Cybernetics and Resilience Engineering: Can Cybernetics and the Viable System Model Advance Resilience Engineering?

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Abstract. Cybernetics as the science of control in the animal and machine provides a paradigm for inquiry into organisational behaviour. Management cybernetics supplies complementary perspectives on managing complexity and organisational performance. Using the Viable System Model (VSM) a qualitative diagnosis can be made of the communication structures in the viable organization. Viability is the ability to maintain the organisational identity in a changing environment. This notion compares well with some proposed aspects of resilience. VSM is suitable for diagnoses of the viability of an organisation and might therefore also be an useful concept for diagnosis and understanding of resilience. A specific function in the VSM scans the organisational environment for threats and opportunities. This “outside and then” function negotiates with the ‘inside and now” function of the organisation about adaptation. This seems to be in line with the proposed requirements for resilience such as anticipation, attention and response. This paper proposes further exploration of management cybernetics for possible answers to the challenges of resilience engineering (RE).

1 INTRODUCTION

In my literature study for my PhD on Safety Management Systems (SMS) I am exploring cybernetics and its applications for management. This paper is intended to share my ongoing discoveries and ask the question how cybernetics can support us in finding ways to engineer resilience.

Cybernetics is concerned with communication and control, therefore it seems compatible with recent safety science development akin RE. In the safety science literature, including publications such as Resilience Engineering, concepts and precepts (Hollnagel, Woods & Leveson, 2006), references to the field of cybernetics are not widespread. The most common reference is to the Conant and Ashby theorem (1970) about the requisite variety a control most poses in order to remain in control. Especially, when the notions of safety as used in the RE domain point to notions such as “loss of control”, “unexpected interaction between (sub-)systems”, I would expect more reference to cybernetics the science of control and communication in the machine and animal (Wiener, 1948).

Cybernetics laws, like gravity, cannot be disregarded. This raises the question how can cybernetics support us in understanding successes and failures of resilience. Remarks for the requirement of “a new language”, “higher order variables” and how to model resilience might be to some extend fulfilled by examining the insights from cybernetics.

Since the safety paradigm is shifting to systems theoretical concepts, cybernetics becomes available as a compatible theory to study safety and resilience.

In this paper I will propose a further use of cybernetics. In specific I will address management cybernetics, described by Beer as "the science of which management is the profession". In his study for the invariance's in communication and control and based on Ashby's laws of variety, he developed the Viable System Model (VSM). This model is helpful in designing and diagnosing the organisational structural mechanisms of communications and control. These structures are produced by people's interactions and provide the organisation with its own identity. The ability to keep this identity in a changing environment is a indication of viability. Also a resilient system must have the ability to anticipate, perceive and respond (Hollnagel, Woods & Leveson, 2006) in an environment of scarcity and pressure. In this essay some pointers will be given towards concepts in management cybernetics that may support maturing of resilience engineering.

2 CYBERNETICS LAWS

Cybernetics is concerned with the properties of systems that are independent of their material components, hence the title of the seminal book by Norbert Wiener: "Communication and control in the machine and animal". This makes cybernetics applicable for different systems such as electronics, brains, organisms and organisations.

A critical concept is that of difference. Ashby (1956) uses *Variety as a measure for the number of possible system states* that can be differentiated from each other. Variety itself cannot be counted (Ashby, 1956) but it can be compared e.g. this system has more variety than that system.

Ashby's law of requisite variety states that:"A controller has requisite variety when he has the capacity to maintain the outcomes of a process within targets, if and only if he has the capacity to produce responses to all those disturbances that influence the process". This means that situational variety, as exposed by the system in different situations, must at least be equalled by the response variety of the controller. This is based on the cybernetic law that: **"ONLY variety absorbs variety"** (Ashby, 1956). An example of this is a person driving a car. When the driver is able to keep the car on the road under conditions where his driving is disturbed by other cars and weather conditions the driver is said to have requisite variety. However when disturbances, such as slippery road and a deer crossing the road, result in an accident the driver is said to have had no requisite variety.

3 THE VIABLE SYSTEM MODEL

Viability means the survival or preservation of identity in a changing environment. Beer argues that a system that maintains its existence is a viable system otherwise it would not exist. In a viable system the variety balancing act between environment and organization seems to function sufficiently. Three elements of a viable system are shown figure 1. For clarity the three elements are shown separate while actual M (management) is part of O (operations) which is part of E (environment). In a viable system the operations, those activities that produce the identity of the organisation (e.g. flights for an airline), are serviced (through e.g. scheduling, accounting) by the management. The operations interact with their relevant environment as does the management. The variety of the environment is larger than the variety of the operations which is larger than the variety of the management. Organisational design must include variety attenuation and variety amplification to provide requisite variety. Communication channels (reports, instructions, discussions etc.) must have a higher capacity to transmit information relevant to variety selection in a given time than the originating subsystem has to generate it in that time. If 'bandwidth' is not sufficient lagging control with its consequences will occur. Furthermore whenever the information on a channel capable of distinguishing a given variety crosses a boundary, it undergoes transduction; the variety of the transducer must be at least equivalent to the variety of the channel. Translation from one language to another is a form of transduction. Recognition of the channel requirements (Beer's (1979) principles of organization) allows effective organisational design.

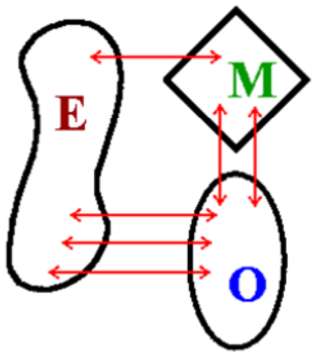

Fig. 1. Variety matching between environment, operations, and management

The VSM describes five organizational functions (Beer, 1979; 1981; 1985) which are *sufficient* and *required* to support viability, these are enumerated as system 1 to 5.

System 1 Primary activities, implementation
System 2 Conflict resolution, co-ordination, stability.
System 3 Internal regulation, monitoring, optimisation, synergy, **3*** Auditing.
System 4 Intelligence, adaptation, forward planning, strategy.
System 5 Policy, ultimate authority, identity

Systems 1,2,3 concern themselves with what is happening "inside and now". System 4 concerns itself with what might happen in the future, "outside and then". The rules of interaction between the two are determined by system 5.

An organisation, such as an airline company, can have viable parts such as passenger transport and aircraft maintenance. Each of these viable parts can have again viable parts in it such as Boeing 777 operations or engine maintenance. This demonstrates the concept of recursion, where viable systems are embedded in viable system and we can shift from one system-in-focus, to a higher or lower system-in-focus. In Fig. 2 two viable systems are embedded in the system 1 of the system-in-focus. The number of recursions to shift up or down depends on the goal of the analysis.

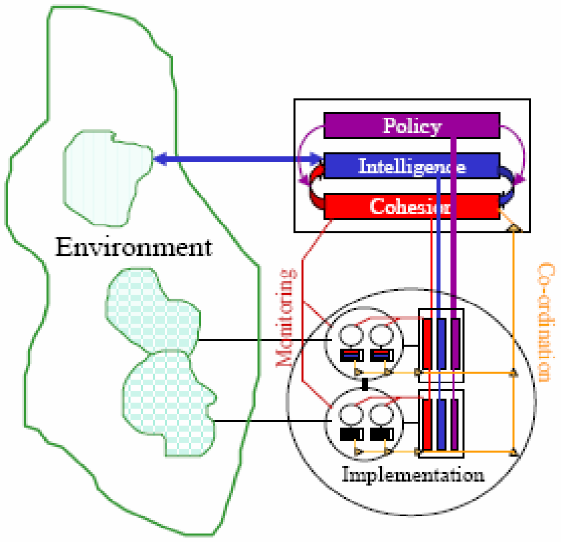

Fig. 2. The Viable System Model

The VSM is not an organizational chart but it models the structural communication channels and interactions between the different organizational functions. Therefore the VSM can be used as a diagnostic tool to evaluate the organizational fitness or viability.

4 RESILIENCE FROM A CYBERNETICS PERSPECTIVE?

I want to compare some quotes from the domain of RE with notions of cybernetics and VSM which may support further RE development.

1. Hollnagel & Woods (2006) state: "... resilience can be described as a *quality of functioning*. has two important consequences.
   A. "they must also be resilient and have the ability to recover from irregular variations, disruptions and degradation of expected working conditions..."
   B. ...Resilience engineering instead requires a continuous monitoring of system performance, of how things are done. In this respect resilience is tantamount to coping with complexity and to the ability to retain control..." (pp. 347-348)
2. "Resilience as form of control: ... In order to be in control it is necessary to know what has happened (the past), what happens (the present) and what may happen (the

future), as well as knowing what to do and having the required resources to do it..." (Hollnagel & Woods, 2006, p. 348)

Below are notions from cybernetics referencing to the two descriptions of RE aspects.

- Ref 1.A: Continuation of processes and ability to absorb perturbations and adaptation appear common in my understanding of resilience and viability. Cybernetics approaches on perturbations, even when originating from outside the design base, have been described by Ashby (1956) with *ultra-stable* homeostasis. Such a system is capable of resuming a steady state after it has been disturbed *in a way not envisioned* by its designer (Beer, 1966).
  Ref 1.B: An understanding of resilience engineering in terms of VSM would include adequacy of system functions to manage variety and the relationship between levels of recursion and requisite variety. Without adequate VSM system functions, e.g. system 4, an organisation might lack ability to respond to environmental changes such as market or technological changes. A underdeveloped function to scan the environment for threats and opportunities will most likely reduce viability and result in more surprises by unanticipated events thus increase demand for resilience.
  The ability to retain control is determined by "available" requisite variety. Leonard (2006), in her comparison of VSM and a risk model, refers to resilience as "*Resilience and survival choices* are the steps that are taken to prepare for the possibility of a catastrophe or sudden change such as cash reserves, computer back-up, security plans and developing robust, redundant communications channels and skill sets. Again, these choices are made by Systems Three, Four and Five but are implemented by System Two and the System One operations. System Three Star may periodically check that these provisions are being followed and are up to date."
  By increasing the level of recursion the organisation increases its variety handling capability. The different levels of recursion in the VSM are *not hierarchical* but more or less autonomous, connected by cohesion to the levels below and above, which increases responsiveness, which is critical aspect of resilience. It might be useful to analyse how the VSM can serve as a model to understand and recover from failure.
- Ref 2: Continuous system performance monitoring (failures and successes) to remain in control as in RE is also applicable to the concept of the VSM operations room or management cockpit for (almost) real-time control of the organisation. The question is of course what indicators or control variables should be used. VSM offers functional systems that can be monitored for their adequacy which brings us one step closer to developing metrics. Also the adequacy of the communications channels to transfer and transduce variety are sources for metrics. The framework of the VSM in combination with a compatible business model offer a way of assigning meaning to the metrics which are closely related to viability and therefore also to resilience.
  In the early 1970's Beer had almost completed an operations room to control the economy of Chile when the project was stopped by the military coup to replace president Allende. Currently a management cockpit, also based on cybernetic and VSM principles, is commercially available.

- Ref 2: Resilience as form of control is compatible with cybernetics the science of control and communication. Cybernetics has also been described as: A framework to make intentions happen" We know that predictions about the future are inadequate and this make it more relevant to have a control system when targets are set. With use of performance monitoring, deviations are recognised and control actions can be executed. VSM offers a structure for assigning control commands.
  The VSM explicitly has a functional description of dealing with the present, "inside and now" (system 1,2,3) and the future, "outside and then" (system 4). The sytem3 - 4 homeostat is the organ of adaptation for the organisation. The balancing of variety between the organisation and the environment is essential for maintaining requisite variety and thus staying in control. Comparison of the multi level Extended COntrol Model (ECOM, Hollnagel & Woods, 2005), which uses competence, control and constructs to model performance, and VSM could reveal interesting analogies.

5 CONCLUSION

Cybernetics and VSM appear, at least on first sight, to be closely related and therefore applications of cybernetics and VSM might be useful in applications of RE. This is not strange when considering the commonality in background of e.g. systems theory. Spare variety could be the expression for resilience in cybernetic language. This opens a whole arena of existing cybernetics scientific research that may be further developed for resilience specifics.

The maximal length of this paper limits the depth of the topic but in my PhD project on the development a Safety Management System I will further analyse the management of safety and resilience using cybernetics and the VSM.

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