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ASHBY'S LAW OF REQUISITE VARIETY: AN EMPIRICAL STUDY

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This study examines Ashby's law of requisite variety: its theoretical origin and its relevance to organization and management. This leads to a statement of hypotheses which are tested empirically. The empirical work includes the operationalization of variety and entropy and the collection of data in an insurance organization. The data are statistically analyzed to test their correspondence to Ashby's law.

1. INTRODUCTION

Over 30 years ago, W. R. Ashby (1964) postulated an organizational law named by him "law of requisite variety." Ashby, a psychiatrist by profession, mostly applied this law to the regulatory activities of the brain and other biological systems. Nevertheless, he stated that the law would apply to any system that performed a regulatory process.

Ashby's law (as it may now appropriately be called) refers to a system in which three stages can be identified: a disturbance or input, a process of regulation, and an outcome. Given a disturbance or input, the system is assumed to respond with a regulatory process or action which in turn leads to an outcome.

The law postulates that to obtain a desired outcome, the system must match the number of states in the input with at least an equivalent number of states in the regulatory process. That is, to attain the desired output, the system must adapt its regulatory process to its environmental input.

Given the prominent role that adaptation occupies in modern management theory, Ashby's law might be expected to the the subject of much research. This has not been the case. Although Ashby's works are widely referred to in the management literature, the law has remained largely unexplored. The main exception to this is found in the work of Beer who, with

regret, has stated that ". . . after thirty years the law of requisite variety is still not understood . . ." (Beer, 1979, p. 84).

The research presented in this paper is an effort to contribute to the understanding of this law from an empirical point of view. Firstly, a broad overview is given of the origin of the law (as far as the author has been able to trace it back in time), the parallel conceptual developments in the contingency theory of organizations and the law's application in Beer's cybernetic model of organization.

Secondly, a theoretical framework is proposed which is suitable for the application of the law to an organizational context including the two variables involved—variety and entropy. Thirdly, the empirical work of this research is introduced by stating a number of hypotheses followed by a brief note on the methodology. This is finally followed by a summary of the statistical results and a discussion of their significance.

2. ASHBY'S LAW AND ORGANIZATIONS

Ashby's law may be considered to have its origin in the development of the science of telecommunications. According to Cherry (1961, p. 427), scientists in the 1920s, faced with the problem of determining the capacity required for a communication channel to transfer a specific message in a determined period of time, stated a law that specified this channel capacity (bandwidth). This law, was further elaborated by Hartley in 1928, and later by Shannon (Shannon and Weaver, 1949), who expressed the law within the mathematical framework of information theory.

Ashby's work followed in 1956, giving this law a more general interpretation, and submitting that its application covered a far wider field than just information and communication theory. In addition to entropy—the statistical measure of uncertainty used by information theorists—Ashby introduced a new dimension, named variety, which measured the number of possible states of a system. Variety provided Ashby with the fundamental measure upon which he built his theory of regulation and he used it to express, in a more general form, the law of channel capacity enunciated earlier by information theorists. Hence he named it the "Law of Requisite Variety."

It was amidst the conceptual envelope of general system theory, and the related disciplines of information theory and cybernetics, that Ashby's law worked its way into modern management thought. While at the earlier stages, and especially in the work of organization theorists, almost no explicit mention is made of the law, its principle played an important role in

shaping theoretical frameworks. This is most clearly exemplified in the set of organizational concepts known as contingency theory (Kast and Rosenzweig, 1973) that emerged in the 1960s.

Thompson's work (1967) is of particular significance here, as he proposed a theoretical framework which contributed substantially to the foundations of contingency theory. Thompson visualized the organization as an input, transformation, and output system and enunciated the mechanisms by which organizations are able to impede uncertainty reaching their core technology. He proposed that to isolate the core technology from uncertainty, organizations employ the following mechanisms: buffering, leveling, forecasting, and rationing.

Although it is not possible to discuss in this limited space the details of these mechanisms, it becomes apparent that the organizational actions Thompson described are the organizational responses to the constraints and demands that Ashby's law puts upon a system. Furthermore, Thompson's discussion of the structure of organizational boundary units and the dependence of their structure upon the environment's characteristics strongly implied Ashby's law.

The advent of contingency theory in the 1960s was followed by a significant amount of empirical research during the 1970s. Part of this research has been directed towards an examination of the impact which the environment has on the structure of organizations (Miles et al., 1974). This research has been focused upon two main aspects. Firstly, efforts have been directed towards the development of measures of environmental characteristics, specifically of environmental uncertainty, change, and complexity (Duncan, 1972; Downey and Slocum, 1975). Secondly, research has been carried out with the purpose of establishing the relationship between environmental characteristics and other organizational variables such as structure, pattern of communications, effectiveness, performance, and leadership (Leifer and Huber, 1977; Tushman, 1979; Osborn, 1976).

This research offers some interesting insights. Overall, the findings seem to substantiate the propositions of Ashby's law, albeit in an indirect manner. Although contingency scholars seldom use a precise input-transformation-output framework in their analyses, the results usually show a corresponding organizational variety and information matched to the environment's variety and uncertainty. Contingency scholars have, however, developed operational definitions which allow too much breadth of definition of the variables, consequently losing the original rigor of the concepts studied. The preservation of this conceptual rigor is indispensable if the notions

of systems theory (such as Ashby's law) are to make empirical sense. For example, Duncan's (1972) measurement of complexity of the environment based on the selection of environmental components and the factors that affect them are substantially similar to the concept of variety as defined by Ashby. However, while measuring perceived uncertainty, Duncan introduced subdimensions which would not, strictly speaking, be considered environmental from the perspective of the input-output model.

In an attempt to empirically investigate Ashby's law, Osborn et al. (1977) used standard deviations between the measures for different dimensions of environment and leadership as an index of variety. The results obtained provided some valuable evidence supporting the claim that organizations are constrained by Ashby's law.

Organizations are expected to achieve a certain output with a variety and uncertainty below a stipulated maximum level. This variety and uncertainty of the output may be correlated with some of the more common measures of organizational effectiveness. If organizations are expected to achieve an output with a variety and uncertainty below a determined level, the variety and uncertainty of the environment must be absorbed within the organization and be reflected in its structure. Thus Osborn et al. (1977), for example, found that for the same level of performance, as environmental variety increased so did the leadership variety. Likewise, Leifer and Huber (1977) found that perceived environmental uncertainty was positively associated with a more flexible organizational structure and with a higher degree of boundary-spanning activity, that is, verbal and written communication with extra work units.

A most significant contribution has come from Beer who introduced concepts of cybernetics ("the science of effective organization," 1966, p. 425) into management science. As in the case of contingency theory, Ashby's law is fundamental to Beer's thought. Thus he declares, "I consider that this law stands in the same relation to management as the law of gravity stands to Newtonian physics" (Beer, 1979, p. 89).

Beer's model of the organization's structure could be said to be broadly speaking, a reflection on the organization's response to cope with environmental variety. Like Ashby and the contingency theorists, Beer assumes that organizations have to achieve a minimum of variety in the output states, that is, they must achieve an output equilibrium which must, in addition, be stable. Consequently, environmental variety must be matched by organizational variety, and thus Ashby's famous phrase, often quoted by Beer: ". . . only variety can destroy variety" (Ashby, 1964, p. 207). This is also reflected in Beer's "First Principle of Organization":

> Managerial, operational and environmental varieties, diffusing through an institutional system, tend to equate; they should be designed to do so with minimum damage to people and cost. (1979, p. 97)

In summary, a survey of the relevant literature leaves the reader with a strong impression that, either implicitly or explicitly, management scholars from different schools consider the relationship proposed by Ashby's law as fundamental and crucial to management theory. While organization theorists have produced plenty of pertinent empirical research, only limited interest has been shown in gaining a deeper understanding of the concepts involved in the law. In the case of management science, and specifically the work of Beer, Ashby's law has provided the theoretical foundation stone to the development of an organizational model. However, there has not been the volume of empirical work which organization theorists have produced.

The research reported in this paper aimed to maintain a balance between giving a proper regard to the theoretical rigor of Ashby's law and the need to operationalize the concept if some empirical application is to be achieved.

3. ASHBY'S LAW IN AN ORGANIZATIONAL CONTEXT

Ashby's law operates upon two organizational dimensions: variety and entropy. The first of these two dimensions has already been mentioned earlier, and, as indicated, it measures the number of possible states that a system can adopt. This would correspond more or less with the concept of "diversity," whether environmental or organizational, which is used often by organization theorists.

The second dimension, entropy, was introduced by Shannon (Shannon and Weaver, 1949, p. 50) and endeavors to measure the uncertainty of the outcome of a given number of events, each with a specific probability of occurrence. In developing the concept of entropy, Shannon assumed that the behavior of the system under study would be Markovian. However, it is possible to use entropy as a measure of uncertainty in systems not Markovian as long as the first condition for entropy is fulfilled. This condition requires that the probabilities of all states for which entropy is calculated must add to one. Entropy is defined as follows:

$$H = K\sum_{i=1}^{n} p_i \log_2 p_i$$

where p_i = the probability of element i occurring, n = number of possible states (variety), and K = a positive constant, assumed to be equal to one.

If information is defined as the opposite of uncertainty, then the information necessary to dispel a given entropy may be considered as equivalent to that entropy but with a negative sign. Therefore, information is termed "negentropy" and defined by the following expression:

$$L = -H$$

Based on the two dimensions defined above, Ashby (1964) introduced a third dimension, constraint, which measures the degree of inability of a system to achieve all the states implied by its full potential variety. Constraint is defined as:

$$C_V = 1 - \frac{V}{V_m} \text{ for variety}$$

or

$$C_H = 1 - \frac{H}{H_m} \text{ for entropy}$$

where C_V = variety constraint, V = actual variety of the system, V_m = maximum variety of the system, C_H = entropy constraint, H = actual entropy of the system, and H_m = maximum entropy of the system.

As a dimension, constraint lends itself as a most useful measure of the degree of order, rigidity, or regulation that exists in an organization.

Reflecting upon this concept Ashby has said that ". . . the existence of any invariant over a set of phenomena implies a constraint, for its existence implies that its full range of of variety does not occur . . .", and ". . . as

every law of nature implies the existence of an invariant, it follows that every law of nature is a constraint'' (Ashby, 1964, p. 130).

Ashby's introduction of the notion of ''law of nature'' has special relevance for the application of these concepts to organizations. It is possible to conceive organizational behavior as being constrained, by representing organizational rules as the organization's equivalent to Ashby's ''law of nature.'' Rules limit the number of states that the organization may assume. Starting and finishing times, job specifications, the designation of formal reporting relationships, and manuals may all be conceived as reducing the potential variety of the organization to a manageable level. In fact, it is possible to consider the whole of the organization's structure as representing a constraint upon the organization.

In addition to the two organizational dimensions defined above (and their derivative—constraint), Ashby's law assumes a regulatory behavior in the organization. This regulatory behavior has three distinct stages. The first of these stages is the disturbance that originates in the environment in which the regulator operates. The second stage is represented by the regulatory process acting upon the disturbance. Finally, the third stage consists of the outcome or state of the essential variable that results from the regulatory process acting upon the disturbance. Hence, the outcome is assumed to depend on both the disturbance and the regulatory action.

According to Ashby, the function of the regulator is to ''. . . block the transmission of variety from disturbance to essential variables'' (Ashby, 1964, p. 199). (In the remainder of this paper, rather than use the terms disturbance, regulatory process, and outcome, the terms input, activity, and output will be used as these latter terms are more appropriate to the organizational situation.)

In light of Ashby's law, we may take the variety and the entropy of the input to represent measures of environmental uncertainty while the variety and the negentropy of the activity represent measures of information which the organization deploys to dispel environmental uncertainty. Given this model of organizational behavior, Ashby's law states that the minimum variety of the output is equal to the following expression:

$$V_{mo} = \frac{V_i}{V_a} V_{ia} \qquad (1)$$

where V_i = variety of the input, V_a = variety of the activity, V_{ia} = variety of the activity once the input is known, and V_{mo} = minimum output variety.

Likewise, the minimum entropy of the output is given by the following formula:

$$H_m(o) = H(i) - H(a) + H_i(a) \quad (2)$$

where H(i) = entropy of the input, H(a) = negentropy of the activity, $H_i(a)$ = entropy of the activity once the input is known, and $H_m(o)$ = minimum output entropy.

In an organizational context, the above expression of Ashby's law would indicate that given an environmental variety and entropy, the variety and negentropy of the activity must match the environment if the output variety and entropy are to be maintained at a minimum (i.e., $V_{mo} = 1$, $H_M(O) = 0$). This would have to take into account in addition the organizational "noise" or redundancy represented by V_{ia} and $H_i(a)$. Equation (1) may be rearranged to define the limits of the variety at each job stage as follows:

$$V_{ma} = \frac{V_i}{V_o} V_{ia} \quad (3)$$

where V_{ma} = minimum activity variety and V_o = variety of the output.
and

$$V_{mi} = \frac{V_o \times V_a}{V_{ia}} \quad (4)$$

where V_{mi} = maximum input variety.

4. AN EMPIRICAL APPLICATION OF ASHBY'S LAW

In the process of attempting to make an empirical application of Ashby's law, there are a number of questions that arise in the mind of the researcher. Some of these are:

1. Can proper measuring instruments be developed to measure variety and entropy in the organization with an acceptable degree of validity and reliability?
2. Assuming that appropriate measuring instruments are developed, will the variables obtained conform to those used in Ashby's law? This question is closely associated with the problem of validity, addressed in the previous question.
3. What levels of variety and entropy are found in the organization above the minimum level stipulated by Ashby's law? The excess above this minimum can only be established empirically.
4. How closely related is the measure of constraint (introduced in the previous section) to the concept of control found in organizations? Does lack of constraint mean the independence of the organizational units?

These questions are broad, and it would require extensive empirical research to answer them appropriately. However, they assisted in providing a direction to this research, and much of the discussion that follows will be addressed to them.

The unit of analysis chosen for this empirical study was the work role or individual job performer. The regulator's framework discussed in the previous section was superimposed on the work role and the three stages were identified as input, activity, and output. Each of these stages was assumed to display some degree of variety and entropy and in addition it was assumed that the work performer exercised a degree of control over these stages.

Given this unit of analysis, a number of hypotheses were stated. The first set of hypotheses tested whether the magnitudes of the actual varieties and entropy conformed to the limits expressed in Ashby's law:

Hypothesis 1: The actual variety of the input is not greater than the maximum input variety [defined in Eq. (4)].
Hypothesis 2: The actual variety of the activity is not lower than the minimum activity variety [defined in Eq. (3)].
Hypothesis 3: The actual variety of the output is not lower than the minimum output variety [defined in Eq. (1)].
Hypothesis 4: The actual entropy of the output is not lower than the minimum output entropy [defined in Eq. (2)].

While separate hypotheses were stated for each of the stages when referring to variety, this was not necessary with entropy, due to the fact that the

entropy equation [Eq. (2)] is linear, and therefore if hypothesis 4 is accepted for the output stage, it must also be accepted for each of the other stages.

The second set of hypotheses tested whether, in addition to conforming to magnitudes, the actual variety and entropy also conformed in pattern to the limit varieties and entropy stated in Ashby's law:

Hypothesis 5: The actual variety of the input is positively correlated with the maximum input variety.

Hypothesis 6: The actual entropy of the input is positively correlated with the maximum input entropy.

Hypothesis 7: The actual variety of the activity is positively correlated with the minimum activity variety.

Hypothesis 8: The actual negentropy of the activity is positively correlated with the minimum activity negentropy.

Hypothesis 9: The actual variety of the output is positively correlated with the minimum output variety.

Hypothesis 10: The actual entropy of the output is positively correlated with the minimum output entropy.

The third set of hypotheses tested whether an increase in input variety and entropy is matched with a corresponding increase of variety and negentropy in the activity as proposed by Beer's first principle of organization:

Hypothesis 11: The actual variety of the input is positively correlated with the actual variety of the activity.

Hypothesis 12: The actual entropy of the input is positively correlated with the actual negentropy of the activity.

The fourth set of hypotheses tested whether there is a relationship between variety/entropy and control:

Hypothesis 13: The control of the input is positively correlated with the variety of the input.

Hypothesis 14: The control of the input is positively correlated with the entropy of the input.

Hypothesis 15: The control of the activity is positively correlated with the variety of the activity.

Hypothesis 16: The control of the activity is positively correlated with the negentropy of the activity.

Hypothesis 17: The control of the activity is positively correlated with the variety of the activity once the input is known.

Hypothesis 18: The control of the activity is positively correlated with the entropy of the activity once the input is known.

Hypothesis 19: The control of the output is positively correlated with the variety of the output.

Hypothesis 20: The control of the input is positively correlated with the entropy of the output.

The first task of the empirical work was the development of a suitable methodology for measuring the variables involved in the work process. Two of these variables, variety and entropy, have been discussed in previous sections. A third variable, control, was added, which reflected the control which the job holder had over the input, activities, and output of his work. The purpose of this variable was to assess the degree of correlation that exists between the control of the job holder as understood in the organizational context and the concept of constraint introduced earlier on.

Because of practical reasons, the means of measuring control were determined largely by the methodological requirements of both variety and entropy. The task of measuring variety and entropy may be approached from two different methodological perspectives: the first methodology would be a direct measurement of variety and entropy. It would include the definition of the system, the separation of its distinguishable elements, and the counting of them. The number of elements counted would be the variety of the system. Likewise, by establishing the frequencies of occurrence for each state it is possible to derive the entropy of the system.

The second method would be based upon the perceptual judgment of the variables by individuals within the organization. It would involve each person in making a perceptual judgment of the variety and entropy of his or her job based on his or her own definition of the system. This judgment would be expressed by the person's selection of a grade in a scale which corresponds to the intensity of the variable.

By taking into account advantages and disadvantages of both methods, it was considered that in the context of this research, the perceptual judgment method was the most feasible option available for the empirical work.

The data collection was carried out through a semistructured interview schedule of 11 questions regarding the level of variety, entropy, and control at each stage of the job process (a description of the measurement instrument is provided in the appendix). Answers were given on a scale of 1 to 5,

representing "very low" to "very high" levels. The questions were presented in a folder, one to a page; the question displayed on the left-hand side and the scale on the right-hand side.

The first page of the folder gave a simple explanation of Ashby's regulator model as applied to the job situation. In addition, examples were given of inputs, activities, and outputs drawn from well-known tasks. The interview began with this explanation and an attempt was made to identify each stage of the model with the respondent's work situation. The second stage of the interview (asking the questions) was not attempted until there were clear signs that the respondent understood the framework.

The second stage of the interview was concerned with the questions themselves. In addition to the formal questions presented in the folder, complementary questions were asked for the respondent to illustrate, in a practical manner, the meaning of the formal questions. Although these complementary questions were not written in the folder, they were written on a separate piece of paper and read by the interviewer so as to make sure that they were always stated in the same manner. The purpose was to make the interview as standard as possible for each respondent, while at the same time allowing sufficient flexibility for the respondent to grasp the meaning of the model and the variables.

While this data collection method was time consuming, it allowed the interviewer to clearly explain the variables involved to the respondents. Thus while the sample obtained was smaller than what would have been obtained with a self-administered questionnaire, the data obtained were more reliable.

Because the measurements for variety and entropy obtained from the survey were used to perform mathematical calculations according to Ashby's law, including the operations of multiplication, division, and addition, it was necessary to assume that measurements were made on a ratio scale. This represents a significant simplification of the relationship that exists between the actual measures of variety and entropy and the measures as perceived by the respondent. However, it was considered expedient that as a starting point for research, such an assumption should be made.

The survey was carried out at a large insurance society in Melbourne, Australia. The sample consisted of the people working in seven departments of the Head Office in Melbourne. In each case, the complete department was surveyed, with the exception of those staff members who were on leave or were not available for an interview on several occasions. In total, this provided 100 observations; the list of departments surveyed and the number of observations per department is listed in Table 1.

TABLE 1. Departments Surveyed and Number of Observations

Department	No. observations
Actuarial	15
Actuarial Systems	7
Underwriting	10
Processing Control	21
Corporate Planning	3
EDP—Systems Analysts	13
EDP—Programmers	17
EDP—Operations	9
Organization and Methods	5
Total	100

5. ANALYSIS OF THE DATA AND RESULTS

A number of statistical tests were carried out to test the hypotheses stated in Section 4. Hypotheses were tested at a .05 significance level.

5.1 Actual and Minimum Varieties/Entropies

A paired-sample t-test was carried out for each set of actual and minimum varieties. The results of this test are tabulated in Table 2, and the following conclusions were reached.

The actual variety of the input was significantly lower than the maximum variety stipulated by Ashby's law; therefore, Hypotheses 1 was accepted.

The actual variety of the activity was not significantly larger than the minimum variety, but a two-tailed test showed that neither was there a significant difference between these variables; consequently, Hypothesis 2 was accepted.

The actual variety of the output was significantly larger than the minimum variety of the output; thus, Hypothesis 3 was accepted.

Finally, the actual entropy of the output was not significantly larger than the minimum entropy, but neither was it significantly different, so Hypothesis 4 was also accepted.

5.2 Correlation between Actual and Minimum Variety and Entropy

A correlation analysis was carried out between the actual and minimum (maximum for the input) varieties and entropies. The results are listed in Table 3. A significant correlation was found in all cases except between the actual and the maximum variety of the input and between the actual and the minimum entropy of the output. Consequently Hypotheses 6, 7, 8, and 9 were accepted, and Hypotheses 5 and 10 were rejected.

5.3 Correlation between Input and Activity Variables

A correlation analysis—the results are listed in Table 4—indicated that there is a significant correlation between the input variety and the variety of the activity ($r = 0.318$) and between the entropy of the input and the negentropy of the activity ($r = 0.552$). Hypotheses 11 and 12 were accepted.

TABLE 2. Paired-Sample t-Test between Actual and Minimum/Maximum Variety and Entropy ($n = 100$)

Variable	Mean	SD	Diff.	t	Significance level		Hypothesis tested
					One-tailed	Two-tailed	
Input variety							
Actual	2.895	1.115					
Maximum	4.252	2.918	−1.357	−4.417	.000		1 A
Activity variety							
Actual	3.410	0.970					
Minimum	3.074	2.170	.336	1.578	.059	.118	2 A
Output variety							
Actual	2.660	1.101					
Minimum	2.207	1.261	.453	3.215	.001		3 A
Output entropy							
Actual	2.435	1.075					
Minimum	2.630	1.524	−.195	−1.131	.131	.261	4 A

Abbreviation: A = accepted.

TABLE 3. Summary of Correlation Analysis between Minimum-Maximum and Actual Variety and Entropies

Variable	Correlation coefficient	t	Significance level	Hypothesis tested
Input				
Variety	.050	.491	.624	5 R
Entropy	.205	2.076	.041	6 A
Activity				
Variety	.268	2.749	.007	7 A
Negentropy	.395	4.258	.000	8 A
Output				
Variety	.295	3.060	.003	9 A
Entropy	.153	1.536	.128	10 R

Abbreviations: A = accepted, R = rejected.

5.4 Correlation between Control and Variety/Entropy

A correlation analysis was carried out (see Table 5) to establish the degree of correlation between the measures of variety and negentropy at each stage and the corresponding control. It was established that there was a significant correlation in each case except for the input stage variety and entropy. Therefore, Hypotheses 13 and 14 were rejected, and Hypotheses 15, 16, 17, 18, 19, and 20 were accepted.

6. DISCUSSION OF THE RESULTS AND CONCLUSIONS

The results showed that the estimated population means of the actual varieties and entropies conformed to Ashby's law; the law requires that each of these varieties and entropies be less or equal to the calculated minimum (or lower or equal to maximum for the input).

TABLE 4. Summary of Correlation Analysis between Input and Activity Variety and Entropy

Variable	Correlation coefficient	t	Significance level	Hypothesis tested
Variety	.318	3.319	.001	11 A
Entropy/negentropy	.552	6.554	.000	12 A

Abbreviation: A = accepted.

TABLE 5. Summary of Correlation Analysis between Control and Variety/Entropy

Variable	Correlation coefficient	t	Significance level	Hypothesis tested
Input				
Variety	.151	1.507	.135	13 R
Entropy	.116	1.155	.251	14 R
Activity				
Variety	.444	4.904	.000	15 A
Negentropy	.320	3.343	.001	16 A
Activity once the Input is known				
Variety	.524	6.084	.000	17 A
Entropy	.250	2.558	.012	18 A
Output				
Variety	.208	2.104	.038	19 A
Entropy	.409	4.441	.000	20 A

Abbreviations: A = accepted, R = rejected.

The law, however, would only be relevant to the organization if the constraint that imposes upon it is real. That is, if the organization is able to deploy an unlimited amount of variety and entropy in its activities, or if the output variety is irrelevant to the organization's purpose, a minimum or maximum variety or entropy requirement would be of no significant interest. The survey showed that in the case of variety the population mean displayed a small excess while in the case of entropy there was no excess at all. This indicates that on the average, Ashby's law imposes a significant constraint upon the worker.

This is further supported by the results of the correlation analysis between the observed variables and the values obtained from Ashby's law. These results indicate that the law not only determines a lower limit (or upper limit in the case of the input) for variety and entropy but exercises a broader effect upon the range of values that these variables may assume. In this case, the mathematical expression of the law would be more like an equation rather than an inequality.

The correlation coefficients obtained indicated that this effect is only slight. Yet a substantial degree of variation from the regression line may be attributed to the mathematical calculations that must be carried out to obtain the minimum and maximum variety and entropy as defined in Eq. 4. This increases the measurement errors and is reflected in the larger standard devi-

ations for the maximum and minimum variables when compared with the actual variables (see Table 2).

Significant support was found for Beer's first principle of organization: as environmental variety and entropy increased, variety and negentropy in the activity also increased as evinced by the correlation between both pair of variables.

There was a significant degree of correlation between the control exercised by the individual upon his activities and the corresponding variety and entropy. These results support the conception held by systems theorists that "disorganization" is associated with organizational uncertainty. In this instance, as the degree of uncertainty of the activities increased, the workers' control also increased, that is, they became more self-directing and independent from work standards and rules.

This same relationship was found to exist at the output stage. That is, uncertainty over outcomes was associated with individual discretion to determine the nature of these outcomes. This may be interpreted as reflecting the lack of "organization" in the system to determine outcomes or objectives.

However, neither variety nor entropy was correlated with control of the individual over the input. This may be due to certain instances where control may be used by the individual to reduce input variety and entropy rather than increase it, reflecting the process of environmental enacting by which "the human creates the environment to which the system then adapts" (Weick, 1969, p. 63f).

In summary, it may be said that despite the preliminary nature of the instruments used to measure both entropy and variety, the data obtained were sufficiently valid to demonstrate conformity with Ashby's law. In addition, the results obtained support other relationships suggested by the theory, such as the relationship between control and constraint. Further refinement of the measuring instruments may produce more significant results, enabling a better estimation of the degree to which Ashby's law determines the structure of the organization.

In concluding, it may appropriate to reflect upon two statements write by Ashby over two decades ago:

> I do not think enough attention has yet been paid to Shannon's Tenth Theorem or to the simpler "law of requisite variety" in which I have expressed the same basic idea. . . . I think here we have a principle that we shall hear much of in the future, for it dominates all work with complex systems. (Ashby, 1962, p. 116f)

It would certainly be an understatement to say that the modern world has become progressively more complex and uncertain. Social institutions, whether government, public, business, religious, charitable, or other, are operating in increasingly complex and uncertain environments. It is not surprising, therefore, that management theory has focused so sharply on the organization's environment. Ashby's prediction has come true, even if in a manner rather different from what he might have expected. It may be hoped that his second prediction, quoted below, may also come to fulfilment:

> I suggest that when the full implications of Shannon's Tenth Theorem are grasped we shall be, first sobered, and then helped, for we shall then be able to focus our activities on the problems that are properly realistic, and actually solvable. (Ashby, 1962, p. 117)

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APPENDIX: SEMISTRUCTURED INTERVIEW SCHEDULE

I Introductory Explanation (first page):

The 3 stages of Your Work

1. INITIAL EVENT, incident or circumstance
   e.g. - phone call from customer
   request from manager
   own decision to do a job
2. ACTIVITIES or tasks carried out
   e.g. - investigate query
   prepare report
   re-organize file
3. OUTCOME, product or result
   e.g. - solved query
   report
   re-organized file

II Formal Questions (one to a page):

1. How much VARIETY is there in your INITIAL EVENTS?
2. How much UNCERTAINTY is there in your INITIAL EVENTS?
3. How much CONTROL do you have over your INITIAL EVENTS?
4. How much VARIETY is there in your ACTIVITIES?
5. How much UNCERTAINTY is there in your ACTIVITIES?
6. How much CONTROL do you have over your ACTIVITIES?
7. Once the initial event is known to you, how much VARIETY is there in your ACTIVITIES?
8. Once the initial event is known to you, how much UNCERTAINTY is there in your ACTIVITIES?

9. How much VARIETY is there in your OUTCOMES?
10. How much UNCERTAINTY is there in your OUTCOMES?
11. How much CONTROL do you have over your OUTCOMES?

Scale (one across the page for every question):

SCALE

VERY HIGH 5
HIGH.....4
MEDIUM 3
LOW 2
VERY LOW 1

III Complementary questions (on a separate sheet of paper—numbers in these questions correspond to numbers in the formal questions):

1. Are there many different initial events or just a few?
2. Are they difficult to predict, say every morning?
3. Can you change or postpone an initial event easily? e.g. can you change a request so that it be made on another date?
4. Do you perform many different activities or just a few? Is your work varied?
5. Is it difficult to predict what kind of activity you will be performing, say each day?
6. Are you the only one that says how certain work is to be carried out?
7. After an initial event has occurred, are there many alternative activities which you could follow or just a few?
8. Think of the moment just after an initial event has occurred, is it difficult to predict which activity you will carry out?
9. Are there many different outcomes in your job or just a few?
10. Are the outcomes in your job difficult to predict?
11. Once you produce an outcome, is it final, or can someone else ask you to change it?

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