The Design of a Dynamic Methodology for the Assessment of Computerised Information Systems

by

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INTRODUCTION

The last decade has seen the accelerated development of what Yadav and Chand term "Organisation Support Systems" - large scale, complex and extremely expensive computer-based information systems (Yadav, 1989). The cost associated with such systems has increased the requirement for a sound methodology to evaluate the expected operational benefits and drawbacks resulting from their implementation, at as early a stage in the system life cycle as possible.

An extensive survey of the literature in the field of information system evaluation, with a particular focus on the methodologies, tools and performance measures being used in practice, preceded the development of the methodology reported in this paper, and is presented in full elsewhere (Watts 1990).

This paper comments on the findings from that review and reports on the development of a system dynamics based methodology for the assessment of proposed computer-based information systems (CIS), in terms of their potential to support organisational objectives.

The methodology has been evaluated by application to two military CIS, at different stages in the system life cycle. These cases are reported separately (Watts and Wolstenholme, 1990; Henderson and Wolstenholme, 1990), but the indications are that the methodology can contribute throughout the system life cycle by providing a continuing reminder of the relevance of the CIS to the real-world system which it is intended to support.

BENEFIT ASSESSMENT

Benefit assessment is becoming an increasingly important component of the CIS life cycle as organisations seek to justify the high level of investment in large-scale systems (Meiklejohn, 1989; Weill, 1989). In information systems terms, benefit assessment is the process of evaluating the likely benefits to an organisation resulting from the acquisition of a computer-based information system.

Amongst the research community there is an increasing awareness of the inadequacies of the approaches to assessment which were acceptable when computers were simply automating clerical processes on a local basis (Bjorn-Anderson, 1988).

Numerous methodologies have evolved to support large-scale system design but few include support for assessment (Bjorn-Anderson, 1988 pp 59-80), indeed the design process itself mitigates against effective assessment.

The reasons for this are clear: Most system design methodologies begin by stressing the importance of understanding the real-world operation which the computer-based information system is to support. However, although the holistic view of the real world is the starting point for the design process, the focus quickly changes from a high level to a low level view, as organisational activities are analysed, in ever-increasing detail, to identify their information needs. At the end of the analysis phase, the detailed requirements are expressed in the format required by the system designers, and are far removed from the high-level situation which prompted the analysis.

It is at this stage that benefit assessments are carried out. The conflict is all too evident. The system to be assessed is described in microscopic detail in terms influenced by the needs of the CIS designers. The clients require a statement in terms of the overall contribution the system will make to organisational performance, and the impact its implementation will have on its current mode of operation. Having progressively decomposed the operation to determine system requirements, assessment demands that the process is reversed.

The concern is that there seems to be a lack of appreciation, amongst those responsible for the assessment of systems, of just how formidable a task this is. It is beyond human cognitive abilities to visualise fully the interaction of a large-scale information system with the physical operation into which it is to be installed. The approach which prevails (Feld, 1988; Huckersby, 1989), however, involves the evaluation of the contribution of each low level improvement - improvements usually related only to increased timeliness and accuracy - against criteria commonly determined by brainstorming. The cumulative effect is assumed to be additive - the more low level improvements which are included in the system, the greater must be its contribution to organisational performance - a view which must be due, at least in part, to the custom of assigning the responsibility for evaluation to the system designers (Watts and Wolstenholme, 1990).

There seems to be no realisation that, in decomposing the organisation to determine its requirements, the information sub-system has been isolated from both the organisational structure and physical activities i.e. the real-world, and that reconstruction of the real-world picture is a pre-requisite to rigorous evaluation. Only by so doing can the complex interactions of the multiplicity of changes in the proposed system be evaluated, and the effect of the physical operation characteristics on the information system be taken into account.

This recognition is implied in both the use of physical simulations to test, for example, the response of pilots to changes in the presentation format of in-flight manuals (Chu, 1979); Rouse, 1980); and also the use of gaming experiments (Chervany, 1974; Daniel, 1984) to evaluate the real-world effect of proposed changes. These approaches are, however, usually expensive to implement and unsuitable for large-scale information system evaluation.

It is interesting to contrast the approaches to benefit assessment with those for the evaluation of the technical aspects of systems. In evaluating the technical performance of the system, designers usually do take a holistic view. Mathematical and/or computer simulation modelling is widely used (Hayes, 1984), the test-bed model being the whole communication and information system. The overall technical performance of the system is not assumed to be the sum of its parts.

What is required for benefit assessment is a similar approach to that for technical performance i.e. a holistic modelling approach.

PERFORMANCE MEASURES

The other concern, in the development of a methodology for CIS assessment, is the selection of measures against which to gauge the performance of the proposed CIS i.e. what indicators

should be used as surrogates for information system success?

The research activity in this field indicates a distinction between the efficiency and the effectiveness aspects of the CIS. In general terms, efficiency is regarded as "doing the thing right" and effectiveness as "doing the right thing". In an information system context, efficiency measures are concerned with the efficient use of computing resources; effectiveness measures relate to the user's or organisation's effectiveness as a result of receiving output (Szyperski, 1978 pp 29-43). Efficiency, therefore, can be regarded as inward-looking, focussing on the productivity of the CIS itself (Kriebel, 1982); effectiveness as outward-looking, questioning whether the increased efficiency of the information system really does result in increased organisational effectiveness.

Of the two, efficiency is easier to quantify and measure and has, therefore, received the greatest attention in practice. Transmission times, throughput, capacity utilisation, resource bottlenecks and output quality are all used to measure efficiency and there is broad agreement on their utility.

In the case of effectiveness, however, the situation is much less certain and tends to be ill-defined. Measures proposed are usually subjective and there is much debate on their suitability. These measures can, broadly speaking, be divided into two groups, representing different viewpoints - the "organisational" viewpoint and the "user" viewpoint.

The "organisation" measures are usually related to a cost/benefit evaluation of the system, although "application to the major problems of the organisation" has been proposed. The "user" measures are those such as "widespread use", quality of decisions and performance" and, "user satisfaction". Although those who are charged with the task of authorising investment would prefer a cost/benefit assessment, the acknowledged difficulty in quantifying the benefits dimension of investment in information systems (Szyperski, 1987 pp 265-283) means that, in practice, the "user" viewpoint receives more attention. The reliability of this approach is in doubt, however.

The reason for the doubts is the interpretation of the term "user". Case studies (Bahn, 1981; Counte, 1983; Grier, 1985) indicate that the "users" whose opinion is sought, are usually those individuals who interact directly with the information system. The term is not interpreted in a broad sense which would include the organisation as a whole. Within a large organisation, therefore, how does one define the users, or groups of users, whose opinion is to be representative of the success of the system? It is highly probable that different groups of users, or even individual users within a group, will have different perceptions of the effectiveness of the system. Kriebel points to evidence of the possible lack of consistency and objectivity of users in determining the effectiveness of an information system (Szyperski, 1987 pp 29-43).

Whilst it can be accepted that a low level of user satisfaction with any part of a system may result in a less than satisfactory performance, the converse - that a high level of user satisfaction is an indicator that a system is effective - must be questionable in cases other than where the prime objective is to improve the facilities available to, and/or the morale, of the users. It is a situation which parallels the practice in methods of assessment, and may also be due, in part, to the practice of assigning the responsibility for the assessment of the effectiveness of the system to those involved in the design of the information system. Their method of evaluation, and the performance measures they choose, must, almost inevitably, be influenced by their technical knowledge of the system, resulting in an "inward-looking" evaluation, which focuses on the system and its immediate environment.

Although the level of user satisfaction with a system is, undoubtably, an important factor to be considered when evaluating a system, it is only one dimension of the "effectiveness" of a system. User satisfaction evaluates the quality of the information and facilities which the system provides. Effectiveness is concerned with the way in which the information and

facilities can be used to maximise the organisational potential.

More importantly, in the context of the research reported here, user satisfaction is a factor which demands the user's experience of the system and can be evaluated only after installation. It is suited only to post-implementation assessment.

However, if user satisfaction is rejected as a measure of effectiveness for pre-implementation assessment, what measures can be used? Unexpectedly, perhaps, post-implementation assessment practice can provide some help in this matter. The somewhat abstract concept of "user satisfaction" is broken down, in practice, to less subjective and organisation specific surrogates, the degree of change in which, the users are able to quantify. On examination, these surrogates are related directly to the performance objectives of the users. The effectiveness of the CIS is measured in terms of its success in improving the performance of the user. If this approach could be widened, extending the user concept to include all groups affected by the information system, the contribution of the CIS to organisation performance could be evaluated.

The approach described by Land takes a much broader view of the environment surrounding the proposed system and offers a more comprehensive technique for determining performance measures (Land, 1976). Land begins from the premise that "Information Systems exist to serve and support the activities of the organisation of which they are a part (and that) any change in information systems must seek to improve the ability of the organisation to accomplish its goals."

He describes a methodology for determining the goals of the organisation and expressing them in terms of quantifiable performance measures which are meaningful to that particular organisation.

His approach is to identify all the potential "beneficiaries" of the proposed system change. The beneficiaries are classified into five groups ... those with a financial interest in the enterprise, the employees of the enterprise, the organisation and its managers, the customers and external relations of the enterprise, and the community at large.

The aim of the proposed change in the information system is expressed as "the maximisation of the organisation's overall utility" and is seen to comprise five lower level objectives related to the above groups - financial return, job satisfaction, organisation structure, customer satisfaction and community utility. Each of these objectives is systematically broken down into subgoals until quantities which can be measured are determined. The overall performance is a function of all the attributes.

This approach to the selection of performance measures is compatible with the holistic modelling approach proposed for the methodology. Performance measures should be determined to represent all parties or stakeholders (Hawgood, 1988), likely to be affected by the changes proposed. They should include measures which relate to the organisational goals as well as to the aspirations of individual user groups and, where possible, should be expressed in quantifiable terms, not abstract generalities. The effectiveness of the CIS will then be measured in terms of the improvement it can bring about in these measures. Senior management must establish the relative importance of the measures, although it should be recognised that this may be dependent on the prevailing circumstances and require regular review.

THE METHODOLOGY

A System Dynamics based methodology will support the objective of a holistic modelling approach. By providing a framework for studying the complex and dynamic interactions between the physical structure and activities and the underlying information sub-system, it has the ability to highlight counter-intuitive effects, a facility lacking in current approaches to assessment.

Its applicability to the study of strategic changes will also facilitate the exploration of new control policies to take advantage of the opportunities provided by the installation of the CIS. Further, it could both enable the identification of possible detrimental effects and assess the "cost" of avoiding them. This is felt to be the most important dimension to CIS assessment.

Whilst comparison of the performance of the model with and without representation of the CIS will provide some indication of the impact of the CIS, it will not provide a complete evaluation of the potential of the system. A computerised information system has been defined as "management by other means" and ought, therefore, to be assessed in terms of its potential to enable beneficial changes in organisational control. By providing a test-bed for examination of the ability of the CIS to support desired policy and structural changes, organisations will be better able to anticipate the extent of adaptation required to take advantage of the CIS facilities, such that the "cost" and implications of change can be discussed before commitment. It will reduce the probability of authorising expensive installations which do not live up to expectations or incur further unanticipated expenditure.

The model

A System Dynamics approach has previously been used by Coyle to assess the work-processing capabilities of military command and control systems (Coyle, 1987). In dealing with the efficiency aspect of the system, the "system" view of information is adopted i.e. the information attributes represented are amount and timeliness. Coyle clearly states that his model does not address the question of the extent to which the system contributes to force effectiveness.

To measure effectiveness, an "organisation" view must be taken. Information must be represented in terms of the way in which it is used by the decision-makers. It is essential, therefore, to recognise that decision-makers are concerned, not with the number of characters of information being communicated, but with the content or meaning of that information. The unit of information of interest to them is the variable. The model must represent information in terms of its generation and usage of information variables. It should focus on how information is used by the decision-makers in the organisation to control the essential activities. It should incorporate the control policies which use the variables and represent information flow in terms of the source, destination, communication pathway, communication delays and quality attributes associated with each variable used in these control policies.

In other words, the test bed for measuring effectiveness, must be a model of the organisation activities, not a model of the CIS as in the measurement of technical performance. In System Dynamics terms, the model will represent the organisation in terms of its physical and information flows and the policies which represent the impact of one upon the other.

To maintain the amenability of such a model to analysis, it was hypothesised that the impact of the CIS on the whole organisation could be inferred by study of a representative activity. This hypothesis makes the clear assumption that it is possible to define a representative activity. In other words, it presupposes that the activities within the organisation under study can be defined in terms of a common set of attributes and characteristics such that only the relative values of the parameters associated with the attributes vary between activities. In complex organisations, it may be that activities have to be classified into groups, with a number of

representative activities being modelled.

For an activity to be viewed as truly representative of its group, its behaviour relative to the CIS, both in a qualitative and quantitative sense, would be independent of its parameter values. This would have to be substantiated by analysis of the behaviour of more than one activity from a group.

If, in the event, the CIS-related behaviour of an activity is dependent on its specific parameters, then the concept of a representative activity in relation to CIS assessment is not valid. An alternative approach would be to regard the classification of activities into groups with common characteristics as the basis for the design of a set of generic models. The impact of the CIS on each specific activity could then be analysed by assigning appropriate parameter values and the results amalgamated into a higher level model.

Whether the representative or generic model approach is chosen, sight should not be lost of the larger organisational picture and the dependencies and influences of individual activities on each other. Facilities for the adequate representation of interfacing functions should be included.

Representation of the CIS in the model

It has previously been discussed that assessment of the effectiveness of a CIS relates to whether the increased efficiency of information processing contributes positively to the organisation performance. It is compatible with this definition, that the CIS should be represented in the model, not in its physical manifestation, but in terms of its effects on organisational activities, reflecting the human and organisational view of changes in the attributes of the information system.

Determination of the effects of the CIS requires the translation of the technical and design specification of the proposed system into statements expressed in terms of organisational variables, terms which are meaningful and specific to the organisation and its members. It should involve consultation with all interested parties. By addressing the question "where will the differences be seen?", it forces the breakdown of abstract concepts into measurable quantities. It is not necessary and, indeed, may not be valid, to assign precise values to the level of change in these effects. Rather, a likely range of values can form the basis for a "what if?" analysis. It is a procedure which has formed the basis for an approach to the evaluation of MRP systems (Huckersby, 1989).

It was proposed that the CIS be represented in the assessment model by altering the nature and attributes of the information flow to reflect the expected effect of the proposed CIS. Information flow will be represented in terms of the source, destination, communication pathway, communication delays and quality attributes associated with each variable.

Installation of a CIS does not alter the quantity of information that is available in an organisation. Rather, it alters the accessibility of that information by providing the opportunity for that information to be communicated to the decision-maker who can use it to be benefit of the organisation. Sources of information may be able to transmit information more often. Additional sources of information may be provided with the means of communicating that information. Information from one source may be distributed via the CIS to an increased number of destinations by the provision of additional communication pathways. Morecroft models the changes in availability of information resulting from implementation of MRP systems to explore the impact on industry cycles (Morecroft, 1979).

The quality attributes of accuracy and timeliness are closely linked. The accuracy of the information available to a decision-maker is measured in terms of the difference between the decision-makers perception of the state of a variable and the true state of the variable. It is a

function of both time and error factors. Time factors include the delays involved in reporting, transmitting, accessing and assimilating information. Error factors to be considered are those inherent in the methods of observation, reporting, transmission and assimilation. Representing changes in delays is straightforward in System Dynamic modelling. Error factors can be represented by associating each variable with a "probability of error" function.

An additional dimension of quality which must be considered is the value or relevance of information. Value is not an attribute that can represented numerically within a model. Information only has value if it can be used gainfully to enable better decisions and control within an organisation, and its potential value to the organisation must be assessed in the knowledge of the cost of generating and communicating that information. The CIS may provide the means of storing and communicating additional information but its value must be measured by its potential to provide better organisational control and performance. A System Dynamics model, as described, will provide a test bed for measuring the value of the information which a CIS can make available, by feeding the variables into policies and studying the effect of the changes on organisational performance.

The final attribute to be considered is "comprehensibility" which is usually interpreted in terms of the amount of information supplied i.e. has all the required information been presented? It can be represented in the model in terms of the effect on assimilation and processing delays.

A second and equally valid interpretation of comprehensibility is that related to the ease with which information can be understood and interpreted. This dimension is a function of the presentation format, and its match to the particular needs of the decision-maker. In the case where a decision-maker is faced with a number of options then it is entirely conceivable that any ambiguity deriving from presentation format could influence the choice and the resulting quality of the associated decision. The representation of this interpretation in a System Dynamics model is still under consideration.

Ideally, the expected effects of the CIS under study should be broken down so that each effect is a function of possible changes in only one attribute. The extent to which this can be achieved will be dependent on the level of aggregation of organisational functions. Effects may also need to be represented in aggregated form.

Summary

The methodology proposed supports the underlying premise that the effectiveness of a CIS should be measured in terms of its potential to support and enhance organisational performance and objectives. A holistic, macro view of the information system, which focuses attention on the way information is used, is taken. A System Dynamics modelling approach has been adopted to enable the dynamic behaviour of the organisation, both prior to and after the installation of a proposed information system to be studied.

The test-bed model represents the organisation into which the proposed CIS is to be installed and the CIS is represented in terms of its expected effects on organisation activities or processes. It was hoped that, by focussing on the flows and dependent decisions and operations of one representative function, assessment could be achieved without multi-characteristic modelling.

The model will enable study of how the present policies and structure of the organisation might restrict the effectiveness of the information system and the changes necessary to realise the full potential of the system. This will facilitate decisions on the acceptability of a proposed system both in terms of the relative costs of the system and the cultural and operational changes required to maximise its benefit.

A three stage methodology to measuring effectiveness of CIS is proposed:

STAGE 1: The development of a model representing the control and operation of a representative essential activity of the organisation, prior to the proposed modification or installation of the CIS.

STAGE 2: The modification of the stage 1 model to incorporate the expected changes in the information flow attributes resulting from the installation/modification of the CIS, and the subconscious changes to control policies and decisions which will be implemented as a result of the expansion of the cognitive boundaries of decisions (i.e. the influence of the increased availability, accessibility and accuracy of information).

STAGE 3: The identification of the opportunities enabled by the installation/modification of the CIS and an assessment, using the stage 2 model as a test bed, of the structural and/or policy changes required to implement them

The identification of of likely detrimental effects arising from the installation of the CIS and an assessment, using the stage 2 model as a test bed, of the structural and/or policy changes required to avoid them.

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