:¹⁰

A. The Existence of Unified Overall Objectives

In our previous discussion we stressed that theoretically we cannot very well justify within an organization the existence of multiple *overall* objectives which are absolutely independent of each other, and that as a result we cannot find absolutely decentralized structures. For partial decentralization, one can assign to subentities parts of the overall objective or objectives with or without translation. This latter process requires that the objectives are in various degrees separable; consequently the translation becomes more difficult the fewer the components of the objective to be assigned. If the objective or objectives, therefore, cannot be broken into subobjectives and factored without introducing excessive interdependencies then other things equal the tendencies will be toward centralization. The difficulty, for example, in breaking the profit objective successively into many profit subobjectives, encourages cost control "decentralization" (cost centers) rather than creation of profit centers within business entities.

⁹ To illustrate this difference, a foreman on an assembly line has control responsibilities in administering decisions taken by higher levels in the organization. The decisions that the foreman can make (which are control-information motivated) are also part of the original decision setting up the control procedures.

¹⁰ These factors are not necessarily mutually exclusive or independent but are listed separately in order to underscore certain distinct points.

B. Complementarity of Resources and Operations for Accomplishing Unified Objectives

Under *A* above, we referred to the impact of objectives on organizational structures. The same type of impact will be caused by the characteristics of operations that are necessary for implementing the objectives. It can be stated, of course, that the more unified the objectives are, the more complementary are usually the operations, other things equal. There is another dimension of complementarity, however, that emanates from the technological as well as technical characteristics of operations and resource utilization, which is also reflected in the design of organizational structures.

The type of complementarity that we have in mind here, implies that there exist differences in the quality of resources and that the latter are highly specialized and indivisible. If no learning processes are necessary for such specialization, or else if the benefits of specialization are smaller than the cost of independent planning, then the structure that will result in the most efficient utilization of such resources will be one of mutual interaction (non-hierarchical), which as we have previously argued is highly centralized from within in its totality. Group planning and decision making are consequences of such complementarities. But as everyone who is familiar with group activities will attest, the amount of information that is necessary for group action is often quite formidable.

C. Interdependence of the Production Functions of Suboperations

This last reason is closely related to *B* above. It simply states that, if we have extensive externalities or "super-additivities" such that for any X_1, X_2, \dots, X_n suboperations the value generated by all together $V(X_1, X_2, \dots, X_n)$ is always greater than the sum of the individual values $\sum_{i=1}^n V(X_i)$ if pursued independently, then relative centralization should be favored. The particular type of centralization that is implied here applies more to decision making than control. In other words under the conditions as described here, the most efficient structure may be characterized by centralized decision making, so as to take advantage of the complementarities, but decentralized control, given the operational objectives, in order that the organization bring intimate operational knowledge to the remedial action process. Illustrating this point is the centralized planning that is characteristic of blast furnace and ingot producing activities of steel companies.

Some Determinants of Decentralized Structures

To the extent that centralization and decentralization are complements, the absence or opposite of the factors favoring centralization will favor decentralization and vice versa. There are several other important factors favoring relative decentralization, however, which merit individual attention. These factors, which again are neither mutually exclusive nor independent, include:

A. Economies of Scale through Specialization of Homogeneous Functions and Entities, and the Existence of a Continuous Technological Learning Process

If resources were somehow *a priori* highly complex and specialized and did not have to be channeled in certain directions at the exclusion of others, then

there would be no need for decentralization and independence for "learning" purposes. We know from experience, however, that there is a lot to be learned and that there are extensive economies of scale to be realized in the learning process itself. Furthermore we often observe discontinuities in the learning function that must be overcome through persistent effort. Consequently unless resources, and processes, especially human, are allowed to concentrate on their task uninterrupted for a certain period of time,¹¹ the economies of specialization will not be realized, progress will be stymied, and stagnation will ensue. The organization will then be composed of a library card file, which will readily be available for retrieval of information at any moment of time, with the only problem that it will not be up to date.

Once knowledge is acquired, there will be a necessity for a centralized structure to spread the benefits of such knowledge. Mass education and production require central planning and standard procedures. One must leave room, however, so that the next breakthrough, which will destroy the existing standard procedures, can develop. All this implies that a viable and progressive organization must go through continuous cycles alternating between centralization and decentralization. Alternatively, it must separate the innovating from the mass producing activities leaving the former decentralized and the latter centralized.

B. The Cost of the Channels of Communication that are Necessary if Control and Decision Making Is to Be Centralized within the Unit

It was pointed out previously that for non-hierarchical (equalitarian or mutual interaction) structures, "the total amount of information that has to be transmitted in the organization will grow at least proportionately with the square of its size" [16, pp. 41-42].

The reasons behind the above observation are as follows:

If we have n members in a group and decide to couple two members of the group at a time, the total number of possible pairs is given by the binomial coefficient:

$$(1) \quad \binom{n}{2} = n(n-1)/2$$

Let us now assume that the members of the group are increased by a factor $c > 1$. Then we have:

$$(2) \quad \binom{cn}{2} = cn(cn-1)/2$$

Dividing (1) into (2) we get:

$$(3) \quad \binom{cn}{2} / \binom{n}{2} = c^2(n^2 - n/c)/n^2 - n$$

but:

$$(4) \quad n/c < n, \quad \text{since } c > 1$$

¹¹ The length of the time period of independence is a function of the conflicting advantages of mutual interaction and the economies of specialization.

and as a result:

$$(5) \quad (n^2 - n/c)/(n^2 - n) > 1$$

Hence:

$$(6) \quad \binom{cn}{2} / \binom{n}{2} > c^2$$

So by increasing the size of the group by a factor of c we caused an increase of at least c^2 in the channels of communication. At the other extreme the channels may increase by much faster than the index of the size of the group for each new number added. As we have previously pointed out, although a structure may be equalitarian, this does not necessarily preclude a hierarchical ranking of knowledge depending on the particular task on hand. Under these conditions we may need to provide channels of communication for all subsets of the group, in addition to coupling each new member with everyone else. That is why hierarchical structures require less information for performing their tasks.

The consequences of the increase in channels of communication are many.¹² First of all we have the cost of maintaining such an information network. Then we have the cost of the time delays, red tape, and possible distortion of information, that may be introduced by the various (inevitable) "filtering devices" that normally follow communication networks. Going now to the cause of the increase in channels of communication, the mutual interaction structure, we find that the latter has a tendency to produce chaos and inaction especially as its size increases. The chaos is not unlike what happens if the members of a group try to call one another on the telephone at the same time. The probability is quite large that a lot of callers will get busy signals, that is to say a lot of noise but no message. Given that an equalitarian structure is geared toward mutual interaction, for decision making, any congestion of the channels of communication will be catastrophic since it will lead to inaction and possibly complete paralysis.

Even if the messages succeed in going through, one has to worry lest the abundance of the channels of communication leads to inaction, due to the tendency of people to "get all the information available" whenever solving problems under uncertainty. Such an eventuality reinforces the arguments presented, under A above, on the conflict between mutual interaction structures and learning processes, and points out—on the negative side only of course—the destructive aspects of equalitarian organizations.

C. Uncertainty, Instabilities and the Risks of Partial Failure

Organizational structures that are equalitarian (highly centralized "from

¹² Our arguments here apply to all types of information systems and both formal as well as informal channels of communication. Often the informal channels of communication are more costly, especially if they are "clandestine." The often advanced claim that the informal channels of communication are more efficient, appears to us to be relative and not universal, because the comparisons are always made between informal and inefficient formal systems. After all if the information systems are efficient there will be no need for "clandestine" surrogates.

within" and non-hierarchical), often create a multifold infinity of instabilities. The latter are caused by the extensive uncertainty that has its origin in the necessity of instantaneous mutual interaction of interdependent entities. The result may be oscillations in performance, that widen with time rather than dampen out and reach a desirable or at least acceptable equilibrium.

One aspect of the uncertainty that we have just mentioned, is reflected in the variance of the sum of dependent random variables. Given n random variables X_1, X_2, \dots, X_n then:

$$\text{Var} \sum_{i=1}^n X_i = \sum_{i=1}^n \text{Var} X_i + 2 \sum_{i < j}^n \text{Cov} (X_i, X_j)$$

or the variance of the sum of n random variables is equal to the sum of the variances plus twice the sum of the covariances of the variables taken two at a time. But the covariance:

$$\text{Cov} (X_i, X_j) = \rho(X_i, X_j) \sigma_{X_i} \sigma_{X_j}$$

where $\rho(X_i, X_j)$ stands for the correlation coefficient of the random variables X_i, X_j , and $\sigma_{X_i}, \sigma_{X_j}$ for their respective standard deviations. If the random variables are independent then their covariance is zero.

As a result of the above, we notice that by definition the sign of the correlation coefficient and that of the covariance of two random variables is the same. Consequently whenever the correlation coefficient is positive then the variance of the sum of interdependent activities is greater than the sum of their variances taken separately, and for $\rho < 0$ the opposite is true. If the random variables are uncorrelated, then the variance of the sum equals the sum of the variances of the random variables.

To summarize then, only in the case where the random variables are independent or uncorrelated¹³ do we have an equality between the variance of a sum and the sum of the variances of random variables. Consequently if our aim is to reduce any unnecessary variance of the overall results from expected objectives,¹⁴ then by studying the covariance matrix we can determine which operations are crucial,¹⁵ in a possible reorganization and assignment of objectives and operations. This approach has been applied in one industrial situation with great success, revealing interrelationships that no one suspected.¹⁶

¹³ If the $\text{Cov} (X_i, X_j) = 0$ it does not necessarily imply that the random variables X_i and X_j are independent. In the special case of the bivariate normal distribution, zero covariance implies independence. However, in general the only statement that we can make whenever $\text{Cov} (X_i, X_j) = 0$ is that the random variables are uncorrelated since $\rho = 0$.

¹⁴ This assumes that even in the case where the deviations of the results of operations from established goals are positive, such occurrences are not particularly desirable in the case of interdependent subactivities. Such an assumption does not appear to be unreasonable for levels below the very top, whenever extensive complementarities exist.

¹⁵ The diagonal of this matrix represents the variance of the random variables, and the other entries are symmetric with respect to the diagonal. As a result one need only concentrate on one of the two off-diagonal sections of the matrix.

¹⁶ This experiment is still being pursued and evaluated. The results and their implications on the accounting system will be the subject of a forthcoming paper.

In mutual interaction structures the covariances are expected to be positive. Only in cases where a lot of flexibility with no depth is required for the common task we may find negative covariances, but then of course, we revert to the case that we cited previously where the members of such a structure perform library card-file functions. Consequently if the uncertainty, as manifested in the magnitude of the variance, is more damaging to the objectives of a group than the elimination of mutual interaction and the cost of achieving it, then operations are "decoupled" to be made "independent" or uncorrelated.¹⁷

One way of reducing uncertainty, is to increase the channels of communication so as to keep all operatives informed on the factors that affect their mutual progress. To a certain extent this may produce desirable results. As we have explained under *B* above, however, there exists a point beyond which the benefits of mutual interaction, in the accomplishment of common objectives, are more than negated by the cost of maintaining the instantaneous communications network that is necessary for transmitting to the operatives continuous information on the moves of each other. Furthermore, we noted certain disadvantages of interference, inaction, and mutual destructiveness that one can attribute to the abundance of channels of communication. If information is received at a high rate then the attempts toward adjustment of behavior will result in erratic patterns of performance, and also the advantages of specialization through learning that we discussed under *A* will not be realized. All these consequences of an increase in the channels of communication and the rate of information flow have been observed by the author in industrial situations.

Another avenue toward the reduction of the amount of uncertainty surrounding the accomplishment of the overall objectives of an organization, is the creation of artificial barriers or substabilities to guarantee short-run independence. In this lies one of the most important theoretical justifications of divisional—horizontal as well as vertical—structures. Intuitively we can see that if the instantaneous mutual interaction of all the operatives is necessary for the accomplishment of each and all tasks leading toward unified overall objectives, then the failure of any one operation to contribute its expected share will cause the collapse of the whole structure. Consequently, for complex organisms, partial independence through divisionalization is necessary in order to create substabilities that will guarantee the survival of parts even though the total may not be accomplished. Our body is composed of an infinite number of such sustabilities. The creation of buffer inventories in process, the necessity for a waiting line efficiency coefficient of less than unity, the allowance for slack time in scheduling, the habit that we have of writing down the digits that we carry forward in long-hand additions, the myriad of industrial subassemblies, the shock absorbers of cars, are just a few illustrations of substabilities for the reduction of uncertainty, and also point out the cost that is associated with their presence.

¹⁷ We must stress that these are also relative terms, and that this process of study suggested here should be also used in reverse. If for example the covariance of "decentralized" operations is found to be negative then one should examine the possibility of merging the operations together.

In addition to the reduction of uncertainty through partial independence, substabilities often create flexibility by enabling multiple use of the results of such substabilities, especially subassemblies. Of course this may be considered as another aspect of uncertainty elimination.

Given our arguments concerning the economies of scale through specialization under *A*, and the economics of channels of communication under *B*, we can readily infer from our discussion under *C*—"Uncertainty, instabilities and the risks of partial failure"—that the planning horizon of a firm must be divided into two parts.

1. A period of artificial independence that is necessary for learning and specialization.
2. A period of duration longer than that of artificial independence over which the subunits need reassurance and guidance on the state of the external (to themselves) environment before these can effectively plan.

Any information and control system, as a result, must be aimed at satisfying these two basic planning needs of each particular subunit. It must first of all, shield each subunit during the time it needs for learning and specialization from any extraneous information, and concentrate on providing "continuous" internally generated data. Secondly, it must provide periodic¹⁸ information on all the "external" factors that affect the subunit's goal orientation and performance, in order to enable the subunit to plan for its subsequent period of isolation.

We must stress here two points that should be more or less obvious:

1. that the terms "internal" and "external" information are relative to the unit. What governs the appropriateness of information are the interrelationships that affect the subunit's objectives. As we go higher up in the organizational structure of the firm, we will find that part of the "external" information that is required is even external to the firm itself. And
2. that the system should have in it appropriate diagnostic properties and provisions for "two-way emergency interruption" procedures.

To summarize then, we have noticed that for the reduction of uncertainty an organization may divisionalize its structure and create substabilities (partial independence). The process by means of which decisions are made concerning the type of substability—how much, how far—is one of trial and error, due to the infinity of practical alternatives. In theory, however, we can say that, other things remaining equal, a marginal divisionalization (for elimination of uncertainty) is justified if:

- (a) The expected value of overall goal accomplishment as generated by the various subunits into which the organization is to be divided, less the expected cost of:
 - (i) the buffers or neutral zones that will be necessary for creating the artificial short-run independence and substability
 - (ii) the information system that will provide "continuous" internal feedback and

¹⁸ The length of the period is determined by the duration of artificial independence.

(iii) the periodic channels of communication that will serve for conditioning the expectations of the various subunits on the state of nature of the overall organization during the periods of assumed independence,

is greater than:

(b) The existing value of goal accomplishment less the channels of communication necessitated under conditions of relative mutual interdependence.

Finally, we must point out that the expected value of goal accomplishment under (a) and (b) may differ not only because the applicable probabilistic distributions are different, but also because the values of the variables are different. The difference in the values of the variables (goal accomplishment) may have its origin in at least two major sources:

- (1) The fact that any subdivision of a unitary objective involves sub-optimizations which will be also manifested in the additivity of the expected values of goal accomplishment as generated by the subunits. Under such circumstances, the summed value of the parts *expressed in terms of particular subunit criteria of efficiency* will be greater than the value of the end result to the overall organization.
- (2) The assumption of independence between the activities of the various subunits over the period of isolation.

D. Psychological Reasons of Motivation

Although the area of psychology of motivation is a vast field full of esoteric issues to which we cannot do justice by a purely cursory exposition, we feel that we must say a few words on those aspects of this subject that relate to our main topic of discussion.

It has been claimed by many researchers in the field of human relations-social psychology, that equalitarian structures offer more satisfaction to the members of an organization than authoritarian structures [7], [8, Ch. 12, 18], [13]. Implicitly they criticize and attribute to "authority, controls and hierarchical structures" negative attitudes on the part of the workers and low productivity. While cases can be cited which substantiate these contentions,¹⁹ yet as we have pointed out here and elsewhere [21], control systems and hierarchical structures are necessary for economic reasons. But even on purely psychological grounds there is no theoretical justification for general condemnation of controls, nor is there any basis for expecting all people to be average members of average groups and purely externally (group) motivated. As long as the tasks are not homogeneous and there are differences among individuals, especially in terms of capacity to work with non-programmable tasks and uncertainty, there will be hierarchical stratifications. Furthermore, we have previously shown that equalitarian structures, although democratic and externally decentralized, are paradoxically centralized from within in their totality. Consequently, if we accept that recognition for outstanding accomplishments is a major factor in motivation and

¹⁹ Actually it is the wrong application and not the existence of controls that is causing trouble.

performance, non-equalitarian and relative decentralized structures will prove to be more efficient, because only then can the individual associate "end results" with his own efforts.

Although, certain aspects of decision making—especially those that refer to remedial action—cannot be divorced from control, there are others that are concerned more with future planning rather than with the study of the past.²⁰ The determinants of decentralized structures that we have so far analyzed apply more to the process of control, given objectives, than to decision making. Now we will turn to two issues that are concerned relatively more with decision making and with what we have previously termed the fringes of subunit and interperiod interdependence.

E. Time Sensitivity of Decisions

In determining where the locus of decision making should rest, one has to examine among other things the time sensitivity of the particular decisions. If the decision is made by the subunit, as we have already pointed out, it is in certain aspects suboptimal. However, the reaction time is faster, by the amount of time it takes for the following necessary steps to be performed.

- (1) The information system must first recognize the necessity for a decision, and transmit a signal indicating the necessity for remedial action, to a decision-making locus outside the subunit.
- (2) The outside locus must then analyze the information, digest it, recognize the existence and nature of the problem, associate it with other similar occurrences if any, determine the consequence of alternative courses of action, structure a decision and translate it into operational instructions, and finally
- (3) The information system must return the instructions to the point of action.

Consequently, if the expected cost of adverse effect during any period of a subunit's inaction (while waiting for instructions) plus the cost of the centralized information system, are greater than the expected loss due to a relatively suboptimal decision at a low level, then decentralization of decision making is justified.

A major assumption behind the necessity for transmission of the information upward for instructions, is that higher levels in a hierarchical structure can make more optimal decisions although removed from the point of action (but see item *F* below). This is so mainly because at those levels people observe more and different interrelationships, and can recognize patterns that others at lower

²⁰ This is not to deny that all decision making carries the advantages of study of the past. Nor can we claim that future planning is completely divorced of the output of control processes. The mere cognizance of the need for future planning is nothing more than the result of a more general feedback control system, that is partly external to existing operations. So for the total organization as well as for each subunit, there are hierarchies of information and control systems, with the more complicated referring to the longest feasible long-run decision making on top of the ladder, and the less sophisticated concerned with the short-run decision-feedback control of day-to-day operations at the bottom. And this let us repeat applies to the subunit as much as it does to the whole firm. Implicit here, of course, is the assumption that the impact of decisions on the overall objectives of the firm is lessened as one moves down in the hierarchy.

levels cannot recognize because they are preoccupied with limited details.²¹ As we have argued previously, any translation of unified objectives to many sub-objectives is *per se* suboptimal. Furthermore, in order to establish false independence and eliminate uncertainty, organizations buffer their subunits and thus hide existing interrelationships at the subunit level. That is mainly why the scope of subunits is limited.

F. Task Characteristics

Another factor that affects decentralization of decision making is inherent in the task characteristics. The latter are reflected as we have already pointed out, in the degree of separability of operational objectives and activities, and the degree of interdependence introduced at the point of translation. The relevant question that has to be answered here, now is as follows: Is on-the-spot knowledge more vital for planning than the external subunit interrelationships? If the answer is yes, then other things being equal decentralization of decision making is advisable. If, on the other hand, the accomplishment of the objectives of a potential subunit is more dependent upon forces that originate outside the subunit than upon the knowledge generated from within, then the decision-making locus is placed outside the subunit.

From the short discussion on the time sensitivity of decisions and task characteristics, it appears, that if an organizational subentity is decentralized from without because of the specialized knowledge of the immediate operatives, then internally the subunit will probably operate in an equalitarian fashion. In contrast, if the external decentralization was dictated by the time sensitivity of decisions, then internally the subunit will probably be hierarchical and relatively decentralized.

In our previous arguments concerning centralization and decentralization of control and decision making, we concerned ourselves mostly with the qualitative characteristics of the various theoretical aspects of divisionalization, and thus had a single system of classification. It has been pointed out that often in practice, a *general* category of decisions and controls may be vested with a subunit, provided that the quantitative level of a particular decision is not "catastrophic" for the subunit.²² And this, not because the subunit "cannot be trusted" or because of excessive interunit interdependence, but possibly because of somehow general-inherent characteristics and capacities of people at the various levels in the hierarchy to think and behave in quantitative terms relative to the scope of their existing operations.²³

²¹ Of course this can work both ways and may result in suboptimal centralized decisions. Also we must not forget the arguments that we presented when discussing the impact of the channels of communication. People at higher levels may be fed with so much information (often colored), that they may be unable to digest it and in the end make a poorer decision on a centralized basis.

²² The author wishes to thank Frank H. Tyaack of Westinghouse for suggesting this dichotomy, and for providing empirical evidence attesting its significance.

²³ Capital budgeting procedures among other business practices seem to be based on such assumptions. Of course we must not exclude the possibility that such a behavior may be the result of successful managerial constraints rather than emanate from basic human characteristics.

A partial explanation of the above mentioned observation can be found in our previous discussion concerning the risk of failure and its impact on the long-run existence of the subentity. In order to increase the probability of survival of the subunit as well as the total organization, management should impose quantitative constraints at the various levels of the hierarchy. Also, the limited exposure of the subunits to single large problems—of a magnitude that necessitates marshalling resources that are quite large relative to those in use—will undoubtedly affect the probability of subunit success adversely. Consequently it is not unreasonable to use an explicit quantitative constraint in addition to what we have suggested, in approaching problems of divisionalization.

Finally a comment on the implications of our discussion on personnel placement. We have argued that hierarchical structures, among other things, eliminate value judgments as one goes down the hierarchical ladder. Such an elimination of value judgment implies, that the uncertainty surrounding the particular task environment is also reduced. Consequently, one of the critical factors that will determine the success or failure of the people who head the various subunits, will be their capacity to adjust and effectively cope with the conditions of uncertainty that characterize their particular operations. As this capacity to live with uncertainty grows, the scope of their responsibilities should be also extended. Those who do not pass this test and cannot stand the pressures that decision making under uncertainty brings about, should be placed in positions where they will be dealing with programmable tasks and thus be led rather than lead.

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