Chapter 2
Enterprises as Complex Systems:
Extended Axiomatic Design Theory and its Application in Enterprise Architecture Practice

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ABSTRACT

The concept of self-evolving/self-designing systems is defined using the notion of life cycle relationships. The authors propose that to design complex enterprises as systems of systems on each level of hierarchy one should maintain a self-designing property, that is, the designers should be part of the system. It is explained that by so distributing the design authority, under certain circumstances the "apparent complexity" of the system visible to any one designer can be reduced. To ensure the success of organised self-design, the approach uses their extension of Suh's axiomatic design theory with the "axiom of recursion." The authors quantitatively demonstrate through two examples the benefits of applying these design axioms in enterprise engineering to reduce the complexity of a system of interest, as well as the complexity of a system which designs the system of interest.

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1. INTRODUCTION

1.1. Uncontrollability of Human-Engineered Systems

One way to look at the history of homo-sapiens is to consider it as the history of inventing, building, using, continuously improving and reinventing tools to support human endeavour. This history starts with the creation of simple tools, such as weapons for hunting and warfare, through to today's complex engineering objects and production, transport, financial and governmental etc. systems.

With the invention and application of computers, humankind has created the means to design and build systems of unprecedented complexity, solving problems and providing services that were impossible before. However, early in the use of computers it was realised that the creation of ever more complex software systems has limits (Brooks 1982). This is a serious problem, because humankind came to rely on systems of which the complexity makes them harder and harder to invent, specify, design, build, operate and control, and finally, to disestablish.

The field of complexity is gaining more importance in science and engineering and goes beyond traditional disciplines, as all of natural science, engineering, as well as social science must tackle the complexity problem (Suh 2005). Suh (2005) points out that due to the lack of "unifying theories" and terminologies, different disciplines and their constituent fields have defined and viewed complexity differently to respond to their "immediate needs" with a lack of a fundamental approach to complexity. However, Suh (*ibid*) points out that "the field of complexity may emerge as a unified discipline using a common set of principles and theories but with a different knowledge base and constraints, and to achieve this goal, we have to define 'complexity' in an unambiguous manner": an ultimate goal of the complexity field is to replace the "empirical approach" in designing, operating and managing complex systems with a more "scientific approach."

Various disciplines have experienced the problem of having to design and construct more and more complex systems and built tools to handle ever more complex models. Our observation is that while improved design methodologies, modelling languages and analysis tools can decrease the designer's problem, they only extend the complexity barrier that a designer (or group of designers) can deal with – they do not remove the barrier. This is because the desired functionality of the system may be intrinsically complex, i.e. the complexity can only be avoided by giving up on some desired system characteristics. Therefore any designer who needs to model the complete system in its entirety will eventually face a problem.

Our hypothesis is that perhaps the system, or system of systems, and the designer should not be separated: systems should design themselves, out of component systems that have the same self-designing property. This means that while the system of systems may have an intrinsically complex nature – by some significant complexity measure – this complexity would only have to be seen by an omniscient external observer, but not necessarily by any involved design authority.

1.2. Enterprises and Complexity

Enterprises could be looked at as intrinsically complex adaptive systems: they can not purely be considered as 'designed systems', because deliberate design/control episodes and processes, such as 'enterprise engineering' using models in the design of the changed enterprise, are intermixed with emergent change episodes and processes – that may perhaps be explained by models.

In stages of deliberate change during their life history, enterprise may be considered a kind of engineered system, where change is supported by