Complex Adaptive Enterprises

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INTRODUCTION

In a world where the market, customer profiles and demands change constantly and the events in the global marketplace are unpredictable, it becomes increasingly difficult for an enterprise to sustain its competitive advantage. Under these conditions of uncertainty, complexity and constant change, it becomes very important for an enterprise to be able to learn from its experience and to adapt its behavior in order to constantly outperform its competitors. An enterprise that has these characteristics is a complex adaptive enterprise.

The interrelationships between resources in a complex adaptive enterprise and its global behavior within the marketplace can be numerous and mostly hidden, and can affect many different resources throughout the enterprise. One of the main challenges of the modern enterprise is to understand this complex web of interrelationships and to integrate this understanding into its business processes and strategies in such a way that it can sustain its competitive advantage.

BACKGROUND

The Chain of Sustainability

According to the resource-based theory, there are dynamic relationships between enterprise resources, the capabilities of the enterprise and the competitive advantage of the enterprise. The complex adaptive enterprise maintains a chain of sustainability that constantly evolves from the interactions between the individual resources and the interactions between the resources and the dynamically changing marketplace.

Resources or assets are the basic components in the chain of sustainability. Example resources are products, employee skills, knowledge, and so forth. These resources are combined into complementary resource combinations (CRCs) according to the functionality that these resources collectively achieve. CRCs are the unique inter-relationships between resources and are the source of competitive advantage in an enterprise, as these relationships cannot be duplicated by competitors. The behaviors of the CRCs define the strategic architecture of an enterprise, which is defined as the capabilities of an enterprise, when applied in the marketplace.

Social complexity refers to the complex behavior exhibited by a complex adaptive enterprise, when its CRCs are embedded in a complex web of social interactions. These CRCs are referred to as socially complex resource combinations (SRCs). In social complexity, the source of competitive advantage is known, but the method of replicating the advantage is unclear. Examples include corporate culture, the interpersonal relations among managers or employees in an enterprise and trust between management and employees. SRCs depend upon large numbers of people or teams engaged in coordinated action such that few individuals, if any, have sufficient breadth of knowledge to grasp the overall phenomenon.

Casual ambiguity refers to uncertainty regarding the causes of efficiency and effectiveness of an enterprise, when it is unclear which resource combinations are enabling specific capabilities that are earning the profits.

The Complex Adaptive Enterprise

A complex adaptive enterprise is an enterprise that can function as a complex adaptive system. A complex adaptive system can learn from and adapt to its constantly changing environment. Such a system is characterized by complex behaviors that emerge as a result of interactions among individual system components and among system components and the environment. Through interacting with and learning from its environment, a complex adaptive enterprise modifies its behavior in order to maintain its chain of sustainability.

It is impossible for an enterprise that cannot learn from experience to maintain its chain of sustainability. The learning process involves perception of environmental

inputs, understanding the perceived inputs (making meaning out of these inputs), and turning this understanding into effective action (Senge, Kleiner, Roberts, Ross & Smith, 1994). The Soft Systems Methodology (Checkland, 2004) is a methodology that was developed that involves perception, understanding and acting in an enterprise.

Understanding Emergence

Self-awareness in a complex adaptive enterprise is instrumental in the maintenance of the chain of sustainability. Enterprises need to understand the interrelationships between the individual behaviors of the resources and the emergent behaviors of the CRCs and SRCs. This will enable the enterprise to understand its own social complexity and causal ambiguity.

Emergence, the most important characteristic of a complex adaptive enterprise, is the collective behavior of interacting resources in the CRCs. Emergence is the same as holism (Baas & Emmeche, 1997). Holism in a complex adaptive system means that the collective behaviour of the system components is more than the sum of the behaviours of the individual system components, for example, a flock is more than a collection of birds and a traffic jam is more than a collection of cars (Odell, 1998).

What does it mean to understand something? According to Baas & Emmeche (1997), understanding is related to the notion of explanation. All complex adaptive systems maintain internal models (Holland, 1995). These mechanisms are used for explanation and understanding.

The human mind is self-aware and capable of self-observation and self-interaction. Consciousness may be seen as an internal model maintained by the mind. In Minsky's *Society of Mind*, internal observation mechanisms called A-Brains and B-Brains maintain internal models consisting of hyperstructures called K-Lines. Each K-Line is a wire-like structure that attaches itself to whichever mental agents are active when a problem is solved or a good idea is formed (Minsky, 1988). Minsky describes how a system can watch itself, using its B-Brain.

Gell-Mann (1994) refers to the information about the environment of a complex adaptive system and the system's interaction with the environment as the "input stream" of the system. A complex adaptive system creates and maintains its internal model by separating "regularities from randomness" in its input stream (Gell-Mann, 1994). These regularities are represented using hyperstructures, which in turn constitute the internal model of the complex adaptive system. The observation mechanism of a complex adaptive system is responsible for the identification of regularities in its input stream, as well as for the progressive adaptation of the hyperstructures to include these regularities.

In the complex adaptive enterprise, the hyperstructures encode the knowledge of the enterprise, and are distributed throughout the enterprise. This knowledge belongs to one of the following component knowledge types:

- knowledge related to internal relationships within the company;
- knowledge related to products and services;
- knowledge related to business processes and business units;
- knowledge related to specific projects and project implementations;
- knowledge related to customers;
- knowledge related to the marketplace.

Component knowledge consists of both tacit and explicit knowledge. Tacit knowledge is usually defined as that which cannot be written down or specified. This knowledge is embedded within the interrelationships between the local behaviors of resources within the CRCs and the emergent behaviors of the CRCs. Knowledge, particularly tacit knowledge, is the most important strategic resource in an enterprise (April, 2002).

Bayesian Hyperstructures

Bayesian networks provide the ideal formalism to be used as hyperstructures in the complex adaptive enterprise. These networks can be used to encode beliefs and causal relationships between beliefs and provide a formalism for reasoning about partial beliefs under conditions of uncertainty (Pearl, 1988). These networks can be used to learn a probabilistic model of what the emergent effects are of certain interactions and behaviors in response to certain environmental states (the causes). Such a causal model can then be queried by an arbitration process to decide which action(s) are most relevant given a certain state of the environment.

A Bayesian network is a directed acyclic graph (DAG) that consists of a set of nodes that are linked together by directional links. Each node represents a random variable or uncertain quantity. Each variable has a finite set of mutually exclusive propositions, called states. The links represent informational or causal dependencies among the variables, where a parent node is the cause and a child node, the effect. The dependencies are given in terms of conditional probabilities of states that a node can have given the values of the parent nodes (Pearl, 1988). Each node has a conditional probability matrix to store these conditional probabilities, accumulated over time.

Figure 1 illustrates a simple Bayesian network, which we adapted from the user-words aspect model proposed by Popescul, Ungar, Pennock & Lawrence (2001). Our