SYSTEMS ENGINEERING AND SOFT SYSTEMS METHODOLOGY : A REVIEW

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Abstract: In this paper, Soft Systems Methodology (SSM), quite a recent development in Systems Engineering, is reviewed briefly. First, a historical background on Systems Engineering that led to the emergence of this area is provided. Here, the limitations of 'Hard' Systems Engineering in dealing with ill-structured socio-economic problems are summarised, and the reasons for SSM becoming a relatively more 'successful' approach are given. The paper is concluded by a review of the SSM Methodology.

Key words: *Systems Engineering, 'Hard' Systems Engineering, System Analysis and Design, Soft Systems Methodology, Socio-Economic Systems*

Özet: Bu makalede Sistem Mühendisliği konusunda en son gelişmelerden birisi olan 'Soft Systems Methodology (SSM)' konusu kısaca incelenmektedir. Öncelikle, SSM' in oluşumunu hazırlayan koşullar Sistem Mühendisliğinin kısa bir tarihçesi içinde sunulmaktadır. Burada ''Hard'Systems Engineering'' yaklaşımının kolaylıkla formule edilemeyen sosyo-ekonomik problemlerin çözümündeki yetersizlikleri özetlenmektedir. Daha sonra, sosyo-ekonomik problemlerin cözümünde SSM' in niye daha başarılı olabileceği tartışılmakta ve SSM Metodolojisi ana hatlarıyla anlatılmaktadır.

Anahtar kelimeler: *Sistem Mühendisliği, ''Hard' Systems Engineering', Sistem Analizi ve Tasarımı, 'Soft Systems Methodology', Sosyo-Ekonomik Sistemler*

SYSTEMS ENGINEERING: A HISTORICAL BACKGROUND

The origins of 'Systems Thinking' and 'Systems Engineering' can be traced to the 1940's. Systems Thinking developed in several different disciplines, mainly in organic chemistry, then in biology, and control and communications engineering. The reasons for the emergence of this thinking, with its institutions and organisations, are related to the 'inadequaces' of science in dealing with complexity. Space and the world we live in are immensly complex entities. To be able to cope with this complexity, human beings reduced the task into separate 'subjects' or 'disciplines' such as physics, biology, sociology, engineering, etc. Such an artificial, even an arbitrary division is not obviously peresent in nature; it is the product of human imagination. If complexity is a problem as far as natural sciences are concerned, it is even a more serious problem in social sciences; social sciences have to deal with messy and ill-stuctured problems. It was Ludwig Von Bertalanffy, a biologist, starting in biology, who developed the idea of generalising 'Systems Thinking' or 'Wholistic Thinking' to any kind of system. Several other contributions were made from pyshcology, anthropology and linguistics into 'System Thinking', but major ideas came from biology, and communications and control engineering. Bertalanffy, together with K.E. Boulding (an economist), R.W. Gerard (a physiologist) and A. Rappoport (a mathematician) established what is known as General Sytems Theory (GST) in 1955. The aims of this theory were: (1) to investigate the isomorphy of concepts, laws and models in various fields, and to help in useful transfers from one field to another; (2) to encourage the development of adequate theoretical models in areas which lack them; (3) to eliminate the duplication of theoretical efforts in different fields; (4) to promote the unity of science through improving the communication between specialists (Checkland, 1993:93). GST emphasized generality but lacked content, hence could not make enough progress. Significant developments came from areas where the use of systems ideas were readily applicable, namely from communications and control engineering. The body of knowledge developed in this area came to be known as 'Hard' Systems Engineering in later years.

'Hard' Systems Engineering is concerned with the *systematic* approach to engineering design by means of model building and model optimization. The computer plays a central role in the design process which includes: deciding what system has to be designed, developing design options, mathematical and experimental evaluation of potential designs according to some defined 'measure of effectiveness', principal design, prototype construction, testing, training and evaluation. The evaluation phase presents special problems, in particular in large-scale system design. The initial ideas on design have to be altered as design progresses, hence evaluation and beginning phases of the process overlap. Checkland (1993:130) descibes Hall's view on the field -Hall is one of the pioneers of Systems Engineering- as follows: "*Hall sees systems engineering as a part of 'organized creative technology' in which new research knowledge is translated into applications meeting human needs through a sequence of plans, projects and 'whole programs of projects'. Thus systems engineering operates in the space between research and business, and assumes the attitudes of both. For those projects which it finds most worthwhile for development, it formulates the operational, performance and econo -*

mic objectives, and the broad technical plan to be followed". Wymore views the field as an interdiciplinary area concerned with 'the analysis and design of large-scale, complex, man-machine systems'. With this definition, Wymore expanded the horizons of Systems Engineering from communication, transportation and manufacturing systems, to education, health and law enforcement systems (Checkland 1993: 132).

In the 1950's, another methodology known as Systems Analysis was developed by RAND – an acronym for 'research and development'- corporation in the USA. In the beginning, the work at RAND was concentrated on the applications of Operations Reseach into anti-submarine tactics and the coordination of the use of radar with anti-aircraft guns and interceptor aircraft. The defence requirements were expressed in terms of a total complex of equipment, personnel and procedures rather than simply as a requirement for a specific piece of equipment. The approach was con sidered to be a comprehensive one, covering finacial, technical, political and strategic factors. Later on, this technique, which was originally developed for resource allocation problems in defence, became popular in applications related to business. The differences are that systems engineering comprises the set of activities which together lead to the creation of a complex human-made entity and/or the procedures and information flows associated with its operation; it may be viewed as a technique for conducting an entire engineering project. Systems analysis, on the other hand, is the systematic appraisal of the costs and other implications of meeting a defined requirement in various ways. Sage, one of the leading figures in Systems Enginering has 'a strong process orientation' view of the field, and defines it as 'Systems Engineering is the design, production, and maintenance of trustworthy systems within cost and time constraints' (Sage, 1992:10). Senhbar (1994:327-332 and 1997: 137-145) gives a more contemporary interpration of Systems Engineering. According to him, a systems engineer is a person who is capable of integrating knowledge from different disciplines and technologies, and seeing problems with a holistic view by applying the systems approach. He emphasizes the close link between engineering and management, and stresses that designing, operating and controlling complex systems always require an engineering as well as a managerial part. In his view, systems engineers are expected to: (1) recognise operational needs, identify market and technological opprortunities, forecast the development of operational and technological processes, (2) formulate new concepts and devise system solution capability of analysing and designing large-scale systems while integrating various disciplines, (3) manage projects of design and develoment of systems while considering the aspects of cost, quality, reliability, manufacturing, marketing, maintenance, service and overall view of the systems' life cycle. In a recently published book, Hazelrigg (1996) introduces an information-based approach to systems engineering. He believes in a rigirous mathematical approach to decion making and views engineering design as a decision making process. As an 'omnidisciplinary activity', he breaks down the engineering design process into three different stages: the identification of options, the development of expectations on outcomes for each option, and the use of values to select the option that has the range of outcomes and associated probabilities that are most desired. His approach is oriented towards design of physical engineering systems.

In the 1960s and 70s, the relative success of 'Hard Systems Engineering' led many attempts to apply the corresponding techniques to social systems, such as formulating public policy. The results appeared to be dissapointing and the idea of making transfers from engineering disciplines were discredited. The 'Systems Paradigm' and its topology involves four kinds of systems: natural, designed physical, designed abstract, and human activity systems. Engineers are basically concerned with designing, modifying, affecting or improving human activity systems. Unlike phyisical engineering systems, human activity systems have the following distinguishing feature: human actors are free to attribute meaning to what they percieve, and they have all different perceptions of what the 'reality' is. Therefore, there can not be a single and a testable account of a human activity system; one can only talk about a set of possible valid accounts. Eventually, these deficiencies of 'Hard' Systems Engineering led to the development of new ways of thinking, such as Soft Systems Methodology and Cognitive Systems Enginering (Rasmussen, Pejtersen, Goodstein,1994: Ch.1).

SOFT SYTEMS METHODOLOGY

Systems Engineering methodology is heavily influenced by Scientific Methodology which may be summarised by the following three characteristics: reductionism, repeatibility and refutation. Science can deal with problems that are scientifically defined, but not adequately with the problems we experience everyday. Even the emergence of 'Management Science' was not able to solve the problems of the 'real-world'satisfactorily since it was seriously influenced by the so called scientific approach. To a certain extent, of course, Systems Engineering and Systems Analysis were succesfull in introducing systematic rationality into decision making. The techniques developed within the body of engineering and defence economics were transferred to 'softer' areas, mostly into 'public decision' and 'policy sciences'. In social sciences, it is either very difficult or almost impossible to define 'the system' and its objectives. In the applications, apart from the difficulty involved in the definition of *operationally useful* objective functions, other difficuties arise. One important problem is related to the way engineers and traditional system analysts think: they are more concerned with the question of *how* rather than *what*. The other major problem is concerned with the engineering approach in formulating problems of social sciences and management; the tools used appear to be too 'rigid'. Also, the idea of finding the 'optimum' solution has no meaningful equivalent in social sciences. In social sciences, the problem may not be 'solved', but a greater understanding of the problem may be developed through a study, and this may be considered as a 'success'. Checkland (1993:145) expresses the problem as' *approaching ill-structured problems through quantitative techniques, systematic knowledge, structured rationality and organised creativity can not deal with the primary uncertainty involved' in the definition of overall goals or objectives.* He also states that application of scientific approach to the problems of social sciences strengthtened the position of the 'anti-technology' school of thought within social sciences.

The roots of the 'soft' approach go back to the 1960's, to Jenkins and Optner (Checkland, 1993: 146-148). Jenkins's methodology starts from an organisational definition of a 'system' as a complex grouping of human beings and machines for which there is an overall objective. The system is then selected and placed in a systems hieararchy, objectives and measures of performance are defined, and the chosen system is designed through model building, simulation and optimisation, and implemented and reappraised in operation. Optner's methodology is based on the idea that businesses and industies are systems. According to him, solutions of problems should not be seen as special cases, but as that of setting up, running and maintaining systems. Soft Systems Methodology (SSM) was developed by Peter Checkland and his colleagues at Lancaster University in the UK (see Checkland and Scholes, 1990, and Checkland, 1993). In this methodology, the problem, as it is percieved by the analyst is expressed in terms of 'structure' and 'process' and the relation between the two, rather than in systems terms. This approach prevents the analyst distorting the problem into a preconcieved or standard form. After this, the analyst is able to assemble some 'relevant' human activity systems and build apropriate conceptual models. The ones that are found *desirable* and *feasible* are examined by the concerned actors, and these system models are then modified and improved. Different actors having different values, perceptions and experiences produce a greater insight into the problem area. The methodolgy is based on an *intellectual construct*, producing a *learning system*. This *learning* system makes use of systems ideas to formulate basic mental acts of *percieving, predicating, comparing* and *deciding*. Unlike the 'Hard' systems methodology, the output is the *learning* aspect which leads to actions, knowing that this will lead not to 'the solution', but to a changed situation and *new learning*. Hence, the methodology is a 'mosaic of activities rather than a required sequence of events'; it involves a number of people engaged in a dialectical debate, and it is a continous, never-ending process. The methodology is not a technique which, properly applied, can guarantee a particular kind of result; it leaves room for personal styles and strategies of problem-solving. Checkland (1993:19) also makes the following important obsevation: "*The nature of social reality implied by the methodology is very different from that implicit in the approach which is usually taken to be the application of systems theory within social science, namely functionalism (functionalism is a part of the Durkheimian (or positivistic) tradition in sociology. Soft Systems methodolgy implies, rather, a model of social reality such as found in the alternative (phenomenological) tradition deriving sociologically from Weber and philosophically from Husserl. It is also compatible with the ideas of the 'Critical Sociology' of the Frankfurt School.*". Fuctionalism has been dominating 'Systems Thinking'for a long time; here comes the breakthrough.

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