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Evaluation techniques for systems analysis and design modelling methods – a review and comparative analysis

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Abstract. *Even though hundreds of modelling methods are in existence today, practitioners and researchers are zealously 'producing' new modelling methods. The 'blooming' production of modelling methods is not the problem; the lack of standardized techniques for evaluating them is. To complicate the matter even further, most of the modelling methods have been introduced based on common sense and intuition of the methods' developers. Many of these methods lack theoretical foundations and empirical evidence to demonstrate their worthiness. With the current state of affairs, studies on evaluation of modelling methods have become necessary and critical. Comparing modelling methods provides us with the necessary knowledge and understanding of the strengths and weaknesses of each method. This knowledge can also guide us in our quest for better modelling methods. This paper reviews various evaluation techniques used by both researchers and practitioners. The evaluation techniques are categorized into three classifications: feature comparison, theoretical and conceptual evaluation, and empirical evaluation. This research also analyses the underlying philosophies and assumptions of these evaluation techniques.*

Keywords: modelling methods, feature comparison, metamodelling, ontology, cognitive modelling, action research

1. INTRODUCTION

New systems development paradigms and methods, such as object-oriented (OO) analysis and design methods, business process re-engineering methods, open source development and agile modelling, are constantly emerging (Erickson *et al*., 2005). Despite standardization of systems analysis and design methods such as The Unified Modelling Language (UML), and OO process, environment and notation, it is unlikely that one standard method will suit all situations. In fact, there is a trend leaning towards more-specialized methods and approaches, such as domain-specific modelling methods (Gray *et al*., 2004). The emergence of UML variants is a prime example of this trend. For example, several UML extensions for website development (Conallen, 1999; 2000), component development (D'Souza & Cameron, 1999), enterprise modelling (Marshall, 2000) and real-time applications (Douglass, 2000) have been proposed. Avison & Fitzgerald (2003, p. 81) mentioned that 'OO approach is still evolving with new methods and techniques'. Further, emerging approaches, such as open source development, agile development, service-oriented architecture and service computing, may need new kinds of modelling methods.

Avison & Fitzgerald (1995) pointed out that there are both academic and practical reasons for comparing methods. First, there is a need to compare methods for scientific purposes. Siau (2004) highlighted that most modelling methods were introduced based on the common sense, experience and intuition of the methods' developers. Theoretical foundation is either non-existence or considered non-essential during the methods' development process (Siau *et al*., 1997). Empirical evidence is scanty at best. Methods evaluation, therefore, becomes necessary to better understand the methods (Oei, 1995) and to assess the methods. Both researchers and practitioners want to have a better appreciation of the characteristics, strengths and weaknesses of methods in order to classify them, improve them, and enhance the information systems development (ISD) process. Second, practitioners use evaluation of modelling methods as a practical tool for selecting methods and tailoring methods for organizational uses. This knowledge will enable them to choose a method for a particular application, a specific development situation and an organization. Third, no one method is suitable for all situations. We need to know when to, or not to, use a specific method. Comparing different methods provides a viable means for us to gather this information.

Although there have been numerous studies on methods evaluation and there are a few conferences that are dedicated to the cause [e.g. Method Engineering, Workshop on Evaluation of Modeling Methods in Systems Analysis and Design, and the Comparative Review of Information Systems (CRIS) series], we could not find any research article that comprehensively reviews the existing literature and provides a holistic view of this research area.

This paper attempts to fill the void by surveying existing literature on methods evaluation. As there have been many studies conducted for the purpose of developing new evaluation criteria, this paper does not aim to do that, but tries to present different perspectives on methods evaluation research instead. The nature of discussion in this paper is broad rather than deep, providing a good starting point for future research and serving as a reference on various evaluation techniques.

The rest of the paper is organized as follows. Section 2 defines the information modelling terminology. Section 3 reviews the three categories of methods evaluation techniques. Section 4 discusses the underlying philosophies of various evaluation techniques. Section 5 concludes the paper and discusses future research directions.

2. INFORMATION MODELLING TERMINOLOGY

Information systems models are constructed according to certain modelling methods. During systems analysis and design, various aspects of systems have to be modelled (e.g. structural, behavioral), and the solutions proposed. This requires a multitude of modelling methods. A method is an approach to model an aspect of a systems development project, based on a specific way of thinking. Some researchers also include tools and/or resources in the definition (e.g. Lyytinen, 1987). We, however, make a distinction between tools and methods, because we believe that tools that support modelling methods form a separate research discipline (e.g. Computer Aided Software Engineering (CASE) research). Methods should also be differentiated from methodologies, which discuss procedures or steps for methodical systems development.

Every modelling method uses a small set of constructs (Siau *et al*., 1996; 1997), which defines the vocabulary of the method. Constructs are concepts, ideas or images specifically conceived for a given modelling method for the purpose of organizing and representing knowledge of interest. For example, in Data Flow Diagram (DFD), the main constructs are data flows, data stores, processes and external entities. In Entity-Relationship Diagram (ER), the main constructs are entities, relationships and attributes. For the Use Case Diagram in the UML, the main constructs are actors, use cases and various types of relationships. Other examples of constructs include components, fragments and packages. The organization of constructs defines the world view of a method and specifies the limits of what can be modelled with a given method (Hirschheim *et al*., 1995).

3. MODELLING METHODS COMPARISON AND EVALUATION

In an effort to provide a holistic view of this research area, we have surveyed existing literature on methods evaluation and offer a classification of these techniques to facilitate broad discussions.

Based on the review of the existing methods evaluation studies, we classified the methods evaluation techniques into three categories:

1 feature comparison;
2 theoretical and conceptual investigation; and
3 empirical evaluation.

The three categories of methods evaluation techniques correspond well to the approaches in comparing systems development methodologies. Feature analysis is a common technique to perform methodology comparison (Avison & Fitzgerald, 1995). To overcome the subjectivity of the feature analysis, Bubenko (1986) offers three alternatives:

1 theoretical investigations of concepts and languages;
2 experiences of actually applying the methodology to realistic cases; and
3 cognitive-psychological investigations.

Not all of the studies fit neatly into the suggested categories, especially new articles that tend to take a more multi-methodical approach or try to triangulate their approaches (Mingers, 2003). In the following, we described and discussed each category of the methods evaluation techniques.

3.1 Feature comparison

The first broad attempt to compare methods according to certain 'yardsticks' can be found in the CRIS series of conference (Olle *et al*., 1982; 1986). The studies in this subcategory were typically based on the idea of using different methods to model the same domain (e.g. the famous conference organization case) and to determine how the various methods tackle the same problem (Olle *et al*., 1982). For a while, this technique was a dominant way of comparing methods (Olle *et al*., 1986).

Using this evaluation technique, researchers developed a 'checklist' of ideal method features. The checklist was then used to evaluate methods either across or within the same modelling paradigm. For example, Yadav *et al*. (1988) used this technique to compare different structured methods. Tozer (1985) applied the technique to evaluate different data modelling methods. Hong *et al*. (1993) and Iivari (1994) used this technique to study different OO methods. In addition, Loy (1990) and Strom (1986) used the feature comparison technique to study OO vs. structured development methods, and OO vs. process modelling respectively. Other examples include the comparisons of OO methods (Champeaux & Faure, 1992; Monarchi & Puhr, 1992) and the study of Normative Information Model-based Systems Analysis and Design (NIMSAD) (Jayaratna, 1994). Bielkowicz & Tun (2001) used this technique to compare requirements engineering methods. Henderson-Sellers applied this technique to compare UML and other OO methods (Barbier & Henderson-Sellers, 2000; Henderson-Sellers *et al*., 2001). Weber & Zhang (1996) formalized this technique towards ontological analysis when they evaluated Nijessen Information Analysis Model (NIAM).

The problem of using feature comparison techniques is their subjectivity. There are at least two levels of subjectivity involved. First, some researchers have to develop the 'checklist', and this is often a very subjective task. Next, researchers (not necessarily the same researchers who came up with the checklist) have to analyse the criteria in the checklist to evaluate the methods, and interpret the vague descriptions provided by the designers and developers of the methods. On the upside, this evaluation technique is relatively easy to perform if the criteria in the checklist are well defined.

3.2 Theoretical and conceptual investigation

In order to reduce the problems of subjectivity inherent in the feature comparison, some researchers have proposed carrying out studies which are based on well-defined and narrow subject areas within specific terms of reference (Bubenko, 1986). This has led to the formalization of evaluation based on properties of metamodels and other reference disciplines such as cognitive psychology and philosophy.

3.2.1 Metamodelling

One of the conceptual techniques for evaluating modelling methods is to use their metamodels as a basis for analysis. In its simplest form, a metamodel is a conceptual model of a development method (Brinkkemper, 1990). Metamodelling can be defined as a modelling process that takes place at one level of abstraction and logic higher than the standard modelling process (Gigch, 1991). A metamodel captures information about the concepts, representation forms (or signs) (Leppänen, 1994), and uses of a method.

Attempts to use a common metamodelling language for evaluating methods have been concentrated on mapping methods to some 'supermethod', or comparing models of methods by identifying their common parts (Song & Osterweil, 1992; 1994; Hong *et al*., 1993). Oei and his associates (e.g. Oei *et al*., 1992; Oei & Falkenberg, 1994; Oei, 1995) introduced a formal language for modelling methods and transforming them into a method hierarchy. Harmsen & Saeki (1996) took this view a little further by evaluating four method description languages based on their metamodels. Halpin (1999; 2002) used metamodelling to compare ER, Object-Role Modelling and UML. These characterization-based techniques have evolved directly from the feature comparison techniques. Despite their similarities, proponents of metamodelling pointed out that this technique is more objective than feature comparison technique due to the fact that researchers have based their analysis on modelled characteristics, rather than on an *ad hoc* compilation of 'checklists' and the identification of features based on the vague documentation on various modelling methods (Tolvanen *et al*., 1996).

If a common metamodel becomes standardized and method developers begin to use it to formalize their methods' definitions, it could be beneficial to the method development community at large. There are some promising steps towards this goal. Nevertheless, unless there is a single dominant or 'right' metamodelling method, each metamodelling technique will produce slightly different results due to the varying and different views of the world.

3.2.2 Metrics analysis

The metrics analysis aims at analysing the complexity-based features of methods based on a standardized set of method metrics, as proposed by Rossi & Brinkkemper (1995; 1996). This technique analyses a formal metamodel of a method and computes the metric values. The metric values can be compared to reference values provided in other research (e.g. Rossi & Tolvanen, 1996; Tolvanen & Rossi, 1996; Tolvanen *et al*., 1996; Rossi, 1997; Siau & Cao, 2001). McLeod (1997) applied function points to compute values for method metrics. Siau & Cao (2001) used the metrics to study the diagramming techniques in the UML. These metrics can provide a valuable aid for comparing methods, but more empirical work is needed to validate the metrics. Work by Siau and his associates (e.g. Siau & Tian, 2001; Siau *et al*., 2005) provides some evidence on the reliability of metrics evaluation.

The metrics technique is a simple and systematic way of evaluating methods. However, coming up with a set of valid and reliable metrics is not easy. For example, Siau *et al*. (2002; 2005) argued that the values produced by Rossi & Brinkkemper's (1995; 1996) metrics are related to theoretical complexity, as the metrics count every object and relationship types in the modelling methods and treat all the constructs as equal (i.e. same weight). However, some constructs are more important and used more often than others. As such, different constructs should have different weights. Theoretical complexity may not be the same as the complexity encountered in practice, which Siau *et al*. (2002; 2005) termed as practical complexity. Metrics technique, nevertheless, is a viable means for evaluating methods, but more research is required to validate and fine-tune the metrics.

3.2.3 Paradigmatic analysis

Several researchers have studied the assumptions behind systems development methods. Notably, researchers of the so-called Scandinavian school of thought, which questioned the technical focus of methods and their comparisons, were strong proponents of this technique. Bjørn-Andersen (1984) and Bubenko (1986) analysed the values and the underlying assumptions or world views of the methods. This paradigmatic analysis area consists of several general frameworks for method analysis. An example is the Iivari & Kerola's framework (1983), which addresses contemporary schools of thought of information systems. Hirschheim and Klein also published a few articles on the underlying paradigms of methods (e.g. Hirschheim & Klein, 1989) and a book (Hirschheim *et al*., 1995). They applied a number of meta-frameworks to position modelling methods according to the underlying assumptions of the methods. Wood-Harper & Fitzgerald (1982) summarized this area of research and identified the major approaches or schools of thought of ISD. Iivari & Hirscheim (1996) and Iivari *et al*. (1998) followed the paradigmatic analysis of Burrell & Morgan (1979) to study the underlying assumptions of modelling methods on organization development process and nature of the systems under development. They also developed a 'dynamic' classification schema for rapidly evolving methods (Iivari *et al*., 1999).

It is interesting to see that despite the effort of these researchers to widen the scope of methods evaluation, many tend to see the newest or broadest approaches as the best ones. The approaches that are 'emancipatory' or 'intersubjectivic' are seen as being categorically superior to technical and individual approaches. While this opinion may be correct, there is little empirical evidence to support it, except for the fact that technical approaches have failed quite often (Glass, 1998).

Although paradigmatic analysis may not be directly applicable to end-users, they can be valuable aids in selecting a method for use within an organization, as Avison & Fitzgerald (1995) have pointed out. These general paradigmatic differences in methods can be of great help in 'bashing' through the method jungle by at least pointing to the part of the jungle to search for the 'best' or most-suitable method.

3.2.4 Contingency identification

Contingencies as well as situations on hand usually have a significant impact on actual systems development process. The contingency identification technique to methods selection uses heuristics to minimize risks and identify problems that are to be addressed by the methods. These rules of thumb can be of great help to practitioners (Davis, 1982; Benyon & Skidmore, 1987; Avison & Wood-Harper, 1991). Davis (1982) proposed that the criteria for selecting methods be based on project contingencies such as: (1) the problem under investigation; and (2) the people who perform the investigation. Some researchers (e.g. Schipper & Joosten, 1996) argued for multidimensional or triangulation approach, which combines contingency technique with other evaluation techniques. For example, Avison & Fitzgerald (1995) developed a 'multi-level' technique, where they applied a contingency technique together with a paradigmatic analysis which then continued into a feature analysis. They claimed that this technique could satisfy the needs of the researchers, and simultaneously aid the practitioners.

3.2.5 Ontological evaluation

Wand & Weber (1990; 1993; 2004) proposed the use of ontological concepts to study systems analysis and design modelling methods. Wand and Weber's ontological model is based on and adapted from Bunge (1977; 1979). The basic idea is to evaluate the constructs in existing methods by matching them with ontological constructs. Wand & Weber (1993) argued that one-to-one mapping should exist between ontological constructs and modelling constructs. They introduced the notions of construct overload, construct redundancy, construct excess and construct deficit (Wand & Weber, 1993).

1 Construct overload: When one modelling construct maps into two or more ontological constructs.
2 Construct redundancy: When two or more design constructs are used to represent a single ontological construct.
3 Construct excess: When a modelling construct does not map to any ontological construct.
4 Construct deficit: When an ontological construct does not have any corresponding modelling construct.

Opdahl & Henderson-Sellers (2002) applied the Bunge–Wand–Weber Ontology to evaluate the UML. Green & Rosemann (2004) provided a synopsis of their studies using ontology. One of the advantages of using an ontological model for evaluation is that it is derived from a philosophical foundation – Bunge's Ontology. However, the question of why Bunge's Ontology was chosen has been raised.

3.2.6 Cognitive evaluation

As modelling methods are intended to capture the knowledge of the problem domain for the purpose of communication and understanding among the project team members (Mylopoulos, 1992), it is important to understand the cognitive aspect of modelling (Siau, 1999). Cognitive psychology is the scientific study of mental events. Some researchers (e.g. Siau, 1997; Siau, 1999; Siau & Tian, 2001) proposed the use of cognitive psychology as a theoretical foundation for evaluating modelling methods. For example, Siau (2004) proposed the use of informational and computational equivalence, based on the theory by Simon (1978), to compare modelling methods. Also, Siau (1997) introduced the Goals, Operators, Methods, and Selection rules (GOMS) technique, a popular theory in human–computer interaction, as a way to evaluate modelling methods. The GOMS technique was applied in Siau & Tian (2001) to evaluate the nine diagramming techniques in the UML.

Cognitive mapping is another technique for evaluating systems analysis and design methods, and has been gaining popularity in systems analysis and design research (e.g. Siau & Tan, 2005a,b; 2006). Cognitive mapping is a general term that applies to a series of techniques for describing mental images that subjects used to encode knowledge and information. For example, in Siau & Loo (2002; 2006), the authors used cognitive mapping to study the difficulty in learning the UML. Siau & Shen (2002) also applied cognitive mapping technique to understand the representation problems in the UML.

The use of cognitive evaluation has the benefit that the techniques are generally well developed and tested in their respective disciplines. The strengths and weaknesses of the techniques, possible applications of the techniques, and ways to overcome the limitations of the techniques are well documented in the respective disciplines. However, applying existing techniques from other disciplines to evaluate systems analysis and design methods is a challenge in itself. The fit of the techniques to methods evaluation needs to be further studied, and the techniques may need tailoring.

3.3 Empirical evaluation techniques

Empirical evaluation techniques are another means of evaluating systems analysis and design methods. Empiricism is said to denote observations and propositions based on sense experience and/or derived from such experience by methods of inductive logic, including mathematics and statistics (Cooper & Schindler, 2005).

3.3.1 Surveys

Surveys gather data on attitudes, opinions, impressions and beliefs of human subjects via questionnaires. This technique allows for the testing of *a priori* hypotheses and offers an iterative approach to the generation of hypotheses. Survey research involves the collection of information through the process of solicitation of information from participants in some structured format. Survey data are gathered via a sample, which is a fraction of the population, with the need to be able to generalize findings from the sample to the population. Although the use of survey is a popular research methodology in behavioural research, the number of studies that use survey technique to evaluate systems analysis and design methods is quite limited. Necco (1987) surveyed computer users to determine systems analysis and design approaches that were used by organizations. Fedorowicz & Villeneuve (1999) used a survey to gather the information systems professionals' perception of OO approach. Fitzgerald (1996) surveyed the use of methods in software organizations.

One of the main difficulties in using surveys is the low response rate. Typical response rates range from a low of a few percentage points to a high of 20–30%. Wand *et al*. (1997) used questionnaires to evaluate the effectiveness and efficiency of DFD and OO methods over a 3-year period. They managed to solve the problem of low response rate by using students as the respondents. Another reason for the unpopularity of survey in modelling methods evaluation research is that it captures perceptional measures. To many researchers, this weakness is an unwarranted limitation, as objective rather than perception measures can be used. However, proponents of the survey technique counter-argue by stressing that the adoption of modelling methods by individuals and organizations is based on the perceived usefulness and advantages of the methods, rather than via objective measures.

Surveys, in comparison with experiments, are often characterized by a high degree of representativeness, but have a low degree of control over extraneous factors. Surveys usually use a random sampling technique, which yields the confidence of the representativeness within specified limits. Due to the fact that surveys do not have experimental and control groups, other factors besides the independent variables may have produced changes in the dependent variables. In general, survey can be a good evaluation technique for systems analysis and design methods, especially if the objective is to gather perception information from many geographically dispersed practitioners.

3.3.2 Laboratory experiments

Experiments in general involve taking actions and observing the consequences of the actions. Experimentation is appropriate for hypothesis testing and is better suited to explanatory rather than descriptive purposes. Numerous laboratory experiments on comparing modelling methods have been conducted (e.g. Jarvenpaa & Machesky, 1989; Jih *et al*., 1989; Batra *et al*., 1990; Davis, 1990; Batra & Davis, 1992; Siau *et al*., 1995; 1996; 1997; Marakas & Elam, 1998; Agarwal *et al*., 2000; Kim *et al*., 2000; Bodart *et al*., 2001; Zendler *et al*., 2001). In a laboratory experiment, the researcher assigns subjects to treatment and control conditions, manipulates the independent variables (e.g. different modelling methods, different modelling constructs), and measures the effects of the independent variables on the dependent variables (e.g. accuracy of modelling, accuracy of interpretation, confidence level, time taken). The strength of a laboratory experiment is the ability to control intervening and confounding variables. Comparing modelling methods using laboratory experiments is a popular technique for many Management Information Systems researchers. For example, Batra & Davis (1992), Batra *et al*. (1990), Davis (1990), Jarvenpaa & Machesky (1989), Jih *et al*. (1989) and Zendler *et al*. (2001) investigated the differences between modelling methods using laboratory experiments with model construction as the task. Kim *et al*. (2000) conducted a laboratory experiment to assess the usability of multiple diagrams as an integral part of a systems development methodology. Other researchers (e.g. Siau *et al*., 1995; 1997; Siau, 1996) used laboratory experiments to investigate the effect of a modelling construct (i.e. relationship construct in their case) on user interpretation of systems analysis and design models. Focusing on individual constructs is a departure from the traditional approach of looking at systems analysis and design method as the level of analysis. Focusing on individual constructs allows the researchers to investigate the effectiveness and efficiency of each construct in systems analysis and design, which is impossible to deduce at the level of modelling method.

The artificiality of the research settings is one of the main concerns of laboratory experiments, which limits the generalizability (or external validity) of the results. For example, critics would argue that real information systems analysis and design projects are not conducted in a laboratory, but in real organizations. As such, the best modelling method in an artificial laboratory environment may not be the best in a real-world modelling situation. The simplicity of the experimental tasks is another concern, as practitioners sometimes consider the tasks in laboratory experiments to be unrealistically simple. Many researchers running laboratory experiments also used student subjects. Critics would argue that student subjects are not the same as systems analysts. However, this depends very much on the type and nature of the experiments. For certain type of research (e.g. studying learning difficulties in a modelling language), one would even argue that student subjects are the most ideal. In short, if determining causality and the ability to control extraneous variables are important, laboratory experimentation is probably the best technique available.

3.3.3 Field experiments

To overcome the artificiality of laboratory experiments, field experiments take place in a ‘natural setting’. Field experiments enable the development of causal models based on information gathered in natural, and hence, more generalizable settings for studying phenomena which could not be easily replicated in a laboratory setting. The researcher manipulates the independent variables and, at the same time, tries to control the most important intervening variables (as it is impossible to control all the intervening variables in the field environment). The researcher then measures the effects of the independent variables on the dependent variables by systematic observation of human subjects. Field experiments are more difficult to conduct than laboratory experiments. Gaining access to organizations is not easy, as most organizations are reluctant to allow researchers to conduct experiments. As such, there is a paucity of field experiments conducted in the area of modelling methods evaluation. Another reason for the paucity of field experiments is that most organizations do not subscribe to a particular modelling method. Rather, they adapt and modify existing methods for their own use (Wynekoop & Russo, 1993). For example, they may use an OO approach for systems analysis and design, but their OO approach is based on a ‘home-made’ recipe. One potential confounding variable in running field experiments is the ‘purity’ of subjects – they are usually familiar with a few modelling methods. For example, they may use an OO approach, but their thinking process is still based on structured approach. One example of field experiments is Abrahamsson (2003), who reports a controlled field study on applying extreme programming practices.

3.3.4 Case studies

According to Yin (1989), case studies can be applied when a ‘how’ (exploratory) or ‘why’ (explanatory) question is being asked about a contemporary set of events in which the investigator has little or no control. Case studies can describe phenomena, help researchers build theories, or test existing theoretical concepts and relationships. Using this technique, a particular subject, group of subjects or organizations using one or more modelling methods are observed by the researcher without any intervention. No independent variables are manipulated, no control is exercised over intervening variables, and no dependent variables are measured. Case studies also attempt to capture and communicate the reality of a particular environment at a point in time. However, not too many researchers are using case studies to evaluate modelling methods. Oliveira *et al*. (1996) modelled an industrial application with DFD, ER and OO methods, and found that multi-modelling methods are of great values in practice with each of the methods representing some aspects of the complex environment. The case study used the framework developed in Lutherer *et al*. (1994) as a common reference for modelling methods comparison purposes. Kawalek & Wastell (1999) conducted a case study to evaluate the usefulness of the Viable System Model. By implementing this new model in a database project, the sales team in this case showed significant improvements. Fitzgerald (1997) augmented his surveys with case studies on systems development practices in organizations. Salo & Abrahamsson (2004) augmented their laboratory experiments with a controlled case study.

As case studies do not require the researchers to intervene in the normal operations of organizations, organizations are usually more accepting of this type of research being conducted. The main concern with this technique is the subjectivity of the researchers' interpretation. The research site is rarely (if ever) randomly selected. This represents one level of subjectivity. Second, the observation is usually interpreted by the researchers alone (or in small groups) – another level of subjectivity. Triangulation is an approach to partly overcome the subjectivity involved in case studies. Case studies are low on control, and low on representativeness. It is difficult to differentiate the cause from the effect, and inferring from the intensive study of one or a few cases involves a high and generally unknown amount of risk. The major advantage of case studies is the richness of data, something that surveys and experimentation are unable to match.

3.3.5 Action research

Action research is the application of fact-finding to solving practical problems. It involves the collaboration and cooperation of researchers and practitioners. Action research allows the researcher to become a part of the research – to be affected by, and to affect, the research. The objective of this technique is not the finite testing of a particular hypothesis but the realization of the 'human creative potential'. Human subjects are 'of the essence'. For example, this technique allows the researchers to take part in the modelling process (usually as consultants) and report their experience. Not only is the objectivity of the interpretation a concern, but the effect of the researchers' involvement in the modelling process is also an issue. Nonetheless, this technique can provide deep understanding and insights on the modelling methods that are very difficult to capture if one is not immersed in the actual modelling process. One could argue that the work of Baskerville *et al*. (1992) on 'amethodical' thinking falls into the category of action research.

3.3.6 Verbal protocol

An important addition to the cognitive evaluation discussed earlier is the think-aloud process-tracing technique, which is also referred to as the verbal protocol analysis (Ericsson & Simon, 1980; 1984). In protocol analysis, subjects are asked to ‘think aloud’ as they solve a problem. This verbal trace of problem-solving activity documents the information and strategies used. Audio and/or video recordings of these verbal protocols are then transcribed and systematically analysed. As an introspective method for studying how people conceptualize specific aspects of reality, the think-aloud process-tracing method helps us to open the ‘black box’ of decision processes during modelling, and constructing and verifying conceptual models (Srikanth, 1994). Siau (1996) used verbal protocol to study the use of relationship construct in modelling. Purao *et al*. (2002) utilized it to understand designed intentions when applying UML.

4. DISCUSSION

In the previous section, we have described and discussed different methods evaluation techniques, including their advantages and limitations. We extend our discussions in this section to address the underlying philosophies of these evaluation and comparison methods.

In Avison & Fitzgerald (1995), the authors provide detailed discussion about the philosophy elements of a methodology, i.e. ontology and epistemology. ‘Ontology is concerned with the essence of things and the nature of the world’ (Avison & Fitzgerald, 1995, p. 448). Two positions of realism and nominalism exist in terms of ontology. Realism postulates that the universe comprises objectively given, immutable objects and structures (Hirschheim, 1991). Nominalism, on the other hand, postulates that reality is not a given immutable ‘out there’, but is socially constructed (Hirschheim & Klein, 1989). ‘Epistemology is the grounds of knowledge . . . [relating] to the way in which the world may be legitimately investigated and what may be considered as knowledge and progress’ (Avison & Fitzgerald, 1995, p. 448). Two extreme positions identified as positivism and interpretivism exist along this dimension. Positivism implies that the scientific method can be used to investigate the causal relationships, whereas interpretivism implies that there is no single truth that can be proven by such investigation (Avison & Fitzgerald, 1995). Lewis (1994) proposed a framework that identifies objectivist and subjectivist approaches to ISD. The identification is based on the positions along the ontology dimension of realism and nominalism, and along the epistemology dimension of positivism and interpretivism. According to Lewis’s (1994) framework, an objectivist approach is both realist in ontology and positivist in epistemology, and a subjectivist approach is both nominalist and interpretive.

With a similar logic, we propose a framework to identify the methods evaluation techniques by positioning them along these two dimensions (ontology and epistemology) to discuss their underlying philosophies (Figure 1).

Quadrant I (realism and positivism)

The techniques in quadrant I are realism in ontology and positivism in epistemology. Compared with other techniques, these techniques in quadrant I are more objective. This is the case for theoretical and conceptual investigations: metamodelling uses methods’ metamodels as a basis

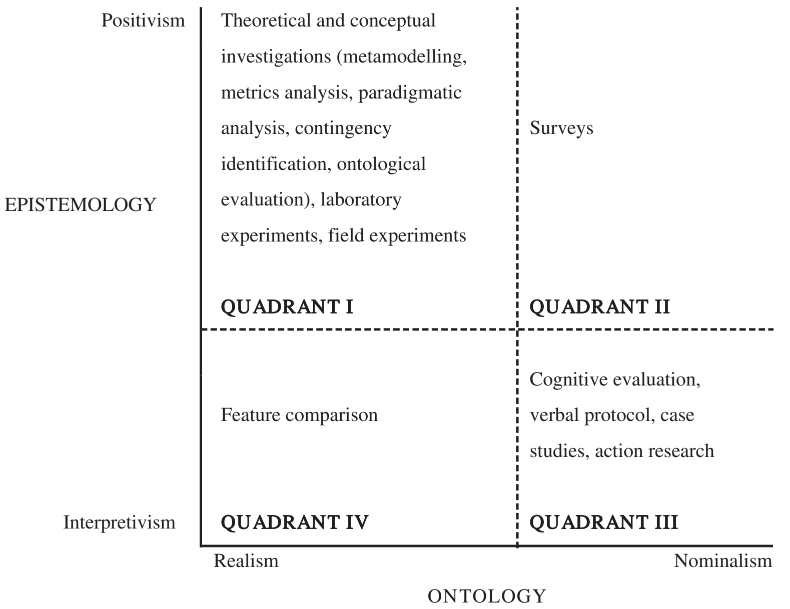

Figure 1. Framework for analysing the underlying philosophies of methods evaluation techniques.

for analysis; metrics analysis aims at analysing the complexity-based features of methods; paradigmatic analysis focuses on the analyses of assumptions behind systems development methods; contingency identification provides heuristics for minimizing risks and identifying the problems; and ontological evaluation compares the constructs in existing methods by matching them with ontological constructs. Experiments, as a type of empirical evaluation techniques, aim to be objective by controlling and manipulating variables to determine relationships among variables. In essence, these techniques try to be independent of the observer's appreciation of the modelling methods as much as possible. These techniques use either narrow and well-defined subject areas (such as Bunge–Wand–Weber Ontology or metamodels) or control, and manipulate variables to reach explanatory conclusions on methods evaluation.

Quadrant II (nominalism and positivism)

The techniques in quadrant II are nominalist in ontology and positivistic in epistemology. Nominalism believes that reality is not a given entity but is socially constructed. Surveys are located in this quadrant because this technique aims at gathering data on subjects' attitudes, opinions, impressions and beliefs on systems analysis and design modelling methods. Positivism implies the existence of a 'truth' that can be investigated using scientific methods. The questionnaires used in surveys are often tested for the validity and reliability to ensure the scientific inference of the outcomes, reflecting the nature of positivism in epistemology.

Quadrant III (nominalism and interpretivism)

The techniques in quadrant III are nominalism in ontology and interpretivism in epistemology. According to nominalism, reality is constructed by individuals involved in the research situation. Thus, researchers with this assumption need to report the multiple realities, relying on voices and interpretations of informants. With the interpretivism epistemological assumption, researchers interact with study participants and try to minimize objective separateness (Creswell, 1998). The methods evaluation techniques in this quadrant are subjective in nature. Through indirect (cognitive mapping) and/or direct (think-aloud protocol) methods, researchers can capture users' subjective understanding and cognitive aspects of modelling methods. The reported evaluation and comparison based on the cognitive psychology techniques essentially reflect one or more of multiple realities. Case study and action research, on the other hand, capture and communicate the reality of a particular environment as interpreted by the researchers at a point in time.

Quadrant IV (realism and interpretivism)

We put feature comparison techniques in quadrant IV, where the ontological assumption is realism and the epistemological assumption is interpretivism. The existence of a 'checklist' by the authors of such studies reveals their belief that there are a set of ideal features that are relevant in the comparison of methods. The interpretivism stems from the subjectivity involved in the process of developing 'the checklist', evaluating and analysing the criteria, and interpreting the vague descriptions of different methods. In other words, no single truth about the methods evaluation and comparison can be shown by such investigations.

It should be noted that our discussions on the underlying philosophical assumptions of the existing studies do not intend to address the legitimacy of these studies. Instead, we try to synthesize different perspectives and provide a good starting point for further discourse. As method developers, ISD researchers and practitioners need different kinds of evaluation tools and criteria, a framework such as Figure 1 allows the selection of suitable evaluation technique for a given use.

5. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This paper reviewed various techniques that can be used for evaluating systems analysis and design methods. As we can see from the analysis, the evaluation techniques range from technically sophisticated to non-technical (e.g. experience reporting), non-empirically oriented to empirical approaches, and mathematical-based to cognitive or philosophical in nature. In this paper, we classify the techniques into four categories. The pros and cons of each technique are discussed and prior studies are documented. We further the discussion by examining the underlying philosophical assumptions of various evaluation techniques.

We must stress that different evaluation techniques fit different purposes. Some of the rigorous and formal techniques are suitable for scientific analysis of methods, whereas more subjective evaluation techniques can be very fruitful for finding appropriate methods for a given practical situation. Selecting one technique over another usually means trading off one aspect for another (e.g. internal validity for external validity). It should be stressed that none of these techniques is inherently superior to others. Also, using a combination of techniques (Mingers, 2003), instead of only one, enables the researchers to corroborate the results and to provide more convincing and reliable findings. The choice of evaluation techniques that are applicable in a given situation should be based on the research questions, the environment, the strengths of the researchers, and the opportunities available.

As there is still considerable debate over whether methods aid or hinder systems development, we believe that thorough investigations of method usage would be very fruitful. We believe that it is important to evaluate methods both conceptually and empirically, and we propose further studies based on our findings. There is a well-developed body of literature on feature comparisons and formal metamodelling of methods. There is, however, little research on empirical evaluation of methods in practical settings despite repeated calls for this type of studies. Despite the problems inherent in organizational studies, we strongly believe that there is a need for field experiments, case studies and action research to study the usability and actual usage of modelling methods in organizations.

It is also ironic that many developers of new methods based their development effort on their intuition, common sense and gut-feeling. Little or no attention is paid to theoretical foundation and/or existing findings in the literature during the methods' development process. We argue that it is not only important for academic researchers to produce results and findings that are useful to practice, but also important that developers of modelling methods utilize existing knowledge (theories and findings) to guide their development or engineering efforts. The same argument applies to practitioners trying to decide on a modelling method to use or attempting to tailor a modelling method to their organizational needs. There is much that the research on evaluation of modelling methods can contribute to academics, practitioners and methods' developers.

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