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Process and Object Models in Software Engineering: A Study of Their Choice and Subsequent Use

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ABSTRACT

This paper provides a research model to analyze how decisions relating to the choice of modeling approach are made in the context of software engineering and how behavioral variables account for the intention and actual use associated with conceptual modeling frameworks. Modeling approach refers to the part of system development that involves investigating the problems and requirements of the users community and from that, developing a specification of the desired system. To that extent the choice of the conceptual modeling approach is a function of the methodology adopted for the entire software development lifecycle. We consider two broad classes of methodologies – the process-oriented approach (also known as the structured approach) and the object-oriented approach. We formalize the question whether there is a difference between object-oriented and structured approaches when it comes to requirements modeling. Secondly, we study decisions processes regarding the adoption of either an object-oriented, structured or combination approaches.

Keywords

Modeling approach, object-oriented, process-oriented.

INTRODUCTION

This study focuses on the determinants and influencers of the choice and use of modeling approaches (MA). Modeling approach refers to the part of system development that involves investigating the problems and requirements of the user community and, developing a specification of the desired system from that (Rolland and Cauvet, 1992). MA addresses two issues: the modeling product (the so-called conceptual schema) and the modeling process (the procedure, techniques and methodology to deliver the conceptual product) and is carried out in the requirements engineering phase. Two major approaches to modeling are structured analysis (SA) and object-oriented (OO) approaches. While there is a huge push to adopt OO approaches, the rate of absorption has not been high. This has been attributed to perceptions and organizational and social issues in the larger software development environment (Perry et al., 1994). Our objective is to develop a research model that can be used to study the choice and use of MA.

Thus far, in the context of MA, researchers have emphasized the design and programming aspect of the software development lifecycle. This has led to the introduction of a variety of conceptual models by which the conceptual schema can be specified so that the software product can be engineered better. Conceptual models consist mostly of modeling concepts and guidelines related to a language for specifying both the structure and the behavior of a system that make the transition from design to product engineering smoother. Such models have contributed to fundamental aspects in conceptual modeling such as modeling of complex objects, system behavior modeling and time modeling. The current evolution of conceptual models places a heavy emphasis on robust and reusable software and is strongly influenced by the principles of the object-oriented approach.

Given the importance of behavioral factors on upstream software development processes and the lack of empirical research on this subject (except for Agarwal et al. (1996 and 1999) and Kanungo, 2002) which focus on only a part of what is being investigated), we ask the following questions. How is the decision regarding the choice of a modeling approach made in a project? How does the decision and decision process influence subsequent use of the modeling approach? How do individual beliefs and attitudes affect the use of a modeling approach? If they do, how, and under what circumstances do they enhance or inhibit an individual modelers effectiveness? In order to respond to these research questions we will review the relevant literature to develop a research model. Finally, we derive implications for research and practice.

THEORETICAL DEVELOPMENT

A modeling approach is an ensemble of techniques, processes and tools that are invoked in the requirements engineering phase of software development. The process of modeling transforms user requirements into a conceptual schema (the product). Given the nature of its use, a modeling approach is considered to be a "technology" since "technology is how people modify the natural world to suit their own purposes." A MA allows modelers to modify users' representations into primitives provided by the MA so as to remove ambiguity and enable communication of these requirements for subsequent steps – design and development.

The nature of the discourse

Deductive arguments and expert observations abound in the debate regarding MAs. An instance of the deductive approach toward analysis of the modeling approaches is the one adopted by Parsons and Wand (1997). The starting point is that object-oriented design methods use ontologies as domain models for specifying software systems. In doing so, object-oriented analysis may interfere with understanding the domain and drawing attention to implementation concerns. For analysis, representation-based foundations are more suitable than implementation-based approaches. In so arguing the weakness of the implementation driven approach of object-orientation, Parsons and Wand (1997), and more recently Kanungo (2004), have argued that representation-based foundations are more suitable than implementation-based approaches. Another instance of such arguments is that implementative considerations rather than conceptual aspects drive the current object-oriented paradigm (Artale, 1996). The object-oriented approach emerged as an implementation paradigm, motivated by the objective of building better software more efficiently (Parsons and Wand, 1997). The implication of such arguments is that conceptualizing the whole system in terms of "objects" is relatively far more difficult that to experience coding improvements as a results of object-orientation. Similar sentiments have been expressed as expert comments. For instance, Glass (1995) reports that in the context of scientific and engineering realm too "users don't think in terms of objects, they think in algorithms and tasks (p.1)." The direct implication is that object-oriented methodologies do not necessarily lend themselves well to understanding and analyzing problems and situations that are inherently process-oriented or have temporal linkages. Consequently, many practitioners depend on "traditional" process-oriented models to analyze business situations and then "translate" those specifications into object-models for implementation.

While we have analyzed object- and process-orientation, studies that predate the widespread use of object-orientation have also remained inconclusive. For instance, Yadav et al. (1988), when comparing Integrated Definition Language (IDEF) and data flow diagrams (DFD) approaches to requirement analysis were not able to make a determination as to which technique yielded a "better result." Recent research is also characterized by inconclusive results. For instance, Duserick (1993) reports tentative findings about how object-oriented approaches produce "better results" than a process-oriented approach to systems analysis. On the other hand, Howard et al. (1998) report that MAs do not seem to account for differences in system design. Their findings are based on a study that showed that systems designs produced by a group that used primarily data-centered methodology were not significantly better than systems designs produced by a group that used primarily a process-centered methodology when applied to a data-intensive system problem. Aggarwal et al. (1996) showed, in controlled experimental settings with students, that DFD's produce higher quality "solutions" in process-oriented tasks and are not inferior to object-oriented methodologies in object-oriented tasks. Such divergent findings with respect to the outcome of MAs have given use reason us to look for differences in *how* these approaches are deployed to seek an explanation for the variation in usage outcomes.

Research propositions

There are two constructs that are of interest in this study. They are the choice of the MA decision and the use of the MA. The study of acceptance of MA lends itself to theories of individual behavior. The most prevalent theory is the theory of reasoned action (TRA) (Ajzen and Fishbein, 1980). This theory states that an individual's behavior (in this case use of MA) is determined by his/her behavioral intentions. A person's behavioral intention is a function of two different factors. The first factor is based on an individual's intrinsic motivations toward the MA. The second factor is extrinsic and is derived from what others (typically supervisors and peers) feel about the MA. Adoption decisions about MA are less understood and we theorize that they lend themselves to be explained by factors such as the decision process in place, number and roles of decision makers, the decision context, goal clarity and risks associated with the decision.

In applying behavioral theories to study the use of MA, we borrow from past studies of information systems use. In particular, we use Hardgrave et al. (2003) as a starting point. In IS studies the domain of technology use is typically the business process and the technology is the "information system." For this research the analogous constructs are software engineering as the domain of technology use and MA as the technology of interest. Since MA almost always manifests itself

as a software-based tool, the MA as a component of a CASE tool or a standalone tool allows us to treat MA as an information technology artifact.

Theories of behavior and fit applied to adoption and use of MA

The technology acceptance model (Davis, 1989) predicts that user acceptance of any technology is determined by two factors: perceived usefulness (PU) and perceived ease of use (PEOU). Perceived usefulness is defined as the degree to which a person believes that use of the MA will enhance his or her performance. Since a MA is an ensemble of techniques and processes, it is considered as a technology and hence we use the TAM. Perceived ease of use is defined as the degree to which a person believes that using the MA will be relatively free of effort. Secondly, we need to formalize the importance of social norms in influencing individual behavior. This means that the more a modeler perceives that others (in the project or organization) who are important to him think she should perform a behavior (use any or a specific MA), the more she will intend to do so (Ajzen & Fishbein, 1980, p. 57). In addition, an individual's confidence in her ability to use a MA (perceived behavioral control) influences not only intention to use a MA but actual use of MA also. These relationships are conceptualized in the theory of planned behavior (Ajzen 1991).

We posit that a MA has a positive impact on a modeler's performance when there is a correspondence between the characteristics of the MA approach (technology) and the task requirement of the users. For instance, the structured approach allows users to convey / describe their tasks in a linear mode (for instance, "I retrieve information item 'a,' then I compute 'b' from 'a,' then I store 'b' in storage area 'c' and then I pass on information 'b' to person 'd' and finally I file both 'a' and 'b' together in a separate location 'e.'"). The OO approach requires users to think in terms of objects (nouns) and actions associated with those objects. Analysts who deal directly with end-users may find it relatively easier to deal with the less formal structured (or process-oriented) approach as compared to analysts who deal with the design team (who may prefer OO formalizations and modeling schemes that is more rigorous). This is an example of interaction between technology characteristics and individual characteristics. Similarly, modelers' tasks can be characterized in terms of knowledge acquisition task (acquiring a comprehensive description of a system), conceptualization task (formalization task by means of a conceptual formalism), validation task (checking whether the conceptual schema is consistent and whether it correctly expresses the requirements informally stated by the users) and evolution management task (concerns the problem of schema evolution according to changes in the real system). Therefore we employ the compatibility construct (the degree to which the MA fits with the potential adopter's existing values, previous experience and current needs) to capture the antecedents of perceived usefulness and perceived ease of use.

These relationships are formalized as research propositions in Table 1.

Hypothesis	Description
H_1	The degree of compatibility of using the chosen MA with existing practices and tasks will positively affect perceived usefulness of the MA.
H_2	The degree of compatibility of using the chosen MA with existing practices and tasks will positively affect perceived ease of use of the MA.
H_3	Perceived usefulness of the MA in use will positively influence the user's attitude toward use of the chosen MA.
H_4	Perceived usefulness of the MA in use will positively influence the user's intention to use the chosen MA.
H_5	Perceived ease of use of the MA in use will positively influence the user's intention to use the chosen MA.
H_6	The user's attitude toward the use of the chosen MA will positively affect the intention to use chosen MA.
H_7	Behavioral intention toward using the chosen MA will positively affect the actual use of the chosen MA.

Table 1: Hypotheses related to technology acceptance

The theory of planned behavior (TPB) holds that attitudes, subjective norms, and perceived behavioral control are direct determinants of intentions, which in turn influence behavior. Taylor and Todd (1995) state that the influence of peers and the

influence of superiors are antecedents to the subjective norm. Taylor and Todd also view self-efficacy, resource-facilitating conditions, and technology-facilitating conditions as determinants of perceived behavioral control. Since tools supporting different modeling frameworks do not exist in a vacuum and neither do software practitioners, the attitudes of clients and peers can positively or negatively influence the attitudes and behavior of MA users. Perceived behavioral control refers to "people's perception of the ease or difficulty of performing the behavior of interest" (Ajzen, 1991). If behavior is not under complete volitional control, the performers need to have the requisite resources and opportunities in order to perform the behavior. The perception of whether they have the resources will affect their intention to perform the behavior, as well as the effective performance of the behavior. There is evidence in the literature that process-oriented modeling approaches are considered easier to use (Agarwal et al., 1999). It is quite possible that based on past experience or because of role requirements, individuals tend to perceive more or less control over use of a specific MA.

These relationships are formalized as research propositions in Table 2.

Hypothesis	Description
H_8	Subjective norm concerning the chosen MA will positively affect the intention to use chosen MA
H_9	The perceived behavioral control with respect to using the chosen MA will positively affect the intention to use chosen MA
H_{10}	A positive relationship exists between perceived behavioral control with respect to using the chosen MA and actual use of the chosen MA

Table 2. Hypotheses related to behavioral control

We have integrated TAM and TPB and tailored it to study MA use along the lines proposed by Taylor and Todd (1995). We have further extended this theoretical model to incorporate how decisions regarding the choice of MA influence eventual MA use.

The decision component

Modeling decisions are complex processes with affective, normative, and control factors expected to be influential. The conceptual modeling decision is often based on hunch and expectations. Therefore, it stands to reason that affective reactions play a significant role in choosing a conceptual modeling framework. Likewise, the influence of peers in the adoption decision is also important. Such normative influences are particularly salient given that those who do not yet have a commitment for one conceptual model or another would be considered later adopters on the diffusion curve (Rogers, 1995). Such later adopters are known to rely on others' opinions to make decisions about innovations (Rogers 1995). Finally, due to the time displacement between the decision to adopt and the actual use behavior, the decision to adopt is considered an antecedent to norms that influence use behavior.

We posit that the process of deciding on the MA is an influencer of how an individual perceives the influences and expectations of others (superiors and peers). We base this on the work of Sawyer and Guinan (1998) who studied software development as a social process. This implies that choice of MA depends on the social dynamics between project team members and others in the organization who are involved in making the choice. The choice of the MA is the outcome of the decision process. The decision process is a major source for an individual to be exposed to these normative influences. The choice of MA may or may not be congruent to user expectations. The resulting dissonance or consonance arising from the choice of the CM framework can then be an influencer of perceived behavioral control – since PBC is a function of self-efficacy with the MA. Note that the link between PBC and actual use, as formally defined by Ajzen (1991), shows that practitioners' use of a MA will be positively related to the user's level of comfort associated with using that MA. In other words, a practitioner will use a MA if s/he anticipates minimum impediments, and available resources and support, for that approach. Similar to the MA adoption decision, the usage model is expected to be driven by affective, normative, and control components. Practitioners hear about the various capabilities and functionalities from peers and industry literature/buzz, thus normative influences play a role in the use of the conceptual model also.

Decision processes (DP) shown in Figure 1 cannot be theorized as completely rational because such decision-making requires information gathering and information processing beyond the capabilities of any organization. In practice, organizational decision-making departs from the rational ideal in important ways depending on: (1) the ambiguity or conflict of goals in the decision situation (goal ambiguity or conflict), and (2) the uncertainty about the methods and processes by which the goals

are to be attained (technical or procedural uncertainty). In the bounded rational mode, when goal and procedural clarity are both high, choice is guided by performance programs (March and Simon, 1993). Thus, decision makers 'simplify' their representation of the problem situation; 'satisfice' rather than maximize their searches; and follow 'action programs' or routinized procedures. In the process mode (Mintzberg et al., 1976), when goals are clear but the methods to attain them are not, decision making becomes a process that is highly dynamic, with many internal and external factors interrupting and changing the tempo and direction of the decision process. In the political mode (Allison & Zelikow, 1999), goals are contested by interest groups but procedural certainty is high within the groups: each group believes that its preferred alternative is best for the organization or the project. Decisions and actions are then the results of the bargaining among players pursuing their own interests and manipulating their available instruments of influence. In the anarchic mode (also known as the Garbage Can model of decision making) (Cohen et al., 1972), when goal and procedural uncertainty are both high, decision situations consist of independent streams of problems, solutions, participants, and choice opportunities arriving and leaving. A decision then happens when problems, solutions, participants, and choices coincide. When they do, solutions are attached to problems, and problems to choices by participants who are present and have the interest, time and energy to do so.

Hypothesis	Description
H_{11}	A positive relationship exists between the perceived decision processes and the subjective norms associated with the chosen MA
H_{12}	The gap between the desired and actual of the MA is negatively related to the perceived behavioral control associated with the MA in use.
H_{13}	The decision process influences the choice of the MA
H_{14}	The decision environment will determine the nature of the decision process

**Table 3. Hypotheses related to MA decisions**

Thus, for both the MA decision and use, our integrated research model is likely to provide a rich description since it accounts for the underlying belief structure. Intention to use a particular MA and use of that approach relies on factors that are influenced by or resulting from the factors that are not accounted for in TAM. The influence of significant others (peers and supervisors) also plays a role in decision-making, is ignored in TAM. The control beliefs incorporated into these models account for factors that may inhibit performance of behavior, such as lack of resources, knowledge, or opportunity for engaging in the behavior (Ajzen 1991; Taylor and Todd 1995). These factors are ignored in TRA and only partially addressed in TAM, yet are particularly relevant for the household environment. Hence our research model encapsulates all these factors and allows for a comprehensive analysis.

The complete theoretical model is shown in Figure 1. The constructs used in that model are described in Table 4.

Construct	Description
Usage behavior	An individual's actual use with respect to the chosen MA (nature and extent of use (Ivari, 1996))
Behavioral intention	A measure of the strength of intention to use the MA that has been chosen
Attitude	Whether a user possesses positive or negative feelings toward the use of the MA in use
Perceived usefulness	The degree to which a user believes that using a particular system would enhance his/her job performance
Compatibility	The degree to which a MA is perceived as being consistent with the existing values, needs and past experiences of the user
Subjective norm	The perception that the user feels that other individual feel strongly about using a specific MA or whether s/he should or should not use the MA
Perceived behavioral control	The perception of the availability of skills, resources, and opportunity with respect to MA in use
Decision process	The dominant model of decision making as perceived by the user in the case of the MA

Construct	Description
	decision and is measured in terms of technical and process uncertainty, ambiguity and conflict.
Decision environment	The decision context, stakeholders, interpersonal interactions. Typically decision environments are negotiated or mandated
Choice of MA	The outcome of the decision process and could be a decision to use OO or PO or a combination of both
Table 4. Constructs and their description	
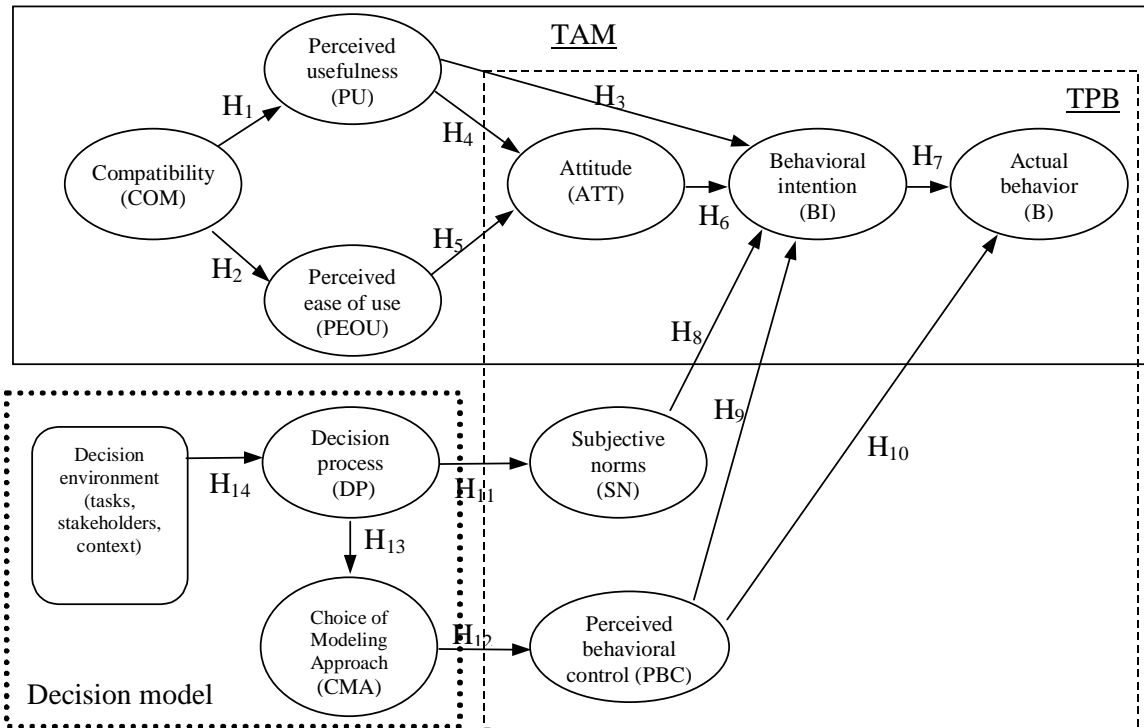
Figure 1. The technology acceptance model (TAM) and the decomposed theory of planned behavior (TPB) extended to incorporate the decision component

DISCUSSION AND CONCLUSIONS

Our model helps in understanding the non-exclusivity of modeling approaches. Kabeli and Shoval (2003) and Soderborg et al. (2003) have argued that it is possible to take advantage of the benefits of the two approaches. Our model provides an explanation of how this can be done. Based on the behavioral control sub-model, it can be seen how in the upstream stages of the SDLC process-oriented approaches would be preferable; however, as the design is decoupled from the analysis, object-orientation would provide far more control for the designers and developers – and would, hence, be preferred.

The contribution of this research is threefold. First, this research is a response to a less understood domain of conceptual modeling. Conceptual modeling is still considered an unstructured domain. Our research is a response to existing research results that are tentative and, at times, conflicting. In attempting to provide results that are more definitive we are addressing the larger issue of adding to the common body of knowledge. The majority of the past research has been conducted entirely in controlled academic settings. Results of our research that is industry-based will be directly applicable in work situations. Our research methodology is a response to the needs of academic rigor as well as relevance.

There are important implications from the finding of this research. From the standpoint of software practice, results could provide guidance to (re-) structure the entire process of software development – especially given that the nature of software construction is also changing to reflect pre-fabricated software components. Such a move should result in a reduced concern for construction-design and free up time and resources for upfront analysis. However, a likely scenario is the limitations placed on information system design by the very presence of finite and robust (and hence cost-effective) pre-fabricated software components. When fewer parts of software will have to be built *de novo*, the emphasis will necessarily have to shift even more toward pre-construction phases.

In specific terms, our study will able to provide answers to some of the process gaps that software organizations still face. For instance, most software organizations do not have a well thought out process for selecting a modeling approach. Our results will provide a framework and an empirical base for software organizations to develop organizational processes to select and deploy modeling approaches. These results could also lead to more informed decisions on choice of methodologies or case tools.

Implications for pedagogy are equally important. Choice and use of a methodology is important. Classroom teaching will benefit from insights into how (and if) a methodology is chosen. Classroom interaction will obtain much needed insights for moving beyond introduction to different methodologies. Empirical findings will allow grounded theories to enable students develop decision-oriented and critical perspectives regarding methodologies and their subsequent use. From the pedagogical standpoint, it will be important to find ways of integrating the main modeling approaches in curriculum and teaching methods. Since many software engineering and systems analysis courses are increasingly becoming tool-centric, findings of this research will be useful in determining the most meaningful strategies for incorporating different aspects of tools in classes and labs. One of the major gaps in the teaching of software engineering or systems analysis courses is the lack of a framework to think through and debate and then choose a specific modeling framework for approaching a problem. Most of the teaching and learning effort is expended on introducing and learning new techniques and models. In short, results of this research will result in the beginnings of "best practices" associated with software development methodology selection.

Our model responds to the fragmented adhocracy that exists in the field of information systems development (Hirschheim et al., 1996). This is characterized by multiple findings, most of which are conflicting. This is a result of the federated research framework at work. In the absence of normative or prescriptive frameworks, consumers of modeling frameworks (users, analysts, designers) do not have a basis to select and use a particular framework or a combination of frameworks. This is reflected in the inefficiencies and delays associated with the selection and consequent use of conceptual modeling frameworks

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