Towards a Taxonomy of System Dynamics Models of the Information Systems Investment Appraisal Process

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Abstract
A number of papers have been published on various issues relevant to System Dynamics (SD) Models of the Information Systems Investment Appraisal Process from several academic and professional viewpoints.

The paper contends that there is a need to catalogue and classify this work in order to highlight potential areas of research in this field of study and to identify system archetypes at different hierarchical levels and discover new ones.

The initial taxonomy is based on a limited literature survey. The contribution and relevance of each of the sources examined is briefly described. The taxonomy classifies the completed investigations into five specific areas of concern and five viewpoints.

1. Introduction

The objective of this paper is to facilitate and structure debate on the use of system dynamics (SD) (Forrester, 1961) for the Information Systems Investment Appraisal [ISIA] Process. It builds on previous papers by the author (Kennedy, 1996, 1999, 2001).

To guide management decision making in the ISIA process a number of "traditional" investment appraisal techniques, based on financial management techniques are normally employed. As commonly used these "traditional" investment appraisal techniques such as Payback, Accounting Rate of Return [ARR], Net Present Value [NPV] and Internal Rate of Return [IRR], are not able to measure many of the benefits offered by IS investments that are intended to gain tactical or strategic business advantages. This is a particular problem with those projects designed to achieve a 'transformation' of the business processes (Kennedy, 1999).

It is contended that these essentially static modelling approaches are inadequate for this application domain because many IS investments are designed to improve the operation of business activities that are dynamic, complex, non-linear systems. Such a system can be characterised by interactions of closed chains (or feedback loops) that, when combined, define the structure of the system and hence how it behaves over time. I therefore believe SD to be an appropriate modelling technique for the ISIA Process. A number of authors have addressed some of the problems of the ISIA Process and the findings from their investigations are outlined in section 3 below.

2. An initial Taxonomy of System Dynamics Models relevant to the Information Systems Investment Appraisal Process

The initial Taxonomy, presented in Table 1, is based on a limited survey of completed investigations relevant to the Information Systems Investment Appraisal Process. The findings from these investigations are briefly described in section 3 below. In light of this limited survey, I believe there is a need to catalogue and classify this work. I present an initial attempt at this below in order to highlight future areas of research in this field of study and to identify system archetypes developed from different viewpoints. The completed investigations are classified into five specific areas of concern (Business Value of Proposed Process Changes, Models to Contribute to our Understanding of the IS Development Lifecycle & Project Management, Process Flight Simulation, Strategic Decision Making Process and the problems of current ISIA practice & the desirable attributes of an ISIA system) and five viewpoints (System Dynamicists [SD], Software Engineers [SE], Investment Analysts [IA] Simulation Modellers [SM] and Domain Specialists [DS]). Some work spans more than one category.

	AREAS OF CONCERN					
		Business Value of Process Change	**I S Dev. Life Cycle & Project Mgt.**	**Process Flight Simulation**	**Strategic Decision Making**	**Problems of ISIA & Desirable Attributes**
VIEWPOINTS	**Systems Dynamics Professionals**	Coyle (1996) Wolsthenholme et al (1993)	Abdel-Hamid & Madnick (1991)			
	Software Engineers		Lehman (1994) Lehman (1996) Lehman (1997) Lehman (1998) Jensen & Tonies (1979) Kahen et al (2000) Wernick & Lehman (1999)	Rubin et al (1994)		
	Domain Area Specialist	Anderson (2000)			Dyson (1990) O'Regan B & Moles R (2001)	Hares & Royle (1994) Willcocks (1992) O'Regan B & Moles R (2001)
	Investment Analysts					Remenyi et al (1996) Serafeimidis & Smithson (1995) Doherty & King (2000)
	Simulation Modellers	De Jong and Looijen(1999)	Savolainen (1995)			

Table 1: Preliminary classification of SD related work in The ISIA Process Management

3. Published Work relevant to the Information Systems Investment Appraisal Process

A number of authors have examined some of the problems with the Information Systems Investment Appraisal Process management domain and suggested ways in which SD may add to the Analyst's armoury. I shall briefly describe a selection of completed investigations and key findings.

Business Value of Proposed Process Changes

Firstly, we may develop models of a business showing business processes before and after a proposed process change. The anticipated value of the benefits derived, (in terms of greater revenues, resources saved or perceived improvements in quality or reputation), can be compared to the estimated costs. This would be of considerable value in evaluating "Process Transformation" or "BPR" type projects.

A classic example of how constructing a SD model may lead to a better decision being taken and, in this instance, avoid an expensive error being made, is the "Domestic Manufacturing Company (DMC)" case study as described and analysed in Coyle (1996). This case (disguised & simplified) is based on a consultancy assignment. It is described in Kennedy (2001).

Coyle summarises the implications for the Information Systems (IS) investment appraisal domain as: "Testing the effects of putative information systems in the inexpensive world of the model is a most fruitful area of System Dynamics application"

This concept can be extended into a structured method. Wolstenholme et al (1993) describes such a System Dynamics based methodology for MIS evaluation, which he and his co-workers termed "BISEM" (Bradford Information System Evaluation Methodology). They state that it is intended to be used as a "complement to existing methodologies for the structured development of MIS". They envisage that it "is to operate in parallel with the evolution of the MIS life cycle, but to remain at an objective, strategic level in contrast to, but supporting, the detailed development of the MIS". It is described in Kennedy (2001).

As in the example drawn from Coyle (1996), above, Wolstenholme et al's work takes a strategic view of MIS and is aimed at providing a systemic and dynamic evaluation of the effect of a MIS on its host organisation. This contrasts with the (isolated) project bias of most Information System Evaluation Methodologies (Hares & Royle, 1994).

A further example of the application in business value to process change can also be noted in health care. Anderson (2000) highlights the benefits of using SD modelling in a health care environment. An example of SD modelling is then applied to a health care situation, particularly the effectiveness of several IT applications to help minimise medication errors that result in adverse drug events (ADE). A SD model was constructed of the situation which (when used in practise), resulted in a reduction of ADE's. Importantly, errors from ADE cost additional monies to correcting mistakes, and the modelled reduction in ADE's helped to reduce costs in the worked example.

De Jong and Looijen (1999) seek to develop a simulation model for evaluation of IT service processes. The authors identify the characteristics of the underlying IT service process and treat these as inputs to the model. IT tasks are then linked together to form IT service processes. The resulting tasks structures are implemented in an ARENA simulation modelling tool. Problems, however, were encountered defining uniform IT tasks, as some tasks could not be placed into a

process. A change of approach was then used focusing on Goals Question Metrics. They conclude that simulation proved to be a good approach for evaluating IT management but found it difficult to process the inputs to form the simulation model.

Models to Contribute to our Understanding of the IS Development Lifecycle & Project Management

Lehman and his co-workers examine the various ways in which SD may contribute to our understanding of the IS development lifecycle, (especially in respect of evolutionary software), from a Software Engineering perspective.

In a sustained series of experiments (Lehman, 1994, 1996, 1997, 1998; Kahen et al, 2000; Wernick and Lehman 1999) termed the "FEAST" study, they have constructed and compared the results from 'black box', 'white box' (SD) and other classes of process models of selected collaborator systems. These systems are selected so as to take advantage of the available process evolution metrics and other global data about process components and structures that other members of the Software Engineering community have collected over many years. These papers are described in Kennedy (2001).

Their major contribution to this area is in providing the evidence (from a Software Engineering perspective) that the IS development lifecycle may be viewed as a "complex multi-level multi-loop feedback system, the long term behavioural patterns and trends of software processes are largely determined by its internal dynamics which, in turn is feedback generated and controlled". In later work they have described the evolution of their own approach towards simulating the effects of the decisions made by the managers of these processes and generally placing greater emphasis on 'human factors', so moving closer to those authors approaching the issues from a traditional SD approach. The key findings of a selection of their papers are described below.

In a counter-point to Lehman and his co-workers, Abdel-Hamid & Madnick (1991), examine the various ways in which SD may contribute to our understanding of the IS development lifecycle (and project management in particular) from a SD perspective. Despite the different starting points there are considerable overlaps in the two teams' conclusions.

They summarise some of the problems of Software Engineering as "the record shows that the software industry continues to be plagued by cost overruns, late deliveries, poor reliability, and users' dissatisfaction."

They conclude that the root cause is that although there have been major technical advances, "A comparable evolution in *management* methodologies, however, has not occurred". Their work is described more fully in Kennedy (2001).

In a similar vein to Lehman's line of reasoning they suggest that this "micro-oriented" work is a useful beginning in helping us obtain a better understanding of software development. They add, "However, before we can say that we have *a complete* understanding, it is necessary to show that our knowledge of the individual components can be put together in a total system."

They quote Jensen and Tonies (1979): “There is much attention on individual phases and functions of the software development sequence, but little on the whole life cycle as an integral, continuous process - a process that can and should be optimised”.

Savolainen (1995) focuses on the need for dynamics to be incorporated in IT evaluation, “the evaluation of IS is a dynamic process as the requirements for evaluation and the forms of evaluation vary with the changing environment.” The paper seeks to highlight the dynamic evaluation with specific regard for the IS life cycle. Firstly, evaluation is taken from the IS developers viewpoints specifically with regard to internal efficiency. Next the focus of different interest groups is studied with specific focus of the change of interests in these groups across the evaluation process. Lastly the change in evaluation criteria over the IS lifecycle is studied. The author concludes, “the performance evaluation framework must always be customised according to the contingencies in the information systems environment.”

Process Flight Simulation

Thirdly, we may develop ‘Process Flight Simulators’. The concept is that a dynamic model is built of an organisation that allows managers to simulate and study situations before encountering them in reality and so deepen their understanding of the organisation and the likely impact of policies and decisions.

Rubin et al (1994) describe the use of “Process Flight Simulation”, using SD techniques in this domain that helps assess the impact of improvements in process maturity. They describe the construction of a dynamic model of an organisation. This model may consist of processes, events, patterns of behaviour, structures and information feedback flows. Once managers are confident that they have developed a satisfactory model of their organisation, they can simulate a wide variety of business circumstances and scenarios. They state “…We have provided a simulation model that helps a manager ask “what-if?” questions about different management scenarios. It’s our strong believe that organisations should simulate their software processes before embarking upon expensive and potentially disruptive changes to their existing organisational culture.”

Strategic Decision Making Process

Fourthly SD can play a significant part in the strategic decision making process. This clearly has implications for the Information Systems (IS) investment appraisal domain but this aspect is not dealt with in detail in this paper. As an example, Dyson (1990), states, “In order to evaluate possible future states of the organisation, which is the result of adopted strategies and the impact on the organisation of uncontrolled inputs, some kind *of corporate system model* of the organisation is required.”

Dyson (1990) states that currently, in most organisations, this will entail the use of a corporate financial model to provide financial projections. Such models typically involve accounting relationships and what Dyson terms “rudimentary attempts” at modelling the behaviour of the organisation. Due to the inadequacy of these “rudimentary attempts”, he states that there has been a “growing interest in the development of behavioural simulation models using ideas of system dynamics”.

O' Regan and Moles (2001), utilise the benefits of SD modelling in a case study on International Minerals Investment. Two examples are used by the authors to demonstrate the benefits of this. They conclude, "the greatest advantage in adopting system dynamics as an analytical tool for investment analysis is that it exposes the many interrelationships which structure and influence the behaviour of a complex system." However they also note SD modelling "does not by itself provide objective answers. Instead it is a learning device, an aid to understanding. It is not a replacement for analytical thinking, but rather complementary to it."

Problems of current ISIA practice & the desirable attributes of an ISIA system

This section of the paper briefly reviews some issues in the Information Systems (IS) investment appraisal (IA) domain. These are examined in greater depth in previous papers by the author (Kennedy, 1996, 1999, and 2001). An exploration and classification of these issues will form the basis of establishing criteria to determine how SD modelling may assist in addressing some of the problems of current ISIA.

Most organisations are still using 'traditional' financial management investment appraisal techniques (Hutchinson, 1995; Weston & Copeland, 1988), such as Payback, Accounting Rate of Return [ARR], Net Present Value [NPV] and Internal Rate of Return [IRR] for evaluating all IT investments (Hares & Royle, 1994; Ballantine et al, 1995; Remenyi et al, 1991). It is argued that although these "traditional" investment appraisal techniques are suitable for evaluating IT investments that automate the organisation's operations, where the prime motive of the project is cost displacement, they are not suitable for evaluating IT investment that are intended to gain tactical or strategic business advantages (Kennedy, 1999).

Hares & Royle (1994) state that there is much to be gained by ensuring that the IA is conducted against a clear strategy plan of projects that are judged to be worthy of investment

It is argued that because one of the major benefits offered by a MIS is gained by an increase in the quality of the decision making within the organisation it cannot be evaluated effectively by techniques that only consider quantitative and financial data. For IT investments that are designed to gain strategic advantage the benefits are likely to be even more difficult to measure than those of an MIS because of the increased number of external and internal factors which are involved (Kennedy, 1999).

A fundamental reason why IA approaches have had difficulty dealing with more "modern" IS investments is that they generally emanated from a traditional view of corporate structures and decision making based on division and analysis, which attempt to break every aspect of the organisation into small, discreet chunks. Since the 1980's the emergence of cross-boundary and integrative models of management such as TQM (Total Quality Management), BPR (Business Process Re- engineering), supply-chain management, enterprise resource planning (ERP) and electronic commerce have lead to a growing interdependence between differing aspects of the organisation (Maani & Cavana, 2000). This change requires an integrated ISIA method that is able to deal with interconnections and feedback.

Research has shown that as a result of the past problems of IT and investments, with various authors suggesting desirable attributes for an investment appraisal tool/method.

Serafeimidis and Smithson (1995) quote figures on the increasingly high spend of IT projects and concern of senior management regarding the IT payback. IT is entering the "transformation" stage and therefore needs more rigorous approaches to IT investment. The authors quote the following requirements for an investment appraisal framework: a conceptual framework; business driven evaluation; increase understanding and learning of the business and of the evaluation process; provide complete life cycle coverage; provide adequate and relevant information for the evaluation process; trigger the identification of stakeholders and improve communication between them. The authors then suggest a framework, which include various modules: CSF's; Objectives; Requirements; Decision; Direction; Delivery. Concluding the authors say "evaluation needs to be more wide-ranging, to incorporate the richness of the intangible and unexpected costs, benefits and risks of modern IT projects."

A similar theme is continued by Remenyi et al (1996). These authors advocate modelling as vital part of ISIA. The issues of the importance of modelling are raised specifically with regard to management and planning of information systems. The authors focus in three levels of modelling: macro (high level), meso (intermediate levels) and the micro (detailed level). Macro models are defined as "the situation which they represent, in general terms." The meso model adds greater detail, especially with regards to results. Lastly the micro model takes the meso model and tries to quantify the situation. Finally, the merits of modelling are put forward, "Unless some detailed modelling is done, management will not have much of an idea of what lies ahead." They also mention, however, care needs to me taken needs to be used carefully "particularly to the assumptions underlying the models."

Doherty and King (2000) focus on the important role of human, organisational and economic issues in systems development projects. Research is highlighted which points to inadequacies in dealing with organisational issues leading to systems failure. Primary research focused on a questionnaire completed by 593 senior IS executives. Results showed an increasing number of organisations addressing a wide range of non-technical impacts throughout the systems development process. But the authors suggest the evaluation process should be more continuous as opposed to pre and post implementation evaluation.

Willcocks (1992) suggests the following evaluation guidelines:

- Link evaluation across stages & time
- Involve key stakeholders in evaluation at all stages
- Assess the actual against the planned impact of IT
- Evaluate & re-evaluate at all stages of the project
- The concept of learning should be central to the evaluation process. The clamour for adequate techniques may reveal a 'quick-fix' orientation; in the long run getting it right may prove more difficult but add greater value

4. Conclusion

SD has a direct, but yet to be realised in widespread commercial application, potential for evaluating IT investments. Several of the approaches examined in this paper utilise a system dynamics modelling tool to simulate the likely effect on the organisation of a proposed IT investment so that the likely benefit can be evaluated by management in advance and without disturbing the actual

system. Additionally, an organisation could have an enhanced understanding of cost structures, time dependencies and human resources that would enable the model to estimate intangible costs and benefits that traditional cost/benefit analysis (CBA) cannot measure.

A fundamental reason why current IA approaches have had difficulty dealing with more "modern" IS investments is that they generally emanated from a traditional view of corporate structures and decision making based on division and analysis, which attempt to break every aspect of the organisation into small, discreet chunks. The emergence of cross-boundary and integrative models of management requires an integrated ISIA method that is able to deal with interconnections and feedback. SD can satisfy this need. (Kennedy, 2000; Maani & Cavana, 2000)

This initial taxonomy brings together work derived from several viewpoints. From a SD viewpoint, Coyle (1996) summarises the implications for the ISIA domain as "Testing the effects of putative information systems in the inexpensive world of the model is a most fruitful area of system dynamics application". While from a SE viewpoint, Lehman (1996) briefly reviews the difficulties encountered in achieving further major improvement in the software evolution process. He suggests that this may be due, in part, to the fact that the "global process" is a "complex, multiloop multilevel feedback system".

In the author's opinion the case for using SD in the ISIA process is considerably strengthened by the congruence of arguments stemming from several academic and professional disciplines. In many cases authors working from different traditions appear unaware of the parallel work being done in other domains. One of the purposes of this paper is to show the links between such disparate work and to attempt to establish an inter-disciplinary consensus.

Kennedy (2001) has suggested some of the possible causes of why there has not been a widespread commercial adoption despite the impressive range of potential advantages for utilising SD in the ISIA process.

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