Complex versus complicated: the how of coping with complexity

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Abstract

Purpose – The purpose of this paper is to demonstrate and explain how distinct approaches to coping with complexity vary in their effectiveness. The different strategies are evaluated as to their respective capabilities of absorbing complexity. Virtuous versus vicious approaches are distinguished.

Design/methodology/approach – Based on two basic formulas for the calculation of variety, a measure of complexity, sensitivity analyses for different strategies are carried out. Recommendations for the how of coping with complexity are derived logically.

Findings – Strategies based on increasing the repertory of behaviour through enhancing the potential states of the elements (component agents) in a system are superior to strategies which pursue an increase in the number of elements.

Practical implications – The imperative to increase the repertory of behaviour and to avoid responses to complexity through complication constitute an approach that leads to an overshoot of eigen-complexity and consequently to inefficiencies or ineffectiveness.

Originality/value – This contribution sheds light on misinterpretations of Ashby's law of requisite variety. The insights derived from the analysis can help real-life organizations to avoid failures and reap substantial strategic advantages.

Keywords Cybernetics, Complexity theory, Behaviour

Paper type Research paper

1. Introduction

Coping with complexity is the crucial challenge for any human or social agent, be it an individual, a team or an organization. It is a decisive precondition for a system's viability. This is nowadays generally known and often stated. Also, the eclectic literature directed to practitioners has come up with pragmatic recommendations for facing complex situations Mattern *et al.* (2003), Heywood *et al.* (2007) and Gottfredson *et al.* (2008). However, not much management research has been aimed at providing generic insights about how the complexity confronting organizations, particularly agents in organizations, can be mastered effectively (exceptions are Luhmann (2000) and Baecker (1999)). Works by several authors, however, provide conceptual reflections on the implications of complexity for organizations and management, in the vein of the "science of complexity" as pursued at the Santa Fe Institute (Stacey, 1996; Marion, 1999; Stüttgen, 2003).

The distinctive aspect of this paper consists in its particular grounding. Based upon the science of cybernetics, it addresses the question of how agents in organizations and organizations, as agents, can master complex situations. Cybernetics, the science of control and communication, since its beginnings (Wiener, 1948) has focused on the management of complex dynamic systems. This contribution is not only grounded in general cybernetics, but it also builds in particular on Organizational Cybernetics, founded by Beer (1966), which focuses on social systems.

The purpose of this contribution is to improve the understanding of cybernetic mechanisms inherent in the interaction of agents with complex situations.

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On that basis, we aim to explain in principle how different approaches to management in the face of complexity vary, and why.

For this purpose, the paper deals with two main aspects. On the one hand, the concept of variety is interpreted in terms of its relevance for the management of complexity (Section 2). On the other hand, the implications of the different approaches to managing in the face of complexity are explored and compared, respectively, (Sections 3 and 4). Finally, a conclusion concerning the insights obtained is provided (Section 5).

2. The concept of variety and its role for the management of social systems

First of all, the concepts of complexity and variety will be defined. On that basis, the implications of complexity for the management of social systems shall be derived.

2.1 The concepts of complexity and variety

Complexity as defined here is a system's property of being able to assume a large diversity of states or modes of behaviour (Malik, 1996, p. 37; Nicolis, 1995, p. 1). Variety is a measure of complexity. It expresses the number of distinct elements (Ashby, 1964, p. 124ff), and, if we consider the proliferation of variety[1], conclusively expresses the quantity of potential states or potential behaviours[2] a system can exhibit[3]. An invariant feature of complex systems is that, in principle, they show an exceedingly high variety, the actual variety of states assumed by a given system being always smaller than its potential variety. A mathematical conceptualization of variety will be carried out shortly.

2.2 The significance of variety for management

One of the crucial challenges of our age is the management of complex systems, given their ubiquity. It is not by accident that the visionary physicist Steven Hawking called the twenty-first century the "Century of Complexity"[4].

Conclusively, the concept of variety is central for the managerial domain. To elucidate this further, let us revert to Ashby's law of requisite variety, which says: "Only Variety can absorb Variety" (Ashby, 1964, p. 207)[5]. The chief implication of this law is that a regulator, to maintain a system under control, must have a variety which is equal to the variety of the system regulated.

In social systems it is normally impossible for a regulator to attain the potential variety of the regulated system physically. Take a manager and his staff, a sales force and the market in which they operate, or a teacher and his class. All of them are a minority within the context in which they are embedded. They are interacting with a system whose potential variety of behaviours is a multiple of their own[6].

2.3 The variety differential and how to cope with it

If we take two interacting systems, one being an agent and the other a situation in which it operates, the given fundamental is a complexity differential: the potential variety of the situation or environment (V_R) is by far higher than that of the agent (V_A) (equation 1):

$$V_R \gg V_A \quad (1)$$

If Ashby's law holds, then a reciprocal adaptation between the two is necessary to avoid instability and disruption, which eventually would lead to the destruction of the agent.

There are two possibilities for the actor to induce a balance between the two systems (Beer, 1985):

- (1) amplification of its own variety "Eigen-Variety"; and
- (2) attenuation of the variety of the environment "External Variety".

Figure 1 (Espejo and Watt, 1988) shows this matter. Combining the two strategies is what Beer (1979) calls "Variety Engineering". Amplification is about the enhancement of degrees of freedom for the actor, and attenuation is about the discovery and design of constraints on the environment.

3. Different approaches to management in the face of complexity

If we strive for an evaluation of different strategies for coping with complexity, a measure for variety is needed.

3.1 Conceptualizing variety mathematically

There are different ways of conceptualizing variety mathematically (Beer, 1966, p. 246ff; Klir, 1991, p. 113ff). Two of the most-used formulas for calculating variety are shown in equations (2) and (3)[7]:

(1) *Element-oriented formula:*

$$V_1 = z^n \quad (2)$$

(2) *Relationship-oriented formula:*

$$V_2 = m \cdot \frac{n \cdot (n - 1)}{2} \quad (3)$$

A Agent, R Environment / Milieu / Situation

V_A Variety of the agent

V_R Variety of the relevant environment / milieu / situation

Code: V , variety; m , number of relationships between each pair of elements; n , number of elements (component agents); z , number of potential states for each element.

We refrain from combining the formulas to express the proliferation of the variety of a dynamic system, which would transcend the purpose of this paper, as already indicated in footnote[2]. In other words, we do not engage in the calculus of all sequences of states, i.e. potential trajectories or lines of behaviour (Ashby, 1964, p. 25; Beer, 1966, p. 251).

Both of the functions referred to here show an exponential increase of variety V as the number of elements in the system n increases. The curve of V according to the first formula (2) has a steeper slope than for formula (3), which, however, is a technical detail, not a question of principle. The principle here is the exponential nature of the phenomenon.

Let us consider an example regarding formula (2). For social systems, the elements are conceived as component agents of the system. For example, if the agent is a team, then the team members are the component agents. The parameter z is a measure of the distinct states, in other words, the gamut of basic potential behaviours in which a component agent can engage.

3.2 Responses to the complexity phenomenon

The basic strategies for coping with a high-variety situation or environment, as has been said, are amplification and attenuation. The question here is how these strategies are designed.

An approach very frequently undertaken is based on the following rationale: "If the situation is complicated, then we have to give complicated answers". This misconceives Ashby's law, and it is also a trap. The cases in which leaders have built up what they call "complex solutions", while getting into the trap of complication, are ubiquitous. These managers tend to maneuver themselves and their organizations into complicated states which they cannot handle. Their misunderstanding stems from their neglect of an important distinction: enhancing eigen-variety is a synonym for increasing the repertory of behaviour, while complication is simply a tendentially counterproductive increase in heterogeneous elements[8].

Variety engineering, then, consists in amplifying eigen-variety while at the same time attenuating the external variety of the situation or environment faced. To abide by Ashby's law of requisite variety, the agent must strive for an equilibrium between the two, so that its repertory of behaviour is commensurate with the complexity challenge at hand. Such an equilibrium is defined as follows (equation 4):

$$V_R = V_A \quad (4)$$

3.3 First mode: attenuating external variety

Let us assume that a company faces a market made up of n_R segments. Let us also assume that each of these segments can adopt z_R discrete states. V_R , the variety of the market, would in this case be (equation 5):

$$V_R = z_R^{n_R} \quad (5)$$

In case there are six segments, each of which can assume two different states (say, "in control" and "out of control"), the variety of the market amounts to $V_R = 64$. This number could become very high if the number of segments were to increase,

and more so if the number of potential states of the segments were to get higher. Let us assume that the number of segments is doubled to 12, and that each of them has four potential states; then V_R would have boomed to 16,777,216. This corresponds to a multiple of 262,144 in relation to the original case. The point is not in counting the potential states one by one, but in grasping the exponential dimensions of these changes.

It is easy to see that a strategy of adding more elements and additional relationships to one's own organization, in order to cope with such an increase, readily leads into the trap of complication, namely, a large organization with little efficiency. It would therefore be more appropriate to check the market for potential constraints that would reduce its complexity: could the 12 segments be collapsed into a smaller set? This would be the case if the crucial differences between certain segments, after careful examination, would turn out to be insignificant. Could a subset of the segments be factored out, because they were unimportant? This would comply with a strategy of focus. Are all potential states of the elements equally important, or could one abstract some of them? The latter would apply, e.g. in the event of a concentration on core competencies.

To take account of such cases we introduce a constant q_R , which denotes the share of those elements which are equal to other elements in the set under study, in this case the market equation (5) would then be extended (equation 6):

$$V_R = z_R^{n_R \cdot (1 - q_R)}, \quad 0 \leq q_R \leq 1 \quad (6)$$

Let us assume a number of market segments n_R of 8, a number of states per market segment z_R of 2, and a q_R of 0.125, i.e. that one of the market segments is indistinguishable from some other element in the set or fused with such an element. In this case, V_R would amount to 128, while we would get 256 twice as much – if q_R were zero, i.e. if all segments were distinct. A q_R of 0.5 would result in a V_R of 16 only, i.e. the gain would be a reduction in variety of 93.75 per cent. The residual variety would amount to a mere 6.25 per cent of the initial amount of 256, which thereby would have been attenuated by a factor of 16. If the number of market segments n_R were 12, a drop from $q_R = 0$ to $q_R = 0.5$ would result in an attenuation by a factor of 64, down from a variety of 4,096.

These numerical examples show that even relatively small alterations in either the basis or the exponent of formula (6) lead to much larger changes in the outcome. Linking this back to the misconception of complicated responses to situational or environmental complexity, the conclusion is straightforward. It is much more effective to pursue a strategy of amplification (of eigen-variety) and combine it with attenuation (of external variety), instead of merely adding new elements to the set of elements constituting the actor A . In the first place, one should examine the possibilities of introducing constraints, by limiting the environment one has to deal with or by structuring it in ways that allow a sustained coexistence or coevolution, i.e. viability of the agent or system under study.

Failures to attenuate external variety can have devastating consequences. Impressive cases of companies that expanded the complexity of their services are reported by Gottfredson and Aspinall (2005). One telecommunications company, for example, sliced its service portfolio into ever more finely differentiated options, in the hope of boosting revenues by precisely fulfilling the specific needs of any conceivable potential customer. The effect was the opposite, however: sales

representatives were overstrained by the multiplicity of promotion codes and discount variations, which drastically impaired their effectiveness.

3.4 Second mode: amplifying eigen-variety

Our point of departure is equation (7), which is symmetrical to equation (5); it expresses the nature of eigen-variety:

$$V_A = z_A^{n_A} \quad (7)$$

At this stage, we will look at the ways in which eigen-variety can be expanded. In principle, both approaches are possible, either through changes in n_A , the number of elements which constitute the agent, or changes in z_A , the number of states per element. A numerical analysis shows that incremental changes in z_A offer a greater leverage on V_A than incremental changes in n_A . Let us take an agent with 5 elements and 2 states per element, the resulting variety being 32. If the number of elements is changed to 6, this results in a 100 per cent increase of variety to 64, while an increase from 2 to 3 states per element, with 5 elements, leads to an increase by a factor of 7, 6 – to a variety of 243, etc. From these numerical examples one can generalize as follows (formula 8):

$$\frac{\Delta V}{\Delta z} > \frac{\Delta V}{\Delta n} \quad (8)$$

In other words, it is more efficient to increase the number of potential states in the elements, i.e. to amplify the repertory of behaviour, than simply to add new elements to the system. Translated into the language of organizations, complexity can be absorbed more efficiently if the organization is kept lean and if flexibility is enhanced, rather than increasing the size of the organization, as is often believed. This may be known intuitively, but the numbers here show that quite small organizations which work on increasing their repertory of behaviours can outperform relatively large organizations which stick to a narrow scope of behaviour. This calls for permanent learning, training, education, as well as the exploration of and experimentation with new modes.

In practice, an infringement of Ashby's law by insufficient amplification of eigen-variety is dangerous. The quest to keep inventories low, for example, can lead to chain effects involving cyclical capacity deficits, technical schedule slippages, and shortages with local suppliers, as has been shown, e.g. for the case of the computer hardware producers (Gottfredson and Aspinall, 2005). The financial consequences tend to be formidable. In such cases, redundancy, as a form of variety amplification, can be crucial. This example shows that not all $+\Delta V_A$ can be achieved by $+\Delta z_A$ alone.

3.5 Focus on relationships: the curse of complication

We have labeled the increase of elements, i.e. $+\Delta n_A$, as "complication", and declared that it is an inferior approach to variety generation next to enhancing the number of states of the elements, i.e. $+\Delta z_A$. It is necessary to substantiate this assertion.

The relative disadvantage of the strategy of $+\Delta n_A$ in comparison to one of $+\Delta z_A$ is that the former is more coordination-intensive. The need for coordination grows progressively with each additional element. In comparison, an additional (potential) state of a component agent, even if it may require accessory skills, does not augment the need for coordination between the agents as much as a rise in the number of component agents.

To visualize this, a numerical illustration may be useful. We start out from an initial situation of $n_A = 5$ and $z_A = 2$, and then compare the two strategies of $+\Delta n_A$ and $+\Delta z_A$. Let the goal be an eigen-variety $V_A > 1,000$. If we increase n_A , then a size of $n_A = 10$ is needed to reach the goal, the result being $V_A = 1,024$. With a $+\Delta z_A$ strategy, however, the goal is achieved if we succeed at increasing z_A to a value of 4, while maintaining constant n_A . It is intuitively clear that the first version leads to a much higher need for coordination. This can be substantiated with the help of formula (3) above.

If we leave z_A constant, and use formula (3) with a relational parameter m_A of the size 2 (i.e. bidirectional coordination), then the need for coordination manifests itself, in the first case (with $n_A = 10$), in a complexity of 90, versus 20 in the second case (where $n_A = 5$). In other words, the need for coordination for the $+\Delta n_A$ strategy is the 4, 5 fold multiple compared with the $+\Delta z_A$ strategy. Herein lies the problem of complication[9].

4. Modes of amplification and attenuation compared

As shown, variety amplification has two modes, which have something in common, but which also diverge in a crucial respect. One of the modes, $+\Delta z_A$, is the amplification of eigen-variety by adding potential states, while the other, $+\Delta n_A$, increases the number of elements. Both modes of variety amplification are capable of absorbing more complexity.

Each mode, however, has distinct implications. Adding states implies a larger gamut of potential behaviours; it means more flexibility, a larger repertory of potential behaviours, and a greater action potential for the respective agent. Adding elements, on the other hand, as has been demonstrated, has the attendant implication of complication, counterproductive growth, inefficiencies, bureaucracy and the like. To stress the difference between the two different modes, one could distinguish between "good Variety amplification" and "bad Variety amplification", or a virtuous versus a vicious approach to variety Engineering.

Now the question arises whether a similar difference of modes exists in the case of variety attenuation. Indubitably, external complexity can be attenuated both ways, by introducing constraints that reduce either the number of different elements ($-\Delta n_R$) or the number of distinct states of the elements ($-\Delta z_R$). As in the case of amplification, reciprocally a constraint on the variety of states is a more powerful attenuator than a constraint on the variety of elements. The difference here can be pointed out by the labels "strong attenuator" and "weak attenuator". However, in practice it appears to be more difficult to reduce the variety of states than the variety of elements in the environment. The former is "stickier", while the latter is "slipperier", provided that the environmental system (or the subsystem, respectively) can be redefined by setting new boundaries. The example of a reduction in market segments used earlier would be a case in point. While, the number of selected segments could be changed with relative ease, it is quite evident that changing the behavioural repertory in the face of a market segment might be extremely difficult if not impossible.

In sum, changes of variety of the Δn type, i.e. by adjusting the quantity of the elements, tends to be fragile, while the Δz type, i.e. changing the repertory of states, is likely to be more robust.

5. Conclusion

At the outset, the concept of variety was defined in terms of the number of states of a system. We have shown in this contribution that it is worth looking at that concept also in terms of (potential) behaviour, in that behavioural variety is an expression of a system's repertory of behaviours.

It has been shown that there are different strategies for dealing with complexity. Essentially two alternative strategies exist: one is either to increase or reduce the number of elements of the interacting systems (namely, the agents that are part of these systems). The other strategy is to change the set of potential behaviours of the component agents, i.e. the variety they can attain. Quantitative comparison shows that the first alternative is much less effective than the second one. This finding is related to the fact that the first strategy, in the sense of an enhancement of eigen-variety, tends to render the system more complicated while showing relatively little leverage for complexity absorption. *Ceteris paribus* (all other things being equal), only the second strategy makes the system capable of absorbing substantially more complexity. In respect of coping with external variety, then, reducing the number of elements in the environment at hand is a less effective strategy than reducing the set of their potential states. However, the latter is more difficult to achieve than the former.

The analysis propounded here also indicates that neither the amplification nor the attenuation of variety alone is sufficient for compliance with the "Law of Requisite Variety". Balancing the varieties of interacting systems generally calls for both approaches. The generic robust strategy is one of amplifying eigen-variety and attenuating external variety at the same time.

However, the misconception of responding to external complexity with internal complication, by adding new elements to the system, tends to lead to an overshoot of eigen-complexity and consequent inefficiencies or ineffectiveness. Therefore, virtuous and vicious approaches to variety engineering must be kept apart.

The practical implication of these insights for a given reference system can be summarized in an imperative for variety engineering:

- Select the environment you interact with in a way such that a sustainable balance of the varieties can be maintained.
- Increase the repertory of behaviour and avoid responses to complexity through complication!

Notes

1. Proliferation of variety is expressed by distinguishing different states of the elements and the relations between them (Beer, 1966, p. 246ff).
2. Behavior is defined as the totality of the possible reactions of a dynamic system (Klaus and Liebscher, 1979, p. 888). Modes of behaviour are squads of lines of behaviour (Ashby, 1964, p. 25; Klaus and Liebscher, 1979, p. 890). We do not engage in calculating these aspects here, because they are not necessary for the demonstration of the points to be made in this paper.
3. For more detailed definitions of complexity and its manifestations, (Rescher, 1998, p. 1ff; Ilachinski, 2001, p. 614ff).
4. "I think the next century will be the century of complexity". (Stephen Hawking, quoted in the San José Mercury News, January 23, 2000).

5. In the original, Ashby wrote "Only Variety can destroy Variety". The verb absorb was inserted by Beer (1979, p. 89).
6. Decentralization and self-organization can mitigate this discrepancy, but not abolish it altogether.
7. For the formal deduction, see Beer (1966, p. 246ff), Klaus and Liebscher (1979, p. 314) and Schwaninger (1994, p. 12). Other formulas, which will not be treated here, measure variety in a logarithmic form (Ashby, 1964, p. 126).
8. Complicated systems are systems made up of heterogeneous elements. If a system has o heterogeneous elements, but one can reduce its function to $n < o$ via pertinent coupling, then its complexity is reduced (Klaus and Liebscher, 1979, p. 314f).
9. The problem is exacerbated if m_A is increased. Studies of random Boolean networks have shown that an increase in connections in a system beyond a certain point leads to instability, stifling adaptation: if the interconnectedness is high ($m > 3$), the system shows chaotic behaviour (Kauffman, 1991).

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