Systems View of Commercial Organizations' Evolution

by

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Abstract

Organizational structure has a significant impact on performance of organizations and the way companies utilize their resources, develop new products and compete in the marketplace. As companies mature and grow, they undergo several developmental stages, characterized by different organizational structures and management styles used. The questions that this research aims to answer are:

(1) What are the reasons for success and failure of various management styles?
(2) What reasons or constraints render certain management styles obsolete or inadequate as an organization develops?
(3) Based on the knowledge gained, what are the guidelines for applying different management styles in organizations at various stages of their growth, whether naturally or through mergers & acquisitions?

This research recapitulates the concepts and principles of General System Theory and Universal Organizational Theory (Tektology) to establish the theoretical and philosophical basis for general methods and frameworks of evaluating complex systems. The broad approach to the studies of organizational structures and evolution is motivated by the conviction that all systems evolve under the influence of the same forces and are subject to the same general principles and universal laws of systems. Therefore, the general system methodologies and frameworks can be applied to solve problems faced by a variety of commercial organizations.

This research confirms that a vast majority of modern organizations are based on division of labor, the principle formulated by Adam Smith in 1776. As the complexity of individuals' tasks is being reduced through specialization of labor and knowledge, and complexity of systems increases, more complex organizational structures evolve.

Common trends of the organizations' evolution are analyzed. This analysis evaluates each stage of the organizational evolution model aiming to identify organizational structures and management styles most suitable at each developmental phase.

As each stage of organizational development is characterized by a period of growth followed by a crisis, the management tends to overemphasize the aspects of organizational behavior that helped solve a previous crisis, inevitably causing the next one. The research highlights the necessity for a balance among several key aspects of organizational performance in order to remain successful at each phase.

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We create our fate every day ... most of the ills we suffer from are directly traceable to our own behavior.

Henry Miller

Chapter 1. Introduction

Many centuries ago in Ancient Greece, philosopher Heraclitus described principles of changing nature of universe and unity of opposites: everything changes, and for every action there is a counter-action, so it takes a hidden harmony, or balance among forces, to achieve relative stability. Ancient Greeks also realized the difficulty that changing environment presents to studying systems. Plato writes:

"How can that be a real thing which is never in the same state? ...Nor yet can they be known by anyone, for at the moment that the observer approaches, then they become other, so that you cannot get any further in knowing their nature or state, for you cannot know that which has no state."

Since then, we are still struggling to understand complex systems and are searching for ways to operate, manage and develop systems in continuously changing environment. There is an ongoing effort of society to maintain the "hidden harmony" among forces that affect complex systems and the expectations that different stakeholders have of system behavior.

The aim of this thesis is to devise and relate a methodology grounded in current systems philosophy, theory, and technology to understand complex systems and to apply such understanding to get insights into design and management of complex organizations.

1.1 Motivation

Today's business environment is characterized by its fast pace and the perpetual transformation of corporations, manifesting itself in mergers and acquisitions, continued realignment of corporate goals, bankruptcies, rapid rate of growth, globalization and corporate profits.

In my ten year career in the information technology service industry, I was able to witness firsthand the ongoing change in organizational structures and processes. As I moved through several organizations of different sizes and maturity levels, and experienced several mergers and acquisitions, there was a continuous flow of company-wide re-organizations, goal realignments and periods of organizational crisis alternating with relatively quiet and short-lived periods of status-quo. In observing various restructuring of organizations and shifting of responsibilities and control among the departments and entities within organizations, a body of evidence emerges that shows the effect an organizational structure has on the (1) quality and architecture of the products, (2) flow of knowledge and the decision-making process within the company, and (3) customer relationship, along with other indicators of organizational performance.

A significant amount of academic research has been carried out on the importance of ongoing reassessment and re-design of a company's internal structure. This analysis potentially helps facilitate efficient use of existing capabilities (Raisch, 2008) and the development of new products (Sosa, Eppinger, & Rowles, 2004). Most importantly, the reassessment and re-design ensure successful future growth of the enterprise.

While many companies plan to grow, they often fail to analyze the suitability of their internal structure to their ambitious growth goals, and to implement the changes to the organizational structure necessary for such growth. In such environments, changes to internal processes are normally made in response to the outside pressures or organizational failures, rather than as a part of an intentional proactive process. There also exists a remarkable similarity among the issues faced by companies in various industries and the way the companies respond to such challenges. Greiner, in his study first published in 1972, pointed to the generalized trends and common issues that companies experience as they grow, and developed a model that describes the growth of commercial organizations and different management styles that could be applied to enable such growth; analyzing his model from a systems point of view may reveal additional insights about the forces facilitating and driving growth, as well as the limitations and causes of crises that often follow periods of growth. Greiner (1998) also points to the cyclical nature of growth by identifying the phases of smooth growth (evolutions) and crisis (revolution), as shown in Figure 1-1. During each evolution period, a growing company is evolving naturally to support growth, until the natural evolution or external factors lead to a management crisis. For the growth pattern to resume, the organization needs to change its structure and management style. If the management teams are successful in re-designing the company's structures and internal policies, the company can return to growth. Understanding forces and limitations of the existing management styles may enable managers to foresee a potential crisis and guide companies through the transformations needed to restore their growth.

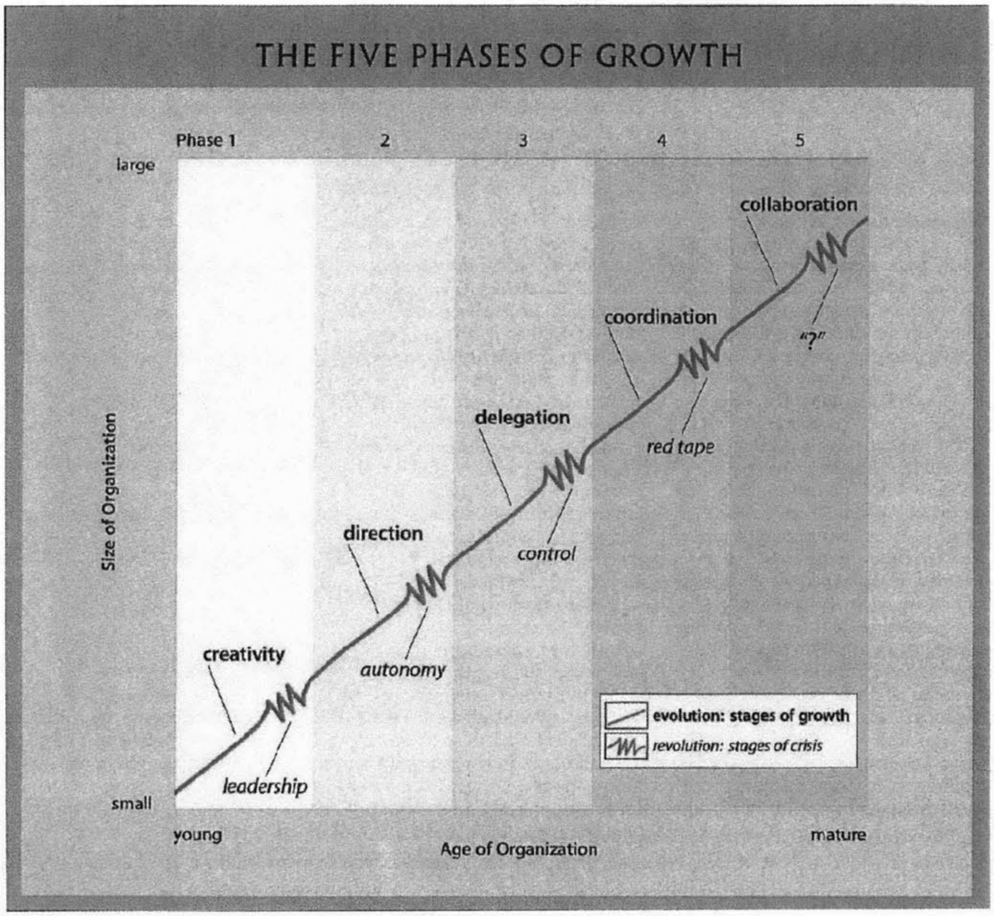

Figure 1-1. Greiner Model of Growth of Commercial Organizations. Adapted from (Greiner, 1998)

Despite the tremendous importance of the management style, many of the adapted organizational design methods seem to oversimplify the process and ignore the fact that the external and internal environments of organizations are continuously changing, and the companies need to be prepared to anticipate or respond to changes. Instead of proactively designing organizations to anticipate changes or adapt to them, many organizations reactively respond to crises, thus losing an appropriate balance of organizational performance and sending entire organizations into fire-fighting mode. The questions that motivated this research are:

(1) What are the reasons for successes and failures of these different management styles?

(2) What reasons or constraints render certain management styles obsolete or inadequate as the organization develops?

(3) Based on the knowledge gained, what are the guidelines for applying different management styles in organizations at various stages of their growth, whether naturally or through mergers & acquisitions?

1.2 Goals and Objectives

The objective of this thesis is to demonstrate use of System Thinking analysis methods to a study of the effects of growth on organizational structures. The ultimate goal is to develop a better understanding of effects that management styles have on the performance of large organizations, as well as better command of methodologies for applying this knowledge to improve organizations' performance.

The broad approach to the studies of organizational structures and evolution is motivated by a conviction that all systems evolve under the influence of the same forces and are subject to the same general principles and universal laws of systems, therefore general system methodologies can be applied to solve problems faced by commercial organizations. Such methodologies are applicable to the evaluation of the evolution of all other types of socio-technical systems.

In studying commercial firms, it becomes evident that commercial organizations have attributes of both designed socio-technical systems and living organisms. Commercial organizations are artificial systems, in a sense that, at some point of time, they are deliberately created to achieve goals of founders or stockholders, and periodic attempts are made to re-design and optimize the organizations. At the same time, organizations continuously evolve and adapt to the changing environment and, just like living organisms, undergo a series of developmental stages as they evolve and grow. Because of this dual nature, methods from social, biological, engineering and other sciences have been successfully applied to evaluate specific aspects of design of organizations. Osorio, Dori, and Sussman (2009) proposed a method that is grounded in the theory of system architecture and builds on the strengths of Object Process Methodology (OPM) and process for representing Complex Large-scale Interconnected Open Socio-Technical (CLIOS) systems. This research complements their work by further establishing a philosophical justification for such an approach and giving it an additional theoretical foundation, formulated in Universal Organizational Science and General Systems Theory, and leverages strengths of OPM and System Dynamics to evaluate rends of emerging behavior.

1.3 Modeling philosophy and goals

A model is a simplified mental depiction of a real or future system, that is generally built to describe (represent) the system at a high level (Morrison, 2009) and to predict and evaluate a system's performance. Modeling philosophy used in this research was largely influenced by Dori (2009) and

Morrison (2009). The process of modeling includes several cycles of making hypotheses about how a system works, identifying the intended behavior, as well as consequences which may cause problems, proposing ways to improve the behavior, and evaluating possible outcomes of proposed actions or changes. The process is repetitive because it may take many attempts to identify possible ways to improve a behavior, and, as more insights about the system are gained, the model can be refined to better address problems at hand. All models are wrong in the sense that they merely represent a simplified depiction of an evaluated system and cannot accurately describe potential system performance; however, models are useful in identifying general trends and dominating forces within the system that must be considered in building and improving the real system. The models are always incomplete; a complete model would be as complex as a real system and not a useful simplification (Morrison, 2009). As needed, more details and nuances can be included in the model to evaluate the impact, but the complexity of the model should never surpass the modeler's understanding of it.

We, as humans, tend to solve complex multi-disciplinary problems by breaking them apart and by reducing complexity of a larger system into smaller, more manageable parts, and then studying and analyzing the individual pieces. Then we try to reassemble the pieces together in our mind (Senge, 2006), and attribute the problematic behavior to one of the components. The shortfall of this method is that in looking at individual components of the problem, we might lose sight of the big picture and miss the issues that are caused not by an individual part, but rather by the way the parts are interrelated to make the larger whole. For instance, a product's quality problems may not originate in a specific functional department of a company; but in how information is transferred among the departments and how the areas of responsibilities are assigned. Alternatively, the problem may come down to how the company is structured. In this case, by looking at the processes within the individual departments, it is impossible to see the source of the problem, so each department starts to blame the others for the source of the issues, and no progress is made in solving the quality problems. To make matters even worse, we may try to fix the symptom of the problem by diverting more resources to quality control measures, only to find that over time the problem gets worse due to shortage of resources in other areas.

In analyzing these types of systematic problems, a method is needed that allows sub-dividing the problem into manageable pieces while maintaining a way to look at the whole problem in a systematic, focused way. Means for evaluating the consequences of our actions and changes to help track the emergence of issues should also exist.

1.4 Hypotheses

While the evidence of commercial organizations can be found in pre-Christian literature, and the division of labor goes back to the time of Adam and Eve (Skousen, 2007), there existed no solid economic theory until the 18^{th} century when Adam Smith published his "An Inquiry into the Nature and Causes of the Wealth of Nations" and identified the division of labor, or specialization, as a major enabler of the economical growth and rise of productivity. Specialization has narrowed the field of work and research of individuals, increased efficiency, and alleviated and accelerated the accumulation of experience and knowledge paving the way for Industrial Revolution; but it also fragmented the knowledge and experience into isolated trades and scientific disciplines, such as physics, chemistry, biology and sociology. Over time, each discipline has developed its own methods, frameworks, knowledge and even language, further segregating the exchange of knowledge among different industries and branches of science.

While the Industrial Revolution had caused an increase in size and number of commercial organizations, most of the organizations remained hierarchical until the middle of the twentieth century, at which time the rise in technical complexity and shift to knowledge work and globalization necessitated the transformation into more sophisticated, cross-functional organizations. The next wave of the evolution of organizational complexity was likely both caused and enabled by the informational revolution and the ease of knowledge exchange among individuals and various groups within social organizations.

Specialization greatly improved productivity and efficiencies, but segregated the sciences and industries. To fully realize the economic and academic benefits of specialization, the knowledge of different academic branches, as well as the results of specialized labor, needed to be assembled into a complete product; this need had only intensified with time as the systems became more complex and required even more specialization, as a result of the Industrial Revolution. At the turn of the twentieth century, Bogdanov[1] developed the Universal Organizational Theory –the foundation for the new discipline that studied the universal structural regularities, general types of systems, general laws of their transformation, and the basic laws of organization of any elements in nature, practice and cognition (Gorelik, 1908, p. 328).

One of the goals of this new science was to organize the knowledge accumulated by different disciplines into a coherent, holistic view, and to allow the knowledge and methods developed in one domain to be applied to problems in another, entirely different scientific or industrial domain, to

[1] Pseudonym for A.A. Malinovskii

systemize the knowledge, and to provide methods for solving cross-discipline problems. In many ways, the goal of this thesis is very similar: to bring together knowledge and theories developed in different academic domains and apply them to commercial organizations.

The organization of processes, resources, knowledge, ideas, and systems of relationships among them in social organizations is similar to organizations of cells in living organisms (Bar-Yam, 2003). The specialization of individual labor and increase of organizational complexity can also be observed in nature (Bar-Yam, 2003). From single cells to humans, we can trace the evidence of evolutionary increase of the specialization as well as the complexity of organizational structures. Single-cell organisms first organized into colonies, which later allowed the specialization of individual cells and strengthening the relationships among them, leading to their organization into a multi-cell organism. Further specialization had eventually led to the emergence of plants, which have specialized cells that make up root, leaves, stem, and so on. Moreover, as the interactions among the cells became more advanced, the cells began to organize into increasingly more complex organisms, culminating with a human and the organization of humans, i.e., civilization.

This similarity of the organization of elements into complex systems was captured by Alexander Bogdanov in the concept of Tektology (from Greek tekton, meaning "constructor" or "builder", and logos, meaning science), the first Universal Organization Theory (Dudley, 1996) published, in parts, from 1908 through1929[2]. Tektology is the discipline that unifies all social, biological and physical sciences by considering them as systems of relationships and by seeking organizational principles that are common to all systems. Bar-Yam (2003) also described the cyclical nature of complexity distribution between the behavior of an individual element and organization of such elements. The hypotheses of this research are in large part influenced by the work of Bogdanov, Bar-Yam and Dori, and are as follows:

Hypothesis 1: There is a general trend in evolution of organizations and issues that they face as they grow.

Hypothesis 2: Commercial originations tend to evolve naturally until changes or constraints limit the growth and threaten the organization's normal existence, at which point deliberate design techniques are executed to resume normal growth of the organization.

Hypothesis 3: It takes "hidden balance" between different forces and interests for organizations to remain stable and successful.

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[2] There are conflicting dates of first publication of Tektology.

Hypothesis 4: As organizations evolve, there is a trend to limit and decrease the complexity of each part's behavior (specialization) by increasing the complexity of the organization, i.e. to balance complexity of an activity with complexity of the organization.

1.5 Research Methods and Organization of this Thesis

One of the research objectives is to bring together knowledge and methods developed in different domains, and to apply this knowledge to study the evolution of organizations and organizational structures in order to develop deeper understanding and control of organizational dynamics. Conceptual models are the means by which complex systems are conceived, architected, designed and built; models show certain aspects of that reality, including function, structure, and dynamics, as perceived or envisioned by the human modeler or system developer (Dori, 2003). By conceptually evaluating the balance between different aspects of a system's behavior and goals, and identifying levers that are used to establish dynamic equilibrium in organizations, I hope to gain an insight for answering research questions and gain better overall understanding of dynamics and inner-workings of complex organizations.

Greiner (1998) identified the general trends in growth and development of organizations, and described both the mechanisms and limiting factors that are characteristic of each of the five phases of organizational development. This research will evaluate each phase of the Greiner model using the systems architecture framework, and develop techniques for evaluating the complexity profiles and dynamics of various forces shaping organizations.

This thesis consists of two parts. Part I of the thesis provides historical and philosophical background to the current state of System Theory, outlines current knowledge in the field of System Engineering and Organizational science, and recapitulates use of several methodologies, which are taught as a part of System Design and Management curriculum. Part II of the thesis applies the methodologies to evaluate evolution of organization structure. Figure 1-2 is a graphical representation – Object Process Diagram (OPD) – of this thesis. Object Process Methodology (OPM) model, shown in figures Figure 1-2 through 1-6 is a detailed, layered view of structure of the thesis and purpose that each chapter aims to fulfill, as well as information flow within the thesis. OPM, the conceptual modeling paradigm aiming to jointly represent a system's form, function and behavior will be further described and explained in Section 3.2.

The purpose of the thesis – its Externally Delivered Function (EDF) - is Scientific Point Making (Figure 1-2), and its Value Related Attribute Object (VRAO) is Knowledge, i.e. value is generated by changing a state of knowledge.

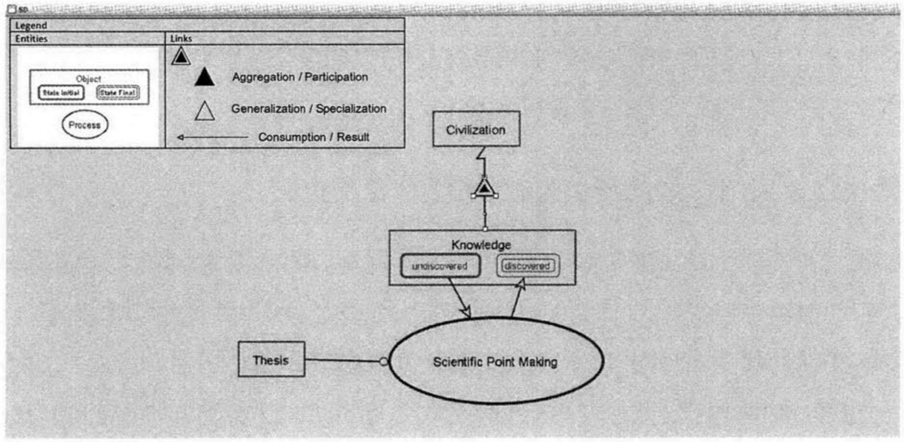

Figure 1-2. Top Level OPD of this thesis.

Process of Scientific Point Making can be decomposed further, and its internal processes are shown in Figure 1-3. Each part of this thesis (Instrument Objects) is responsible for performing a specific function. The function of the Introduction is to "Define problem and Hypothesize about Explanation" with respect to the cause of the problem. The body of the thesis is divided into two parts. Part I recapitulates current academic knowledge and outlines current methodologies and frameworks; in Part II these methodologies are applied to evaluating organizational lifecycle. In Conclusions, hypotheses of the research are evaluated.

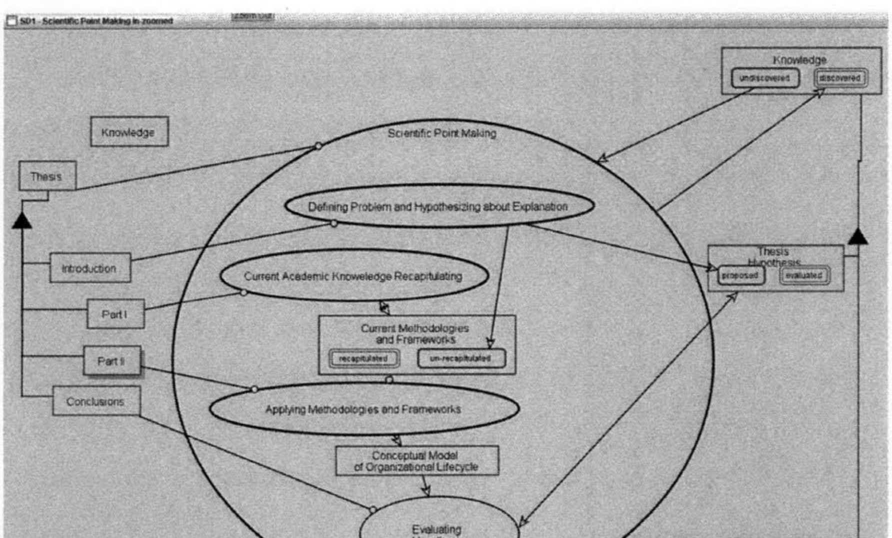

Figure 1-3. Internal Processes for Scintific Point Making

The introduction section, as shown in the figure bellow, contains discussion of motivation, goals and objectives, as well as the research methods and the hypothesis. The function is connected to its respectful Introduction's section via an instrument link; the main result of the Introduction being the proposed thesis hypothesis.

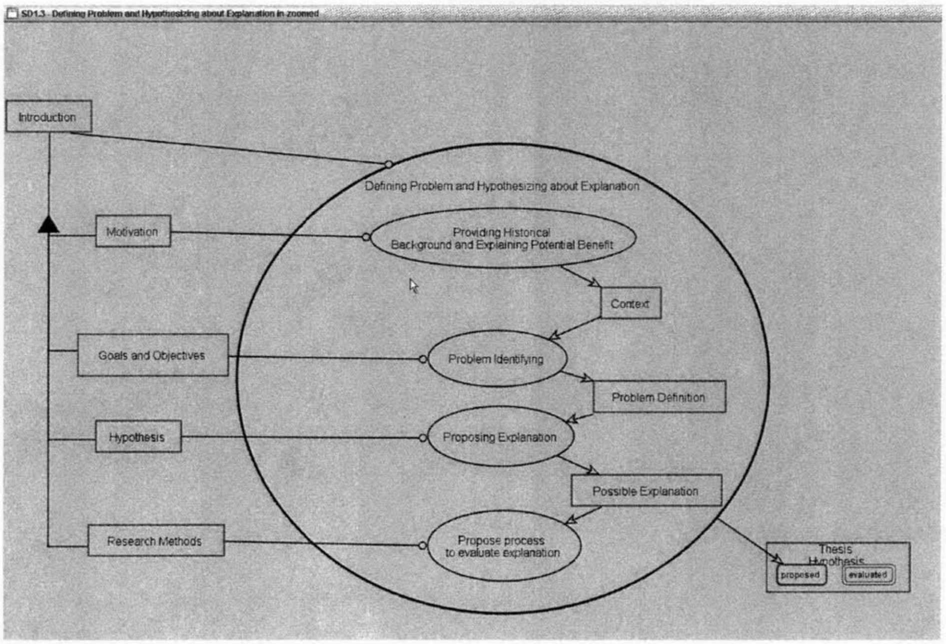

Figure 1-4. OPD of Introduction Section of this thesis

Part I of this thesis consists of Chapters 1 and 2 and provides the theoretical and philosophical justification and foundation for the methods and frameworks used. It also summarizes current methodologies and theories (see Figure 1-5 bellow).

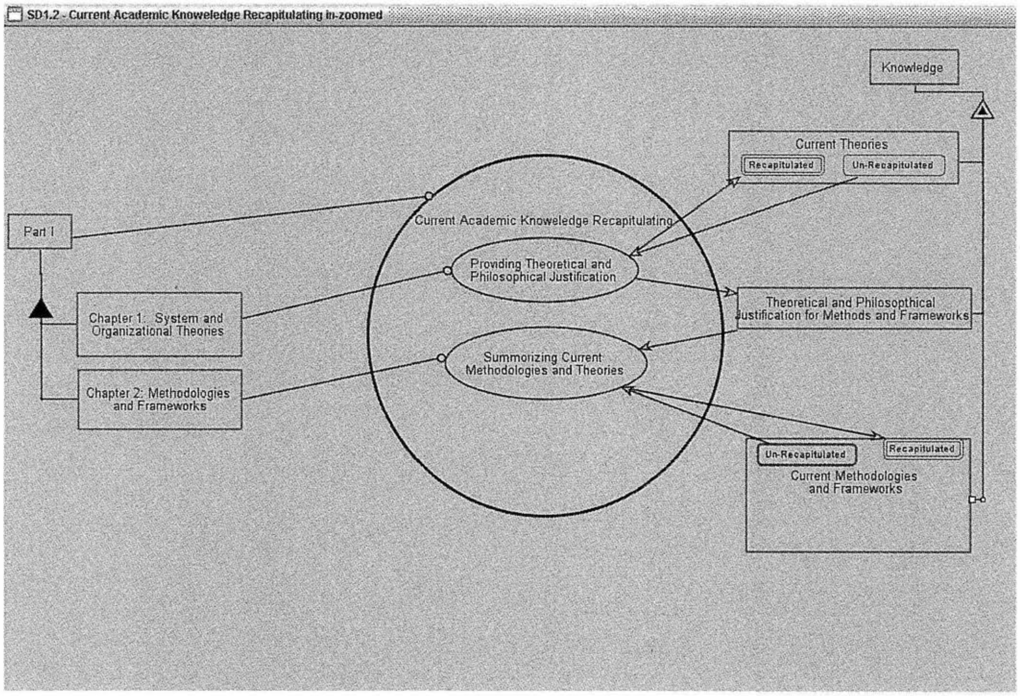

Figure 1-5. OPD of Part I of this thesis

Part II applies select Crawley methods and evaluates the evolution of organizational structure.

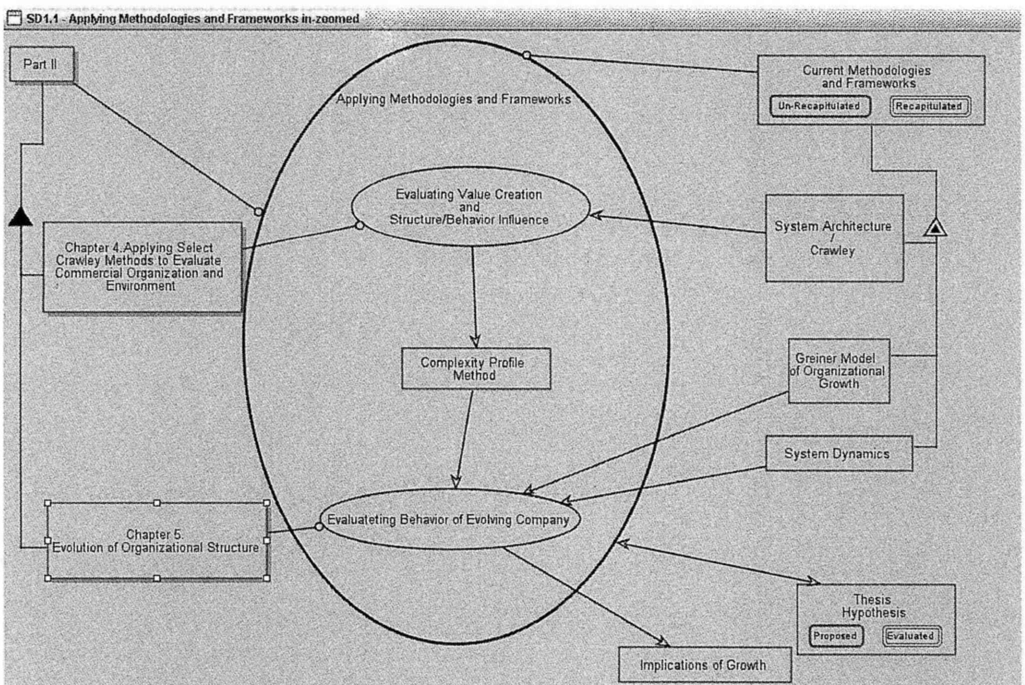

Figure 1-6. OPD of Part II of this thesis

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Part I. Literature Review and Contributions to Theory

As previously discussed, the over-specialization had dispersed knowledge into somewhat arbitrary scientific disciplines, which hindered our ability to advance knowledge and build increasingly complex multi-discipline systems. At the same time, knowledge and methods discovered and widely used in one discipline were not known to other closely related disciplines. These factors necessitated a science that would bring together knowledge and methods from specialized disciplines and would focus on fitting the different components together to form a system. While the need for such science was felt for centuries, only within a last hundred years theories for such science –System Theory - emerged (Dudley, 1996). The emergence of System Science was also aided by the manifestation of evidence of universal nature of systems and applicability of principles and methods discovered in one discipline to the others.

Adopting the systems inquiry model from International Society for the System Sciences (Bnathy & Jenlink, 2003), this research evaluates the philosophy, theory, methodology and application aspects of approaches used to study the issues; this first part of the research summarizes selected previous works on the subject.

Chapter 2. System and Organizational Theories

In this chapter, I will recapitulate the fundamental theories and methodologies of System Science. While Systems Theory is considered a relatively modern phenomenon in science, the origins of the system can be traced back to antiquity. Aristotle is credited with formulating the basic principle of Systems Theory (Dori, 2002, p. 383):

The whole is more than the sum of the parts.

It has been recognized for some time that there exists a certain unity of properties that are shared by all systems, living and artificial. Dori (2002, p. 387) stipulates that living organisms have provided ample inspiration for system researchers in their quest for common system characteristics and ideas for devising artificial systems, and that natural and artificial systems alike exhibit three major aspects: function (what these systems do), structure (how they are constructed) and behavior (how they change over time)(Dori, 2002). However, System Science was born from the belief that the same universal forces shape all systems, and the two early theories of System Science – Bogdanov's Universal Organization Theory (Tektology) and Bertalanffy's General Systems Theory – take their philosophical fundamentals from such beliefs.

2.1 Universal Organizational Science and Systems Theories

"Modern Science is characterized by its ever-increasing specialization"

A. Bogdanov, 1912

"The vital imperfection or contradiction of specialization consists in that it can gain organizational experience only by its increasing fragmentation"

L. Bertalanffy, 1955

The two statements above, taken nearly 40 years apart (Dudley, 1996, p. 273), collectively explain the need for generalized study into systems and express the phenomenon of such study– that it is a specialized science in generalizing and organizing systems. While Adam Smith believed that the specialization and division of labor are dynamic engines of the economic progress (Smith, 1776), Bogdanov and Bertalanffy, in their early works on what became System Theory, also saw specialization as the limiting factor of progress. Over-specialization creates insurmountable barriers to the transfer of knowledge and experience and fragments knowledge into isolated silos. They did not deny the need for specialization, but they denied the idea that all knowledge can be gained through specialized sciences.

Since ancient times, there was an understanding of unity of some principles in physical, biological, and social systems; Bogdanov also identified knowledge and experience as evolving systems. Like many before them, Bogdanov and Bertalanffy saw the need for a general system theory, partially as a response to this crisis of over-specialization, but mostly as a natural cross-disciplinary approach to the efficient understanding of the world (Dudley, 1996, p. 275), and a science that gives such approach a theoretical basis. The formal aims of such science, adapted by the Society of General Systems Research in 1954 (Gorelik, 1975, p. 3) were:

1. investigate the isomorphy of concepts, laws, and models in various fields, and help in useful transfers from one field to another;
2. encourage the development of adequate theoretical models in the fields which lack them;
3. minimize the duplication of theoretical effort in different fields; and
4. promote the unity of science through improving communication among specialists.

Bogdanov – a politician, novelist, medical doctor, and philosopher, proposed unifying all social, biological and physical sciences by considering them as systems of relationships and by seeking the organizational principles that underlie all systems. Bogdanov's work in Universal Organization Theory - Tektology, first published in 1908, greatly preceded and surpassed[3] in scope the works of Bertalanffy (Dudley, 1996, p. 283), who developed his ideas in 1930[s] and published in 1955 (Dori, 2002, p. 384) but for political reasons, most of Bogdanov's work was suppressed[4], and only recently rediscovered (Gorelik, 1975, p. 3), so it is likely that both theories, while very similar, were developed independently. While Bogdanov can be credited with giving the Universal Organizational Theory its philosophical backing (though he himself did not think of such science as philosophy), Bertalanffy, on the other hand, popularized the general systems theory and granted the theory and its methods a precise mathematical formulation.

Tektology is concerned with "universal structural regularities, general types of systems, general laws of their transformation, and the basic laws of organization of any element in nature, practice and cognition." (Gorelik, 1908, p. 328). In response to the continuously mounting evidence of certain unity in organizational methods in nature and society, Tektology presents an approach to study a phenomenon from the point of view of its organization. Bogdanov's philosophy was that "organization of all elements

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[3] Tektology also includes elements of Cybernetics and System Dynamics

[4] Many saw Bogdanov as a rival to Lenin; after the Soviet revolution, his works were suppressed and taken out of circulation, therefore, Tektology was published in Russia only until the 1920s. It was translated and published in Germany in 1928. The first English edition was published in 1980.

is following same laws of nature, and all of the forces of the universe have to do with organizing elements into complexes."

To Bertalanffy, on the other hand, the General Systems Theory (GST) did not only flow from the nature of universe; it also represented a necessary mode of understanding, or specifying, a useful simplification and mental model to comprehend the world (Dudley, 1996). Much like in physics, where simplified mental models are used to understand processes that we know to be more complex, GST can be used to focus on similarities of systems, keeping in mind that there are also dissimilarities. The complexity of systems that were built in the past was within the competence of the engineer responsible for building it. But emergence of increasingly complex systems that are *"assembled from components originating in heterogeneous technologies, relations of man and machine, and innumerable financial, economic, social and political problems necessitates ...systems specialist (or team of specialist) to consider alternate solutions and to choose those promising optimization at maximum efficiency and minimal cost in a tremendously complex network of interactions"*(Bertalanaffy, 1955, p. 4).

Bogdanov and Bertalanffy saw the world as a "system of systems", or a layered organization of elements, though Bogdanov has abandoned the classical concept of "system," which gives shape and imparts final state to the nature of things. To emphasize the co-determinant dynamics of systems and environments, becoming rather than being of systems, Bogdanov coined the usage of complex (Zeleny, 1988, p. 332); this research uses the terms system and complex interchangeably, consistent with today's notions. Elements are simply those parts into which an object can be decomposed in order to study a particular problem at hand. Bogdanov (1908, p. 43) writes:

The concept of "elements" in the organizational science is completely relative and conditional: it is simply those parts into which, in conformity with a problem under investigation, it was necessary to decompose its object; they may be as large or small as needed, they may be subdivided further or not; no limits to analysis can be placed here. Gigantic suns and nebulae have to be taken as elements of star systems; enterprises or individual people as elements of society; cells as elements of an organism; molecules or atoms or electrons as elements of a physical body, depending on the question at hand; ideas and concepts as elements of theoretical systems; representations and voluntary impulses as elements of psychic associations, etc.

Bogdanov believed that the aim of mankind is to dominate over nature and harness its forces; to gain such dominance, mankind had to be organized into working collectives, ranging from the small primitive communes of the primordial epoch to the contemporary cooperation of hundreds of millions of people (Bogdanov, 1908, p. 1), and that such organization needed to be studied at the universal level.

While there are similarities between organizations of people and organizational activity in nature, people, over time, developed instruments of organization that separated them from nature. Those instruments that humankind organized from abilities given by nature are word, idea and social norms (Bogdanov, 1908, p. 3). They allow humans to communicate, coordinate activities, exchange ideas and visions, and establish and regulate the relations among people in a collective[5] and, thus, strengthen their connections.

Bogdanov and Bertalanffy provide a few arguments to support homogeneity of the organizational functions and principles from different domains. For instance, Bogdanov argues that a man's imitation of nature within itself can be a sufficient proof of such homogeneity, as there cannot be an imitation where there is nothing in common (Bogdanov, 1908, p. 7). Nature organizes the resistance of many living organisms against the action of cold by covering them with fluffy furs and feathers, i.e. materials that have good insulation; man achieves the same results in a similar way by making warm clothing.

Mankind long recognized such similarity in the way that different systems operate. As evidence, one can consider the phenomenon of metaphor. In order to understand one system, living or physical, we can equate it to another, more familiar and understood system, and apply knowledge from another domain to better understand the unknown system.

One of the Bertalanffy's examples of homogeneity of evolutionary forces is parallelism – similarity in the phenomenon of parallel evolution starting from common origins but developing independently (Bertalanaffy, 1955, p. 81). Bertalanffy provides several examples, taken from linguistics, biology and archeology, of development of similar properties in isolated systems. For instance, human and octopus split very early during the evolutionary development; it is unlikely that their common predecessors had eyes. However, human and octopus eyes, as complex as they are, are remarkably similar.

2.2 Tektological[6] Concepts and Principles

While a credit must be given to Bogdanov for the original theory, most of the concepts and principles in GST and Tektology are very similar. To preserve the terminology of the original work and to identify the universally applicable principles and concepts with a catchy name, we will call them Tektological. Tektological concepts, the significance of which was devotedly recognized by Dudley

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[5] a.k.a. organization

[6] Tektology is also spelled as Tectology by some authors. George Gorelik, author of a number of Tektology summary papers and translations of Bogdanov work to English, uses "Tektology", so this research adopts this spelling.

(1996), Gorelik (1975 & 1980), Zeleny (1988) and others, can also be identified in Bertalanffy's General Systems Theory, cybernetics, and system dynamics.

2.2.1 Complex

In Tektology, a complex – or a dynamic system – is a combination of interacting elements. There are three types of complexes with respect to the combinations of activities and reactions of systemic elements: organized, disorganized, and neutral. If the whole activity of a system is greater than the sum of its parts, the system is organized; neutral implies that the whole is equal to the sum, and disorganized is less than such sum. The significance of the organized system is that existing activities are combined more effectively than the opposing resistances, which indicates a high level of organization (Gorelik, 1975). A complex is a process, or a continuous flow of independent component-producing processes, concatenated in self-triggering circles of build-up and degradation.

There is a distinction between the **organization** and **structure** of the system. The term "organization" refers to the network of component-producing processes (rules of interaction, behavior or conduct). The term "structure" then refers to a particular spatio-temporal pattern of produced components (Zeleny, 1988, p. 333). A complex (unlike a system) cannot be separated from its environment, because it does not simply exist or interact within its environment: it is structurally coupled with its environment and, thus, co-evolves with it its own environment. In modern literature, there often exists a distinction between simple and complex systems; such distinction corresponds to Complexes and Systems in Bogdanov's view.

2.2.2 Bi-Regulator

The idea that the environment affects the complex as much as the complex affects its environment – in a mutually affective, circular and non-hierarchical fashion - was represented in Bogdanov's concept of Bi-regulator and has evolved into today's concept of feedback (Zeleny, 1988, p. 332). Bi-regulator is a combination in which two complexes mutually regulate each other (Gorelik, 1908, p. 330): a thermostat does not only regulate the temperature; the temperature also changes the state of the thermostat. In general, activity (actions, natural forces, etc.) and resistance (reactions) are not independent, but mutually related concepts. Such feedback structures and their implication on the systems are formally defined in modern Cybernetics and System Dynamics and will be discussed further in next chapter.

Since the environment, in its ever-changing state, is structurally coupled to a complex, the organization (in a Tektological sense) of the complex is inexhaustible, and complex systems never stop adopting and evolving with their environment.

2.2.3 Dynamic Equilibrium

The principle of equilibrium, formulated by Le Chatelier for physical and chemical systems, but also independently discovered in many other disciplines, is an expression of structural stability. In Tektological, or universal form, the Le Chatelier's principle can be formulated as follows: *if a system of equilibrium is subjected to an influence changing any of its conditions of equilibrium, than processes appear in it which are directed to counteract such changes* (Bogdanov, 1908, p. 113).

Only few principles demonstrate their universal applicability as much as equilibrium. Scientists in many disciplines have independently noted that a system develops forces which counteract the disturbance and restore a state of equilibrium.

Heraclitus, a pre-Socratic Greek philosopher, saw the duality of all forces, and called them "The Unity of Opposites": *the way up is the way down ...they go on simultaneously and result in "hidden harmony".*

Paul Samuelson, the acclaimed MIT economics professor and first American to receive Nobel Prize in Economics, formulated a similar principle in economics (Samuelson, 1995, p. 267).

In electromagnetic studies, Lenz Law represents the same concept, and Volterra had shown the principle's applicability in social studies (Bertalanaffy, 1955, p. 76). In System Dynamics, such phenomenon is called Policy Resistance (Sterman, 2000, p. 5), and is fundamental to evaluating unintended consequences resulting from all actions.

Morrison (2009) explains the dramatic impact that resistance of a system has on our ability to comprehend system behavior: it results in unintended consequences to our actions, conscious and un-conscious resistance to change, and counter-productive efforts. When the resisting force is distant in space or time, humans have very little experience in recognizing its source. Such phenomenon is studied in detail in the field of System Dynamics.

2.2.4 Centralist and Skeletal Forms

In studying complexes, or systems, the focus in on

1. how complexes are formed,
2. which conditions affect their change,
3. how can complexes change, and
4. how do they age and fall apart.

In Tektology, there are two most extreme structures of complexes: skeletal and centralist; most real complexes would fall somewhere between these extremes.

A centralist system (or part of a system) can be characterized by a clearly defined central source of control. In the human organism, for example, the brain is a central complex, while other organs are subordinated to it (Bogdanov, 1908, p. 175) and, to some degree, are dependent on the brain in their own reactions. In such complexes, activities – resistances of the whole to changes from outside – can be concentrated at various points in a system, but overall control comes from a central location. Our society, while having centralist forms throughout its history, also has a tendency to let peripheral complexes to diverge from central control and form centralistic complexes of their own, thus creating hierarchies. More complex structures may have multiple centers.

Skeletal complexes, on the other hand, are defined by external or internal skeletons, supporting and protecting complexes. For instance, the skin protects the human body from outside influences and defines a Tektological boundary, while the skeleton supports the body. A drop of water can also have skeletal complexes – most outside molecules, by forces of surface tension, cohere more strongly, thus holding structures of water drops.

2.2.5 Formative Mechanisms

Formative mechanisms are responsible for appearance, destruction, development and expansion of all organizational forms; destruction necessarily follows creation. Basic formative Tektological mechanisms are: conjunction, ingression, linkage, disingression, and conjunctive and disjunctive crisis.

Conjunction of systems from elements and complexes can only be done through linkage between them, while destruction is characterized by breaking of such linkage; such breakage is generally the start of a (new) conjunctive process (Gorelik, 1975, p. 5). *Conjunction triggers the changes in organizational nets through forming linkages of common processes, or mutual structural couplings of elements. Negative ingression, or disingression, represents a breakdown in the linkage of complex and a creation (or re-creation) of a new Tektological boundary. Only through disingression can a complex remain structurally coupled with its environment; otherwise, it would become an isolated closed system, non-existent in nature* (Zeleny, 1988, p. 333).

2.2.6 Regulatory Mechanisms

"All happy families are alike, while every unhappy family is unhappy in its own way".

F. Dostoyevsky

Regulating mechanism is the concept of selection, adopted from biology. Structural stability of organizational patterns is brought by progressive selection, both positive and negative; the break in Tektological boundary is most likely to occur where the link is the weakest. The difference between positive and negative selection is very important. Only positive selection can give birth to a new creation; negative selection, on the other hand, eliminates unfitted, aging, non-stable organizations of elements, but cannot create anything new. Negative selection is by far more common; positive selection is so rare in nature, that sometimes it may seem as if it stopped completely. *For positive selection to continue, the totality of conditions must be favorable for the preservation of development of a complex. For negative selection to take place, it is sufficient to have a single unfavorable condition, unsuitability of the complex in at least one respect, for disorganization to occur* (Gorelik, 1975). This can also explain certain convergence of forms and architectures of the highest evolutionary-developed organisms. Organisms, created and evolved as a result of positive selection, are going to be similar in various unrelated environments, because the number of combinations to yield such an organism is very limited.

Gorelik (1980) showed how Tektological principles could be applied to explain the predominance of the negative selection process and necessity of holistic approaches for creating entirely new systems. Bogdanov distinguished between compact (fused) and diffused systems. In compact systems, the connections among elements are firmer because the boundaries are shorter than in diffused systems. Gorelik (1980) extrapolates this observation to social systems:

Apparently, negative selection manifests itself more intensively in diffused systems. Both positive and negative selections are less intensive in compact systems. Which structures then, compact or diffused, are more conducive to the preservation and development of systems? It turns out that under conditions of negative selection, compact structures are better; and, under conditions of positive selection, diffused structures are most appropriate. Thus, for example, centralization of management is to be preferred to decentralization from a point of view of preservation and development in social systems in "hard times" – the reign of negative selection process; on the other hand, under conditions of positive selection prevailing during periods of prosperity, decentralized management is more favorable to systemic preservation and growth.

2.2.7 Convergence of Forms

We have recognized the fact that the same forces applied to the same matter result in similar results; casting and stamping industries are based on it. The implications, however, need to be understood in a much broader context: the environment will promote emergence of similar forms from quite different matters. For example, if we use the same mold to cast metal and plastic, the resulting parts will be almost identical in shape. In some contexts, it is useful to understand this similarity of shape, while in others, it is important to recognize that the parts will inherit properties of the material used.

The structure of atom is, in many ways, analogous to the structure of planetary systems. Another example of such convergence can be found in dolphins and whales: mammals that moved from land into the water had acquired many features in common with the body of the fish (Bogdanov, 1908, p. 158).

The convergence is the result of a similarly directed selection applied to a part in a similar environment. Selection, both positive and negative, promotes dominance of successful forms and disappearance of un-successful, and plays a generalizing role on systems.

2.2.8 Irreversibility of Change

You could not step twice into the same river; for other waters are ever flowing on to you.

Heraclitus of Ephesus (535BC-475BC)

Another translation of the above quote is *"No man ever steps in the same river twice, for it's not the same river and he's not the same man",* meaning that both the system and its environment continuously change, and there cannot be same combination of states of the environment and the complex system. In the dolphins and whales example from section 2.2.7, these marine mammals exhibit distinct characteristics indicating that at some point they lived on land. When the animals returned to live in the water, they retained previously developed features that enabled them to dwell on land, even though they were no longer needed.

2.2.9 States and Transformations

A change in the system can only be considered from the point of view of the difference in form between its initial and final points, and such changes are irreversible. Organizational problems are emerging from the systemic divergence, and there are two possible solutions to these problems: systemic crisis (destruction, catastrophe) or systemic transformation. Negative selection occurs everywhere; what it takes is irrevocably carried away, destroyed forms leave the economy of nature, nature itself is now different, and all that is new is created under the new conditions.

2.2.10 Tektological Crises

A crisis is a sharp transition, a disturbance to continuity, a process, which has a character of struggle; until a crisis struggle goes away, the situation is indeterminate and fluctuating, and the complex is in a state of rapid transition. Externally, a crisis is a change in the organizational form of a complex. Internally, a crisis is a disturbance of equilibrium, and at the same time a transition to some new limiting equilibrium.

This new equilibrium is limited by changes and forces resisting changes to the complex. If we know the tendencies of the crisis and those conditions under which they unfold, it is possible to predict the final result of the crisis - that limiting equilibrium to which it tends (Bogdanov, 1908, p. 238).

Bogdanov recognized two types of crises:

- C-crisis (conjunctive), which breaks up Tektological boundaries and forms new conjunctions and linkages, and
- D-crisis, which breaks up linkages and forms new Tektological boundaries (Zeleny, 1988, p. 7).

All crises begin with the C-crisis and end with the D-crisis.

2.2.11 Invisible Hand

Adam Smith, widely cited as the father of modern economics and Economic System of Natural Liberty (O'Rourke, 2007), is acclaimed for introducing the concept of Invisible Hand. Adam Smith himself only used the term "Invisible Hand" three times in his writings: it first appeared in "The history of Astronomy"[7]; it was also used in "The Theory of the Moral Sentiments"(1759) and, most famously, in "On The Wealth of Nations"(1776); however, the concept and principle of the "Invisible Hand" is vital in his writings and almost always generalized by others beyond specific scope or context in which it was used (Skousen, 2007). The most often cited Adam Smith's quote from the Wealth of Nations, "*It is not the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest*" (1776), is thought to summarize the concept of Invisible Hand and is interpreted to say that, under conditions of fair competition and well-informed and moral trade of goods and services, all stakeholders will benefit each other while pursuing their own goals and self-interests.

The self-interest, in a state of equilibrium of satisfaction of all conflicting goals, results in fair and beneficial outcomes for all. This balance, created by the universal competition, controls the behavior of all systems and, by force of the Invisible Hand, resolves competition for resources, divides benefits of exchanges fairly, and creates an intelligent system of harmony and growth. In a free trade, by definition, both the seller and the buyer benefit from each transaction, so the system is only successful if all stakeholders' interests are satisfied. In predator-prey interaction of any kind, the survival of the predator depends on the well-being of the prey and sustainable prey population, so optimal but gentle balance is established in each ecosystem.

[7] One of the early Adam Smith writings, but was published for the first time only after his death

The broad applicability of this principle has a tremendous effect on systems. Stable and continuously operating systems have to have a balanced flow of value to all stakeholders and participants of the system, or the forces of negative selection would disjoin the under-valued elements from the system, causing the entire system to undergo a transformation until a state of equilibrium is found. This means that a customer's satisfaction is as important as an employee's satisfaction, since the participation of both is essential to the system of trade. By implications, the Invisible Hand controls the relationships among cost, price and profit for any continuously existing product or service; driven by self-interest of sellers and buyers, Tektological Crises would destroy a system if equilibrium beneficial to all is not found.

The Invisible Hand is also credited with matching demand and supply and controlling the rates of return on goods and services, because, over time, should some product or service gain unusually high rates of returns for the producers, new producers, guided by their self-interest, would enter the market niche and, via competition, drive the rates of return down (Morrison, 2009).

2.2.12 Balancing Complexity Profile

While Bogdanov did not explicitly identify Balancing Complexity principle, he eluded to it in his discussion of stability of systems. This principle is largely formulated by Bar-Yam (2003) and Smith (first published in 1776). Smith (1776) advocated a form of organizational structure based on reduced complexity of individual activity (specialization).

Bar-Yam, inspired by the similarity of organizational behaviors and patterns of vastly different systems (as shown in Figure 2-1), analyzed the human social environment using complexity profile, a mathematical tool used to characterize collective behavior of a system, and found that the complexity of individual behavior is decreasing while overall complexity of civilization is increasing.

The trend of balancing excessive complexity by distributing complexity of behavior of individual and complexity of organization is likely Tektological, and will be further evaluated in the next chapter.

Much work still needs to be done on how to evaluate and quantify complexity; most current methods are related to the amount of information needed to describe the system, and, thus, indirectly relate to the number of components and interfaces. To quantify complexity profile of an organization of elements, Bar-Yam (2003) counted the number of independent behaviors that are visible at a particular scale. Matti Kinnunen, a fellow SDM alumnus, proposed a set of complexity measures, which are usable with the models defined using the Object-Process Model (OPM). In order to do this, he introduced a new concept of interface complexity multiplier for compensating the hidden information at interfaces. He also defined a set of complexity metrics for system architecture models.

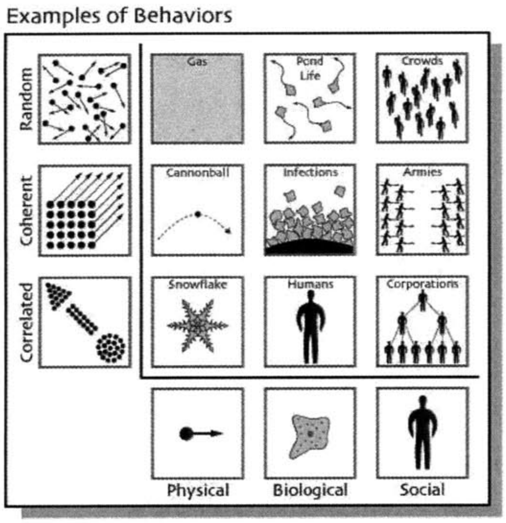


Figure 2-1 Similarity of behaviors of organizations of different elements. Adapted from (Bar-Yam, 2003)

In Chapter 5, the attempt will be made to use these methods to estimate complexity, to compare complexity profiles of organizations, and to validate this principle in context of commercial organizations.

Chapter 3. Methodologies and Frameworks

3.1 System Architecture

Because system architecture as a cross-domain academic field is a fairly new discipline, there is a lack of consensus on formal conceptualization and clear definition of the field and scope of its study. Osorio, Dori and Sussman (2009) recapitulated most common definitions from different domains and proposed their own: **A system's architecture is the embodiment of a concept for achieving the desired system's function in terms of its form, i.e., structure-behavior combination.**

Figure 3-1. Summary of System Architecture Definitions. Adapted from Osario, Dori and Sussman

Definition of System Architecture	Function defined in terms of	Concept defined in terms of	Form defined in terms of	Source
"the minimal set of properties that determine what programs will run and what results they will produce"	Architecture as the functional appearance of the computer	Not explicit	Structure is not part of the architecture, but rather falls into a design domain	(Blaaw 1997)
"what things exist" in a network, "how they operate" and "what form they take"	The effect created by network components, topology and protocols, decoupled by layers	Network topology,	Network components are the basis of form in a network, and protocols drive their behavior	(Black 1989)
(i) a vehicle for communication among stakeholders, (ii) capturing early design decisions, and (iii) providing a basis for transferring and reusing parts of the system.	Overall desired performance of a software	Understood as different architecture styles	Code, which is affected by external forces	(van Vliet 2001)
"a set of elements… depicted in an architectural model, and a specification of how these elements are connected to meet the overall requirements of an information system"	"Overall requirements of an information system"	Specification on how the elements are connected	Elements on a model	(TOG 2001)
"scheme by which function is allocated to physical components"	The function of a product	Scheme	Physical components	(Ulrich 1995)

"the way in which a concept matches form to function"	A system's Externally delivered function	Overall system's concept	Form	(Crawley and Weigel 2004)
"the overall system's structure-behavior combination, which enables it to attain its function while embodying the architect's concept"	Overall system's function	A particular architecting concept	Structure-behavior	(Dori 2002)
"conceptually design, evaluate and select a preferred structure for a future state enterprise to realize its value proposition and desired behaviors"	The enterprise's value proposition and desired behavior	A particular concept of design, evaluation and selection	The preferred structure of a future state enterprise	Nightingale and Rhodes (2009)
Adopted Definition: **A system's architecture is the embodiment of a concept for achieving the desired system's function in terms of its form, i.e., its structure-behavior combination.**	A desired system function	A particular architecting concept	Form as a structure-behavior combination	Osario, Dori and Sussman

As implied by all of the above definitions, a system's architecture, constrained by a concept and a function, defines a structure and a function of the system. Crawley (2007), building upon the work of many others in the field, outlined a cross-domain framework and methodology for designing a system's architecture. As a preface to further discussion and critique of the Crawley's methods, Section 3.2 provides the synopsis of the major building blocks in Crawley's approach – Object Process Methodology (OPM) and Object Process Diagram (OPD).

3.2 Object Process Methodology and Object Process Diagrams

Object-Process Methodology (OPM), a systems modeling methodology authored by Dov Dori, is used to define a system by graphically representing relationships of a system's form and structure to its processes, functions, and behavior, and modeling emergence of function and behavior of a system from its structure (form), and vice versa. It has been a basis and a fundamental tool for several system engineering and system architecture courses at MIT, and is extensively considered to be a part of combined methodologies, such as Object-Process-Based Modeling Language for Multi-Agent Systems

(Sturm, Dori, & Shehory, 2009), and COIM, Object-Process-Based method for analyzing architectures of complex, interconnected, large-scale socio-technical systems (Osorio, Dori, & Sussman, 2009).

OPM uses a single diagramming tool - a set of OPDs, and corresponding subset of English –Object Process Language (OPL) - to diagram and model the hierarchical decomposition of a structure, function and behavior (Dori, 2009). Without making any assumptions about the nature of the system considered, OPM and OPD rely on very few concepts and building blocks to represent any system.

The uniqueness and effectiveness of OPM stems from combining representations of form and function of a system within same diagrams and conceptual models. OPM represents any system in terms of stateful objects (things) and processes and relationships among them. Dori (2009) explains that the major features of OPM allow for hierarchical decomposition of the system into objects, or physical elements, and processes – internal functions – in a well-defined manner at various levels of the hierarchy. This is done by expressing relationships among objects and processes via structural and procedural links. (Osorio et al., 2009, p. 14).

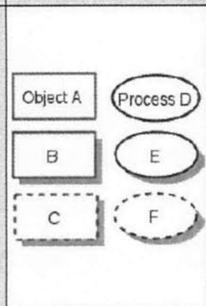
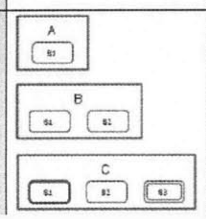
3.2.1 Key OPM concepts and example

Key building blocks of OPM diagrams are objects and processes. An object is a thing that exists, or has a potential to exist, and can have different states. For example, an object – Person – can be Single or Married. A process – such as Marrying in the example above - is the cause of the change: processes can consume, transform (change state) and create objects and other processes.

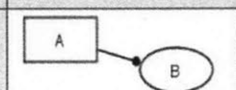
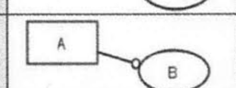
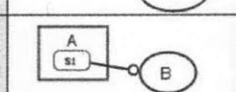
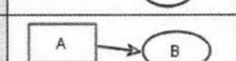
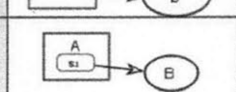
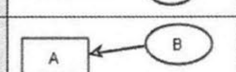
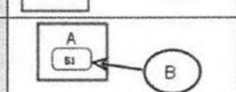
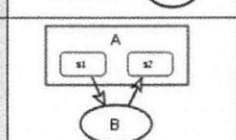
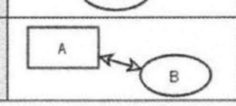
Structural links are used to represent the hierarchical composition of objects and processes; to reduce complexity, the hierarchical levels can also be encapsulated and abstracted within the model by using in- and out- zooming. Table 3-1 shows valid OPD entities and corresponding OPL statements and definitions, and provides an example adapted from Dori (2002) and demonstrating some of the OPD concepts.

Table 3-1. OPD key concepts, symbols and definitions. Adapted from (Sturm et al., 2009, p. 7)

ENTITIES

	Name	Symbol	OPL	Definition
Things	Object Process		B is physical. (shaded rectangle) C is physical and environmental. (shaded dashed rectangle) E is physical. (shaded ellipse) F is physical and environmental. (shaded dashed ellipse)	An object is a thing that exists. A process is a thing that transforms at least one object. Transformation is object generation or consumption, or effect—a change in the state of an object.
	State		A is s1. B can be s1 or s2. C can be s1, s2, or s3. s1 is initial. s3 is final.	A state is situation an object can be at or a value it can assume. States are always within an object. States can be initial or final.

ENABLING AND TRANSFORMING PROCEDURAL LINKS

	Name	Symbol	OPL	Semantics
Enabling links	Agent Link		A handles B.	Denotes that the object is a human operator.
Enabling links	Instrument Link		B requires A.	"Wait until" semantics: Process B cannot happen if object A does not exist.
Enabling links	State-Specified Instrument Link		B requires s1 A.	"Wait until" semantics: Process B cannot happen if object A is not at state s1.
Transforming links	Consumption Link		B consumes A.	Process B consumes Object A.
Transforming links	State-Specified Consumption Link		B consumes s1 A.	Process B consumes Object A when it is at State s1.
Transforming links	Result Link		B yields A.	Process B creates Object A.
Transforming links	State-Specified Result Link		B yields s1 A.	Process B creates Object A at State s1.
Transforming links	Input-Output Link Pair		B changes A from s1 to s2.	Process B changes the state of Object A from State s1 to State s2.
Transforming links	Effect Link		B affects A.	Process B changes the state of Object A; the details of the effect may be added at a lower level.

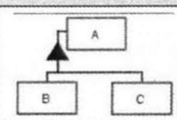
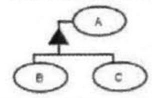
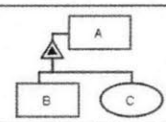
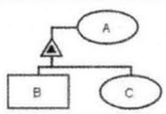
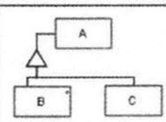
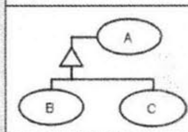
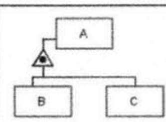
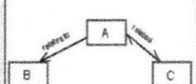
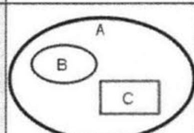
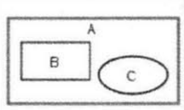
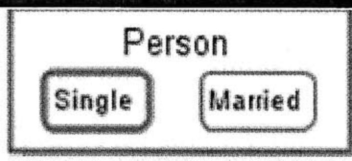
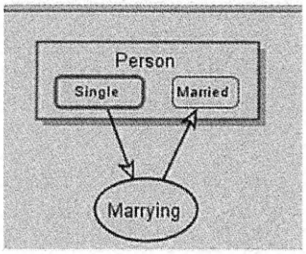
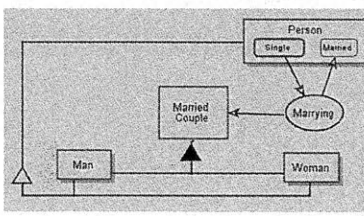
STRUCTURAL LINKS & COMPLEXITY MANAGEMENT				
	Name	**Symbol**	**OPL**	**Semantics**
Fundamental Structural Relations	Aggregation-Participation		A consists of **B** and **C**.	A is the whole, B and C are parts.
			A consists of **B** and **C**.	
	Exhibition-Characterization		A exhibits **B**, as well as **C**.	Object B is an attribute of A and process C is its operation (method). A can be an object or a process.
			A exhibits **B**, as well as **C**.	
	Generalization-Specialization		**B** is an **A**. **C** is an **A**.	A specializes into B and C. A, B, and C can be either all objects or all processes.
			**B** is **A**. **C** is **A**.	
	Classification-Instantiation		**B** is an instance of **A**. **C** is an instance of **A**.	Object A is the class, for which B and C are instances. Applicable to processes too.
Unidirectional & bidirectional tagged structural links			A relates to **B**. (for unidirectional) A and C are related. (for bidirectional)	A user-defined textual tag describes any structural relation between two objects or between two processes.
In-zooming			A exhibits **C**. A consists of **B**. A zooms into **B**, as well as **C**.	Zooming into process A, B is its part and C is its attribute.
			A exhibits **C**. A consists of **B**. A zooms into **B**, as well as **C**.	Zooming into object A, B is its part and C is its operation.

Table 3-2. OPD example. Adapted from Dori (2002)

OPD	OPL	Comments
	Person is physical. Person can be Single or Married. Single is initial.	Person can be either single or married. In OPD, Single or Married would be states of object.
	Person is physical. Person can be Single or Married . Single is initial. Marrying changes Person from Single to Married .	Process of Marrying changes state of a person from Single to Married Process Marrying "consumes" Single Person and results in Married Person.
	Person is physical. Person can be Single or Married . Single is initial. Married Couple consists of Man and Woman. Man is physical. Man is a Person. Woman is physical. Woman is a Person. Marrying changes Person from Single to Married . Marrying yields Married Couple.	Process of Marrying results in a Married Couple, which is the union of one Man and one Women. OPD allows to specify cardinality; One is default cordiality.

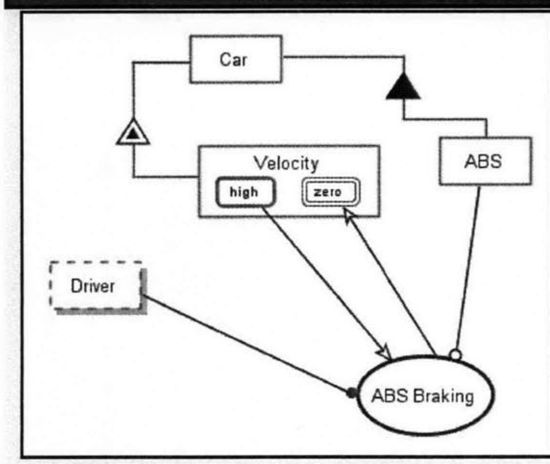
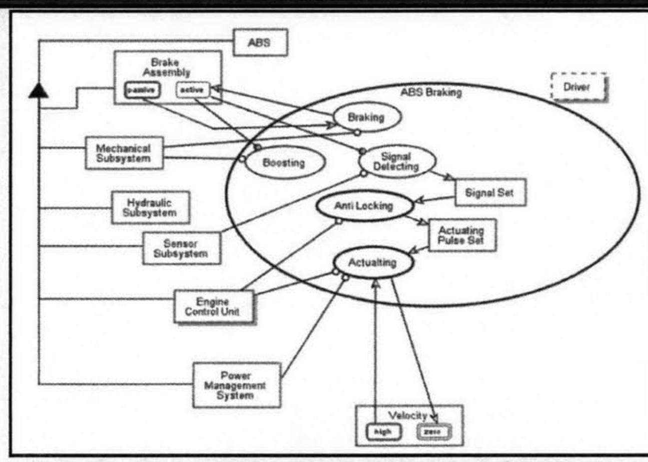
3.2.2 Function

Function is a problem-oriented concept detailing a goal the system is expected to achieve, while architecture is a solution-oriented concept which specifies how the system function is to be achieved by a specific architecture (Dori, 2003). In OPD, function is a special process, corresponding almost exactly to

Crawley's (2008) Externally Delivered Function (EDF). EDF is the reason for systems existence, whereas internal processes and the structure provide the means for accomplishing the system's goals.

The best practice for representing EDF (function) on OPM diagrams is as Main Process, with all other processes and elements of structure as an in-zoom of it. The system's function is understood by decomposing and disaggregating it into several processes -internal functions (Osorio et al., 2009, p. 10). Table 3-3 shows EDF for the ABS Braking system with its in-zoom.

Table 3-3. Example of EDF and internal processes. Adapted from Dori (2008)

EDF: ABS Braking	In-zoom of EDF: internal structure and processes
	

The concept of main function is not limited to the artificial systems; behavior of all systems and organisms can be understood in term of their functions.

Dori (2003, p. 64) writes:

Like biological systems, many contemporary artificial complex social and man-made systems have evolved over years of human history without an explicitly stated, predetermined, well-defined goal. This is especially true for systems with an intensive human component, namely organizations of various kinds. Still, in retrospect, by examining a system's architecture, or its structure-behavior combination, one can usually infer its function, that is, the goal or purpose it serves.

In Tektology, however, the goal of each system is to organize its forces and forces of its environment; the function of the mankind is the *organization of external forces of nature, organization of human forces, and organization of experience,* i.e. the function of civilization is organization (Bogdanov, 1908, p. 3).

3.3 System Architecture Framework and Methodology

Perhaps the most known application of OPM, at least to the System Design and Management community, is its use by Professor Edward Crawley in his System Architecture methodology and framework. Crawley expanded on OPM by explicitly identifying Flow of Value, Designer's Intent, and Stakeholder Needs on the OPDs, thus, bringing the context-free OPM into the Product System domain.

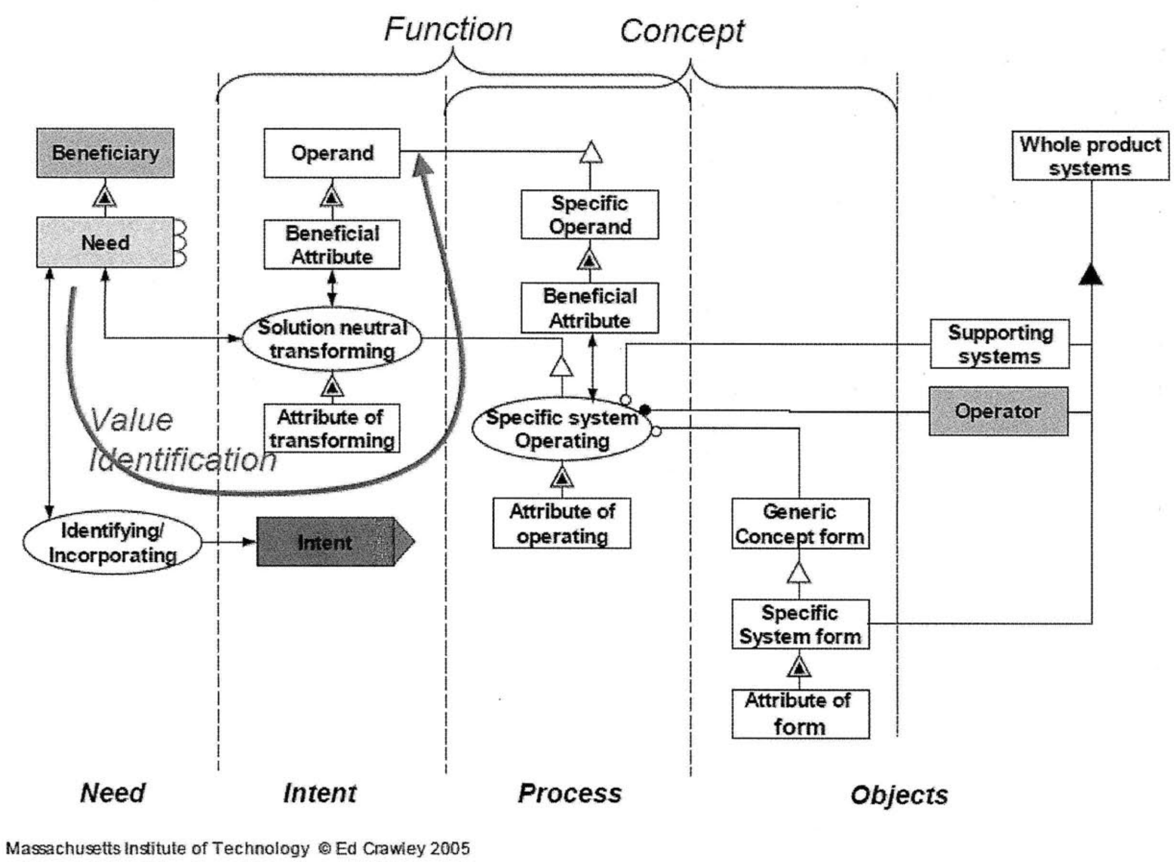


Figure 3-2. From Need to Value transformation. Adapted from (Crawley, 2008).

The system's architecture design process – as any design process – is highly iterative by its nature. Figure 3-3 shows the basic flow of such process, and the framework assumes multiple passes through the system.

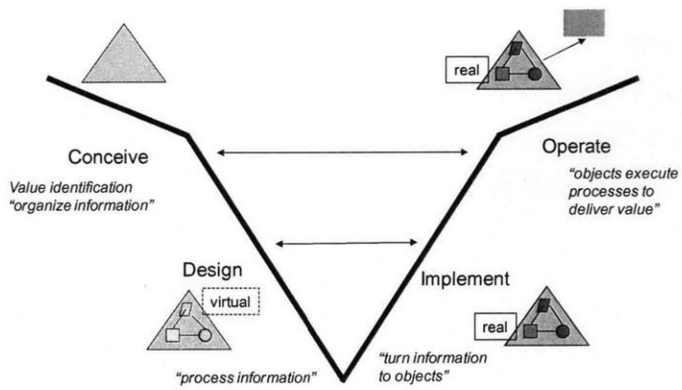


Figure 3-3. Design Process. Adapted from Crawley (2008)

3.3.1 From Needs to Goals Approach

Crawley begins to define a system by identifying needs of the stakeholders the system should satisfy and then identifying goals, or value, the system should provide to all stakeholders. By implication of the "Invisible Hand" principle discussed in section 2.2.11, all stakeholders and participants of the system must have a fair balance between what they contribute, give-up and receive from the system; the success of the system is contingent upon finding an equilibrium of all stakeholders' value exchanges.

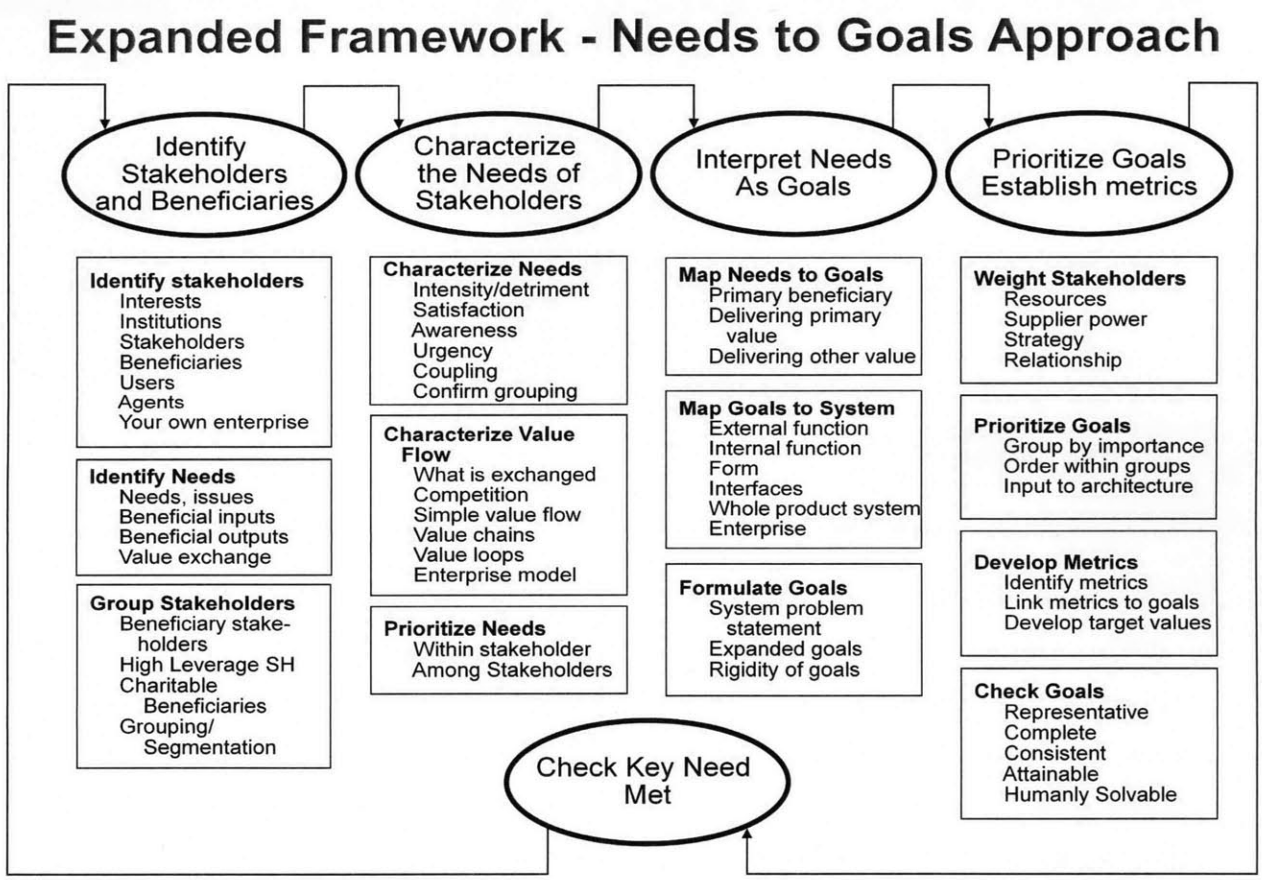
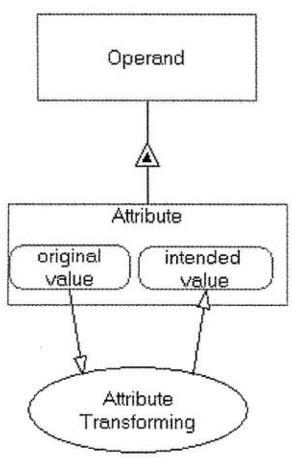
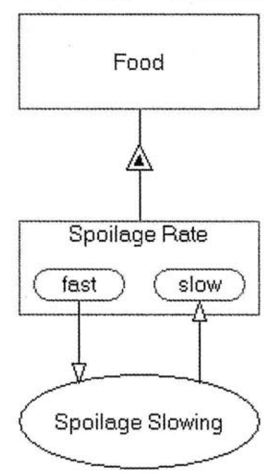


Figure 3-4. Crawley Needs to Goal Framework. Adapted from Crawley (2008)

Value is a benefit at cost, and is achieved by transferring the state of a value related attribute object (VRAO). For example, as shown in Table 3-4, the value related attribute object of a refrigerator is food, and the refrigerator generates value by slowing its spoilage rate.

Table 3-4. Identifying Goal as State Transformation of Value Related Operand. Adapted from (deWeck & Crawley, 2002)

General Form	Refrigerator Example
	

It is important to note that to be successful, the refrigerator, as a product system, needs to provide a value to all stakeholders. The stakeholders, of course, are not limited to the potential customers, but also include the manufacturers, distributors, and even governments and non-government agencies. Figure 3-5 shows the flow of value to all stakeholders of a commercial refrigerator, and Figure 3-6, adapted from Crawley (2008), depicts the flow of value among different stakeholders for an enterprise-wide project (presumably similar to the productization of a refrigerator), as the Invisible Hand principle equates the importance of all stakeholders' interests. Essentially, as shown by the value flow maps and described by Adam Smith, the commercial organizations contribute to overall well being of the society by generating monetary and non-monetary wealth distributed throughout the system.

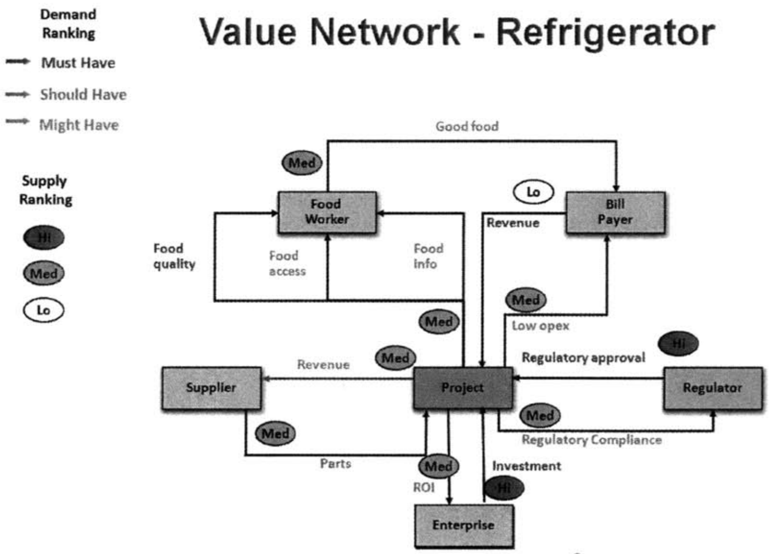


Figure 3-5. Value Network of Commercial Refrigerator. Adapted from (Crawley, 2008)

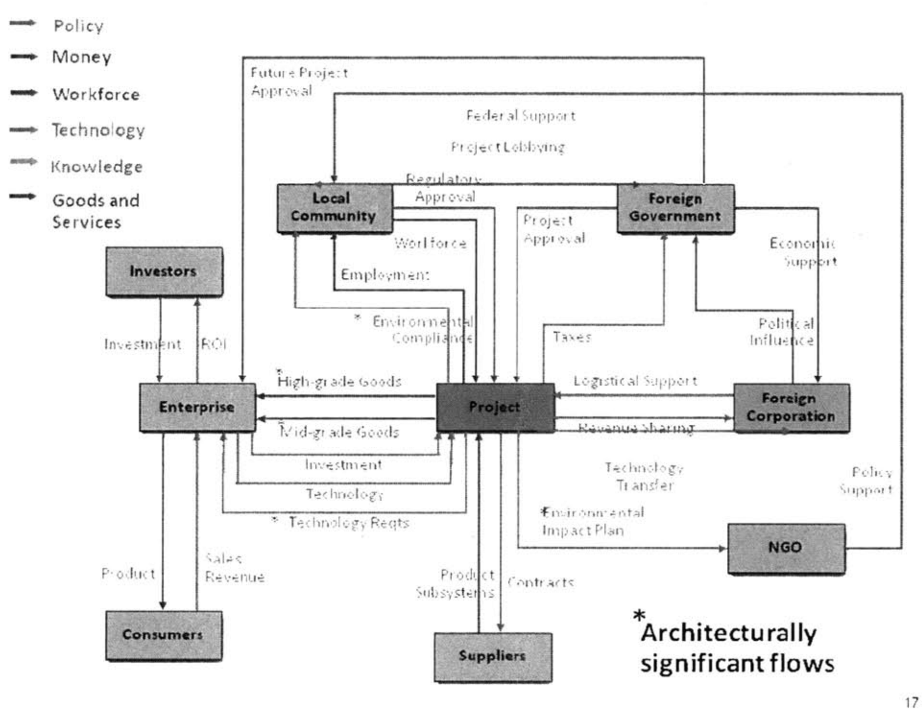


Figure 3-6. Transfer of value between stakeholders in a system. Adapted from (Crawley, 2008)

Crawley (2008) also describes a subjective benefit ranking system and a semi-quantitative system that can be used to translate a stakeholder's needs into the goals of the system.

3.3.2 Concept Selection

Once the goals and context of the system are identified, a system's architect can begin generating concepts for the system. A concept is a working vision, which embodies working principles and provides a mapping from function to form (deWeck & Crawley, 2002).

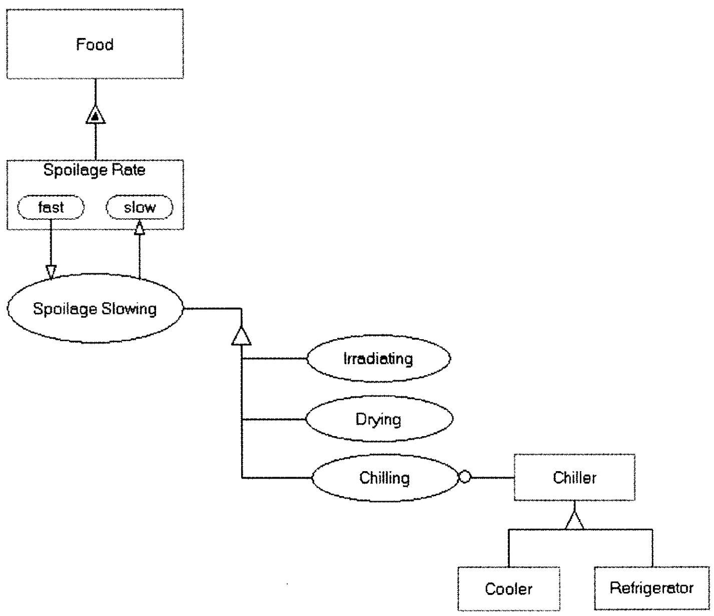


Figure 3-7. Concept selection. Adapted from (Crawley, 2008)

As shown in Figure 3-7, several different processes can be used to slow down spoilage of food. A refrigerator can be selected if it can provide the most value to all stakeholders in the considered context. A cooler, for example, can be used to perform the same function; the analysis of secondary customer needs and product system context would be necessary for selecting the most appropriate concept.

3.3.3 Decomposition of Function and Form

Crawley (2008) explains that the process of designing architecture of a system is highly hierarchical and iterative. To evaluate the breakdown of parts into modules, the architect must look at the performance of lower level components; however, the performance can only be properly evaluated after the product has been operating for some time. That is why any framework must include multiple iterations throughout the design and system architecture process, as well as re-evaluation of decisions. Crawley proposes the evaluation of the architecture to be performed at least at 2 levels of decomposition, as shown in Figure 3-8 and detailed in Table 3-5.

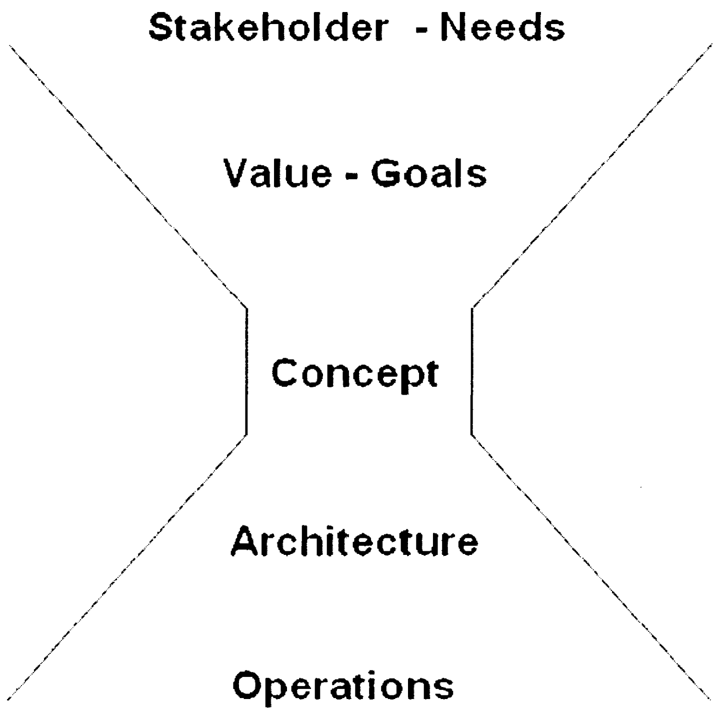


Figure 3-8. Levels of Architectural Decomposition. Adapted from Crawley(2006)

Crawley proposes defining the system's architecture in layers, with each successive layer revealing more details. Each process on layer N becomes an intent on layer N+1, with a minimum of 2 layers. *Wisdom about architecture at level N is revealed by analyzing decomposition at level N+1.*

Table 3-5. Crawley's Form and Function Architectural Decomposition Framework. Adapted from Crawley (2008)

	Level 0		Level 1		
	Intent	Concept	Intent	Process	Object
Documentation and knowledge capture	1. What are the current goals?	2. What concepts are embodied? Which were	3. What is the current architecture?		
			3c. Design intent capture?	3b. Principles of operations,	3a. Diagrams, drawings,

		considered and abandoned?		processes?	schematics of objects?
	Documents?	Documents?	Documents, drawings or oral history?		
Analysis	4. Write the current goals as origin goals: System problem statement, descriptive goals. Analyze the requirements as operand, attribute, transformation, attribute	5. Analyze the concept as process and object	6. Analyze the current architecture		
			6c. Intent, linked to current understanding of origin goals	6b. Process/ object mapping using explicit representation or object/ suppressed processes representations	6a. Object/ hierarchy Object structure - Special/ topology/ suppressed implementation
Critique	7. Reflect on goals: Representative Complete? Consistent? Solution neutral?	8. Reflect on the concept.	10. Intents map goals to objects and processes in appropriate manner?	9. Reflect on the architecture: deliver primary value process? deliver other value process? interface cleanly? elegant decomposition?	

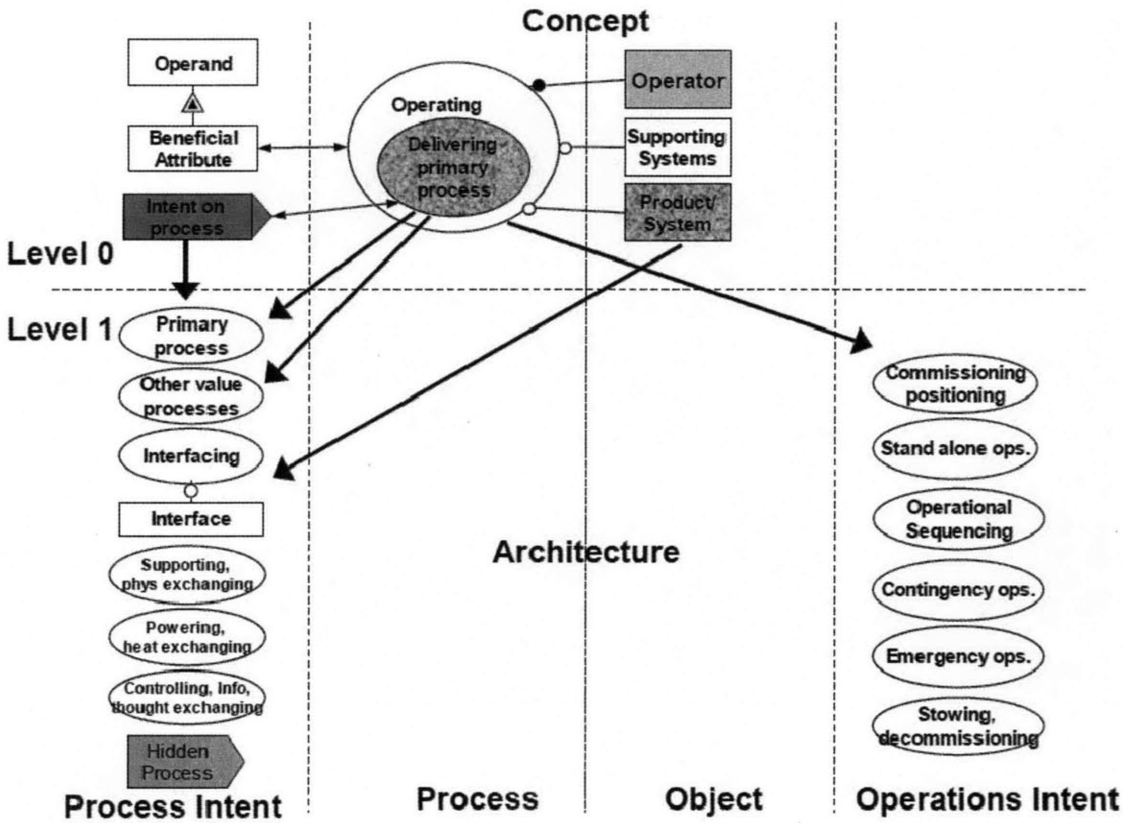


Figure 3-9. Relationship between Levels of Decomposition. Adapted from Crawley (2008)

3.3.4 Applicability of System Architecture to Organizational Design

Martino (2007) adapted the Crawley's framework to evaluate the performance of an engineering services organization, and found it to be a valuable tool for documenting the organizational structure, communications and other reference information (Martino, 2007, p. 100). Based on the Crawley's framework, she devised a list of questions enabling the architect to discover and document the details of the system's current function and architecture. The answers to the questions uncovered the forms, structure, processes, needs, value, and intents that define the organization (Martino, 2007, p. 23). While such evaluation helps to document and communicate details and insights about the organizational structure, such framework does not explicitly assist in evaluation of the appropriateness of the organizational structure for its environment, or provide insights about emergence of behavior. Crawley's framework, originating in a simpler physical product design domain, includes the evaluation criteria important for socio-technical systems, but does not provide explicit methodologies to properly evaluate such criteria, nor does it provide methodologies for evaluating long term performance of a system, when stakeholders, their goals, and overall function of the system change.

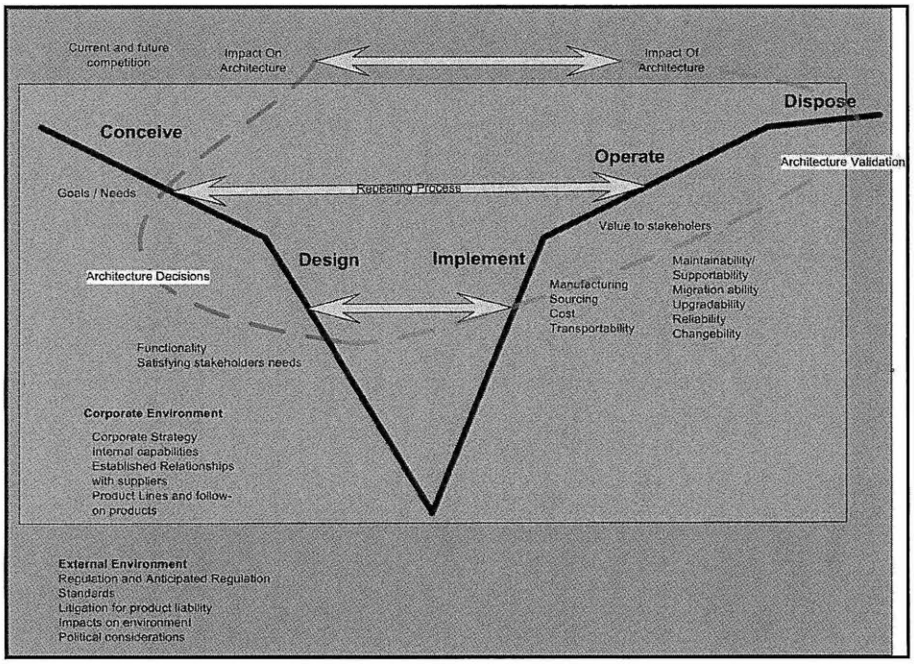


Figure 3-10. Generic System Engineering Process

More complex systems, especially those with substantial social components and ad-hoc characterizes, require additional frameworks and methodologies to evaluate the architecture of such systems. While Crawley is very specific as to the iterative nature of the process of designing a system's architecture, the process of evaluation of the system's architecture is never complete. A change to the system at any point during system lifecycle propagates throughout the entire system. At each stage of the design process, there are considerations that are affected by the product's architecture, and, at the same time, influence the system's architecture. During each pass through the design process, the effectiveness of the system's architecture is refined, as shown in

Figure 3-10. It is assumed that the iterative nature of the design process insures that decisions made in the early stages of the process are validated by modeling or practice, and the architectural choices are refined, dismissed or confirmed. Evaluating a system's architecture is an iterative process that must take into account all aspects of the system's lifecycle. At any point in time when evaluating a system's architecture, there will be uncertainties and assumptions as to how well the system's architecture meets its goals; it is not always possible to anticipate changes in external environments or customer needs. That is why iterative runs through the architecture processes are needed to refine the system's architecture and validate the concepts and assumptions used, and such process is never complete.

In practice, the system engineering process is often more "spiral" in its nature, for the sake of cost effectiveness. While it is essential to identify several concepts and validate their applicability, designing, evaluating and creating several prototypes could be costly. That is why the first few iterations through the design process are normally quick, aiming to dismiss obviously bad concepts; through each iteration of the process, each concept and design decision is evaluated in more detail.

3.4 System Dynamics

System Dynamics was founded by Joe Forester in the 1960s at the MIT Sloan (Morrison, 2009); however, many concepts were introduced in prior works, most notably by Bogdanov, Bertalanffy and Wiener. The modeling technique aims to aid our understanding of the world by building structured conceptual models and gaining an understanding of causality of a system's behavior, as well as modeling the behavior of the system over time.

In System Dynamics, relatively few concepts and abstractions are used to represent the systems and dynamics within them, and two types of diagrams – Stocks and Flow Diagram, and Casual Loop Diagrams, - are used to explain the behavior of a system.

3.4.1 Stocks and Flow Diagrams

Changes in systems are represented by Stocks, or accumulation of material, and Flow, or rate of flow. Graphical representation is shown in Figure 3-11.

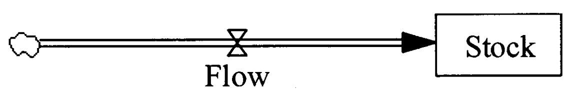
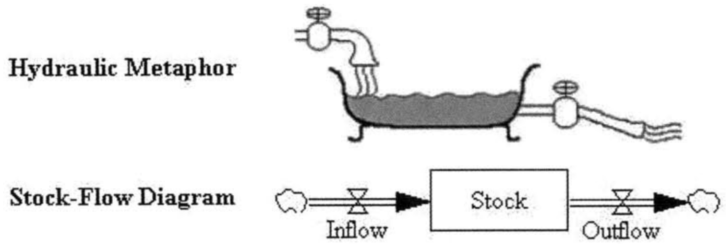


Figure 3-11 Symbols for Flow and Stock

Figure 3-12 demonstrates a very common example of Stocks and Flow Diagram. The level of water in the bathtub - Stock – is controlled by two valves, inflow and outflow. The level (accumulation of water) is equal to all of the water that ever entered the bathtub through inflow, minus all of the water that exited the bathtub through outflow.



Integral Equation $Stock(t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock(t_0)$

Differential Equation $d(Stock)/dt = Net\ Change\ Rate = Inflow(t) - Outflow(t)$

Figure 3-12. Example demonstrating concepts of Stock and Flow. Adapted from (Ossimitz & Mrotzek, 2008, p. 5)

An increase in inflow rate, with all other factors remaining the same, causes an increase in the level of water in the bathtub, thus, the 'S' designator next to causality link on the diagram shown in Figure 3-13. 'O', standing for Opposite, indicates the decrease in level of water if the outflow increases[8].

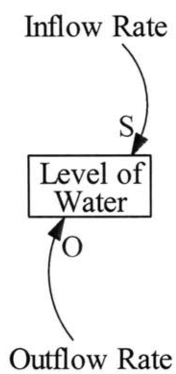


Figure 3-13. Causal Diagram

3.4.2 Causal Loop Diagrams

Two types of feedback loops are fundamental in understanding a system, Balancing and Reinforcing loops. "Word of Mouth" reinforcing feedback loop, shown on the right of Figure 3-14, shows that an increase in the number of adaptors of new products also causes an increase of the adaption rate; however, "Market Saturation" balancing feedback loop explains that an increase in Adaption Rates will eventually cause a decreased number of potential adapters, thus eventually causing a decrease in the adaption rate; actual behavior of the adaption rates in this diagram depends on which loop dominates at a given period

[8] +, indicating same, and -, indicating decrease, are also commonly used qualifiers of causality; however, to avoid confusion with quantifiers in OPD, this research will use 'S' and 'O'

of time. Understanding of the delay in the feedback is also important in explaining reactions and difficulties with identifying sources of problems in a system's behavior.

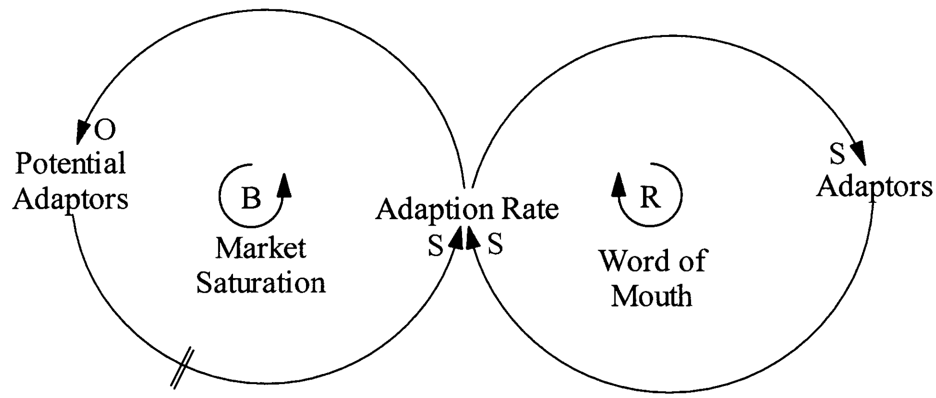


Figure 3-14. Feedback loop structures, Balancing (left) and Reinforcing (right). Double cross-lines indicate delay in feedback.

It is important to note that Reinforcing loops, denoted with R in the center, are normally responsible for change (increase or decrease) in the system: the adaption rate keeps feeding on itself, because the more people adapt, the quicker word of mouth spreads. Balancing loop, on the other hand, is responsible for resisting change or eventually constraining the growth: once the market is saturated, the adaption rate drops, as there are no more potential customers.

3.5 Design Structure Matrix

Design Structure Matrix (DSM) is a method for representing, analyzing and optimizing the structure and processes within a system. It can be traced back to the 1970's (Sharon, Dori, & de Weck, 2009), and was popularized by Whitney and Eppinger (Go, 2007) at MIT. Sharon, Dori and deWeck (2009) presented a method to convert OPL representation of a system to DSM. Crawley showed the use of DSMs in evaluating the modularization of the system. DeWeck (2009) used DSM for multi-goal system optimization and system program management. Sosa et all (2004) employed DSM to evaluate the alignment of product architecture and organizational structures in complex product development.

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Part II. Evaluating Commercial Organization's Structure

Commercial organizations, from sole proprietorships to multi-national corporations, represent the building blocks of the world economy; despite the tremendous diversity in size, trades, strategies and structures, there are certain similarities in their underlying organizational objectives and the general mechanisms used to achieve these objectives. In Part I of this research, we outlined the relevant theories, philosophies and methodologies to lay the groundwork for evaluating structures and architectures of complex systems; in this part of the research, we will apply the methodologies to conceptually evaluate commercial organizations and the evolution of their structures.

Chapter 4. Evaluating Concept of Commercial Organization

The Crawley's framework, discussed previously, provides a general methodology for evaluating and designing a system's architecture. The same framework can be applied to designing organizations and their structures, as an organizational structure is a formal system of task and authority relationships which controls how people coordinate their actions and use resources to achieve organizational goals (Jones, 2007, p. 6).

4.1 Value and Goal

Value creation is the objective of every commercial organization, worker and leader. Traditionally, value creation is defined in terms of financial measures – profitability, revenue increases, or cost savings. From sole proprietorships to multi-national corporations, the ultimate goal of an organization is to bring monetary value (profits) to its owners, or, in a publicly owned company's terms, increase shareholders' value.

Considering only the financial part of value creation is similar to the simplicity of the novice: it is accurate but incomplete (Cameron, Quinn, Degraff, & Thakor, 2006). In the "History of Moral Sentiments," Adam Smith stated that his inquiry is not concerned with the matter of right; it is rather concerned with the matter of fact (Smith, 1759, pt. II, notes). Same applies to his economic model (O'Rourke, 2007): forces, created by self-interest, competition, and supply and demand are establishing a system of dynamic equilibrium and distributing value among participants in a free-trade system. Guided by the forces of Invisible Hand, corporations and individuals exchange goods and services for monetary compensation; all participants of such exchange, by voluntarily participating and acting in their self-interest, benefit each other and contribute to accumulation of wealth. Therefore, while the essence of the modern economic activity is the exchange of money for goods and services, the role of a commercial organization is to deliver products and services that its customers want at acceptable and competitive price. Essentially, commercial organizations are multi-goal systems; their goal is to provide value to all stakeholders of the system (see Figure 4-1).

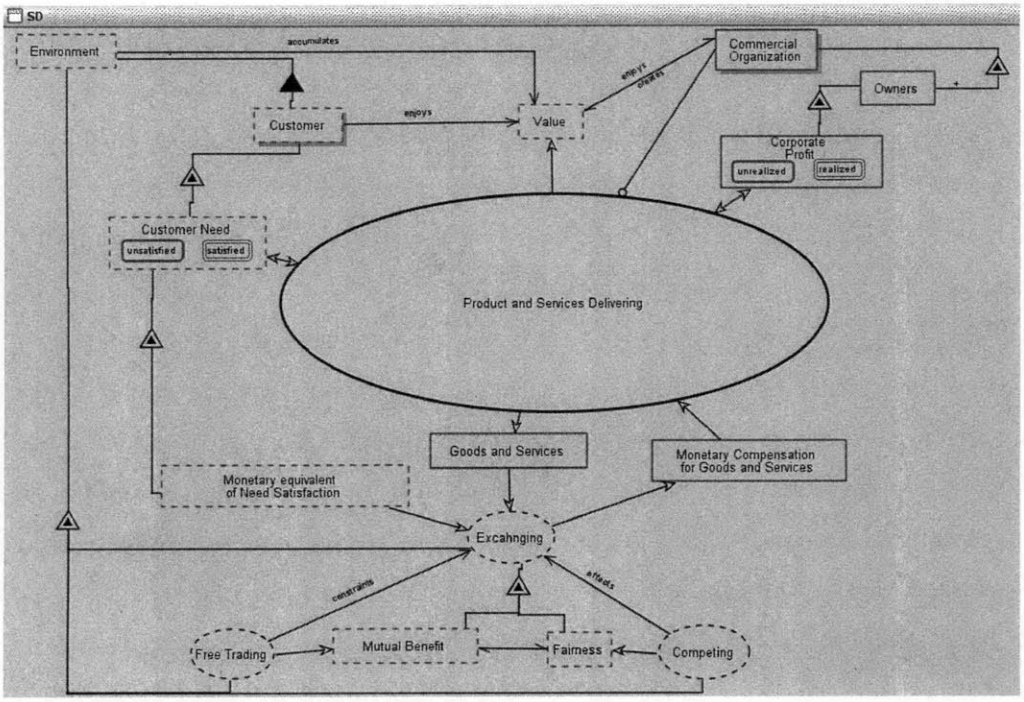


Figure 4-1. OPD of context of Commercial Organization

4.2 Externally Delivered Function and Value Related Operand

Externally Delivered Function (EDF) of commercial organization is **Product and Services Delivering**, and Value Related Attribute Objects (VRAO) are Customer Need and Corporate Profits, as shown in Figure 4-1 above. By Delivering Products and Services (EDF), commercial organizations are transferring a customer need from unsatisfied to satisfied state; successful organizations generate value to customers and profits to themselves. The external environment – economy – provides self-controlled mechanisms for transferring value generated by EDF into a benefit for all stakeholders. Thus, to achieve their own goal, i.e. profits, commercial organizations must satisfy the needs of the customers, as well as adapt to the environment in ways that allow acceptable levels of goal satisfaction for all stakeholders. In other words, commercial firms need to be concerned not only with their own goals, but with those of their customers. As previously mentioned, the Invisible Hand, in effect, equates the importance of self-interest of all participants in a free trade, and a sustainable system requires harmony among interests of all stakeholders.

The concept of organization can be described in terms of organizing specialized functions to achieve Externally Delivered Function more efficiently. Why is it more beneficial for a customer to purchase goods and services, rather than to produce them? Organizations can produce more complex products and, by utilizing specialists, do so more rapidly and cheaply. To demonstrate the increase of productivity, Adam Smith (1776) describes operations of a pin factory. A person, without the specialized equipment, can produce no more than twenty pins a day, while a factory operated by 15 workers can make enormous quantity of such pins. Of course, Smith's example was based on operations of a 17th century factory; however, we can safely assume that the developments in technology only increased the benefits of specialized labor and equipment, thus, even further advancing productivity. For an individual who needs a pin, it is more beneficial to buy one, rather than spend a day manufacturing it; it is assumed as self-evident that a day of individual labor is worth more than a pin. On the other hand, a single pin, when produced in bulk by a pin factory, costs very little to the factory operator; the price that a consumer is willing to pay for the pin would be substantially more than its cost. With enough pressure from the forces of competition, supply and demand, and self-interest, the goals and needs of the individual in need of a pin and a pin-making company can come to a point of equilibrium; at such point, both parties would make a deal that is beneficial to both. The concept of today's economy and the reason for domination of division of labor are explained by the fact that organizations are able to satisfy customer needs more efficiently; in many cases, it is not feasible for customers to produce goods and services of their own.

4.3 Stakeholders, Goals and Needs

John Mullooly, in his SDM thesis on implementation of growth strategy at Pratt & Whitney (Mullooly, 2001, p. 49), provides a great example of a company reflecting the interests of all stakeholders in its goal statement:

1. Be One Company
2. Customer Focus
3. Employee Motivation
4. Quality Processes and Products
5. Financial Focus

Despite the argument made in section 4.1 that ultimate corporate goals are financial in nature, achieving such goals unavoidably involves finding the dynamic balance in the degree of goal satisfaction for all stakeholders that makes the free-trade economy work. As was shown by Crawley, the entire network of enterprise stakeholders is quite large; at a minimum, the influential stakeholders of a commercial organization include customers, employees and owners. In most cases, each of the stakeholder groups can be divided even further.

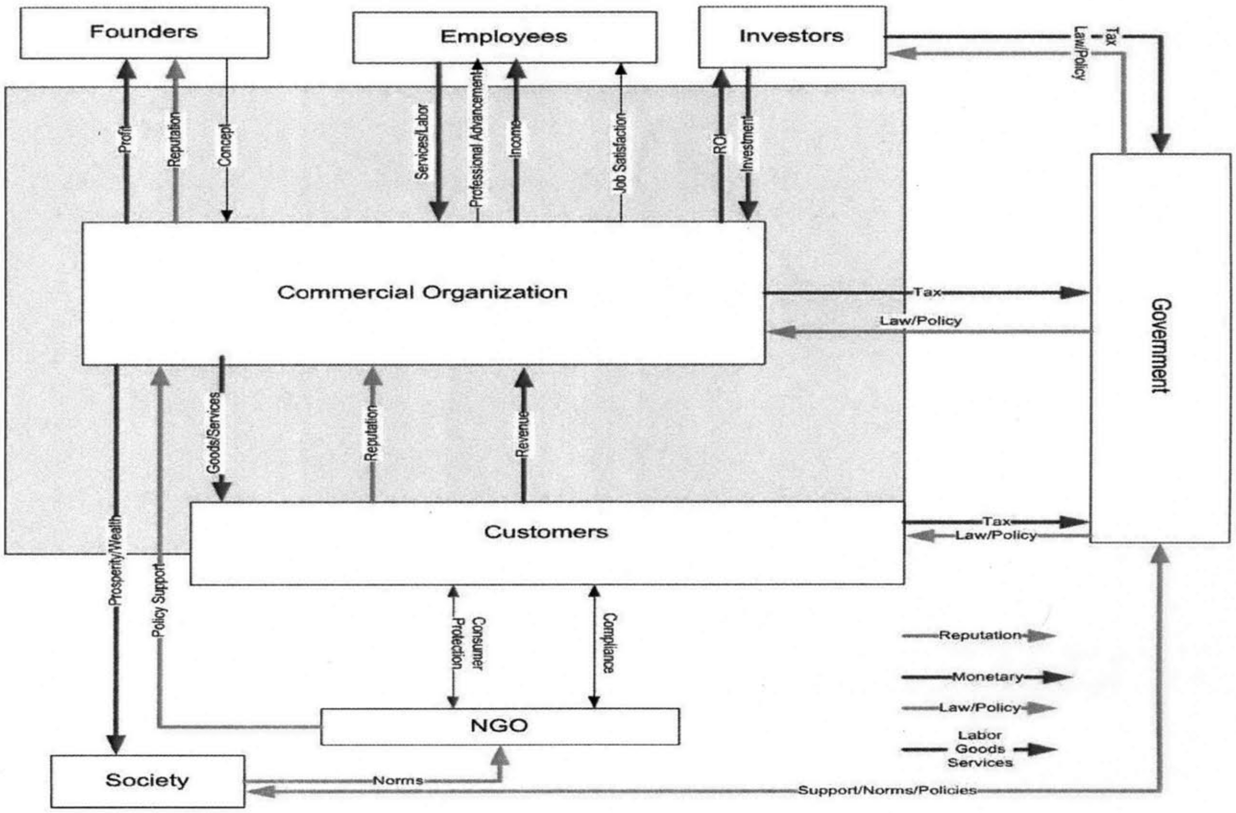


Figure 4-2. Commercial Organization Flow of Value Map

4.3.1 Customer

Most products aim to satisfy diverse customer needs. In a business-to-business environment, a customer can be an entire organization or a group within organization, as well as an individual. The needs for goods and services range based on customer preferences, and an organization should be able to deliver products and services that satisfy those diverse needs. Customer preferences for any product or service can generally be described as a balanced bundle of four attributes – cost, time, variety and quality (Anupindi, Chopra, Deshmukh, Mieghem, & Zemel, 2006, p. 11).

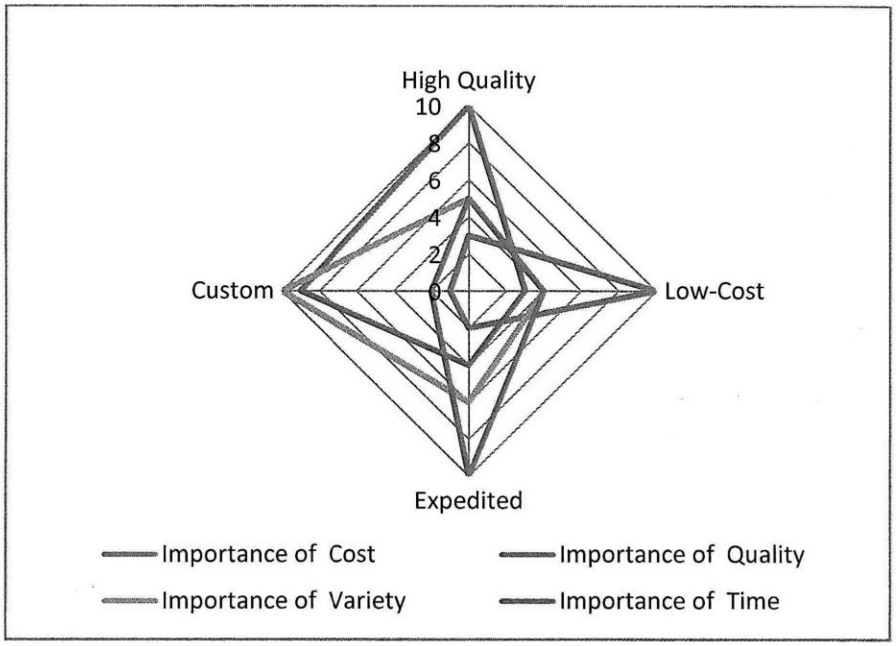


Figure 4-3. Product Space Matrix of the importance of aspects to customers

4.3.2 Employees

Employee satisfaction and motivation are instrumental to organizational performance; the major drivers of employee performance are not limited to financial compensation, but also include job satisfaction, self-fulfillment and feeling of self-importance, professional development, and peer approval (Tulgan, 2000). As will be discussed further, organizations' internal stakeholders, i.e., employees, can have different, at times conflicting, needs and goals. Engineers are normally motivated and incentivized by technological advancement and integrity of products; project and product managers, on the other hand, are more interested in and are incentivized for meeting deadlines and market demands, and satisfying commitments. Larger organizations are forced to design their incentive systems to affect employee goals and achieve a balanced performance; in smaller organization, where there exist no departmentalized functional divisions, the conflicting goals can be more easily resolved on personal levels, as the division of responsibilities is more flexible.

4.3.3 Owners and Stockholders

While owners and stockholders are concerned with profits and the financial performance of an organization, their needs are also not uniform; the interests of owners may range from achieving their aspirations, short term profits or long term prosperity. Short term profitability demands mechanistic structures which rely on standardization, specialization, centralization and hierarchy to ensure the efficient exploitation of existing capabilities. Profitability in a long run is achieved through organic structures that enable the exploration of new growth opportunities, innovation and flexibility (Raisch, 2008, p. 483). Once again, finding a balance of the conflicting interests is necessary to achieve sustainable solution.

4.4 Forms of Commercial Organizations

From the time of Adam Smith, the most widespread form of organization was hierarchical; during the past 40 years, a drastically changed economic and technological landscape forced the development of more flexible flat organizational configurations (Jaros & Dostal, 1999). New forms of organizations were aimed to allow for more optimal operations of organizations and development of more complex, cross-discipline products and services. Tom Allen (2009) shows that, thus far, the structure of any organization can be described as a combination of Integration Product Teams (IPT) and Functional Departments, as shown in Figure 4-4.

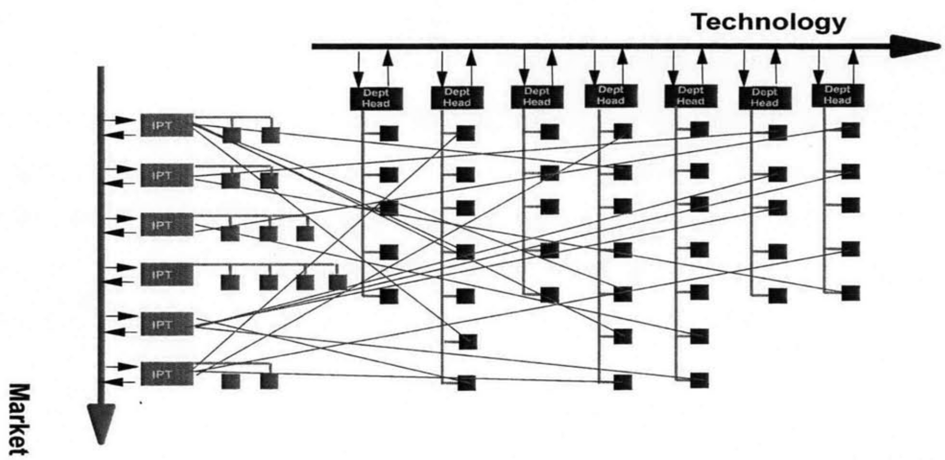


Figure 4-4. Conceptual forms of organizations. Adapted from (Allen, 2009)

To achieve its EDF – Delivering Products and Services, an organization performs several key processes. At the conceptual and abstract level, the steps to provide value to customers by delivering goods and services are shown in Figure 4-5. It is not unusual for goods or services to go through several commercial organizations before reaching the end customer. Although organizational structures will vary depending on the industry, target customers, scope and scale of the business, the general trends, according to Greiner (1998), will remain the same as the company matures and grows.

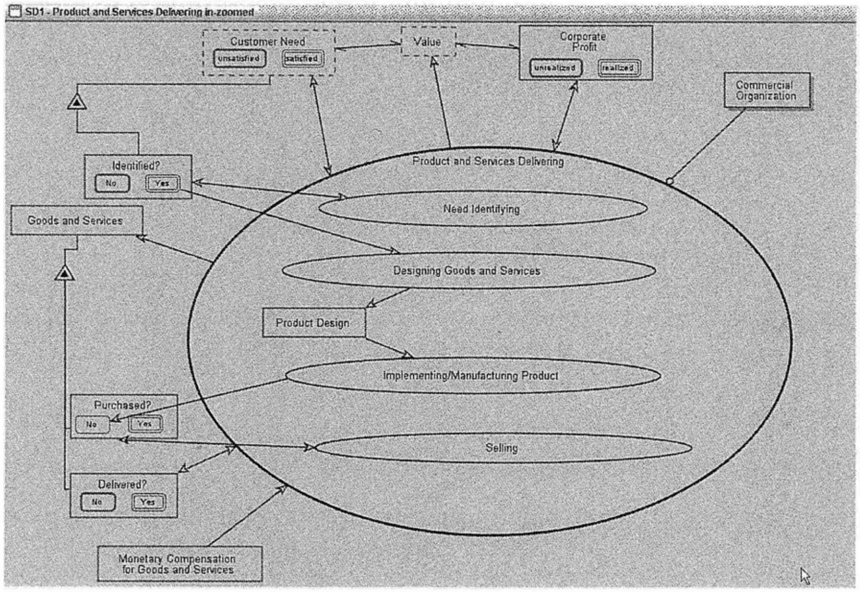


Figure 4-5. Product and Services Delivering: Internal functions

4.4.1 Effect of Structure on Organizational Behavior

It has been recognized that the behavior of a system, at least in part, is controlled by the system structure and the established rules and policies that emerge from it. Morrison (2009), citing previous authors and his own observations, shows that in the Beer Game, where participants compete by managing simulated beer distribution system, when constrained by the system's structure, participants with very different educational and professional backgrounds achieve very comparable and extremely sub-optimal results.

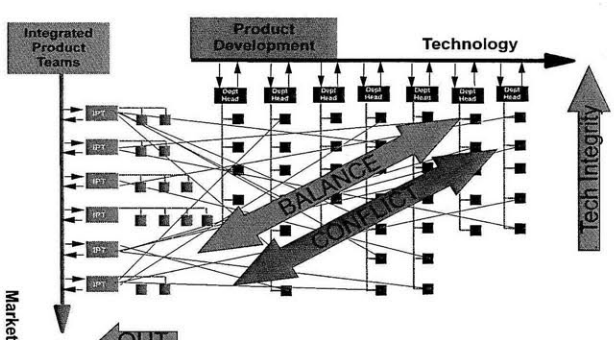


Figure 4-6. Emergence of Performance Characteristics from organizational matrix structure organization. Adapted from (Allen, 2009)

Figure 4-6 shows that the structure of any matrix organization can be represented as a combination of functional and project teams. Companies that are mainly organized as sets of functional departments tend to focus more on maturity and integrity of technologies and quality of products; the shift to project-based product teams puts more emphasis on adherence to schedule and time to market. This, in part, is due to employee motivations: as discussed in section 4.3.2, engineers and heads of functional departments are more interested in technology advancement and product maturity, while product teams' managers are more motivated by project performance. In matrix organizations, this creates an unavoidable conflict between functional and project teams, and the absence of such a conflict is an indication of inappropriate balance, according to Tom Allen.

Figure 4-7. Competing Values Framework. Adapted from (Cameron et al., 2006)

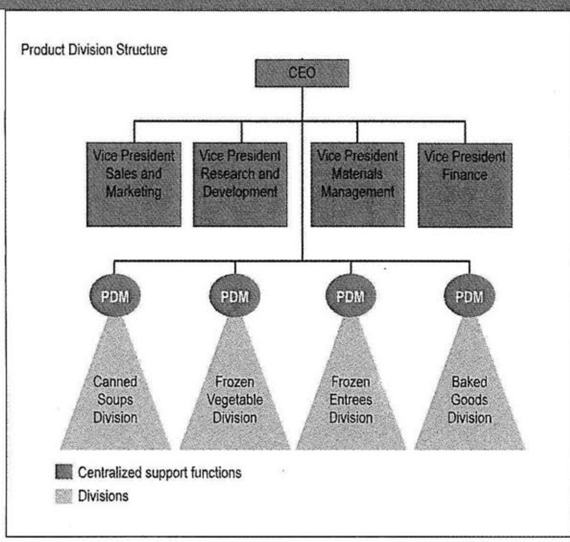
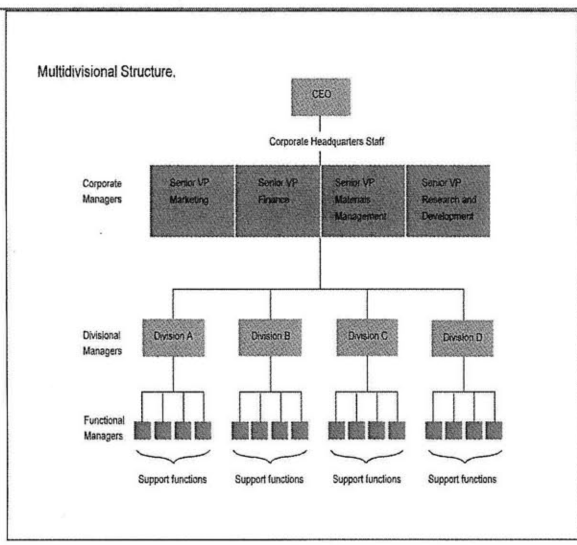
Sullivan (1998) supports Tom Allen's hypothesis as he describes a shift in the aircraft turbine production industry from technical innovation to process innovation as the industry matured in the 1990s. As the product - the turbines – matured and the amount of architectural innovation decreased, the organizational structures of companies in the industry also shifted from functional divisions to the more project focused Integrated Product Teams organizations and the focus of the organizations shifted from scientific advancement and technological innovation to optimization of processes and reduction of costs and development times for new products.

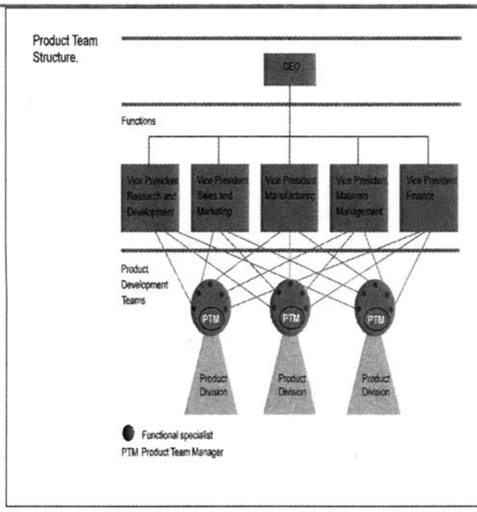
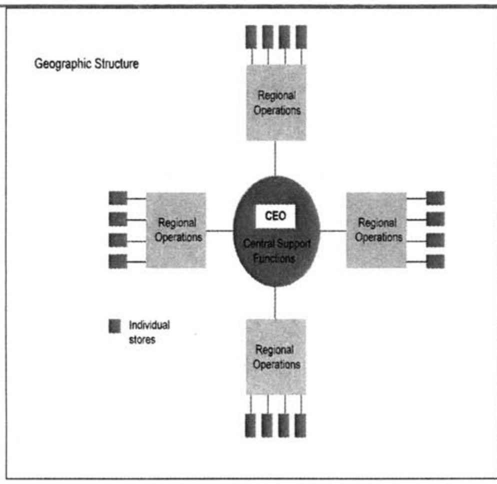
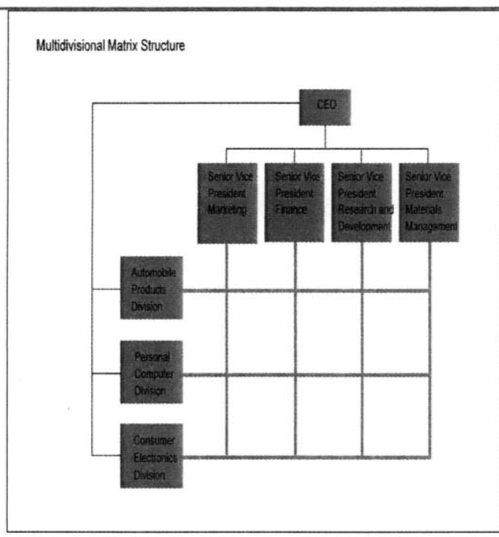
Cameron, Quinn, DeGraff and Thakor (2006), in part inspired by a recent biological study, which showed that drives to bond, learn, acquire and defend account for all human behavior, tied together organizational behavior, structure and stakeholders' goals and designed a framework for improving value creation in organizations by appropriately balancing drivers that control organizational behavior (see Figure 4-7).

4.4.2 Organizational Structures: Specialization and Control

While Tom Allen (Figure 4-4) conceptually described organizational structures as combinations of functional and project related forms, Jones (2007, chap. 6) describes the rationale for various choices of organizational structures and ways in which each structure allows to achieve control and effective use of specialized resources.

Table 4-1. Organizational Structures. Adapted from (Jones, 2007, chap. 6)

<table>
<tr><th>Organizational Structure</th><th>Rationale/Advantages</th></tr>
<tr><td>
</td><td>Characterized by centralized set of support functions and separate production units under Product Division Manager (PDM); benefits from high efficiency of specialized production units and lower overhead of centralized control.</td></tr>
<tr><td>
</td><td>Self-contained divisions are essentially separate business units. Corporate staff is responsible for long term planning and strategic decisions; division managers are concerned with tactical, day-to-day activities of their specific business units(divisions)</td></tr>
</table>

<table>
<tr>
<td>
</td>
<td>Essentially, each product team is its own self-contained division that includes specialists from functional departments. Each team is responsible for all aspects of its operations.
Teams can be formed ad-hoc.</td>
</tr>
<tr>
<td>
</td>
<td>Allows divisions to specialize on specific geographic regions.</td>
</tr>
<tr>
<td>
</td>
<td>Flexible, can respond quickly to changes
Opens up communications
Allows organizations to effective use resources
Promotes concerns for costs and quality (Per Tom Allen, through conflict among functional and project teams!)

Conflicting control and authority lines.</td>
</tr>
</table>

4.5 Perception of Complexity of Organization and Individual Activity

Kinnunen (2006) showed that complexity can be referred to as the amount of information required to describe a system, and, citing Meyer's Part Counting Method, described structural complexity of a system in terms of number of parts, interfaces and types of parts. If we let N_p equate to the number of parts in a system, N_t – to the number of different types of parts, and N_i – to the number of interfaces among parts, than Meyer suggest to quantify complexity as

$$Structural\_Complexity = \sqrt[3]{Np * Ni * Nt}$$

Equation 4-1. Formula for structural Complexity.

Dori (2002, p. 211) proposed an approach to derive each of the factors to the Meyer equation directly from the OPM and corresponding OPL, and to establish standard complexity measures by assigning weights to various complexity factors; complexity measures can be normalized by comparing the complexity to the Ultimate OPD and its corresponding OPL script.

For this research, we distinguish between the complexity of individuals' activity and complexity of organizations. Complexity of an individual's activities can be calculated as a number of processes in a system N_a divided by a number of distinct agents N_t (or instruments) responsible for them; in other words, complexity of activities is a measure of specialization of work of individuals. Complexity of work, which likely correlates with complexity of product, does not impact complexity of activity in our model, as perception of complexity is subjective to state of knowledge (Crawley, 2008); we assume correlation between complexity of product and state of knowledge of employee working to produce it.

$$Activity\_Complexity = Na / Nt$$

Equation 4-2. Average individual's activity complexity witin a system

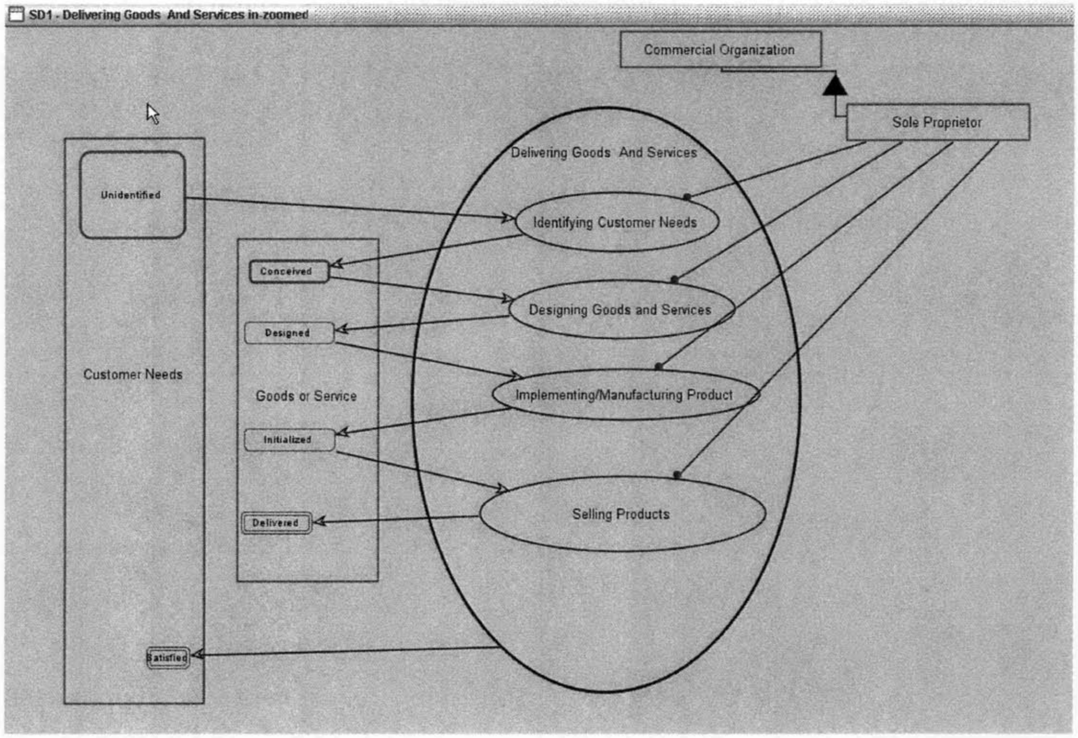


Figure 4-8. Sole Proprietor Organization

Of course, such simplified measurements as those shown above are not absolute and should only be used as a point of comparison. To insure that calculations are made at the same levels of abstraction and decomposition, and that the modeling style does not skew the calculation, relative complexity will be calculated by comparing system architecture to the OPD/OPL representation of the simplest form of organization – a sole proprietorship. While sole proprietorship is a special case of organizational structure, it has the same EDF and underlying internal functions and processes as larger companies; though it lacks the complexity of some of the coordination activities and structural hierarchies: a sole proprietor would be responsible for all four internal functions composing the EDF (Figure 4-5).

4.5.1 Defining contributors to complexity from OPM/OPL

Object Process Language, generated from the OPD of the system, can be processed computationally to determine the number of objects, interfaces, object types and activities. Table 4-2 summarizes the variables and how they are obtained from the OPL. Figure 4-9 provides OPL, corresponding to the OPD shown in Figure 4-9, and demonstrates how various factors contributing to complexity can be identified from the OPL of the system.

Table 4-2. Variables used to calculate complexity

Variable	Definition	OPL mechanics
N_P	Number of parts	Calculated as number of distinct layers in organizational structure, i.e. lines of "consist" statements in the OPL structural definition of a system
N_i	Number of Interfaces	Crawley(2009) distinguishes between 3 types of interfaces: matter, energy and information. This research assumes that there is an interface of some kind associated with any kind of consumption, result or state in object change. Number of State Changes and Consumption/Result activities, i.e. lines containing "consumes|yields|changes|invokes" in OPL script is used to determine number of the interfaces of the system.
N_t	Number of different types of parts	Individuals in the hierarchy involved in conceptually distinct activities
N_a	Number of activities	Number of processes (activities) connected to instrument or agent links

Customer Needs **can be** Unidentified **or** Satisfied.

Unidentified **is initial.**

Satisfied **is final.**

Goods or Service **can be** Conceived, Designed, Delivered, **or** Initialized .

Conceived **is initial.**

Delivered **is final.**

Key phrase "consist of": indicates Aggregation/ Participation link

Key word "handles": indicates agent link

Commercial Organization **consists of** Sole Proprietor.

Sole Proprietor **handles** Selling Products, Implementing/ Manufacturing Product, Designing Goods and Services, and Identifying Customer Needs.

Number of comma delimited tokens after key word corresponds to number of activities for the agent

Delivering Goods And Services **yields** Satisfied Customer Needs.

Delivering Goods And Services **zooms into** Identifying Customer Needs, Designing Goods and Services, Implementing/ Manufacturing Product, and Selling Products.

Identifying Customer Needs **consumes** Unidentified Customer Needs.

Identifying Customer Needs **yields** Conceived Goods or Service.

Each of the yields/consume keywords combinations and appearance of each of the "changes" key words is used to identify iterfaces

Designing Goods and Services **changes** Goods or Service **from** Conceived **to** Designed.

Implementing/Manufacturing Product **changes** Goods or Service **from** Designed **to** Initialized .

Selling Products **changes** Goods or Service **from** Initialized **to** Delivered.

Figure 4-9. Identifying contributors to complexity from OPL

Chapter 5. Evolution of Organizational Structure

Companies are forced to grow; at the same time, excessive or uncontrolled growth can be detrimental to an organization. Growth increases shareholders' value (Christensen & Raynor, 2003, p. 1), allows companies to better compete for resources and provides better opportunities for economies of scale and scope (Jones, 2007), but very few companies are capable of maintaining sustainable growth for prolonged periods of time, and, in most cases, companies run out of steam after a period of growth. Only one in ten companies is able to sustain the kind of growth that translates into an above-average increase in the shareholder returns for a period longer than five years[9] (Christensen & Raynor, 2003), and even most prominent and successful companies can decline and disappear. As an example, only one company (General Electric) out of 12 largest and most commonly held public companies that made up the original Down Jones Industrial Average in 1896 still exists today[10] ("Dow Jones – The Deepest Secrets Revealed," 2009). Some of the crises can be attributed to unfavorable market conditions or overall declines of industries; however, market conditions alone cannot explain all failures, as even in declining industries there are companies that remain highly profitable (Probst & Raisch, 2005, p. 91).

Probst and Raisch (2005) studied 100 largest organizational crises for the 5 years ending in 2002, and found that 70% of the declines and crashes of commercial firms can be attributed to Burnout Syndrome, or the companies' inability to sustain growth rates. Another 20% of declines and crashes are due to Premature Aging Syndrome, or the companies growing too slowly and letting others to take over their respective market shares, while the markets themselves remained prosperous. This underscores the need to understand the balance that must exist in a system: same factors, which lead to success of organizations, at certain point start to have counterproductive effect and lead to decline of companies.

For years, high growth rate, ability to change continuously, highly visionary company leadership, and success –oriented company culture were considered to be the key success factors; Probst and Raisch empirical study found that companies that have abundance of such factors can also crash: it is the balance that keeps a company successful.

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[9] Christensen & Raynor (2003) extrapolated this statistics from a number of studies, though no true meta-analysis have been completed.

[10] Now DJIA index now includes 30 largest and most commonly held public companies and, with other major indexes, is used as a gauge performance of industrial sector of U.S. Economy.

Table 5-1. Pitfall of most common success factors. Derived from (Probst & Raisch, 2005)

Factor	Pitfall
High Growth Rate	Reduced Effectiveness in core Operations Lack of suitable management to coordinate the increasing complexity of an organization
Ability to change continuously	Loss of "heart and soul", organizational identity Disruption and destruction of existing practices and routines
Highly visionary company leadership	Too powerful leaders disrupt system of checks and balances Early success leads to hubris
Success –oriented company culture	Incentive system encourages "shark-like" behavior Increased rivalry and competition between employees can be detrimental to trust Lack of job satisfaction leads to degraded job performance

Quinn and Cameron (1983) reviewed models of organizational lifecycles proposed to date and found that there is an overall agreement in the academia with respect to the common trends of organizational development. While each of the nine models that Quinn and Cameron reviewed focused on different organizational phenomena, such as structure of the organization, primary focus of its management, or organizational problems, there was an overall consensus that organizations undergo several stages of development as they mature and grow. The models described each developmental phase in terms of different criteria (organizational structure, primary activities and social control), but there was a general consensus that in each stage there is a set of distinct characteristics and management styles that makes companies successful.

Guinn and Cameron showed that all accepted models of organizational growth they have reviewed contained entrepreneurial stage (early innovation, niche formation, creativity), a collectivity stage (high cohesion, commitment), a formalization and control stage (stability and institutionalization), and structure elaboration and adaptation stage (domain expansion and decentralization)(Quinn & Cameron, 1983, p. 40). As demonstrated in Figure 5-1, the Greiner Model of Organizational Growth, which defines stages in terms of revolutions (organizational crises) and evolutions (prolonged periods of growth), overlays almost precisely with Quinn and Cameron model (Izadkhah, 2005)

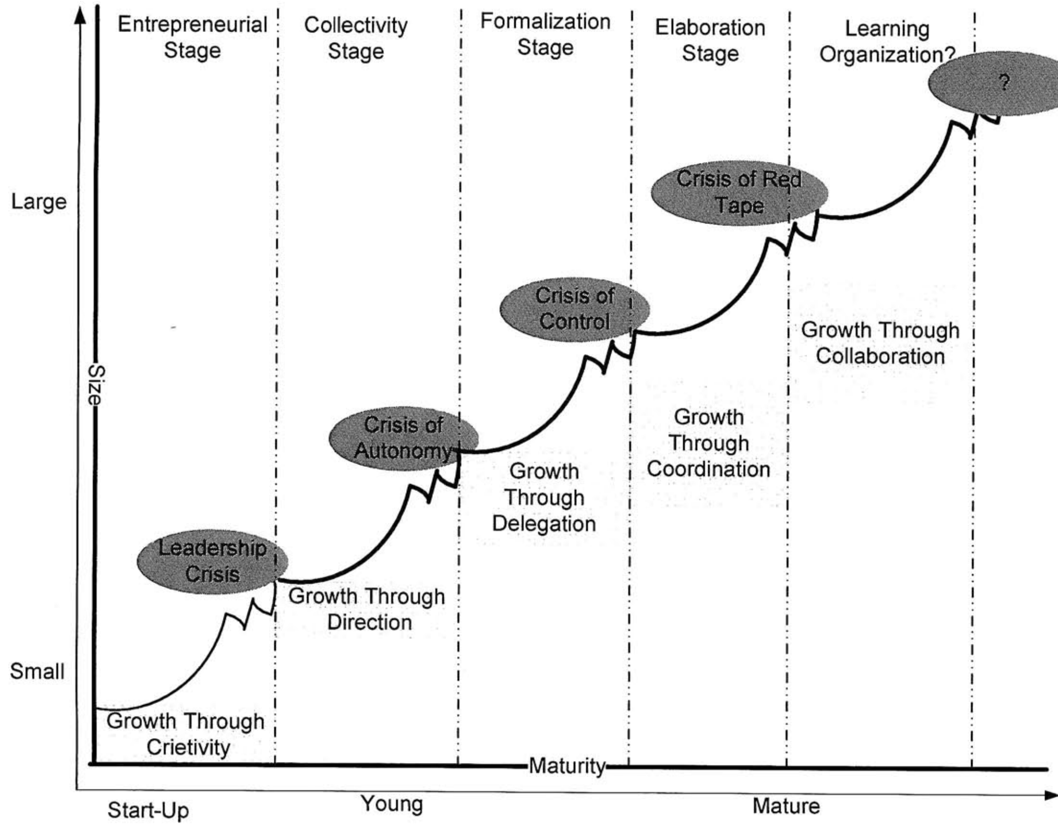

Figure 5-1. Organizational Life Cycles. Overlay of Greiner and Quinn and Cameron models. Adapted from (Izadkhah, 2005)

5.1 Evolution of Organizational Structure: Greiner Phases

While we can assume, for the purposes of this conceptual model, that the high level processes within an organization are as shown in Figure 4-5, the relative importance and complexity of those processes and organizational forms needed to effectively perform them varies depending on the size, age, maturity and trade of an organization, as well as the market conditions. Table 5-2 outlines the key organizational characteristics that are used during each phase of Greiner Model of Organizational Growth.

Table 5-2. Managerial practices during phases of evolution of Greiner Model. Adapted from (Greiner, 1998, p. 8)

CATEGORY	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5
Management Focus	Make and sell	Efficiency of operations	Expansion of market	Consolidation of organization	Problem solving and innovation
Organizational Structure	Informal	Centralized and functional	Decentralized and geographical	Line staff and product groups	Matrix of teams
Top-Management Style	Individualistic and entrepreneurial	Directive	Delegative	Watchdog	Participative
Control System	Market results	Standards and cost centers	Reports and profit centers	Plans and invest-ment centers	Mutual goal setting
Management Reward Emphasis	Ownership	Salary and merit increases	Individual bonus	Profit sharing and stock options	Team bonus

Next, we discuss each phase of Greiner model further, with a focus on impact that organizational structures bare on growth and crises during each phase.

5.1.1 Phase I. Growth through Creativity

Greiner called the first stage of his lifecycle model Growth through Creativity. In this phase, an entrepreneur starts a new company and tries to accomplish his vision and bring new products to market. The first few employees of this start-up company do not have clearly defined areas of responsibilities; everybody pulls their weight to get the job done. The employees are motivated by the vision of the founder/entrepreneur and expectations of future profits. Communications among team members are frequent and informal; the decision making process is very dynamic and is highly sensitive to marketplace feedback. Since there are no clearly defined roles, there is very little specialization in employee activities; at the same time, each employee can be very creative and has high influence within the company. Organizational structure is flat; the founders do most of the control and coordination activities, however, the norms and values of the organizational culture, rather than the hierarchy and organizational structure, control people's behavior. Appendix A contains OPDs and OPLs of organizations in each stage of Greiner Model.

5.1.2 Crisis of Leadership

As the organization grows, informal communications become insufficient to control the company and the increased number of employees. While the initial goal of the organization was to get the company off the ground, a new objective – increased efficiency – gains importance as the company establishes itself among the competition. The founder of the company – the entrepreneur – is unwilling or unable to get involved in the managerial activities and an organizational crisis emerges – Crisis of Leadership.

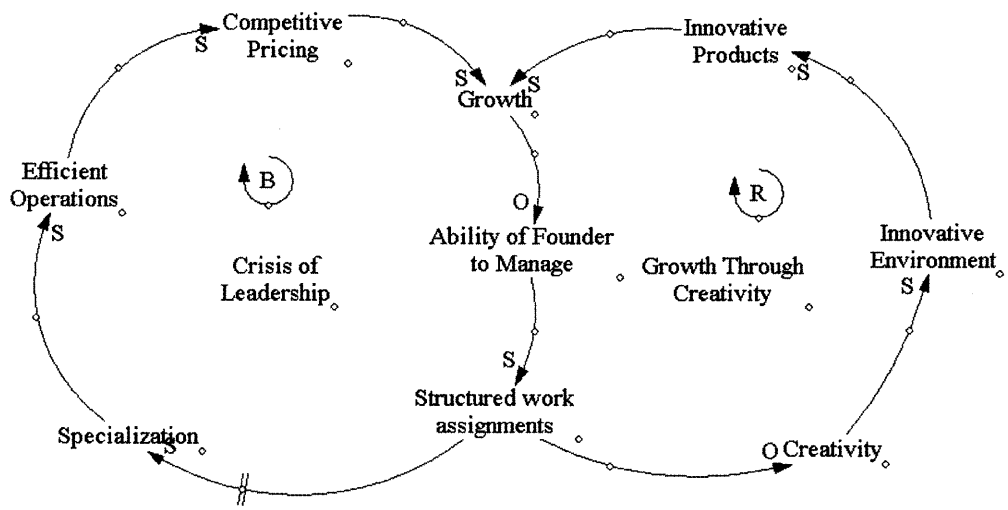

Figure 5-2. Phase I Growth and Crisis Causal Diagram. Growth through Creativity (Reinforcing Loop) leads to Crisis of Leadership (Balancing Loop)

5.1.3 Phase II: Growth Trough Direction

To overcome Leadership Crisis and return to growth, the founders of the companies need to step aside and bring in professional business managers. The top management of the company takes responsibilities for directing the company's strategy, while the lower-level managers assume key functional responsibilities. Greiner called the second stage "Growth through Direction". As the company focuses more on efficiencies, a formal organizational structure emerges. To increase effectiveness, a functional organizational structure is introduced and incentives, budgets, effectiveness goals and work standards are adapted.

5.1.4 Crisis of Autonomy

As the company's structure becomes more formal, there is a dramatic increase in specialization of the individuals' activities. The decision making within the company becomes very centralized, and many employees and low-level functional managers, who were used to the original creative and innovative environment, become unhappy with the bureaucracy and their decreased influence. As the company continues to grow, the centralized structure becomes inappropriate for controlling the more diverse and complex organization, as the top management does not possess enough operational and technical expertise to effectively control the larger organization. A solution that is adopted by most companies is to move toward more delegation.

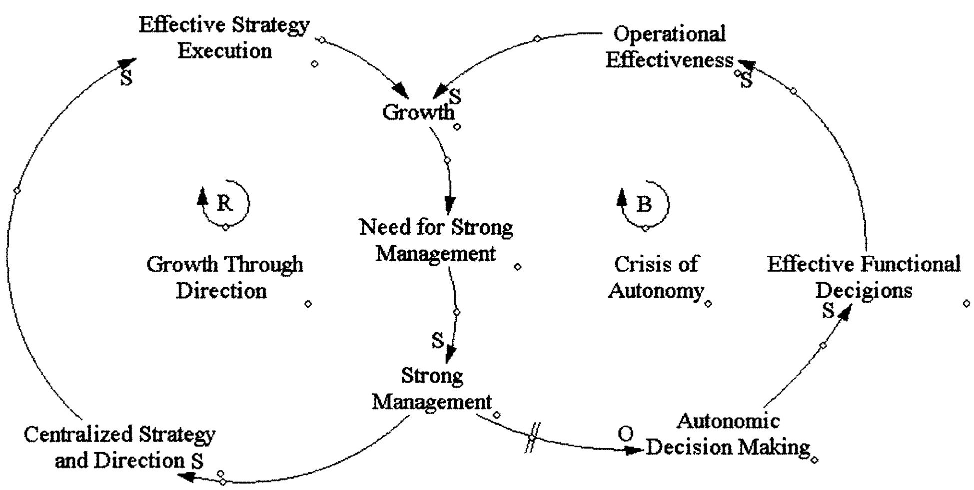

Figure 5-3. Growth and Crisis Causal Diagram. Growth Through Direction (reinforcing loop) leads to Crisis of Autonomy (balancing loop)

5.1.5 Phase III: Growth through Delegation

Once the organization outgrows the capabilities of its centralized control structure, it reaches Crisis of Autonomy. A typical solution to Crisis of Autonomy is delegating more authority and decision making power to the lower level management. The functional managers are given much more control and flexibility over their respective functional departments' day-to-day operations, which give the top management an opportunity to focus on the overall growth of the company. By delegating authority to the functional managers who know their areas best, the company is able to grow for an extended period of time; however, after a period of growth and increasing independence of functional departments, headquarters management loses control over coordinating activities of functional areas.

5.1.6 Crisis of Control

As the functional groups grow and essentially become cost centers and sometimes even their own business units, Crisis of Control emerges. Activities of the functional departments become uncoordinated, and some functions are duplicated between departments to compensate for the lack of coordination. Autonomous field managers prefer to run their own shows without coordinating plans, money, technology, and personnel with the rest of the organization. As a result, efficiency and competitiveness suffers.

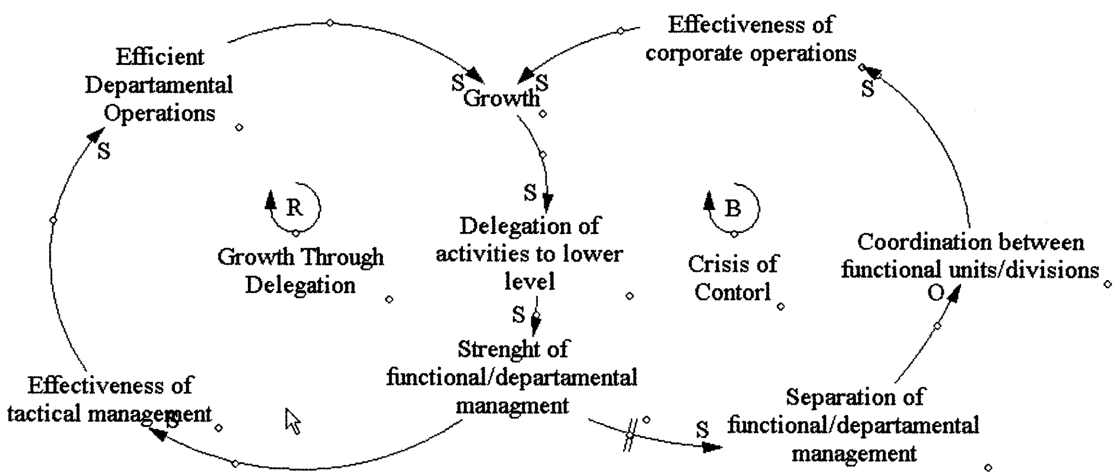

Figure 5-4 Growth and Crisis Causal Diagram. Growth Through Delegation (reinforcing loop) leads to Crisis of Control (balancing loop)

5.1.7 Phase IV: Growth through Coordination

The essence of Crisis of Control is that companies lose the appropriate balance between the centralized control needed to coordinate activities of functional units, and decentralized control essential to running the units effectively. To continue to take advantage of delegating control and decision power to lower level managers, but to coordinate activities of different divisions more effectively, the top management abandons most of the hands-on management practices and starts to manage by policy, leaving it up to the lower level managers to run their units within the constraints of corporate policies, which returns the company back to the growth pattern. Additional layers of management and bureaucracy are added to monitor performance of the individual units and devise corporate policies.

5.1.8 Crisis of Red Tape

After a while, as growth of the organization continues, the increased bureaucracy becomes unable to keep up with the organizational growth, and adds too much overhead while constraining the abilities of lower-level management to act effectively. Communications within the organization become too formal, and the corporate culture evolves that suppresses the spirit of entrepreneurship.

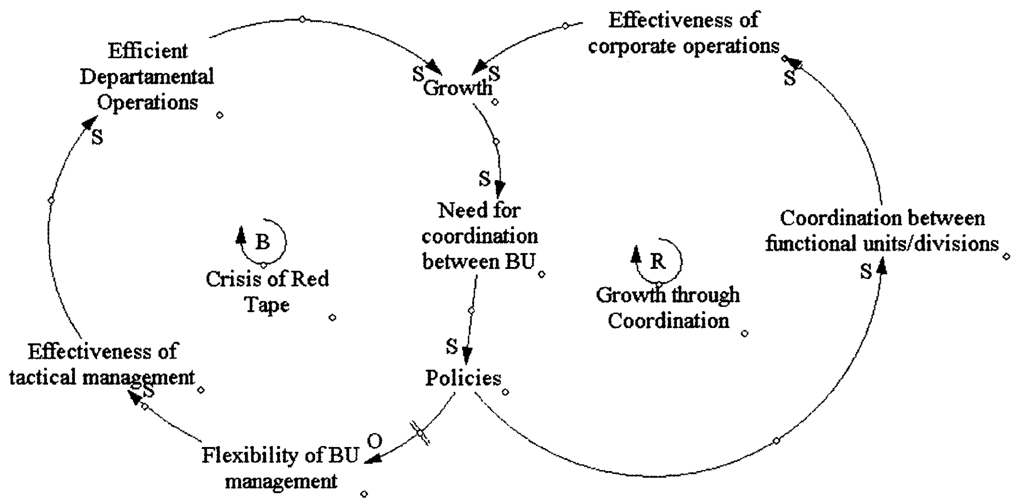

Figure 5-5 Growth and Crisis Causal Diagram. Growth Through Coordination (reinforcing loop) leads to Crisis of Red Tape (balancing loop)

5.1.9 Phase V: Growth through Collaboration

The final stage of Greiner Model is Growth through Collaboration. Crisis of Red Tape is worked around by distributing authority and decision making power to the team and individual levels. Social control and self-discipline guided by the corporate vision and encouraged collaboration among teams and individuals are responsible for most of the formal decision making. Ad-hoc matrix teams are formed to address tasks and challenges. Collaboration makes the organization more organic by making greater use of mutual adjustment and lesser use of standardization – so during the transition into this phase, both complexity of the organization, and individual activities are rising.

Greiner did not specify a crisis that can stop growth of organization at this stage.

5.2 Trends in Evolution of Organizational Structures

A few clear trends emerge from analyzing the evolution of the organizational structures as a company grows. The significance of the trends should not be separated from the fact that there are substantial differences in the way that companies grow; the trends are rather indicative of the problems that companies are facing and typical ways that managers work around them.

5.2.1 A Solution to One Crisis is the Cause of the Next

The first crisis – Crisis of Leadership – is largely caused by the shift in organizational priorities from getting off the ground to becoming sustainable and profitable and lagging capacity of management team, or founders, to deal with shifting priorities; every crisis after that, ultimately, is caused by a solution to a previous crisis. From the causal diagrams, it is clear that delayed feedbacks to the very same actions taken to overcome a crisis cause next crisis. Resistance to change – a natural reaction to the feedback mechanisms and consequence of Dynamic Equilibrium principle – contributes to organizations' waiting too long to address an arising crisis, "sticking with what works", and ignoring other aspects of organizational behavior that were not as important when the organization was dealing with a previous crisis. The general trend is that organizations overemphasize the aspect of organizational behavior that caused a previous crisis until the imbalance in behavior leads to another crisis.

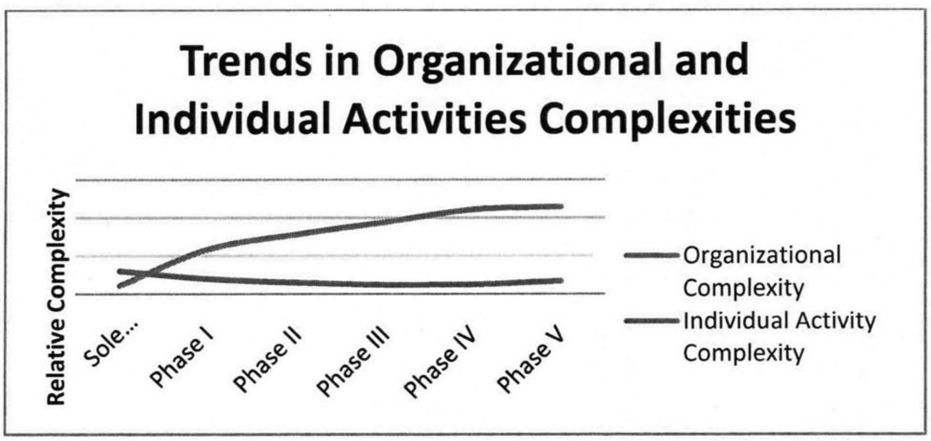

Figure 5-6. Trends in complexity of organizations and activity of individuals

5.2.2 Complexity is Rising

Complexity profile of organizations is continuously increasing with growth. While complexity of products and product systems is not reflected in our comparative measurement of complexity, the overall trend is that the complexity of organizations is rising. Complexity of individuals' activities, on the other hand, decreases in a more mature organization due to increased specialization (see Figure 5-6). However, possibly as the natural benefits of specialization are reached, the trend reverses, and complexity of individuals' activity increases, mainly due to the rise in decision making and communications activities that each employee becomes responsible for.

These trends are found to be consistent with Bar-Yam's (2003) findings that there exists a continuous rise in complexity of organizations throughout history (see figure Figure 5-7).

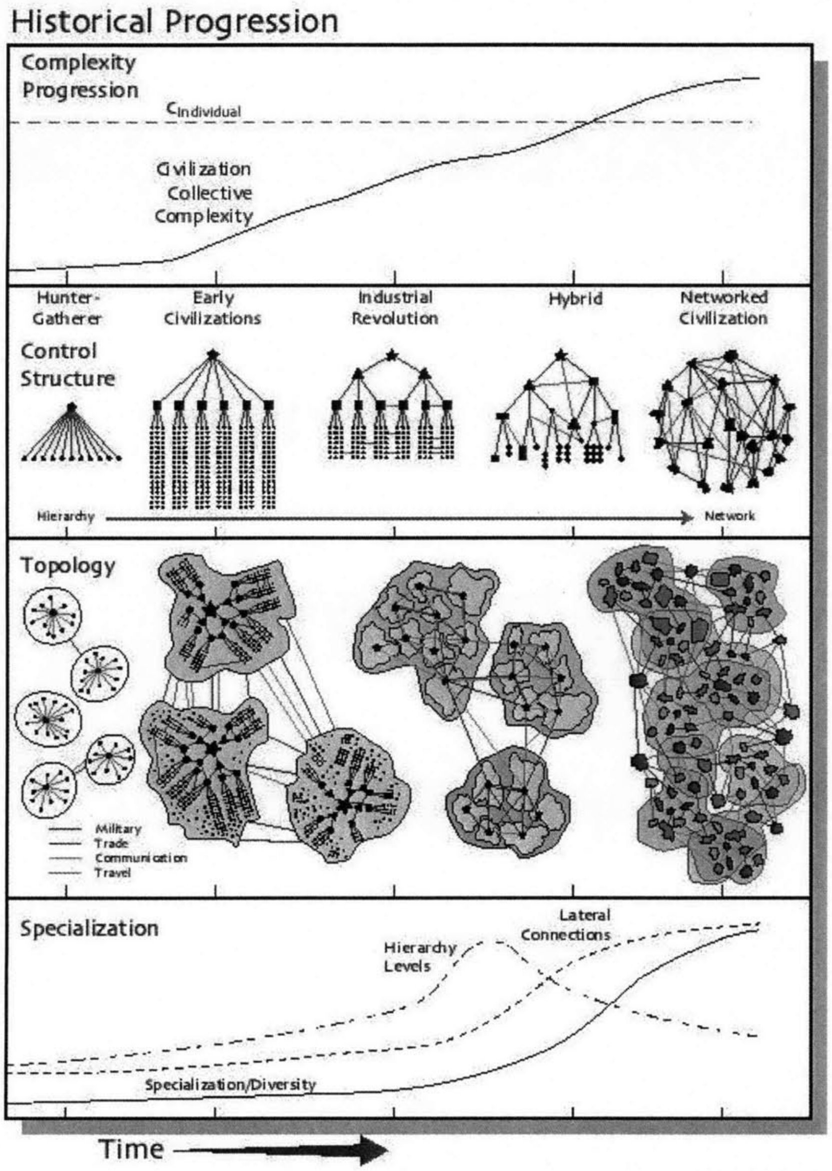

Figure 5-7. Rise of Complexity of Civilization. Adapted from (Bar-Yam, 2003)

Chapter 6. Conclusions

This research had several objectives. The implicit objective was to validate the applicability of General Systems Theory and Tektology, proposed by Bertalanaffy in 1928 and Bogdanov in 1908, respectively, to the study of organizational issues in commercial enterprises. Explicitly stated objectives were to evaluate hypotheses, as stated in section 1.4.

Table 6-1. Tektological Principles and Concepts Related to Hypothesis

Hypothesis Point	Related Tektological Principle and Concepts
There is a general trend in evolution of organizations and issues that they face as they grow.	Homogeneity of Evolutionary Forces Conformity of Forms
It takes a "hidden balance" between different forces and interests for organizations to remain stable and successful.	Dynamic Equilibrium Bi-regulator (a.k.a feedback and policy resistance) Formative and Regulating Mechanisms
As organizations evolve, there is a trend to limit and decrease the complexity of each part's behavior (specialization) by increasing the complexity of the organization, i.e. to balance complexity of an individual's activity with complexity of the organization.	Complexity Profile
Commercial originations tend to evolve naturally until changes or constraints limit the growth and threaten the organization's normal existence, at which point deliberate design techniques are executed to resume normal growth of the organization.	Regulating Mechanism Tektological Crisis

6.1 Applicability of Tektology to Commercial Organizations

Applicability of Universal Organizational Theory (Tektology) to commercial organizations can be confirmed by verifying conformity of organizational structures' evolution to Tektological Principles. All hypotheses flow from or relate to Tektological principles and concepts, as shown in Table 6-1 above; confirming these hypotheses gives a strong indication of validity and applicability of Tektological principles.

6.2 General Trends (Hypothesis 1)

Through evaluation of organizational evolution, Cameron et al. (2006), Greiner (1998), Probst & Raisch (2005), Quinn & Cameron (1983), among others, identified the general trends in development of commercial firms and issues they face. Universality of these issues, at least in part, is due to human constraints and similarity of goals and objectives of organizations. To illustrate the point, start-up companies that have the drive and the potential of becoming viable players in the market place need to timely shift their focus from creativity (the crucial aspect to developing their first products and introducing them to the market) to efficiency, which is essential to the survival in a competitive environment. Therefore, it is best for the founders, who usually are more creative and not concerned with efficiencies, to make room for new leaders in the organization. After a solution to the Leadership Crisis is found, the companies tend to "stick with what worked," dealing with crises as they arise, and continuing general trend of growth.

6.3 Hidden Balance (Hypothesis 2)

As Greiner in his Organizational Lifecycle Model has shown, organizations grow through Creativity, Direction, Delegation and Coordination until they experience crises of Leadership, Autonomy, Control and Red Tape, respectively. All of the factors, both leading to growth and preventing the growth, are important steps in the organizational lifecycle; organizational crises occur when management overstresses the importance of certain factors over the others, causing the company to become unbalanced.

The Irreversibility of the Change principle, in this case, implies that, unless an organization internalizes the nature of a crisis in its culture, it is unable to move on to the next phase.

6.4 Specialization Trend (Hypothesis 3)

Organizational structures that are based on division of labor and were first identified by Adam Smith, still dominate today's economy. Modern organizations aim to reduce complexity of individuals' work using specialization of labor and knowledge, which enables them to create more complex systems. As current measurement of complexity does not allow for comparison of non-similar systems (i.e. individual activities and organizations), this research does not conclusively identify balancing effect of structural evolution on complexity. We evaluated general trends in complexity of organizations and individuals' activity, and found that, in modern organizations, the complexity of individuals' activities decrease until the organization becomes very mature and interconnected; then, complexity of activity rises slightly, likely as a result of distribution of decision and self-regulation activities to lower-level employees. The complexity of organization itself, on the other hand, rises continuously from formation of organization to its maturity. It is noteworthy that specialization trend reverses only in most advanced forms of organizations.

6.5 Natural Growth vs. Deliberate Design (Hypothesis 4)

Evidence from the studies (Christensen, 2003; Greiner, 1998; Raynor, 2003; Quinn & Cameron, 1983; Sullivan, 1998) showed that almost always organizations fail to be proactive; deliberate design activities are not very active in organizations until it becomes clear that an organization is unable to continue to grow without changes to the management style. In all of the phases of Greiner Model, management did not act until a crisis was evident.

There is little support for the presumption that it may be possible to avoid crises altogether. Greiner stipulated that managers can be aware of the trends, recognize the crises early, and take proactive steps to lessen the impact of a crisis on the organization.

6.6 Final Remarks

This research presented the philosophical bases of Universal Organizations Theory (Tektology) and General System Theory and recapitulated methodologies and frameworks of System Architecture and System Engineering, academic disciplines that evolved from such theories; it also argued for applicability of general and universal principles, methods and frameworks for evaluating issues in commercial organizations. As the validity of Tektological Principles expressed in a form of hypotheses of this research, were confirmed[11], the argument was made for applicability of Tektological Principles to the evolution of commercial organizational structures.

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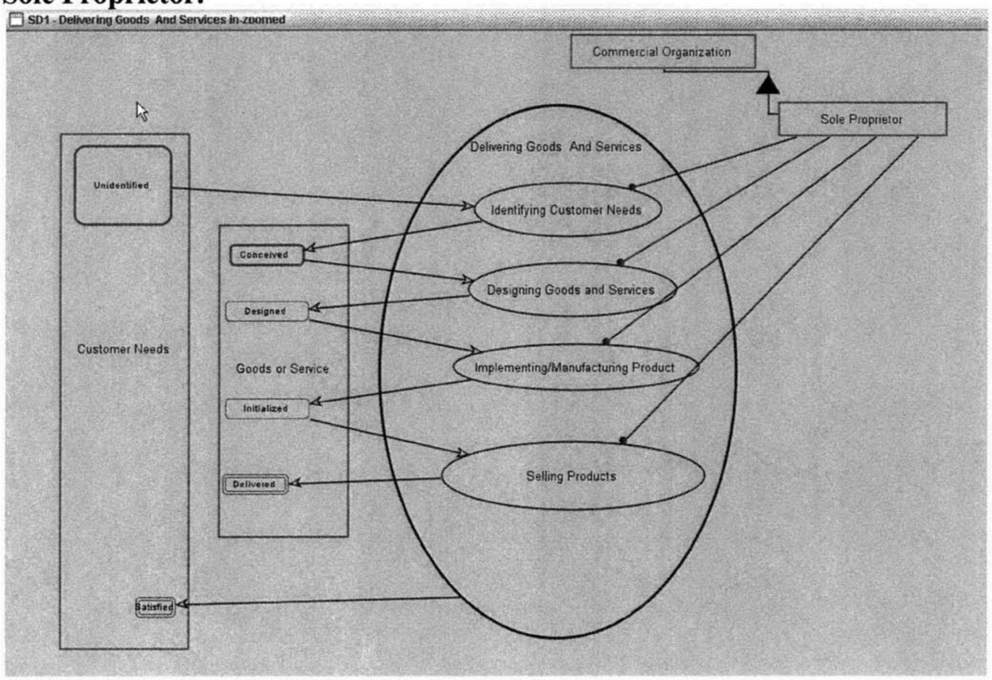
[11] Hypothesis 3, Balancing Complexity, was only partially confirmed. Further research into complexity and its quantification is needed to confirm or disprove this hypothesis

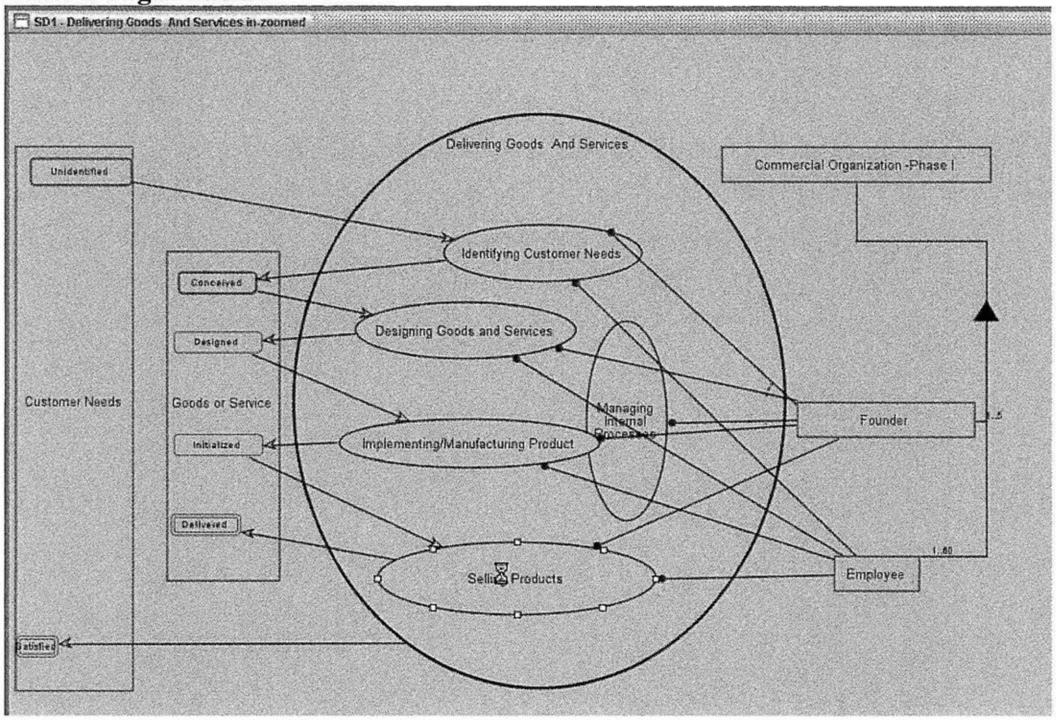
Appendix A. OPD and OPL for Organizations in Different Phases

Sole Proprietor.



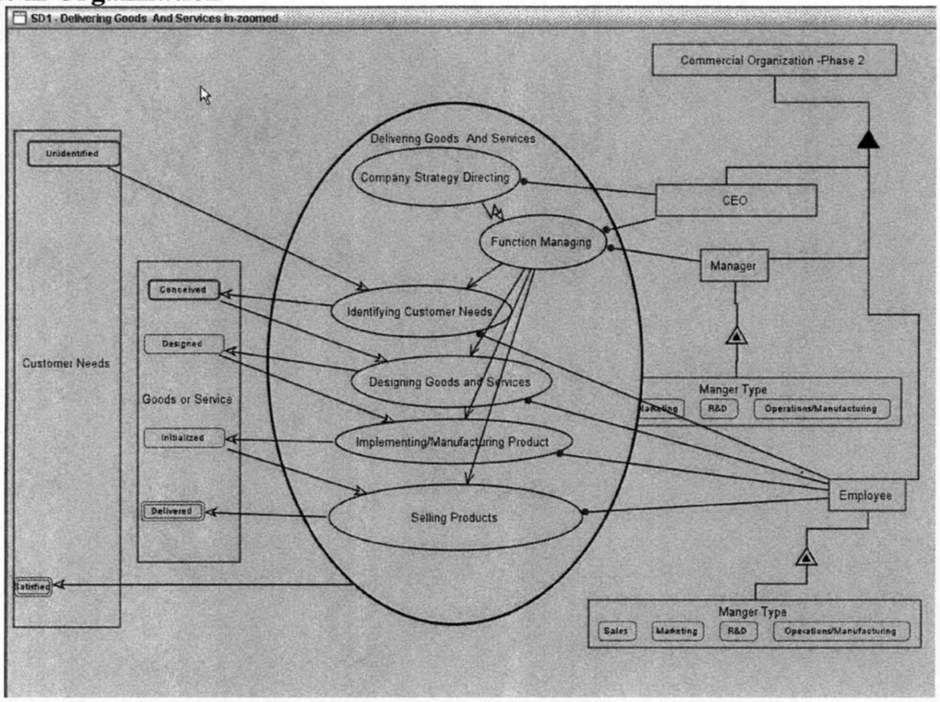
Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.
Goods or Service can be Conceived, Designed, Delivered, or Initialized .
Conceived is initial.
Delivered is final.
Commercial Organization consists of Sole Proprietor.
Sole Proprietor handles Selling Products, Implementing/Manufacturing Product, Designing Goods and Services, and Identifying Customer Needs.
Delivering Goods And Services yields Satisfied Customer Needs.
Delivering Goods And Services zooms into Identifying Customer Needs, Designing Goods and Services, Implementing/Manufacturing Product, and Selling Products.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized .
Selling Products changes Goods or Service from Initialized to Delivered.

Phase I Organization



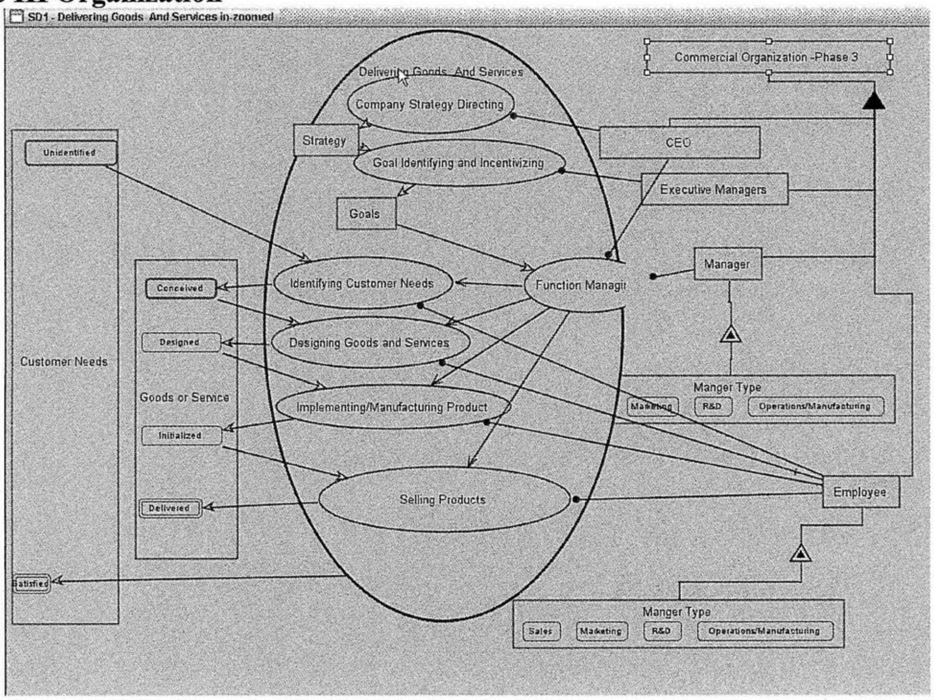
Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.
Goods or Service can be Conceived, Designed, Delivered, or Initialized.
Conceived is initial.
Delivered is final.
Commercial Organization -Phase I consists of 1 to 5 Founders and 1 to 60 Employees.
Founder handles Managing Internal Processes, Selling Products, and Implementing/Manufacturing Product.
Founder handles either Identifying Customer Needs or Designing Goods and Services.
Employee handles Identifying Customer Needs and Selling Products.
Employee handles either Designing Goods and Services or Implementing/Manufacturing Product.
Delivering Goods And Services yields Satisfied Customer Needs.
Delivering Goods And Services zooms into Identifying Customer Needs, Managing Internal Processes, Designing Goods and Services, Implementing/Manufacturing Product, and Selling Products.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized.
Selling Products changes Goods or Service from Initialized to Delivered.

Phase II Organization



Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.
Goods or Service can be Conceived, Designed, Delivered, or Initialized.
Conceived is initial.
Delivered is final.
Commercial Organization -Phase 2 consists of CEO, Employee, and Manager.
CEO handles Function Managing and Company Strategy Directing.
Employee exhibits Manger Type.
Manger Type can be Sales , Marketing , R&D, or Operations/Manufacturing.
Employee handles Selling Products and Implementing/Manufacturing Product.
Employee handles either Designing Goods and Services or Identifying Customer Needs.
Manager exhibits Manger Type.
Manager handles Function Managing.
Delivering Goods And Services yields Satisfied Customer Needs.
Delivering Goods And Services zooms into Company Strategy Directing, Function Managing, Identifying Customer Needs, Designing Goods and Services, Implementing/Manufacturing Product, and Selling Products.
Company Strategy Directing invokes Function Managing.
Function Managing Designing Goods and Services.
Function Managing Identifying Customer Needs.
Function Managing Implementing/Manufacturing Product.
Function Managing Selling Products.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized.
Selling Products changes Goods or Service from Initialized to Delivered.

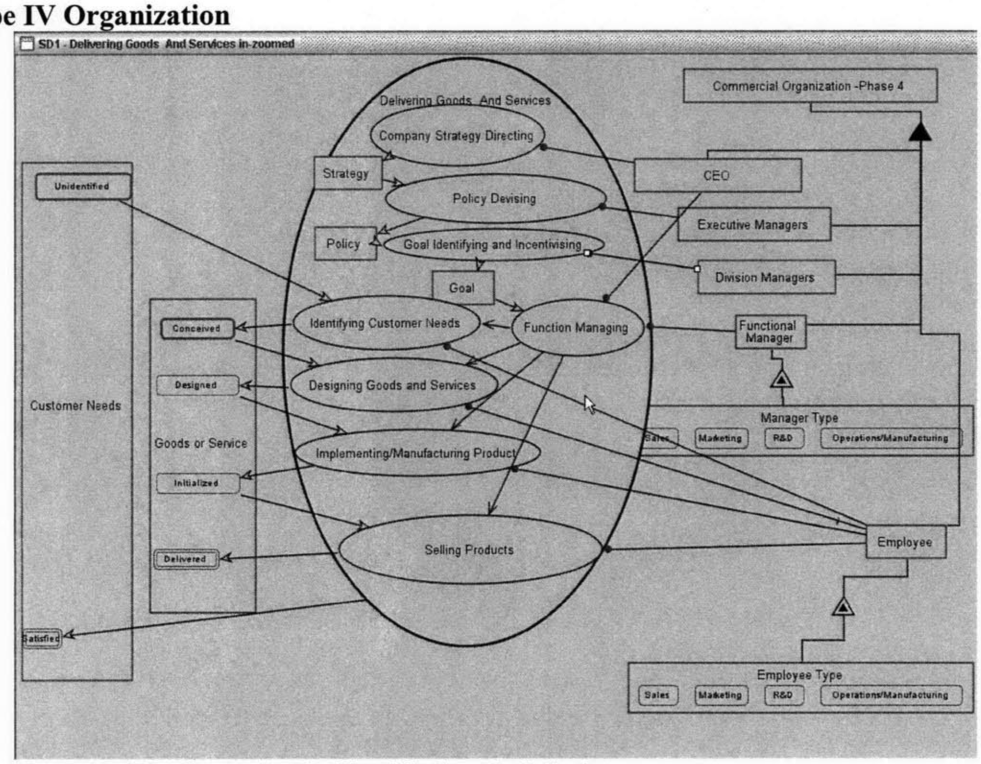
Type III Organization



Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.
Goods or Service can be Conceived, Designed, Delivered, or Initialized.
Conceived is initial.
Delivered is final.
Commercial Organization -Phase 3 consists of CEO, Employee, Manager, and Executive Managers.
CEO handles Function Managing and Company Strategy Directing.
Employee exhibits Manger Type.
Manger Type can be Sales , Marketing , R&D, or Operations/Manufacturing.
Employee handles Selling Products.
Employee handles Implementing/Manufacturing Product either Designing Goods and Services, or Identifying Customer Needs.
Manager exhibits Manger Type.
Manager handles Function Managing.
Executive Managers handles Goal Identifying and Incentivizing.
Delivering Goods And Services yields Satisfied Customer Needs.
Delivering Goods And Services zooms into Company Strategy Directing, Goal Identifying and Incentivizing, Identifying Customer Needs, Function Managing, Designing Goods and Services, Implementing/Manufacturing Product, and Selling Products, as well as Goals and Strategy.
Company Strategy Directing yields Strategy.
Goal Identifying and Incentivizing consumes Strategy.
Goal Identifying and Incentivizing yields Goals.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Function Managing Designing Goods and Services.
Function Managing Identifying Customer Needs.

Function Managing Implementing/Manufacturing Product.
Function Managing Selling Products.
Function Managing consumes Goals.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized.
Selling Products changes Goods or Service from Initialized to Delivered.

Type IV Organization

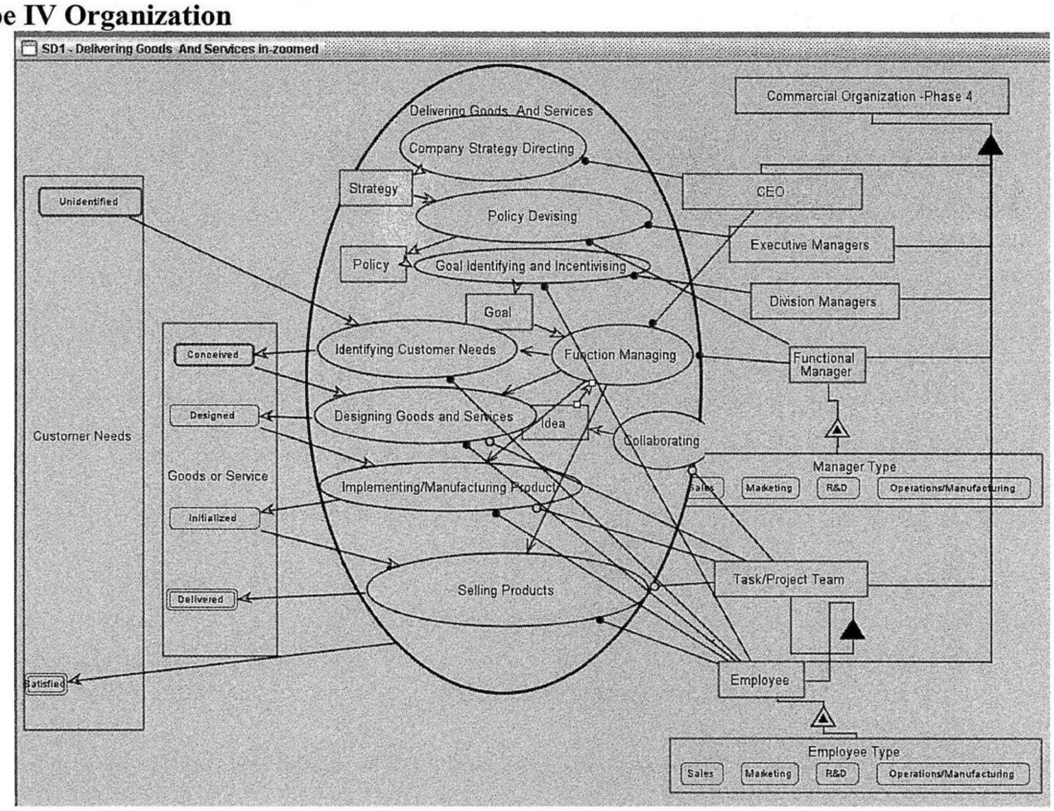


Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.
Goods or Service can be Conceived, Designed, Delivered, or Initialized.
Conceived is initial.
Delivered is final.
Commercial Organization -Phase 4 consists of CEO, Employee, Functional Manager, Executive Managers, and Division Managers.
CEO handles Function Managing and Company Strategy Directing.
Employee exhibits Employee Type.
Employee Type can be Sales , Marketing , R&D, or Operations/Manufacturing.
Employee handles Selling Products.
Employee handles Implementing/Manufacturing Product either Designing Goods and Services, or Identifying Customer Needs.
Functional Manager exhibits Manager Type.
Manager Type can be Sales , Marketing , R&D, or Operations/Manufacturing .
Functional Manager handles Function Managing.
Executive Managers handles Policy Devising.
Division Managers handles Goal Identifying and Incentivising.
Delivering Goods And Services yields Satisfied Customer Needs.

Delivering Goods And Services zooms into Company Strategy Directing, Policy Devising, Goal Identifying and Incentivising, Identifying Customer Needs, Function Managing, Designing Goods and Services, Implementing/Manufacturing Product, and Selling Products, as well as Goal, Policy, and Strategy.

Company Strategy Directing yields Strategy.
Policy Devising consumes Strategy.
Policy Devising yields Policy.
Goal Identifying and Incentivising consumes Policy.
Goal Identifying and Incentivising yields Goal.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Function Managing Designing Goods and Services.
Function Managing Identifying Customer Needs.
Function Managing Implementing/Manufacturing Product.
Function Managing Selling Products.
Function Managing consumes Goal.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized.
Selling Products changes Goods or Service from Initialized to Delivered.

Type IV Organization



Customer Needs can be Unidentified or Satisfied.
Unidentified is initial.
Satisfied is final.

Goods or Service can be Conceived, Designed, Delivered, or Initialized.
Conceived is initial.

Delivered is final.
Commercial Organization -Phase 4 consists of CEO, Functional Manager, Executive Managers, Division Managers, Task/Project Team, and Employee.
CEO handles Function Managing and Company Strategy Directing.
Functional Manager exhibits Manager Type.
Manager Type can be Sales , Marketing , R&D, or Operations/Manufacturing .
Functional Manager handles Policy Devising and Function Managing.
Executive Managers handles Policy Devising.
Division Managers handles Goal Identifying and Incentivizing.
Employee exhibits Employee Type.
Employee Type can be Sales , Marketing , R&D, or Operations/Manufacturing.
Employee consists of Task/Project Team.
Employee handles Goal Identifying and Incentivizing, Selling Products, and Implementing/Manufacturing Product.
Employee handles either Designing Goods and Services or Identifying Customer Needs.
Delivering Goods And Services yields Satisfied Customer Needs.
Delivering Goods And Services zooms into Company Strategy Directing, Policy Devising, Goal Identifying and Incentivising, Identifying Customer Needs, Function Managing, Designing Goods and Services, Collaborating, Implementing/Manufacturing Product, and Selling Products, as well as Idea, Goal, Policy, and Strategy.
Company Strategy Directing yields Strategy.
Policy Devising consumes Strategy.
Policy Devising yields Policy.
Goal Identifying and Incentivising consumes Policy.
Goal Identifying and Incentivising yields Goal.
Identifying Customer Needs consumes Unidentified Customer Needs.
Identifying Customer Needs yields Conceived Goods or Service.
Function Managing Designing Goods and Services.
Function Managing Identifying Customer Needs.
Function Managing Implementing/Manufacturing Product.
Function Managing Selling Products.
Function Managing consumes Idea and Goal.
Designing Goods and Services requires Task/Project Team.
Designing Goods and Services changes Goods or Service from Conceived to Designed.
Collaborating requires Task/Project Team.
Collaborating yields Idea.
Implementing/Manufacturing Product requires Task/Project Team.
Implementing/Manufacturing Product changes Goods or Service from Designed to Initialized.
Selling Products requires Task/Project Team.
Selling Products changes Goods or Service from Initialized to Delivered.

Appendix B. Summary of Contributors to Complexity and Relative Organizational and Individual Complexity

	Sole Proprietor	Phase I	Phase II	Phase III	Phase IV	Phase V
Np	1	2	3	4	6	6
Ni	5	11	12	14	16	19
Nt	1	2	3	4	5	5
Na	4	5	6	7	9	11
Organizational Complexity	1.666667	14.66667	36	74.66667	160	190
Individual Activity Complexity	4	2.5	2	1.75	1.8	2.2

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