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Integrating System Dynamics Modelling and Case Study Research Method: A theoretical framework for process improvement

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Abstract

The case for integrating research methods generally, and more specifically that for combining system dynamics modelling and case study research approaches is strong. Yet, research designs that extensively combine both system dynamics modelling and case study in requirements engineering process modelling are rare. Triangulation of methods while not new, has not been applied in requirements engineering process modelling and improvement research. This paper aims to provide a useful and systematic reference point for researchers who wish to work in the RE process improvement and generally to encourage careful work on the conceptualisation and execution of Dynamic Synthesis methodology in RE process and to a wider software process modelling field. The paper addresses the philosophical and theoretical issues concerning the nature of combining the case study and process simulation research approaches, and methodological issues on conduct and reporting of this type of research design. The paper suggests that the potential usefulness of the Dynamic Synthesis Methodology is in aiding researchers in improving both building and testing theories in the requirements engineering process modelling and improvement.

Introduction

This paper proposes a model-based modelling and analysis methodology that brings together two complementary methods using system dynamics modelling approach. Simulation modelling and case study are powerful research methods, for modelling and analysis whose added advantages can complement each other in terms of theory building, testing and theory extension. Problem solving, in this paper is used loosely to refer to the process of investigating variables ranging from specific, short-term and well-defined issues to more general long-term and ill-defined issues in attempt to generate some improvement (Keys, 1983). Studying a real world sequence of events in the requirements engineering process provides a foundation for understanding and explanation of how particular outcomes in the RE processes are arrived at. In order to aid such an understanding of the RE process, this paper proposes a problem solving model-based paradigm – Dynamic Synthesis Methodology (DSM).

The rest of this section is divided into six subsections. Section 2, discuses the philosophical basis of the Dynamic Synthesis Methodology, while 3 discuses the characteristics of a desirable process modelling and analysis methodology. Section 4, explores the underpinning theoretical anchors of the Dynamic Synthesis Methodology. Section 5 introduces the reference study and the basis for triangulating case study and process simulation research methods, while model verification and validation approaches used by the Dynamic Synthesis Methodology.

Philosophical Basis for Dynamic Synthesis Methodology

Dynamic Synthesis Methodology refers to the integration of theoretical concepts and structuring of parts and elements of a process over time in such a manner to form a formal functional entity, underpinned by synthesis as as philosophy of science.

Synthesis is an attempt to fuse the findings of various branches of science into one coherent view, in order to explain why things operate the way they do. According to the Greek lexicon "ΣΥΝΘΕΣΗ" Synthesis means:
(i) Αρμονικη ενωση μερων για τη συγκροτηση ενος ολου or "*harmonic composition of the parts to form a whole*".
(ii) Ο τροπος κατα τον οποιο συνθετομε κατι. (*The way in which we are to combine something*,
(iii) Εκθεση Ιδεων (*Exposure of Ideas*). *Synthesis* is comprised of two Greek words (ΣΥΝ) "Syn" meaning together and (ΘΕΣΗ) "thesis" meaning position (Ταβουλαρη Στ.,1977). Longman's Dictionary of the English language defines synthesis as "*a composition or combination of parts or elements so as to form a whole" or "as a process of combining often diverse concepts into a coherent whole" pp. 1523*). Within Dynamic Synthesis Methodology case study research method is complemented with system dynamics modelling to form a framework for aiding empirical explanation and prediction the behaviour of complex systems RE process performance.

In requirements engineering process, synthesis may be considered in the specification activities when checking for logical correctness and coherence; while in the RE decision engineering synthesis is considered at the problem design stage where quantitative analysis is carried out concurrently with qualitative analysis (Williams and Kennedy, 2000). RE process modelling and analysis research, particularly for large-scale projects, is a complex process. A great deal of work has been carried out on RE process-based approaches to requirements engineering (Pohl, 1993), but very little has been done in utilising dynamic process-based tools. This paper contributes to developing such an understanding by proposing a methodology that facilitates modelling and analysis of RE process. Both simulation and case study research methods have been used in the development of theories in software development process. However, triangulation of both methods to study the RE process modelling and analysis phenomenon has not been used before (Finkelstein, 2000). The next section discusses philosophical issues of triangulating simulation modelling and case study research methods for studying in the RE process modelling field.

Applied Research Design

In model-based systems engineering, traditional research approaches and pure science generally take the format of: Observation, Experimentation, and Generalisation. Notable researchers have proposed variations of applied research methods like (D'Abro, 1951 pp.3):

- observation stage
- experimentation stage
- the theoretical and mathematical stage (in Physics).

While Ackoff (1962, pp.26) proposes expansion of the three stages into 'cyclic' six phases:

1. Formulating the problem,
2. Constructing the model,
3. Testing the model,
4. Deriving a solution from the model,
5. Testing and controlling the solution, and
6. Implementing the solution.

Early discussion on primacy of observation or theory was reported in Churchman, (1961). Modern philosophical analysis shows that observation always presupposes a criterion of relevance. Ackoff (1962) observes that, *"some modern philosophies of science, assert the cyclic and interdependent characteristic of these stages of scientific method" (pp.26).* Table 1 presents a comparison of pure and applied research approaches to problem solving as examined by D'Abro (1951) and Ackoff (1962).

Table 1 Comparisons of Pure and Applied Research Approaches

Pure Research	Applied Research
Observation	Formulating the Problem
Generalisation	Model Construction
	Derivation of the Solution
Experimentation	Testing the Model
	Implementing the Solution

Ackoff contends that *"the control phase of applied research corresponds with efforts to further generalise the results of pure research, and implementation corresponds with efforts to use the results of a piece of pure research in another" (pp.26).* This paper extends Ackoff's (1962) applied methodological research design strategy, modified by integrating Yin's (1984) case study as a basis for theory development. The applied methodological research approach described by Ackoff (1962) is similar to that proposed in this paper for dealing with systems-based problems discussed in section four (Richardson, 1981). The advantage of modelling in the system dynamics environment's pseudocode is its iterative nature that yields understanding, which forms a basis for further analysis, theory testing and extension (Meadows, 1982).

Dynamic Synthesis Methodology proposed here is not just a simple alternative to other problem solving methodologies in RE process modelling and analysis, but their exist fundamental difference between DSM and other approaches. However it can be applied as a complementary methodology in a contingency approach given its flexibility. Principles that underlie the dynamic synthesis methodology are the need to understand and improve our social theories (Lane, 2001). In particular the philosophical basis of DSM is reflected in its paradigm, objective, generecity and application specific. (Avison and Fitzgerald, 1996). In terms of the concept of the paradigm as defined by Kuhn (1972) and Burrel and Morgan (1969) and further classified by Wood-Harper and Fitzgerald (1982) this paper uses a third paradigm: the systemic approach. The systemic approach combines both the natural science and the systems paradigms. This paradigm formulates problems and generates solutions using epistemological notion of systems. The natural science paradigm with its successful history consists of reductionism, repeatability and refutation. (Checkland, 1981); while systems paradigm is largely concerned with the whole picture, the emergent properties and other relationship between parts of the whole (Lane and Oliva, 1998).

The advantage of a systemic paradigm is that it can be used to explore (description) and explain (prescription) both living and those categorized as human activity systems is an important aspect that may shed light on the treatment of causality in SD (Philips, 1987). This is a positivist position that uses an applied science method to investigate existence of causal relationship between variables of interest. (Williams, Hall and Kennedy, 2000). The above concept underpins the importance of DSM in solving differing views of reality in systems requirements engineering. This is an important characteristic of the DSM as it makes its philosophical objectives very explicit, as the focus of the methodology is not necessarily computerisation but also improvement in RE process modelling, which in practice may not require computerised changes. The overwhelming objective is to provide improved understanding of social theories, literature and stakeholder concerns. The dynamic synthesis methodology proposed in this paper extends Ackoff’s (1962) applied research approach where he argues that the study of scientific method has been a major part of the philosophy of science. Ackoff (1962) makes a claim that this branch of philosophy has at least three other types of science including:

- Conceptual analysis: the attempt to define concepts or problem areas in such a way amenable to scientific study;
- Examination of assumptions: concerning the reality that 'underlies' science;
- Synthesis: the attempt to fuse the findings of various branches of science into one consistent view of reality, "weltanschauung" (pp. 27).

It is the third branch of philosophy of science (synthesis) that is adopted in this paper to explain the emergent properties of the whole RE process modelling and improvement based on systems theory, servomechanisms theory and measurement theory as theoretical anchors. Synthesis as a method of performance evaluation identifies the behaviour inherent of a system of which the emergent properties to be explained is part. Table 2 compares two modes of designing problems, analysis and synthesis in aiding the understanding of the emergent patterns meaningful to the whole RE process modelling and improvement. Ackoff (1981) uses Descartes' principles of 1637 to raise the concept of reductionism as fundamental to problem solving. In systems analysis, as illustrated in Table 2, parts are put together by synthesis in order to understand why things operate the way they do (1981).

Table 2: Understanding facilitates explanation of the Whole [adapted from Ackoff, 1981]

Analysis	Synthesis
Focuses on structure, it reveals how things work	Focuses on functions, it reveals why things operate as they do
Yields Knowledge	Yields understanding
Enables description	Enables explanation
Looks into things	Looks out of things

Table 2 illustrates that gaining an understanding of the social theory and the factors that lead to its effective explanations is the prerequisite for improving the our literature, methods and concerns. The advantage of dynamic synthesis methodology is in its ability to incorporate the results of earlier research (Churchman and Ackoff, 1950).

The usefulness of the system dynamics modelling in this methodology is its ability to capture 'hard' and 'soft' concepts into a formal model, thus bringing together theoretical constructs that impact on the research phenomenon of the system dynamicists (Bell and Bell, 1980; Lane, 2001). System dynamics currently does not guide researchers how to carefully collect data that is relevant to the phenomenon of interest. In order to attain the specified mechanism, a research design strategy for collecting and synthesising data and information must be adopted. As Popper (1972) puts it *"the activity of understanding is essentially the same as that of problem solving*". This concept reflects to the domain of SD particularly where paradigms that support social and natural sciences may play common roles for effectiveness of research methodology. Kuhn (1970) proposes a need to change our conception of science to "*more appropriately*" in terms of problem or puzzle solving. This is in line with Ackoff's (1962) applied research approach and extended in the DSM proposed in this paper.

An effective system dynamics research methodology and tool should be able to capture both informal and fuzzy concepts often relevant to social theory or models of inerest. The pseudocode generated by SD software provides a basis for formalising these often-diverse concepts. A good modelling methodology should lend itself to automation. The concept of dynamic synthesis as system dynamics –based research methodology is underpinned by the relevant theoretical anchors in the next section.

Dominant Theoretical Anchors of the DSM

There are several theoretical foundations that anchor the Dynamic Synthesis Methodology, including: General Systems Theory, Servomechanisms Theory, and Measurement Theory.

General Systems Theory

Boulding (1956), one of the founding fathers of general systems theory developed a systems hierarchical classification that transcends from hard systems structures through soft to transcendental. This classification has guided the way researchers classify their problem solving approaches. General systems ideas also go back to the works of Churchman (1966), Weinberg (1968) and von Bertalanffy (1968). The concept of a system is connected to the idea of purposive behaviour. Wiegner (1948), a mathematician, studied goal seeking mechanisms that could be used to improve automatic radar, and this lead to the idea of feed-back loops to implement purposive behaviour in machines. Goal-directed and goal-seeking concern in systems development approach has given rise to two broad problem-solving paradigms: the "hard" systems and "soft" systems methods. Jirotka and Gorguen (1994), Loucopulous and Karacostas (1995) Mumford (1989), Macaulay (1996) Hirscheim (1985) acknowledge that requirements for socio-technical systems span the areas of concern of both "hard" and "soft" aspects of SD phenomenon. This aspect has serious implications for current methods, tools, models and techniques used in system dynamics research. The systems approach provides a model for describing the hierarchy of systems concepts, situations in systems terms, so as to give clear understanding (Hutchins, 1982).

Servomechanisms Theory

Servomechanism Theory is a specialised study of feedback control systems. A servomechanism is a term that originates from electrical engineering field and is a power-amplifying feedback control system, in which controlled variable *C* is a mechanical position, or a time derivative of the position such as velocity or acceleration. Feedback theory helps us to articulate the relationship between feedback control systems' input process, output and control process like those developed in SD Modelling. Here we see System dynamicist modelling engineered systems, however these engineered systems are modelled in a social process. Two methods exist for designing servomechanisms problems:

1. design by analysis, and
2. design by synthesis.

In the analysis phase, the focus is on an investigation of the properties of an existing system, while in the design phase, the problem is the choice and arrangement of system components to perform a specific task. This paper proposes a design of system dynamics research methodology by synthesis as illustrated in table 2. Three basic representations (model) of components, systems and their relationships are used extensively in the study of servo mechanisms problems:

- mathematical models in the form of differential equations or other mathematical relations, for example Laplace and z transformations. Underlying the structure in SD problems are differential mathematical equations specifying relationships between variables,
- block diagrams: these are the same as stock and flow diagram connections used in system dynamics for conceptualising problems,
- signal flow graph: these are the same as influence diagrams conventions used in system thinking for problem structuring.

These three representation modes are used in this methodology to enact and solve SD problems. The use of systems thinking (influence diagrams) in identification of structural relationships variables and their dynamic behaviour can facilitate understanding of the phenomenon and explanation of its emerging properties.

Measurement Theory

Measurement is the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined rules (Roberts, 1979; Fickelstein, 1982). Most System dynamics studies rely on empirical data collected for other purposes in order to define relation between and among variables. Most SD Models lack empirical evidence to demonstrate these causal relationships are rare. Data Collected in SD research studies are static normally Linear and assume causal relationships to exist.
A number of data collection strategies have been postulated, (Sterman, 2000, Coyle and Exelby, 1998). Wolstenholme et al (1990) suggests a breakdown of entities into attributes and further into respective dimensions. The measurement approach used in this paper combines the above variables and Wolstenholme's approach, to define variables, attributes, their relationships and interactions.

The theoretical concepts discussed in this section aid the positioning data collection in its contextual setting. Van Maanen (1983) asserts that one may not describe the observed behaviour of a phenomenon until they have developed a description of the context in which the behaviour takes place and have attempted to see the behaviour from the position of the problem owner. Theories that anchor the DSM conceptualised in this section serves as a useful foundation to stimulate and organise research efforts in System dynamics. In order to position this paper in the epistemological theory of knowledge (Churchman and Ackoff, 1950), dynamic synthesis methodology has potential to play an important role in increasing the acquisition of knowledge, so as to bring together a breadth of techniques to facilitate understanding of System dynamics problems.

The domains of these philosophical and theoretical characteristics in the applicability of DSM as a model-based problem solving, for requirements engineering process modelling and analysis as described in the reference study.

The Reference Study

The case for combining methods generally, and more specifically that of combining qualitative (case study) and quantitative (System dynamics modelling) is strong (Klein et al, 1993, Wynekoop, 1992; Galliers; 1984; Visala, 1991; Gable 1994; Kaplan and Ducheon, 1988 and Orlwowski and Baroudi, 1991; Ives et al, 1980). Wynekoop (1992) suggests that 'micro level' quantitative analysis should be integrated with qualitative 'macro-level' analyses, in order to understand the ways in which individual variables' behaviour have an impact on organisational phenomenon. Gable (1988) takes the same position by adding that "*the ways in which macro phenomenon has effects through individual variable may be explicated*" (pp. 115).

The notion of combining qualitative and quantitative research methods has been said to increase the robustness of results. Findings can be strengthened through cross validation achieved when different kinds and sources of data converge and are found to be congruent (Kaplan & Ducheon, 1988; Gable, 1988). Klein et al (1991) and Galliers (1984), calls for tolerance of methodological pluralism and recognition of method and personal bias. Orlikowski and Baroudi (1991) claim that given human limitations, individuals must specialise in a limited number of methods. For example, three methods have tended historically to dominate information system research: survey, laboratory experimentation and case study.
Simulation modelling is a form of laboratory experimentation with very high levels of constraints. Visala (1991) contributes to the debate by proposing a conceptual framework to help overcome the gap between positivist and interpretative research approaches. Visala's work is adapted from the information systems research framework proposed by Ives et al (1980). Visala (1991) cross-references epistemological approaches (causal model, technological explanations, hermeneutics, dynamic structure models, formal methods and phenomenology) with classes of variable of interest in Information Systems research proposed by Ives et al (1980). However Visala does not explore how specific research methods, for example simulation and case study, ought to be operationalised in combinations. Williams, 2000, 2001 urged the combination of case study and simulation methods in Requirements Engineering process modelling and analysis, in order to improve the stakeholder's understanding of how requirements changes over time.

Case Study Research Method

A case study is an empirical investigation that probes and examines responses of convenient influences within the real operational environment of the task, user, and system. The case study approach generally refers to group methods, which emphasise qualitative analysis (Yin, 1984; Gable 1988), although some case studies are quantitative in nature. In the SD literature quantitative case studies have been used to validate SD simulation models (Senge and Forester, 1980; Graham, Morecroft, Senge and Sterman, 1982). However, the unit of analysis may differ between case study and Process Simulation modelling, for example in a RE process at simulation level, and information systems development project or IS use at Case Study level.

Data collection from Software Development Organisations (SDOs) thorough techniques such as surveys, interviews, observation and documentation analysis may vary. The case study method seeks to understand the problem being investigated. Gable (1988) articulates that the word *understand* is used in the phenomenological or hermeneutic sense, where "understanding" the meaning held by a subject or group is contrasted to 'explanation' produced by a scientific observation (pp 113). This position is consistent with that of Graham, Morecroft, Senge and Sterman (1992). The proponent and advocate of qualitative methods, Yin (1984), suggest that case study is appropriate where the objective is to study contemporary events, and where it is not necessary to control behavioural events or variables. This lack of experimental control in case studies makes it difficult to minimise possible confounding of variables effects than in a formal experiment. Perhaps most importantly Yin (1984) suggests that single case studies are appropriate, if the objective of the research is to explore a previously not researched subject vehicle but multiple case studies are desirable for description, theory building, or theory testing. Sage (1991) suggests “there are no really good methodological frameworks for conduct of case studies or use of case study research” (pp193). The qualitative bias of case studies may be contrasted with the quantitative bias of System dynamics modelling.

System Dynamics Modelling

System dynamics modelling is the technique of constructing and running a model of an abstract system in order to study its behaviour without disrupting the environment of the real system. Simulation is the process of forming an abstract model from a real situation in order to understand the impact of modification and the effect of introducing various strategies on the situation. Pidd (1992) describes simulation as an approach, which involves experimentation on a computer based-model in a trial and error way. It is a process of imitating important aspects of the behaviour of a system in real, compressed time or expanded time by constructing and experimenting with a model of the system. Simulation is one of the main strategies used in this research. The main objective of the simulation program is to aid the user, most often an operations research specialist or systems analyst, in projecting what will happen to a given situation under given assumptions. It allows the user to experiment with real and proposed situations otherwise impossible or impractical.

Hill (1996) describes the process of simulation as carried out by creating an abstract of a real system (model) to evolve in real time in order to assist the understanding of the functioning and behaviour of this system and to understand certain of its dynamic characteristics, and with the aim of evaluating different decisions. This technique therefore allows simulation of the operation of existing or non-existing systems, for a given work load (studies of transient operations, testing of different strategies). The assumptions made in order to simulate some process tend to be a key to the accuracy of the results. The more simplified the results, the less reliable the results, whereas the more details included, generally the better the results. No matter how detailed the program, the prediction obtained will be inaccurate if the initial assumptions are incorrect. In this case, the simulation program becomes invalid as a prediction tool. Simulation experiments have a series of advantages that can be used in various applications areas.

Advances in hardware and software technology have greatly reduced the two major weaknesses of simulation, cost and the unavailability of the data necessary for building and validating the model. The integration of simulation modelling and case study research methods provides a conceptual framework for a dynamic synthesis research methodology.

This paper proposes a strategy that combines System dynamics modelling (Forrester, 1961; Richardson and Pugh, 1981) and case study research method. (Galliers, 1984; Mason and Mitroff, 1973). The Case study research method (Yin, 1984) involves identifying key factors that may affect the outcome of an activity and then to document the activity's inputs, constraints, resources, and outputs. Simulation experiments (Law and Kelton, 1988; Coyle, 1996) are rigorous controlled activities, where key factors are identified and manipulated to document their effects on the outcome. Combining case study and System dynamics modelling makes Dynamic Synthesis Methodology a powerful empirical research method that potentially makes useful contribution to body of System Dynamics. 134 successful PhD research dissertations in Information System, between 1971 and 1973 by Manson and Mitroff, (1973) and Ives et al (1980) support combinations of this sort. Figure 1 presents the overall reference study for the DSM proposed in this paper. The DSM includes six iterative research process phases, namely: Problem statement, Field Studies, SD Model Building, Case Studies, Simulation Experiments and Model Use and Theory Extension.

In Information Systems (IS) Janvenpaa (1988) and Galliers and Land (1988) suggest the use of alternative IS research approaches in the process of theory building, testing and extension. The conceptual synthesis proposed here (Figure 1), extends Vogel and Wetherbe's (1980) criteria of parsimony and completeness. It also draws on the application areas reported in Galliers and Land (1987) as a foundation for a research method, being a paradigm suitable in context of System dynamics. The Dynamic Synthesis Methodology is grounded on well-tested and developed theoretical anchors and builds on an existing epistemological philosophy of science in the acquisition of knowledge (Churchman and Ackoff, 1950), as a basis for theory building and extension in the field of System dynamics.

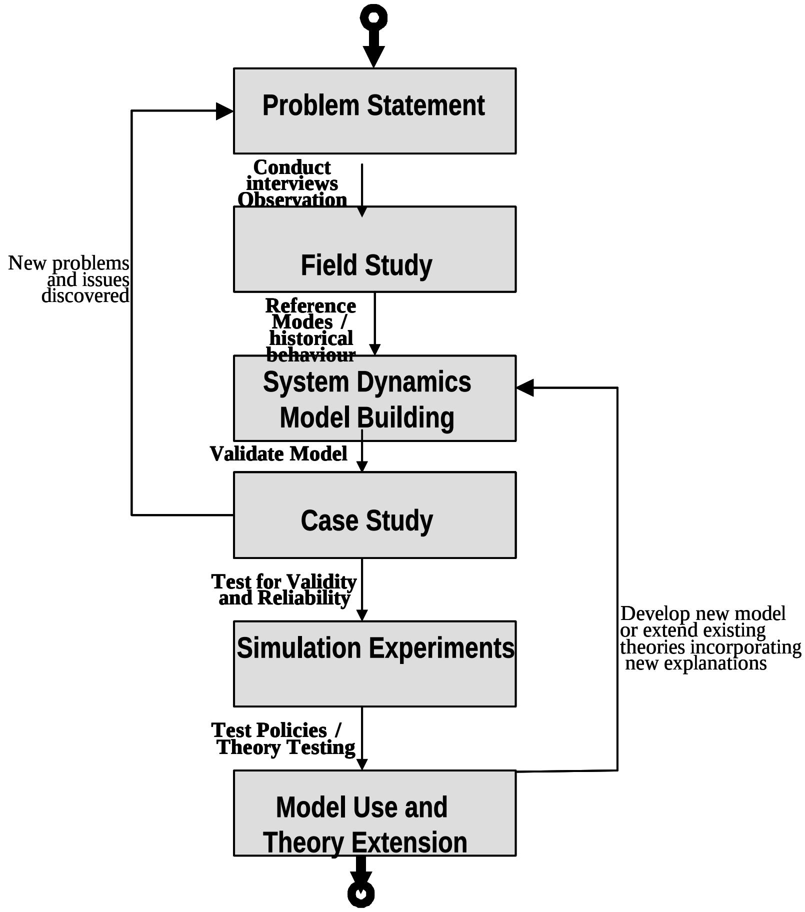

Figure 1: Dynamic Synthesis Methodology Research Design

In the SD literature, researchers have proposed the use of either case study or purely problem simulation modelling, however researchers have not stated the advantages of combining the two research methods (Williams, 2000; 2001a/b). Jick (1983) on the other hand underscores the desirability of mixing methods given the strengths and weakness found in each single method design. While other researchers have examined the relative merits of quantitative (simulation modelling) and qualitative (case study) debate.

The case study (Yin, 1984; Munford et al, 1985; Benbasat et al 1987; Lee, 1989; Smith, 1990) and Simulation (Graham, Morecroft, Senge and Sterman 1992; Pidd 1992; March et al, 1992; Roberts 1983; Hill 1996; Meadows 1983; Law and Kenton, 1988; Morecroft, 1979, 1988) methods have seen extensive application in software and systems research. Based on figure 1, the next section discusses each of the six phases of the Dynamic Synthesis Methodology.

The Problem Statement

The word "*problem statement*" is used in preference to research question(s) because modelling and analysis being part of System dynamic requires solving problems rather than answering questions. System dynamics modelling refers to a 'problem' to be solved (Richardson and Pugh, 1981), while other qualitative methods like case studies refer to the "research question" (Lane, 2001; Checkland and Scholes, 1990. The statement of the problem is an important early phase in modelling and analysis. Kerlinger (1986, pp.16-17) lists several characteristics of a good problem statement:

- The problem statement should state the expected relationships between variables (in experimentation this is a causal relationship)
- The statement of the problem must at least imply the possibility of an empirical test of the problem (hypothesis).
- The problem should be stated in form of a question .
- Reviewing the state of the art relevant to the problem statement refines the problem. Field studies may be necessary, through a pilot case study, in order to understand important variables.

Field Studies

Field studies and supporting data collection methods provide invaluable insights and discoveries during the System dynamics research. Field study is a term that applies to variety of research methods, raging from low to high constraints. These methods share a focus on observing naturally occurring behaviour under largely natural conditions. Curtis et al (1988) have used field studies to study large-scale systems in software development. Like field study research falls near the low-constraint end of Graziono and Raulin's (1996) classification presented in table 3.

Table 3: Low-High Constraints Categories of Field Research [After Graziano and Raulin, 1996]

Naturalistic Observation	Direct observation of events as they occur in natural world
Archival research	Studying information from already existing records made in natural settings.
Survey	Asking direct questions of persons in natural settings.
Case Study	Making extensive observation of a single group or person.
Program Evaluation	Conducting evaluation of applied procedures in natural settings
Field experiments	Conducting experiments in neutral settings where casual inferences are sought.

As illustrated in Table 3, the RE process field studies may take different forms, but all low-constraint field research constitute naturalistic observations, archival research, case studies, and surveys, while high-constraint include programme evaluation and field experiments. These low-constraint field research methods are not necessarily inferior to higher-constraints research. The appropriate level of constraint in any research and indeed in a RE process depends upon a number of factors, the most important of which is the nature of the process research questions or problem statement.

Gable (1988) urges that fieldwork is a poor method for objectively verifying hypotheses. However Attwell and Rennle (1991) suggest that the use of data collection techniques like the survey is strong in areas where field methods are weak. The strengths of field studies are the collection of data, and description of the phenomenon in its natural settings. Surveys, semi-structured interviews, participant observation and document analysis are data collection techniques used in this paper and recommended in the DYNASIS Descriptive Framework. Field studies are used to collect on site information on the current systems; process owners and required proposed system are gathered to facilitate identification of user and specification of system requirements, and constraints. Input and output information to activities identified in a Descriptive process model resulting from field studies are used to identify activities, resources and products used by the process. Data on processes, resources and product are used to develop a generic system dynamics model.

System Dynamics Model Building

System dynamics model development is a system stage process that begins and ends with understanding. The result of field studies should provide a descriptive model, on which SD conceptual feedback structure can be developed. The feedback structural model is developed with the help of a causal loop diagram. The next stage is the conversion of the cause loop diagram into stock and flow diagrams, which is a formal quantitative model of the problem in question. In order to simulate the model, we must define the mathematical relationship between and among variables. Pugh and Richardson (1981) in Figure 3-2 suggest that a system dynamics modelling effort begins and ends with understanding.

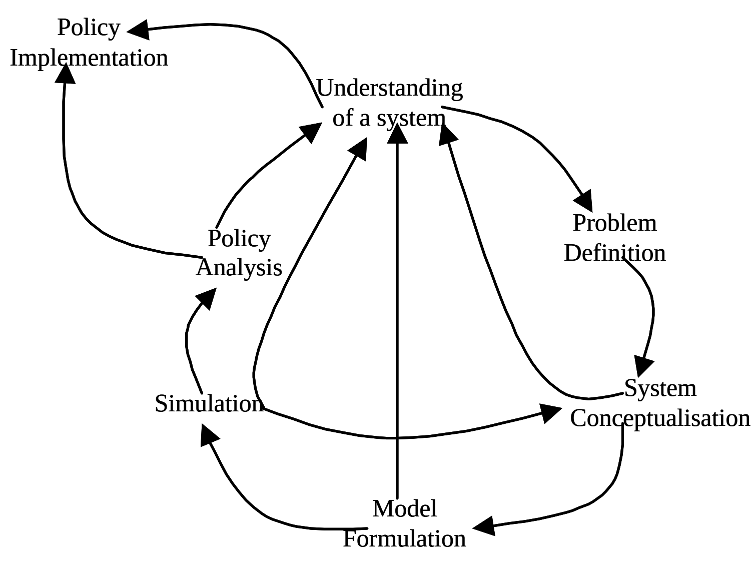

Figure 2: System Dynamics Modelling Process [Adapted from Richardson and Pugh, 1981]

Simulations can then be run on the important variables. Once confidence is gained, through validation and ownership by RE process stakeholders, then the model is available to test hypotheses or policies of interest. In some cases a developed model can be validated, using a post-mortem analysis or cases studies in RE processes, for prediction or prescriptive purposes.

Case Studies

Case Study is an exploratory (single in-depth study) or explanatory (cross-case analysis) research strategy, which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence. Apart from case study, other sources of information may facilitate the practical grounding of theories in the RE process domain. To attain reliable and high quality data of high-level requirements, RE project data need to be captured. The forms specifically elicits information on RE projects' resources, processes and products, their cost and time expended. Example of these RE process metrics can be: number of changes, the decisions taken and why, number of reviews, errors discovered, total number of requirements, requirements traced, rejected, frozen, documentation size, number of pages, document production cost, cost per page. The duration of each activity within the RE process, and any other factors that the requirement team thinks might have an influence on the way the projects are managed, are collected and documented for analysis and simulation experimentation.

Simulation Experiments

Simulation models are abstracts of the real worldview of a system or problem being solved. Shannon (1998) defines simulation as "*the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and /or evaluating various strategies for the operation of the system*". During the course of simulation, the model mimics important elements of what is being simulated. The model is used as a vehicle for experimentation in a “trial and error” way to demonstrate the likely effects of various policies. Those policies, which produce the best result in the model, will be implemented in real life as illustrated in section 5.5, Figures 5-28 through 5-34. It is sometimes necessary to study the behaviour of a system in order to find answers to a problem or predict the possible outcome of policies adopted but it may be impossible or impractical to experiment on the real system. In such situations, simulation can be an effective, powerful and universal approach to problem solving in different areas of application (Matko et al, 1992), to extend existing theories or identify new problems (Williams, Hall and Kennedy, 1999).

Model Use and Theory Extension

The System dynamics modelling approach takes a philosophical position that feedback structures are responsible for the changing patterns of behaviour we experience in complex problems (Richardson and Pugh, 1981). System Thinking /System Dynamics notation can be used to model and test different hypotheses propounded about RE process modelling and analysis. A dynamic hypothesis, can be tested verbally, or as a causal loop diagram or as a stock and flow diagram. In view of SD’s capacity to deal with the dynamic complexity created by interdependencies, feedback, time delays and non-

linearity. Steer (1992) suggests that it should be used to complement traditional scheduling and project management tools. Figure 2, provides a detailed description of DSM and how the resulting products of each research phase contribute to theory building and testing. Earlier sections discussed the merits and objectives of the dynamic synthesis methodology presented and overall reference research design. The main objective of Figure 2 is to depict input and outputs of each phase and their relationships and outputs and to identify data requirements and data collection methods of each phase, and validation and verification points within the methodology.
DSM as an applied research methodology has to demonstrate its usability in practice (Jayaratna, 1994). While customers may understand the problems that need to be solved, problem solvers or researchers may refine those problem statements depending on known problems. The Dynamic Synthesis Methodology uses a general model, (Figure 1) to illustrate the relationship and interconnections between different phases and artefacts. The phases, their relationships and resulting artefacts are dynamic. The degree of connections depends not only on time and space but also on the process stakeholder. This means different people perceive different connections and process problems differently and would make different choices to solution approaches (Kleindorfer et al, 1993).

As a process modelling and analysis methodology, DSM can be used to study a range of problems in both fields of science (systems engineering, operational research, control science) and social science (i.e. behavioural science, political science and management science). However, intended problem solvers need to acquire the richest possible understanding of organisational problems if they are to become effective problem solvers. (Jayaratna, 1984). An analysis of the strength and weakness of case study and process simulation methods suggests complementary sources of evidence and ideas appropriate to RE process modelling and analysis. While case studies can be used to capture reality description, simulation models can be used to build theories or test them.

Figure 2 aids different stakeholders to view requirements engineering process problems from shared contexts to facilitate shared understanding and common ownership of problems.

A Descriptive framework is a set of theories and associated experimental evidence and field studies concerned with how actual RE process stakeholders perform the process modelling and analysis. The dominant features of the descriptive theory are the limitations in cognitive abilities of decision makers, (Kleindorfer et al, 1993).

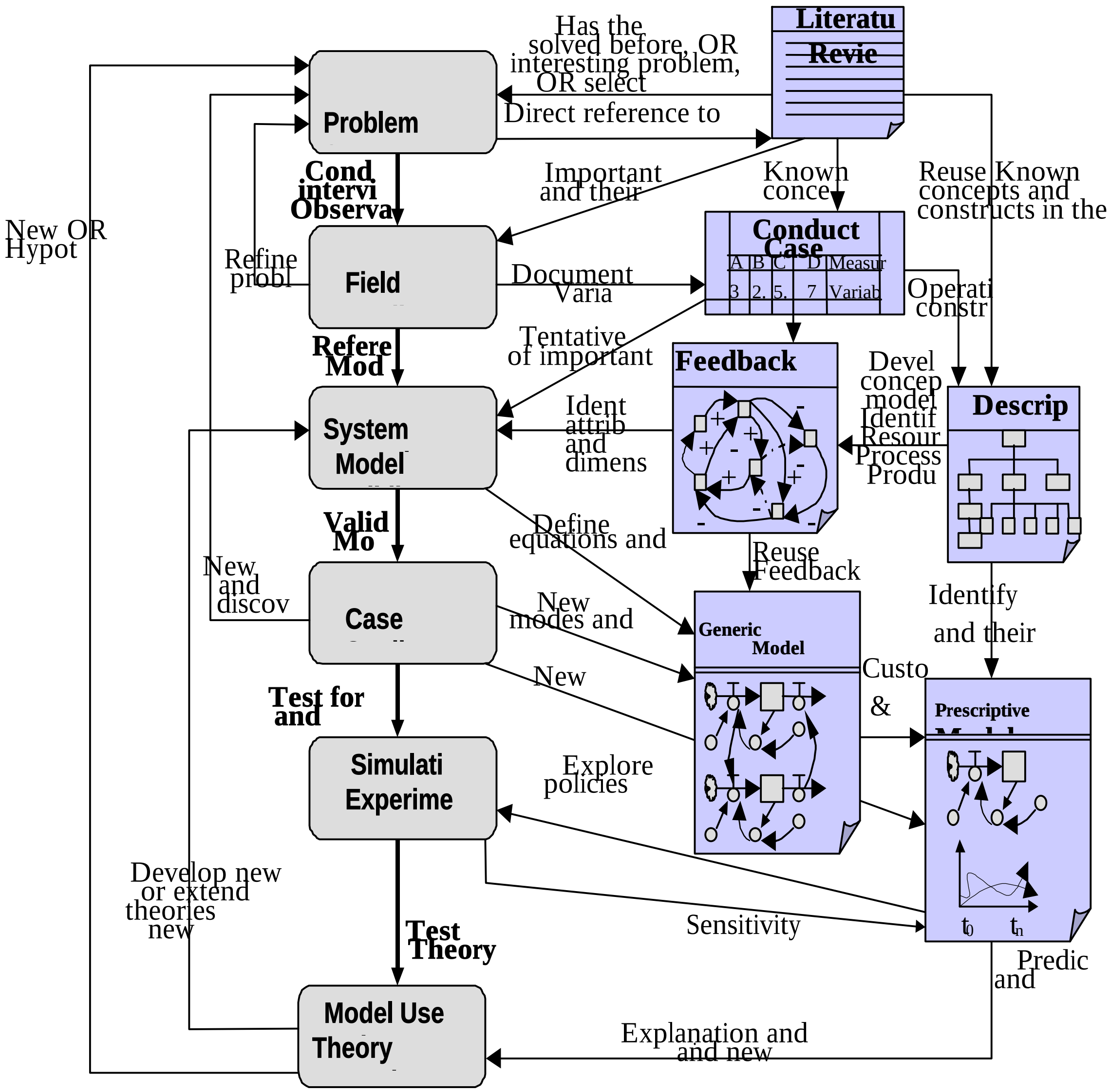

Figure 3: Detailed Reference Model for Dynamic Synthesis Methodology

As depicted in the reference study in Figure 3, the key outputs from the DSM are DYNASIS Descriptive and Prescriptive frameworks.

A Prescriptive framework is a set of theories and associated experimental evidence and field studies concerned with helping SD problems stakeholders improve their performance in problem-finding and problem-solving, given the complexities and constraints of a real life SD research (Williams, Hall and Kennedy, 2000). DYNASIS Prescriptive framework is an integrative dynamic feedback approach aimed at improvement and not necessarily optimisation.

The Dynamic Synthesis Methodology context consists of groupings of activities, technology and stakeholders (people), transforming customers' needs, into the finished

requirements engineering specification product and its likely performance. In the RE process many approaches have been used to gain knowledge. Some of these approaches place little demand on the adequacy of the information and the nature of the processing of that information. On the other hand formal approaches place very high demands on the processing and formality of information. Graziano and Raulin (1996) contrast research phases of a method and their levels of constraints in scientific research.
The benefits of DSM over case study or process simulation research methods are due to the fact that it is well structured for effective data collection purposes. Yin (1984), suggest that case studies are appropriate where the objective is to study contemporary events, and where it is not necessary to control behavioural events or variable. Case study as a qualitative research method is difficult to manipulate variables independently and have a high risk of interpretation (Kerlinger, 1986). On the other hand, simulation does not generate optimised solutions, such as those obtained by linear programming or other analytic methods and provides statistical estimates, not exact results. Each simulation model is applicable to a particular situation and transferring the results to other problems is generally not difficult (Law and Kelton, 1991).

Model Verification, Validation and Credibility

Building valid and credible process models is an important aspect of a researcher's representation of the actual system being studied. In determining the accuracy of a given model, three important terms are used, namely verification, validation and credibility.
Verification is the process of determining that a simulation computer program (or model) performs as intended. Verification checks the translation of the conceptual model (e.g. influence diagrams, flowcharts and assumptions) into a correctly working program or pseudocode in the Dynamic Synthesis methodology.

Validation is the process of determining whether the conceptual model (as opposed to the computer program or model) is an accurate representation of the system under study. Law and Kelton (1991) suggest that if the model is "valid", then the decisions made with the model should be similar to those that would be made by physically experimenting with the system *(pp. 299)*. This position is similar to that of Fishman and Kiviat (1968).
A model is said to be credible when a simulation model and its results are accepted by managers/customers as being valid, and used as an aid (tool) in making decisions. In respect to the DYNASIS tool implemented in section five, credibility is as important as validation in terms of actual implementation of simulation results, although credibility has not been discussed in great detail in simulation literature (Carson, 1986; Law and Kelton, 1991). In respect to DYNASIS tool, animation of the RE process was an important aspect of establishing credibility, "since animation is an effective way for the researcher and other RE process stakeholders to communicate the essence of the model to the manager" (Law and Kelton, 1991, p. 299). STELLA one of the system dynamics tools has the capability to animate the stock-and-flow diagrams (HPS, 1996-2000). The DSM proposed in this section presents the timing and relationships of validation, verification and establishing credibility. In the DSM approach credibility is established by process owners i.e managers, who sponsor the RE process. In the absence of the

sponsors, to establish credibility of the model can be performed by a focus group as surrogate stakeholders (Weigers, 1999).

Many researchers in the general simulation literature have suggested important approaches to validation, verification and establishing credibility in simulation models. Law and Kelton (1991) suggest that validation should be contrasted with output analysis, which is concerned with determining (estimating) a simulation model's true measures of performance. In the system dynamics literature, perhaps the most sighted approach to validate models is that proposed by Senge and Forrester (1980). This section has dealt extensively with the Dynamic Synthesis Methodology and its application to RE process modelling and analysis, and has suggested the various approaches to verification, validation and model credibility.

Theoretical Evaluation of DSM as a RE Process Methodology

Evaluation of Methodologies in Information Systems

In the SD literature researchers have proposed the use of either case study or purely problem simulation (Richardson, 1996), however researchers have not stated the advantages of combining the two research methods. Jick (1983) on the other hand underscores the desirability of mixing methods given the strengths and weakness found in each single method design. Other researches have examined the relative merits of quantitative (process simulation) and qualitative (case study) debate. The case study (Munford et al, 1984; Benbasat et al 1987; Lee, 1989; Smith, 1990; Lin, 1984) and Simulation (Graham, Morecroft, Senge and Sterna 1992; Koskossidis and Brennan, 1984; Pidd 1992; Sharon 1988; March et al, 1992; Roberts 1983; Hill 1996; Meadows 1983; Law and Kenton, 1988; Morecroft, 1987, 1988) methods have seen extensive application in information systems research. Examples of such approaches have been reported at the IFIP WG 8.2 Colloquium on information Systems research (Mumford et al, 1984). Keys (1988) discusses alternative research approaches in respect to problem solving methodologies, while Benbasat (1984) provide alternative research approaches in the field of management support systems. In light of the above different evidence on the choice and appropriate research approaches exist. Galliers (1984) develops a partial taxonomy presented in Table 4 to assist the would be researchers in choosing an appropriate information systems research approach. The partial taxonomy is applied to Dynamic Synthesis Methodology (DSM) proposed in this paper, and extensively discussed in Williams (2000).

Table 4: Approaches to Information Systems Research [Adapted from Galliers, 1985])

Researchers' Approac	*Van Horn (1973)*	*Hamilton & Ives (1982)*	*Vogel & Wetherb e (1984)*	*Galliers (1985), Galliers & Land (1987)*	*Farhoomad (1987)*	*Williams (2000) DSM*
Laboratory Experiments	✓	✓	✓	✓	✓	✓
Field experiments	✓	✓	✓	✓	✓	✓
Surveys	✓	✓	✓	✓	✓	
Case Study	✓	✓	✓	✓	✓	✓
Theorem of Proof				✓	✓	✓
Subjective /Argumentative		✓	✓	✓	✓	
Empirical			✓			✓
Engineering			✓			✓
Reviews		✓				✓
Action research				✓		
Longitudinal				✓		
Descriptive /Interpretive				✓		✓
Forecasting /futures research				✓		✓
Simulation				✓		✓

Table 4 compares IS research approaches suggested by other researchers like Van Horn (1973); Hamilton and Ives (1982); Vogel & Wetherbe (1984); Galliers (1984); Galliers and Land (1988) and Farhoomand (1987) with the Dynamic Synthesis Methodology reported in Williams, (2000) and presented earlier in section three. Subjective analysis shows the potential of the DSM in the context of RE process modelling and analysis has greater coverage in terms of theory development, testing and extension than most other research approaches contrasted in table 4.

Complementary Strength of Dynamic Synthesis Methodology

An analysis of strength and weakness of case study and simulation research methods suggests complementary sources of evidence and ideas appropriate to RE process modelling and analysis. While case studies can be used to capture a description of reality, simulation models can be used to build theories or test them.

Some of these approaches place little demand on the adequacy of the information and the nature of the processing of that information. On the other hand, formal approaches place very high demands on the processing and formality of information. Graziano and Raulin (1996) demonstrate the relationship between the research phases of a method and their levels of constraints in scientific research. "Levels of constraint" refers to the degree to which the researcher imposes limits or controls on any part of the research process. As illustrated in Figure 2 and Table 5, the DSM starts with low constraints levels of methods i.e. naturalistic observation and case study methods. Although this is a subjective analysis, but provides an indication of the constraint levels likely to be in the DSM after extensive evaluation.

Table 5: Levels of Constraints and Phases of the Dynamic Synthesis Methodology

DSM Phases / Levels of Constraints	Problem Statement	Field Studies	SD Model Building	Case Studies	Simulation Experiments	Model Use and Theory Extension
Observation	Low	Low				
Case Study Method				Low		
Correctional Research			Medium			
Differential Research			High			
Experimental Research	High				High	High

Table 5 indicates that as the process matures, it ends with very high constraints levels of methods similar to differential and experimental research methods suggested by Graziano and Raulin (1996). In RE process modelling, problem, case studies can provide exploratory insights with further syntheses using simulation modelling to provide prescriptive insights. Prescriptive RE process model can be used to test tentative patterns if important variables are identified in the descriptive model and the literature. Table 6 summarises the relative strengths and weaknesses of process simulation and case study along the dimensions discussed earlier. Gable (1988) has also used similar dimensions and ratings to analyse the relative strength between case study and survey research methods. I have extended Table 6 to include the exploratory and prescriptiveness dimensions, which are specific to the dynamic synthesis methodology.

Table 6 Relative Strength of Process Simulation, Case Study Method and DSM

Dimension	Process Simulation (Forrester, 1961)	Case Study (Yin, 1984)	DSM
Controllability	High	Low	High
Deductibility	Medium	Low	Medium
Repeatability	Medium	Low	High
Generalisability	Medium	Low	Medium
Explorability	Medium	High	High
Explanatory	Low	High	High
Descriptiveness	Low	Medium	Medium
Prescriptiveness	High	Low	High
Predictability	High	Low	High
Representability	High	Low	High

The analysis presented in Table 6, subjectively confirm the strengths of combined process simulation and case study methods. This combination compensate for weaknesses in each individual methods. In many cases *triangulation* or the use of multiple methods (both qualitative and quantitative) to crosscheck each other, is desirable and can enhance confidence in findings. This symbiotic interaction between deductive and inductive approaches, theory building and testing, and exploratory and explanatory research is the strength of the Dynamic Synthesis Methodology proposed in this paper. Other researchers (McGrath, 1979; Babbie, 1989) highlight the benefits of combining inductive and deductive research approaches. Ackoff (1962) sums up this concept by stating that "is probably the best representation of the *scientific research cycle"* (pp 62).

Evaluation for the Characteristics of DSM with other Systems Analysis Methodologies

This section evaluates Dynamic Synthesis Methodology as a modelling and analysis methodology in relation to a sample of other systems analysis methodologies using a framework proposed by Avison and Fitzgerald (1996). Fyod (1986) suggests "we must view methods themselves as objects of study". Avison and Fitzgerald (1996) contribute to the debate that *"such methods for the investigation of methods, concepts for the description and comparison of methods, and criteria for their evaluation and assessment must be developed"* (p.445). Wood-Harper and Fitzgerald (1982) argue that different methodological approaches might in fact be complementary and usefully exist side by side, or be applied in a contingency approach. The purpose of a methodology in the context of its purpose may vary between organisations and individuals, but there are three main categories of rationale, including:

- a better end product,
- a better development process, and
- a standardised process.

Jayaratna (1994) and extended later by Avison and Fitzgerald (1996) propose a framework for evaluating methodologies. A ten element criteria was proposed to evaluate the effectiveness of methodologies. Some of the elements in the framework are further broken into sub-elements, including:

- Philosophy
- Model
- Techniques and Tools
- Scope
- Outputs
- Practice
- Product
- Development Scope
- Document size
- User Customisation

Table 7: Basic Elements of the Framework for Evaluating Methodologies with DSM

Criterion		Information Systems Development Methodologies			
Element	Element	SSADM	OOA	ISAC	SSM
1. *Philosophy*	Paradigm	Science	Science	Science	Systems
	Objectives	Problem Solvir	Problem solving	IS Development	Problem/system understanding
	Domain	Systems analysi	Systems analysis	Systems analysis	Planning, Strategies, human activity
	Target	Large organisat	Small organisation	Large organisation	Human system
2. *Model*		DFD	DFD	DFD	Rich Picture
3. Effectiveness of *Techniques and Tools used*		✓✓✓✓	✓✓✓	✓	✓
4. *Scope*		Feasibility, Ana	Analysis	Analysis	Analysis
5. *Outputs*		Process Model		A-Graphs	Human activity model
6. *Practice*	Background	Commercial	Commercial	Academic	Academic
	User Base	✓✓✓✓	✓✓✓	✓✓	✓✓✓✓
	Players	Analysts	Analysts	Analysts	Facilitator
7. Product		✓✓✓	✓✓	✓✓	✓✓✓✓
8. *Speed*		Low	Medium	Low	High
9. *Doc size*		Medium	Low	Low	High
10. *Customisation*		Low	Medium		Low

This paper uses these elements to compare Dynamic Synthesis Methodology (DSM) with other methodologies applied in requirements engineering. Methodologies can be compared for either academic or practical reason. For academic reasons (Avison and Fitzgerald, 1996) is to better understand the nature of methodologies in order to perform classification and to compare future information systems development. For practical reasons, Avison and Fitzgerald (1996), in comparing methodologies involve a selection of a methodology for a particular applications or a group of applications. Table 7 uses these elements to compare Dynamic Synthesis Methodology (DSM) with other four methodologies known to be applied in requirements engineering, including SSADM, OOA, ISAC, SSM and Rational Unified Process Model (RUPM) in terms of supporting the elements and sub-elements demonstrated in table 7.Analysis portrayed in table 7, may not be objective until a rigorous validation programme has been undertaken. A program of research on advanced systems and decision engineering will be instituted to test the usefulness of Dynamic Synthesis Methodology in many different domains in terms of external projects with SDOs.

Dynamic Synthesis Methodology as a Programme of Research

The combination of case study and process simulation should be viewed as complimentary and be designed to objectively discover and validate many of the RE process issues and concepts.

The benefits of DSM over case study or process simulation are in its theoretical grounding and well structured methods for effective data collection. The data collected can be objectively represented in the SD model as mathematical formulas with numerical value of various parameters from both the soft and hard aspects of the RE process. This is a significant contribution to scientific knowledge in the RE process management field. The requirements engineering process, as a social process, needs approaches or problem solving paradigms that can captures both the quantitative and qualitative issues commonly found in complex systems, as opposed to traditional techniques that support either hard or soft issues only (Williams and Kennedy, 1997). The issue raised here is the need to reorganise the role qualitative sociological process inputs play in facilitating exploration and understanding of a system's RE process. Although there is insufficient literature on the use of sociological qualitative methods (Macaulay, 1996; Hirscheim, 1984; Earneson, 1991; and Eastely-Smith, 1991), the scientific paradigm adopted by the natural sciences is appropriate to the social- technical information systems only in so far as it is appropriate for the social sciences (Hirscheim, 1984). These tools and techniques can be used in the RE process modelling to improve its effectiveness. Methodological pluralism or paradigms that support both hard and soft should be welcomed, regardless of inherent differences in epistemological and ontological issues (Galliers, 1984), particularly when researching systems requirements engineering process.

Dynamic Synthesis: A new general Methodology of Investigation

Application of Synthesis as suggested by Ackoff (1962) has been demonstrated and extended in this paper as a philosophy of science and system dynamics modelling approach to the problems of requirements engineering process. This cumulative effort has improved our understanding of the RE field. The usefulness of SD over case study based qualitative analysis identified forms the basis for originality of Dynamic Synthesis Methodology an extended applied research approach proposed in this paper.

A System Dynamics Model of the Requirements Engineering Process

The main contributions of this paper is the provision of a general theory of RE process (model), DYNASIS Tool, anchored on synthesis as a philosophy of science and underpinned by theoretical concepts.

Understanding of the Requirements Engineering Process Problems

The synthesis of the various theoretical concepts and the use of the resulting DYNASIS tool facilitate understanding, as a basis for decision engineering the RE process is a major contribution of this paper.

Summary and Future Direction

This section discussed various elements that constitute DSM including philosophical underpinning, model, techniques, scope, outputs, practice and product and the purpose of the methodology (Jayaratna, 1994). This section also made a key contribution to the requirements engineering debate and to the literature on model-based systems and decision engineering by proposing the DSM. Viewing RE process problems from a dynamic feedback control viewpoint provides an enhanced understanding enshrined in the Dynamic Synthesis Methodology – a major contribution of this paper. Although the heading may not be mutually exclusive with other methodologies, there are obvious inter-relationships between DSM and other problem-solving methodologies. For example, aspects of philosophical background and practice are reflected to some extent in all other problem solving methodologies (Avison and Fitzgerald, 1996). DSM is still in its infancy, but has a lot of potential in developing into a practice-based RE process modelling and analysis. Further academic evaluation and improvements and practice-based validation will be necessary in order for the DSM to be accepted both in industry and academia as a general problem solving methodology, applicable also to RE process modelling and analysis. The DSM helps to provide a basis for collecting data about a phenomenon and then experimentation to predict the behaviour with what if dynamic analysis.

The DSM can be used to understand the various RE process stakeholders' qualitative meaning of concepts while objectively simulating quantitative behaviour of variables that help to explain the patterns akin to requirements engineers and managers. The solution to many of the problems of the RE process management and improvement are found in the definition of DSM. The DSM does not only integrate case study and process simulation modelling methods but it also integrates concepts from the general systems theory, servo mechanisms theory, scientific management theory, measurement theory and statistical process control methods, underpinned by synthesis as a philosophy of science.

A number of projects are being developed aimed at the empirical validation of DSM to test the Dynamic Synthesis research Framework and to develop theories that may explain the patterns experienced in RE process management and improvement. Based on my initial work, I have identified four specific further research programmes where future research may be directed:

1. development of Dynamic analysis requirements engineering metric tool.
2. empirical validation of DSM.
3. understanding Technology transfer process.
4. RE process assessment and improvement and development of a Flight Simulator - based learning and training environment.

The value of the research process model in theory building, testing and extension was highlighted in the paper. The paper suggests that the model has the potential to provide a framework for building a body of knowledge on RE process management. There are practical implications of the framework for both theory and practice. The paper therefore calls for a comprehensive research programme that tests the strengths and weakness of the Dynamic Synthesis Framework on requirements engineering process assessment and improvement.

References

Abdel-Hamid, T., and Madnick, S., (1991). Software Project Dynamics. Prentice-Hall, Englewood Cliffs, NJ.

Ackoff, R L (1962) Scientific Method. John Wiley, New York

Babbie, E., 1989. The practice of social research, Belmont, CA: Wadsworth.

Bell, J.A and Bell, J. F. (1980) System Dynamics and Scientific method. In elements of the System Dynamics method, Randers, J (ed) MIT Press Cambridge, MA; 3-22.

Benbasat I, Goldstein D K and Mead M (1987) The case study research strategy in studies of information systems.. MIS Quarterly September 369 -386.

Checkland, P. B and Scholes.J, (1990) "Soft Systems Methodology in Action", Wiley, Chichester

Churchman, C W (1961) The design of Inquiring Systems, Basic Books New York

Coyle, R. G., (1996). System Dynamics Modelling--A Practical Approach, London: Chapman & Hall. 413 pp.

Curtis, B. Krasner, H. and Iscoe, N. (1988). A Field Study of the Software Design Process for Large Systems. Communications of the ACM, 31(11): 1268-1287.

Curtis, B., Kellner, M., Over, J., (1992). Process modelling. Communications of the ACM 35 (9), 75-90.

Finkelstein, L (1982) Theory and Philosophy of Measurement. In Handbook of Measurement Science, Volume 1: Theoretical Fundamentals: P.H Sydenham (ed.), Wiley

Forrester, J. W. and Senge, P. (1980), Tests for Building Confidence in Systems Dynamics Models. *TIMS Studies in the Management Sciences* 14, pp209-228.

Forrester, J.W., (1961), Industrial Dynamics. Cambridge, MA.: MIT Press, 1961.

Gable G G (1994) Integrating case study and survey research methods: an example in information systems. European Journal of Information Systems 3(2), 112-126.

Galliers R.D. (ed) (1985) Information Systems Research: Issues, Methods and Practical Guidelines. Information Systems Series., Alfred Waller Ltd Henley-on-Thames

Graziano, A.M and Raulin, M. L (1996) Research Methods: A process of Inquiry, Addison-Wesley

Hirschheim, R. (1995) information systems epistemology: An historical perspective. In *Research Methods in Information Systems.* E. Mumford, R. Hirschheim, R. Fitzberald et al., Eds. North-Holland, Amsterdam, 1985. pp. 13-38.

Ives B, Hamilton S and Davis G (1980) A Framework for Research in computer based management information systems. Management Science 26 (9), 910-934

Jirotka M., and J. A. Goguen,(1994) "Introduction," in Requirements Engineering Social and Technical Issues, M. Jirotka and J. A. Goguen, Eds. Great Britain: Academic Press pp. 1-13.

Kaplan B and Duchon D (1988) Combining qualitative and quantitative methods in information systems research: a case study. MIS Quarterly 12(4), 51-586.

Kerlinger, F.N., 1986. Foundations of behavioural research, Holt, Rinehart & Winston, New York.

Klein H K, Nissen H-E,and Hirscheim R S (1991) A pluralist perspective of the information systems arena. In Information systems Research: Contemporary Approaches & Emergent Traditions (Nissen H-E, Klein H K, and Hirscheim R, Eds), pp 347-364. Elsevier, Amsterdam.

Kuhn, J. S (1972) The Structure of Scientific Revolutions (2nd Ed.), University of Chicago Press, Chicago.

Lane, D.C (1999) Social theory and System dynamics practice. European Journal of Operational Research, 113(3): 501-527.

Lane, D.C and Oliver, R. (1998) The greater whole: towards a Synthesis of System dynamics and Soft Systems Methodology. European Journal of Operational Research 107(1) pp. 214- 235.

Lee A S (1989) A Scientific Methodology for MIS case studies. MIS Quarterly 13(1), 32-50.

Loucopoulos. P., and Karakostas.V., (1995) System Requirements Engineering., McGraw-Hill.

Macaulay, L. A., (1996) Requirements Engineering Applied Computing., Springer

Morecroft, J. D. W. (1979) An integrated approach to Industrial Dynamics. Working Paper, Sloan School of Management, MIT Cambridge, MA 02139

Mumford E., (1984) Participation from Aristotle to today. In Th. Bemelmans, editor, Beyond Productivity: Information System Development for organisational effectiveness pages 95-105. North-Holland

Orlikowski W J and Baroudi J J (1991) Studying information Technology in Organisations: research approaches and assumptions. Information Systems Research 2(1), 1-28

Philips, D.C. (1987) Philosophy, Science and Social enquiry: Contemporary methodological Controversies in Social Science and Related applied Fields of Research, Pergamon: Oxford.

Pohl, K. (1993). The three dimensions of requirements engineering. In Rolland, C., Bodart, F., and Cauvet, C., editors, 5th International Conference on Advanced Information Systems Engineering, pages 275-292. Springer-Verlag.

Popper K R (1972) Objective Knowledge, Clarendon Press Oxford

Richardson, G. P,. (1996) Modelling for management I and II: Simulation in Support of Systems Thinking. Dartmouth, Aldershot, UK

Richardson, G. P., and A. L. Pugh III., (1981) Introduction to System Dynamics Modelling with DYNAMO, MIT Cambridge, MA.: Productivity Press

Roberts, F. S., (1979) Measurement Theory with Application to Decision making, Utility, and the Social sciences, Addison Wesley

Senge, P., (1990). The Fifth discipline: the art and practice of the learning organization. Doubleday, New York.

Senge, Peter. M(1993) The Fifth Discipline: The art and Practice of the Learning Organisation., Century Business

Smith N C (1990) The case study: a useful research method for information management Journal of Information Technology 5, 123-133.

van Maanen J (1983), Qualitative Methodology Sage Beverly Hills, California.
Vazquez, M., M. Liz and J. Aracil., (1996) Knowledge and Reality: Some Conceptual Issues in System Dynamics Modelling, System Dynamics Review, Vol.: 12 No 1 Spring john Wiley & Sons
Visala S (1991) Broadening the empirical framework of information systems research. In Information systems Research: Contemporary Approaches & Emergent Traditions (Nissen H-E, Klein H K, and Hirscheim R, Eds), pp 347-364. Elsevier, Amsterdam.
von Bertalanffy L. (1968) General Systems Theory - Foundations, Development, Applications. George Braziller, New York.
Wiegner N. (1948) Cybernetics. MIT Press. Cambridge. Mass USA.
Williams, D., (2000) Dynamic Synthesis: A Theoretical Framework for Research in Requirements Engineering Process Management, 11th YOR in Eds. Andrew Tucson, Tutorial and Keynote Papers, Operational Research Society. ISBN: 0 903440202
Williams, D., (2001) A System Dynamics Theory of Requirements Engineering Process. International System Dynamics 2001 Conference, Atlanta, USA, 23-30 July
Williams, D., and Kennedy, M. (2000/b) Towards a Model of decision-Making for Systems Requirements Engineering process Management, International System Dynamics 2000 Conference, Bergen, Norway, 6-10 August
Williams, D., Hall, T and Kennedy (1999) A Framework for Improving the Requirements Engineering Process Management, In Eds: C. Hawkins, G. King, M. Ross and G. Staples Managing Quality : Proc. of Software Quality Management Conference, Southampton, UK, 29 - 31 March. pp 203-217
Williams, Ddembe.W., and Kennedy M. S (1997). A viewpoints conceptual framework for improving the organisational information requirements: A System Dynamics perspective. In Yaman Barlas, Vedat G. Dicker and Seckin Polat Eds.15th International System Dynamics Conference, Istanbul, Turkey, Vol 2, pp: 475-479. System Dynamics Society.
Wolstenholme E. F, (1990) "System Enquiry-A System Dynamics Approach", Wiley, Chichester
Wolstenholme E. F, (1994) "A Systematic Approach to Model Creation in John D.W. Morecroft and J.D. Sterman (Eds) *Modelling for Learning Organisation*, System Dynamics Series", Productivity Press.
Wolstenholme, E. F., A. Gavin, K. M. Watts, and S. Henderson, (1990) The design of Dynamic Methodology for the Assessment of Computerised Information Systems. Procc. Of the 1990 International System Dynamics Conference, Eds, D. F. Andersen, G. P. Richardson, and J. D. Sterman. III: pp 1346-1354
Wood-Harper, A.T and Fitzgerald, G (1982) A taxonomy of current approaches to systems analysis. *Computer Journal*, Vol 25, 1
Yin R K (1984) Case Study Research: Design and Methods. Sage, Beverly Hills, California.
Yin, R. K (1988) *Case Study Research*: Design and Methods Applied Social Research Method series Volume 5 Sage Publications, London
Ταβουλαρη Στ. (1977).Το Λεξικο της Δημοτικης, Ορθογραφικο Ερμηνευτικο Ετυμολογικο, Εταιρεια Ελληνικων Εκδοσεων. (Tavoulari St. (1977), To lexiko tis Demotikis, Orthografiko Ermineytiko Etymologiko, Etairia Ellinikon Ekdoseon.

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