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A QUALITATIVE MODEL FOR BARRIERS TO SOFTWARE REUSE ADOPTION

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Abstract

With the increased pressures to deliver software applications at a faster rate and at a lower cost, software reuse is rapidly becoming an influential technology for software development. In this paper, software reuse is viewed as a systematic approach, encompassing all attempts to leverage software assets across systems by reusing them in development efforts. This paper focuses on grounding a descriptive and explanatory theory of the individual and organizational barriers associated with the adoption of reuse. A *case study* research method was used. A series of five cases were selected on the basis of theoretical replication. The five sites share commonalties in issues critical to the research. The findings of this research indicate that barriers occur at both the individual and at the organizational level. One of the key findings was that barriers at the individual level are actually a consequence of the interaction of barriers caused at the organizational level. Several other significant findings emerged as well.

Keywords: Software engineering, IS development methods and tools, IS project control and software reuse

1. INTRODUCTION

Software reuse has generated much interest among researchers and practitioners as a viable technology for shortening the software development cycle and reducing the cost of building applications. While interest in software reuse has been growing invariably, the outcomes of the adoption process have varied widely (Frakes et al. 1991). Some organizations are capable of adapting to change quickly, others are likely to resist change and stifle the adoption process (Kim and Stohr 1998). Both individual and organizational factors affect the implementation process. The research effort reported in this paper suggests that, by shifting the focus away from the *spirit* of reuse to understanding the individual and organizational beliefs toward the technology, we may be able to better explain the variance in the outcomes of reuse adoption.

Most of the literature on reuse assumes a deterministic position toward the reuse technology (Basset 1997; Mili, Mili and Mili 1995; Poulin 1997; STARS 1993). This resulted in an emphasis on the capability of the technology to achieve productivity gains without moderating the effect of the social and historical context of the organization. Furthermore, there have been studies that exaggerate the economic value of reuse without allusion to the time and costs required to achieve these benefits and the uncertainty in realizing them. Reuse researchers have made use of reuse metrics, collected from a number of high profile organizations such as GTE, AT&T, and HP (Basset 1997). Reports of these organizations demonstrate high productivity gains but typically avoid discussion on problems encountered in developing a reuse infrastructure and the barriers that might stifle the adoption of reuse.

A review of the reuse literature reveals that there is a paucity of studies focusing on barriers to reuse. Researchers have alluded to the importance of non-technical aspects of reuse as a conceivable source of problems (Basset 1997; Fafchamps 1994; Frakes 1994; Hooper and Chester 1991; Joos 1994; SPC 1993; STARS 1993, 1996a, 1996b). Typical causes that are reported revolve around concepts of resistance to change or human nature and personal characteristics (Frakes 1994). As a result, little is known about why developers resist reuse or what aspects of human nature defy the successful implementation of the technology. While researchers suggest that elements of the organizational context are important, these are rarely examined for their effect on the adoption of reuse. Experiences with other technology implementations in the past suggest that without understanding the nature of relationships that might exist between the technology and the organizational elements, including individuals, it will be hard to successfully introduce and implement new technological approaches within the organizations.

Following the grounded theory approach (Glaser and Strauss 1967), this paper qualitatively examines barriers to reuse adoption. The research questions addressed are (1) why do individuals and organizations constrain the adoption of reuse? and (2) what are the forms of these barriers? The study examines the individual beliefs of four reuse stakeholders that have been identified by the literature and supported by practitioners as having the biggest influence on the adoption process. The stakeholders identified are *the reuse expert or reuse champion*, an individual who fosters the idea of reuse and tries to institutionalize reuse across the organization; *asset creators*, individuals responsible for the development of reusable components; *asset utilizers*, users of the assets who are involved in developing business specific solutions; and, finally, *IT managers* who make decisions regarding the development and use of reusable assets.

Our screening process resulted in the selection of five cases. The selection process was based on three selection criteria: interest in reuse; the availability of reuse stakeholders in each of the four categories identified; and the availability of documented experiences or other indications related to barriers to reuse adoption. The organizations were intentionally selected from different industries to extend the generalizability of the findings and to provide a rich explanation as to why barriers occur. The cases included in the study draw from three fundamentally diverse industries: oil and gas, telecommunication, and software consulting.

2. DESIGN AND PROCEDURES

In keeping with the tenets of grounded theory, we alternated between the data collection and analysis to examine if new categories needed to be developed. The process followed is iterative, causing an emergence of new categories as the data is reexamined and recategorized. The constant comparison of categories among the groups helps identify relationships between these categories and formulate interesting hypotheses. During the iterative process of data analysis and data collection, some hypotheses were dropped, others were verified, and new ones emerged. We followed this process until the saturation stage, i.e., when no new modifications were made during the comparison process, and when the list of categories collapsed to a shorter and more abstract list.

2.1 Research Design

A multiple case study approach was adopted to gain an in-depth understanding of the relationships that exist between the adoption of reuse technology and elements of the organization. As suggested by other IT adoption studies (Benbasat, Goldstein and Mead 1987; Bourgeois and Eisenhardt 1988), where possible embedded units within the organization were considered for explaining the existence of barriers to technology. In each case, two levels of analysis were conducted: the first focused on individuals affected by the technology while the other addressed the organizational context in which the technology was being implemented. The four stakeholders included in this study were: reuse champion, asset creators, asset utilizers, and IT management. The beliefs of these stakeholders regarding reuse and their perspective as to why barriers occur were examined in an attempt to identify attributes of the belief system that constrain reuse. Next, two constructs suggested by the Technology Acceptance Model (Davis, Bagozzi and Warshaw 1989), *perceived benefit* and *perceived ease of use*, were utilized. These were suggested by the industry experts as appropriate measures of the stakeholders' belief toward reuse. The perceived benefit of reuse measured the belief that reuse is capable of reducing the cost and time for development of new applications as well as improving the quality of the end product. The perceived ease of implementing reuse examined the stakeholders' beliefs regarding reuse complexity and compatibility with elements of the organizational context. The objective behind these two measures is to unfold any individual resistance to the notion of reuse and test the validity of a hypothesis like the "not invented here syndrome."

A second perspective to reuse focused on IT adoption studies suggesting that elements of the organizational context, such as strategies, resources, and culture have an impact on reuse adoption (Markus and Robey 1988; Orlikowski 1993). This viewpoint causes a targeting of our inquiry into organizational readiness for adopting reuse. In particular, the focus was on the organizational support to the reuse infrastructure in terms of setting goals, formulating strategies, and providing resources. Additional information was collected that provided insight into the organizational mission and culture, software development practices, reuse methods, and the basic reuse infrastructure management support for the implementation of a reuse program.

The initial list of lead questions (Table 1) was formed before conducting the interviews. The questions for the interviews were originally formulated using a start up list of concepts identified from the reuse literature (lists of the concepts identified before and during the data collection stage are provided in Appendix A). These constructs were used to guide the research in formulating a protocol for the interview and not as a priori explanation of why barriers exist within organizations (Eisenhardt 1989; Kirsch 1997).

Table 1. Initial List of Questions for the Interviews

Unit of Analysis	*Question*	*Category*
Individual beliefs	• What does software reuse mean to you?	*Meaning of reuse*
	• From your own perspective, what are the benefits of software reuse that you have experienced over the years?	*Perceived benefit*
	• Do you believe that the technology is easy to implement? • Do you believe it is easy to create reusable assets? To locate these assets? To understand these assets? To integrate these assets in other applications?	*Perceived ease of use*
	• What are the main barriers that exist within the organization to software reuse? • What are the problems that are constraining reuse?	*Perceived barriers to reuse*
Organizational readiness	• Where do you think reuse fit within the IS goals? • Why do you think your organization is interested in reuse?	*Strategic importance of reuse*
	• Are there any policies or strategies that govern reuse?	*Policies*
	• What resources are allocated to a reuse program?	*Resources*
	• Are you aware of any policies or strategies that unintentionally constrain reuse?	*Structural barriers*
	• How is your performance evaluated?	*Performance evaluation*
	• Do you think the organizational culture values individualism more or collectivism? • Are people in the organization willing to share their experience freely with others? • Are organizational members willing for the organization to capture their knowledge?	*Culture*
	• Are there formal organizational incentives for reuse stakeholders to adopt reuse? • Does the organization reward members for knowledge sharing?	*Rewards*

2.2 Site Selection

The organizations studied were selected based on their relevance to the central phenomena of this study; barriers to the adoption of reuse. Each company contacted expressed an interest in software reuse and acknowledged the fact that some types of barriers exist. The final selection of sites was based on theoretical sampling as opposed to the random sampling used in theory testing research studies. A total of five cases were selected.

- **Case 1:** The Energy Solution Group (ESG) at SCC, a leading software consulting firm. ESG develops accounting systems for customers in the energy industry. They realized the importance of designing reusable components to develop applications at a fast rate.

- **Case 2:** Reuse II at OGC, an Oil and Gas Company (OGC) that operates worldwide. The group develops assets for computer applications that deal with subsurface data in the exploration and production field. All of their customers are internal customers.

- **Case 3:** The Production and Operation Management (POM) group at OGC The department studied developed software solutions for refineries and chemical plants operation.

- **Case 4:** The client server computing group at ITS, a leading software consulting firm with offices in 13 states. The client server-computing group provides solutions to telecommunication companies.

- **Case 5:** The Customer Billing Systems at TCC, a worldwide telecommunication firm that provides local and long distance services to customers worldwide. Several attempts have been launched within the organization to capture corporate knowledge and disseminate it among the different information seekers within the organization.

2.3 Data Collection

The data collection activity primarily used structured interviews. A set of open-ended questions (see Table 1) were posed to each of the participants at the beginning of the interview. The aim was to allow the interviewees to freely express beliefs related to personal experiences. After the initial round of interviews, a new set of questions was added to the list in light of concepts that emerged from the data. Follow-up interviews were conducted to collect data on emerging concepts that were not considered in the original interviews. This approach is deemed legitimate in grounded theory methodology.

Beside interviews, archival data in the form of articles, promotional material and Internet web pages were collected. The collection of supplemental material facilitated data and construction validation by triangulation. A number of stakeholders at different organizational levels were interviewed, providing us with a rich data set at various grades of abstraction. Our goal was to slice vertically through the organization to obtain data from multiple levels and perspectives.

A total of 33 interviews were conducted for the five organizations; 29 interviews were taped and transcribed. In the course of the remaining four interviews, the interviewees refused to be taped. With the permission of the participants, in these interviews, extensive notes were taken. A distribution of interviews among the five organization is presented in Table 2.

2.4 Data Analysis

Data analysis in this research effort was iterative. In fact, we alternated between data collection, coding, and data analysis to decide on new sources of data required for grounding the theory. The data analysis commenced with the transcription of every single interview and the inclusion of the comments taken during the course of the interview. Every transcribed interview was carefully read for the extraction of codes. The QSR NUD*IST© software was used to dissect every interview to a set of quotes categorized under a code. QSR NUD*IST© allows the transcribed interviews to be imported as text files and subsequently each interview was browsed and every sentence categorized following the scheme identified in Appendix A. We followed an *open coding* approach as recommended in grounded theory methodology (Strauss and Corbin 1990). In addition to coding, a Contact Summary Form (Miles and Huberman 1983; see Appendix B) was prepared to address the following:

Table 2. Type and Amount of Interviews Conducted at Each Site

Position	SCC	ITS	POM at OGC	Reuse II at OGC	TCC	Total
Reuse Expert	1	1	3	1	2	7
Asset Creators	2	2	2	1	1	10
Asset Utilizers	2	1	4	1	2	11
Project Managers		1	one of the reuse experts	1	2	2
Managers		the reuse expert	1	reuse expert	1	2
Total	5	5	10	4	8	33

1. What are the main issues that struck the researcher in this contact?
2. Summarize the information collected under the research questions.
3. Identify new concepts that struck the researcher as a salient, interesting, illuminating or important in this contact.
4. Identify new target questions that the researcher has in considering the next contact with this site.

The main focus was to compare and contrast the causes and forms of barriers to reuse adoption. Concepts and categories were compared for interviews within and across cases. A result of the comparative analysis appears in Table 3.

At the second level of analysis, a connection between the categories through what Strauss and Corbin term the *paradigm model* was developed. This involves identifying the *causal conditions* for the *phenomena* under study, the *context* surrounding the phenomena, the structural conditions that affect the relationship between the phenomena and the causal conditions, the strategies taken to respond to the phenomena, and the *consequences* of the interaction of the aforementioned meta-constructs. Axial coding resulted in Figure 1.
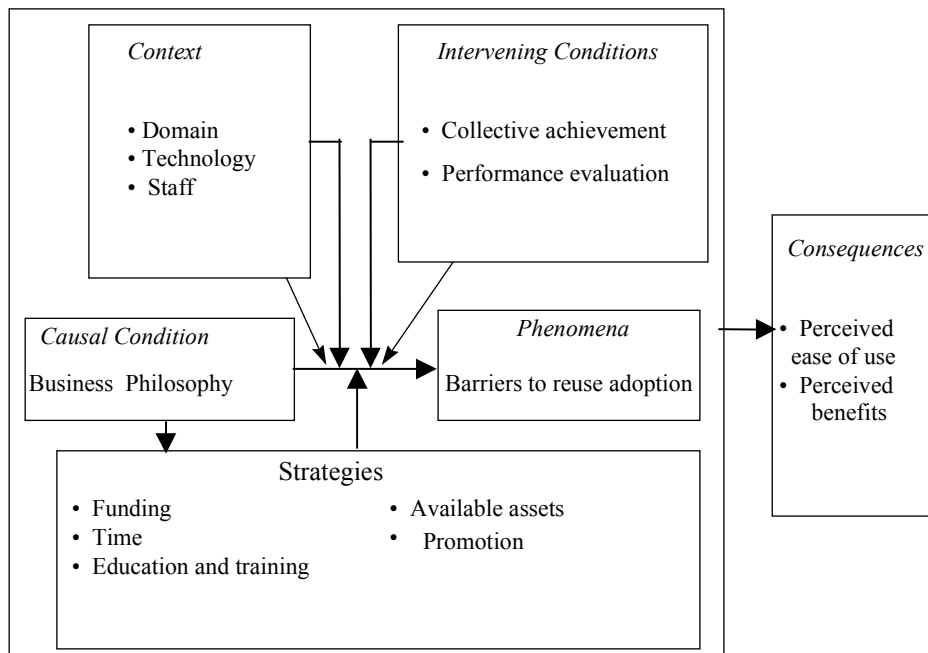

**Figure 1. A Conceptual Model of Barriers
to Reuse Adoption**

Table 3. A Comparison of the Barriers to Reuse Adoption Across All Five Sites

Category	SCC	Reuse II at OGC	ITS	POM at OGC	TCC
Perceived Benefits	High perceived benefits	High perceived benefits	High perceived benefits	**Aware of the claims that reuse can achieve benefits but need proof it will work at OGC**	**Believe there are benefits to the technology as well as problems**
Perceived Ease of Use	The implementation of reuse is getting easier with experience	High perceived ease of use	Dependent on the domain	**Reuse is difficult to implement**	**Reuse is difficult to implement**
Compatibility	Compatible with personal values and the methodology	Compatible with personal values and the methodology	Compatible with personal values and the methodology	**Not compatible with personal values or the methodology**	**Compatible with personal values but not the methodology**
Observability	**Can see but can not convey benefits**	Can see and convey benefits	Can see and convey benefits	**Can not see or convey benefits**	**Can see but can not convey benefits**
Reuse Policies	Defined reusability standards	Defined reusability standards	Defined reusability standards	**No defined reuse policies**	**In the process of defining one**
Business Philosophy	**Focus on project delivery and customers requirements**	**Recent focus on short term profits and time to market**	**Focus on delivering solutions to customers when they needed it**	**Focus on integrating solutions for clients using third party components. Must deliver on time**	**Focus on delivering in three months or less**
Collective Achievement	Is highly encouraged	Is highly encouraged	Is highly encouraged	**Believe that individual achievement is more critical**	Is highly encouraged
Freedom of Choice	**The manager mandates reuse**	Team members decide on reuse	Team members decide on reuse	Team members decide on reuse	Team members decide on reuse
Focus on Reuse	Reuse is considered strategic	Reuse is considered strategic	Reuse is considered strategic	**No clear focus on reuse**	**No clear focus on reuse**
Domain Scope	Reuse initiatives are scoped to a specific domain	Reuse initiatives are scoped to a specific domain	Reuse initiatives are scoped to a specific domain	**Domain is not scoped**	**Domain is not scoped**
Domain Stability	Domain is partially stable	Domain is functionally stable	*Domain is not stable*	*Domain is not stable*	Domain is partially stable
Domain Importance	Domain is considered strategic	Domain is considered strategic	Domain is considered strategic	**Domain is not strategic**	**Domain is not strategic**
Domain Commonalties	High degree of commonalties	High degree of commonalties	High degree of commonalties	*Few commonalties*	High degree of commonalties
Domain Knowledge	Rely on domain experts.	Rely on domain experts.	**Domain is not well understood**	**Domain is not understood**	**High staff turnover causes a loss of domain knowledge**
Funding	**Cofunded by management and external customers**	**Cofunded by management and internal customers**	**Cofunded by management and external customers**	**Funded by projects**	**Cofunded by management and external customers**

Category	SCC	Reuse II at OCG	ITS	POM at OCG	TCC
Staff	Limited skills but compensated with on the job training	Necessary skills are available	Necessary skills are available through mentoring	**Lack of staff that under-stands the domain**	**Lack of staff that understands the domain and the concepts of reuse**
Time	**Limited due to focus on projects**	Available at the start but limited now.	**Limited due to focus on projects**	**Limited due to focus on projects**	**Limited due to focus on projects**
Communication	Good communication among group members	Good communication among all stakeholders	Good communication among group members	Good communication among team members	Good communication among team members
Technology	Have a domain layered architecture, adopt OO, and the methodology does not hinder reuse.	Have a domain layered architecture, adopt OO, and the methodology supports reuse.	Have a domain framework, implement OO and component based technology, and the methodology supports reuse. No central repository	**No consistent technology or methodology across projects, no central repository**	Have a domain architecture, use mainframe technology, and **the methodology doesn't support reuse, no central repository**
Education and Training	**Not targeted to reuse, rely on mentoring**	**Not specifically targeted to reuse but covers its concepts**	Covers reuse but focuses on building with reuse	**Not targeted to reuse**	**Not targeted to reuse**
Target Market	Have a specific target market	Have a specific target market	Have a specific target market	**Have no target market**	**Have no target market**
Available Assets	Wide variety of assets	Wide variety of assets	Wide variety of assets	**Utility components**	**Mostly utility components**
Promotion	Active promotion to management	Active promotion of the assets to customers and management	Active promotion of the assets to customers and management	*No promotion of the assets*	*No promotion of the assets*
Support	**Limited documentation and use scenarios**	Documentation, example programs and consultation	Use scenarios, documentation, and mentoring	**Support depend on physical proximity**	**Support depends on documentation and the architecture group**
Asset utilization	Mandated	Highly encouraged	Highly encouraged	*Opportunistic*	**Encouraged but still opportunistic**
Commitment	All stakeholders are committed	All stakeholders are committed	All stakeholders are committed	*No commitment*	**Some degree of commitment**
Evolution of the Assets	Committed to the evolution of assets	Committed to the evolution of assets	Committed to the evolution of assets	**Hard to evolve the assets when working on projects**	Evolve the architecture
Assessment of Progress	**No assessment of progress**	**No assessment of progress**	*No assessment of progress*	**No assessment of progress**	**No assessment of progress**
Performance Evaluation	**Reuse is not a factor/ no reward for reuse**	**Reuse is not a factor/ no reward for reuse**	**Reuse is not a factor/ no reward for reuse**	**Reuse is not a factor/ no reward for reuse**	**Reuse is not a factor/ no reward for reuse**
Culture	Supports reuse	Supports reuse	Supports reuse	**Focus on short term goals and delivery today**	**Supports building with reuse but not for reuse**
Structure of the Reuse Group	**No separate reuse entity**	Has a separate reuse group	**No separate reuse entity**	**No separate reuse entity**	**No separate reuse entity**

From the paradigm model, it became apparent that the causal condition for the existence of barriers to reuse adoption is the business philosophy of short-term goals. Elements like the domain of focus for reuse, the technology, and the staff are contextual factors that affect the relationship of the business philosophy with barriers. Collective achievement and performance evaluations are structural conditions that also affect the aforementioned relationship. The strategies taken to respond to the barriers concerning elements like funding, education and training, and reuse policies also affect the relationship between business philosophy and barriers.

3. RESEARCH FINDINGS

The analysis focused on answering the two research questions. The first research question addresses the reasons for the existence of barriers to reuse. The categories that answer this question are illustrated in Figure 2. The second research question focuses on the forms of barriers that constrain the adoption of software reuse (see Figure 3). We originally started with a list of categories that explained the forms of barriers suggested from the literature. There were no studies cited that integrate these categories into a framework and there were no suggestions offered to explain why these barriers occur. The following sections attempt to answer the research questions in terms of the emerging categories from the qualitative data.
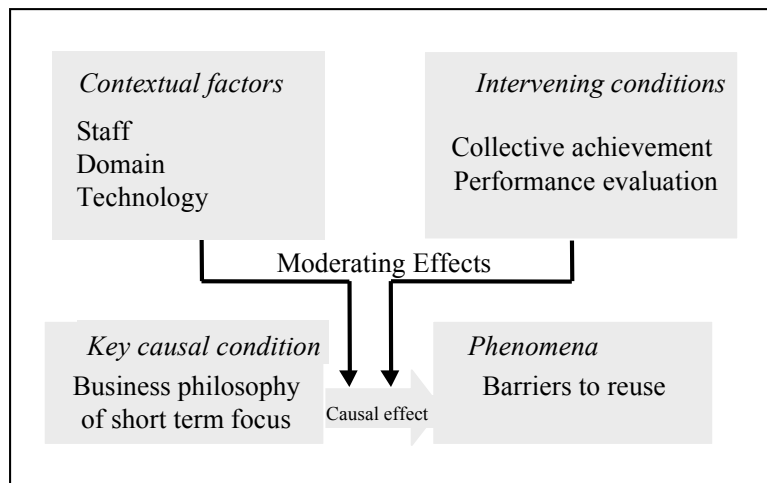

**Figure 2. Why Organizations Constrain the
Adoption of Reuse**

3.1 Constraining Reuse: A Business Philosophy Perspective

There was unanimous consensus among all of the stakeholders that the business philosophy of short-term goals constrains the adoption of reuse. All developers interviewed adamantly insisted that management's stress to urgently market solutions to clients is the main cause of barriers to reuse adoption. The focus on delivering customized solutions diverted attention and resources away from the initiative to systematize reuse, which requires methodical examination of commonalties and variations within reusable domains. As a result, reuse stakeholders complained of shortage of resources in the form of (see Table 4):

- lack of funding for the creation of reusable assets
- lack of time to engineer reusable assets
- lack of skillful staff to build for reuse and support the integration of reusable assets within on-going projects
- lack of education and training on reuse technology and reuse methodology
- lack of a variety of strategic assets that would conjure interest in a reuse library
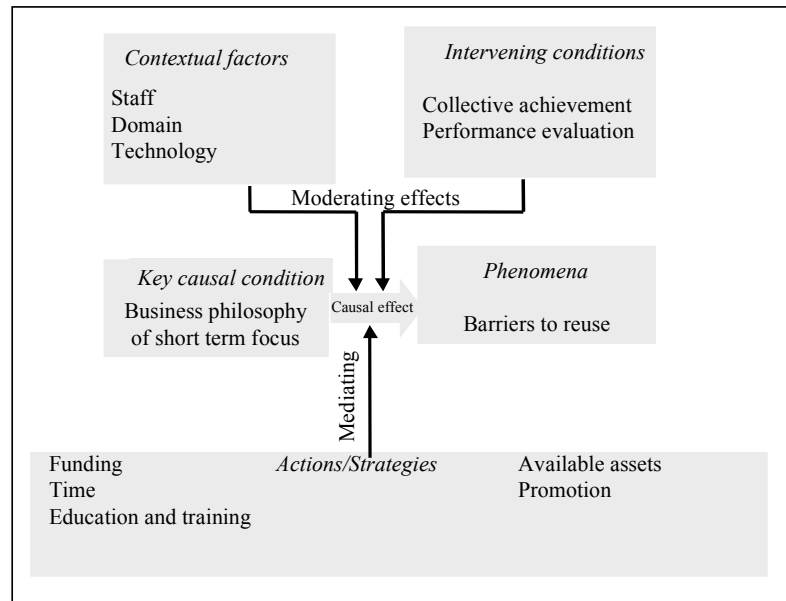
**Figure 3. Why and How Organizations Constrain the
Adoption of Reuse**

The only exception was the initial stages of the Reuse II project in the oil and gas company. Reuse II was launched for the sole purpose of establishing a reusable architecture for the subsurfacing domain. At the time the case was studied, Reuse II was losing support and was converted to a cost and profit center, to be solely financed by its different clients. Despite the limitations and constraints caused by the business philosophy, three of the cases studied managed to get their reuse projects beyond the initiation stage. The success of the reuse initiative for these three cases was heavily dependent on a number of contextual factors that redressed the effect of business philosophy on reuse adoption.

3.2 Contextual Factors

Several factors moderated the effect of business philosophy of short-term goals on the adoption of reuse. The existence of a visionary reuse expert with a clear understanding of the reuse technology had a visible impact on the success of reuse and its perceived benefit by other stakeholders, especially asset creators. The nature of the domain of focus and the technological infrastructure dampened the effect of business philosophy on the adoption of reuse and the existence of barriers.

3.2.1   Staff

The availability of talented asset creators played an important role in moderating the effect of business philosophy on reuse adoption. Asset creators who understood the concepts of reuse and knew how to implement it were inherently prone to develop reusable assets. At all three sites, the asset creators were selected based on their experience in the domain of focus for reuse and their competence in analyzing and designing a domain.

The asset creators acted as mentors to the asset utilizers for two reasons: first, to train them to be prospective asset creators, and second, to assist them in integrating assets within applications. Their communication skills were stressed as important to support asset utilizers in comprehending the design rationale and integrating the assets. Asset creators should also seek the feedback of asset utilizers on the performance of the assets. At SCC, part of the job of the asset utilizers is to speck out new requirements for the existing assets that would improve on clients' productivity.

Table 4. The Effect of Business Philosophy on Barriers to Reuse at the Five Sites

Company	The Effect of Business Philosophy on the Adoption of Reuse
SCC	One thing I kind of feel strongly about is that in some cases the model in a lot of the consulting companies is such that it does not encourage that. The bottom line here is billable hours, so it is only going to take us 10 people to maintain a system instead of 20 but we are getting paid time and material for it, for the most part we will have 20. There are definitely things that discourage reuse. But that's more specific to SCC. Billable hours and measurement of materials to charge to a client and a lot ways we build something that is reusable, however in a lot of situations it may not be directly chargeable to a client. Our organization is in general against packaging systems. SCC really isn't in the business of developing software. We're kind of a unique situation that we've developed the software products that we're installing in many clients. SCC's general approach is to go to a client and come to a specific solution for that client and implement it.
Reuse II at OGC	Many years ago it was a cost center. We just tried to provide the low cost computing services to our clients. Now, recently, two years ago, we are now a profit and loss center where we actually are trying to make, we are responsible for turning a profit, which means we care very much about the bottom line. And that does put more of a short sided look on things because if you show that, "Gee, if you want to invest money in this risky opportunity, you'd better show what the upscale potential is," otherwise it's like you're throwing money away. So yea, it might be more difficult now to convince management to take a long term approach with doing something of this magnitude. Every year brings out a new business philosophy and you know, sometimes the philosophy is, "Oh yea, take the long term approach, look five years down the road." And then sometimes, and it seems recently, it's actually, we're in it for the short term.
ITS	I think that reuse is definitely a goal that's achieved over the long term, not the short term. And so if you have a situation where the organization is focused on achieving short term benefits, that's not compatible with doing a lot of reuse. There has to be some focus on the long term in order to achieve it. Our primary focus is to build business solutions in time frames or market windows that those business solutions have value to the customers. So because that is our focus and that's why our business users pay us, that's our priority number one. Reuse is definitely high up there on the list of our priorities, but sometimes it's a trade off between delivery time frames and business value and striving for the ultimate reuse. I think that many barriers in my personal page to reuse are tactical focus versus strategic vision. Whenever as an individual or as a team or as a company we tactically focus on something that's going to deliver short term, immediate results like, "We're going to get this project out quick and get the check," we lose our strategic vision. We want to be well respected, high quality providers that have a long future because of the flexibility of the things we build and the quality and the strength of what we deliver. And so I think that's the biggest barrier is when we put the tactical blinders. When we believe that we've got to deliver in a certain time, we've got to make our budget, and we've got to, got to get this done so that I can go onto my next project or whatever. Those are the things that really screw up reuse is when people just look at the immediate payoff and not at what it can mean for them in the long run.
POM at OGC	There's a different strategy to push projects quickly out the door and no consistency and IT strategies then I just see it as a barrier for reuse. It's not so much a specific strategy or policy that inhibits it, but it's just kind of the way we've done our jobs in the past has prevented productive reuse.

Company	The Effect of Business Philosophy on the Adoption of Reuse
TCC	It is not overt or documented or official policies, but sometimes the attitude that an organization has, the willingness to sacrifice everything for the time to market is essentially a constraint. And while it's not a documented policy, for a long time it certainly has been, and we are trying to address it, an implicit policy that, you know, "I don't really care what you do as long as you get it out when they said they want it or earlier." The telecommunications industry moves so fast that we're constantly trying to keep up and possibly if we can stay ahead of our competitors. And our customers come to us and say, "We need this by March," because if we don't have it by March our competitors are going to announce something similar to it in April. And so we have to beat them. If you are talking about training people in reusable technology or tools that will help you in that arena, maybe you have to have two or three weeks of training. And two or three weeks of training around here are a lot of time. So, in order to become good at reusable technology, you know, it's six months to a year really, to become good at it.

The lack of skillful staff at TCC and POM at OGC was reported as a barrier. Even though the reuse experts in both companies were very knowledgeable about reuse, mainly because of their industry connections with several external reuse entities, they did not take an active step to educate other stakeholders. They acknowledged the lack of consistent views about reuse across the organizations and admitted the need for competent developers, but there was no effort taken to rectify the problem. They were aware of the challenges posed by management's focus on short-term goals, but no strategic attempts were taken to amend these challenges. At TCC, the chairman of the reuse working group that coordinates the reuse efforts across TCC believed that reuse is a far-fetched goal and a challenge because it is hard to implement. The reuse experts at POM expressed similar beliefs. The lack of commitment of top management was taken for granted, and there was no attempt to persuade management through a pilot project or a small initiative. The reuse expert believed that reuse will only work through a top down approach, while management felt that a success story is seriously needed to convince them that reuse will work. There was no attempt to consolidate both views.

3.2.2   Domain

Data from the five sites suggested that the properties of the reuse domain, such importance, stability, and scope, have significant impact on software developers' attitude toward reuse and management readiness to support adoption. The strategic importance of the domain of focus for reuse was an important factor in gaining the commitment of asset utilizers and management. At Reuse II, the domain of subsurfacing was considered complex and strategic. The complexity of the domain necessitated that the developers be in close proximity to the end users in order to understand the domain knowledge. At the same time, as the domain was very strategic, OGC could not risk outsourcing it to external consulting firms or contractors and jeopardize its competitive advantage. Because of the importance of the domain, management commitment to the reuse initiative was highly visible at the early stages of the reuse project. Management provided the necessary funding and human and technical resources required for the project. The group was even granted a truce period to build the reuse infrastructure without being asked for results. The initiative proved to be a great success within five years of its inception. Reuse II even attracted external entities who were interested in marketing the assets developed as industry standard components.

SCC and ITS also focused on strategic domains in their lines of business. Even though members of the managerial board in both companies were not actively engaged in the reuse initiative, the importance of the assets developed for the different applications contributed to their high utilization rates. Both organizations followed a bottom-up approach to reuse where they started with a small-scale effort that demonstrated reuse benefits to management. The two groups were committed to the persistent improvement and evolution of the design of reusable assets. Contrary to what happened at ITS and SCC, the reuse initiative at POM and TCC focused on utility components that were not considered strategic. Both asset creators and asset utilizers felt that a number of off-the-shelf components would readily substitute for in-house reusable components.

The domain stability also played an important role. Reuse II was the only initiative that experienced a stable domain. This has helped the group in gaining high benefits from the assets built 10 years ago. ITS experienced the most changes in its domain. ITS's response to the instability of the domain was to focus on leveraging best practices across projects. While the reuse of code is more

valuable to customers than models, developers at ITS believed that the reuse of best practices yielded better results because of its low sensitivity to changes in the domain. Both TCC and POM complained about domain instability but did not resort to any strategies to proactively respond to changes.

Scoping the domain was also important for the creation of reusable assets. In all three successful sites, the assets were not developed as universal assets but were scoped to a particular field. At SCC, Reuse II, and ITS, the reuse efforts focused an a well defined scope and targeted the assets to specific customers.

3.2.3   Technology

Although all reuse stakeholders interviewed believed that the technology does not play a critical role in the success or failure of reuse, some properties of it appeared important. At POM and TCC, the instability of the technology was considered a deterrent to reuse. At both sites, investing in the development of reusable assets was considered a risk due to the continuous evolution of new technological breakthroughs. At Reuse II and SCC, the reuse experts were aware that changes in the technology might affect reuse investment but decided to lock their assets in one technology for a number of years to recoup their investment. At ITS, they resorted to the reuse of designs and patterns rather than code to alleviate the effect of frequent technology changes. This decision enabled ITS to move the assets to different technologies without losing the flexibility and the adaptability of the design.

3.3 Intervening Factors

Performance evaluation and collective achievement are seen as the two intervening conditions that are not directly related to reuse but proved to have an effect on its adoption. Data from all five sites confirmed that there are no specific measures adopted to assess individual efforts toward reuse. Asset creators and asset utilizers at ITS, SCC, Reuse II, and TCC, however, believed it positively contributes to their performance evaluations. Asset utilizers believed that the reuse of existing assets speeds up the development of applications and, thus, they are considered more productive. Asset creators are rewarded for their development of assets that benefit other groups and, thus, contribute to the overall success of the organization. At POM, reuse stakeholders believed reuse has no effect on their performance evaluation.

Not one of the five organizations rewarded asset creators or asset utilizers symbolically or monetarily. At SCC, Reuse II, and ITS, the lack of reward was not considered a barrier given the high commitment of the reuse stakeholders. At TCC and POM, the lack of reward was viewed as a deterrent, in particular because it takes a considerable amount of time to build for reuse. Reuse stakeholders strongly believed that there were no incentives for developers to contribute to reuse given the business philosophy.

Collective achievement is another condition that facilitated the adoption of reuse. In organizations that fostered and nurtured the concept of collective achievement and knowledge sharing, developers were receptive to the idea of reuse. All organizations studied, except for POM at OGC, stressed the importance of collective as well as individual achievement. They believed that collective achievement is important for reuse because it augments the chances of cooperation between asset creators and asset utilizers. Although TCC did not have a formal reuse initiative in place but was in the process of defining one, it is unlikely they will experience difficulty with getting asset creators to share their components with other projects given that a strategy is in place first. As the reuse expert believed, it is part of their culture to freely share experience. At POM, the developers believed that, although collective achievement was touted, individual achievement was the main factor in evaluating their performance and, thus, individuals focused on accomplishing direct assignments.

4.   VALIDATING THE FRAMEWORK

With the aim of bringing further credibility to our findings, two steps were taken to validate the findings of this research. The framework and findings of this effort were presented to a panel of four experts on software reuse. Each of these experts is a practicing professional in the software industry and each of them has provided consulting services to several organizations that adopted reuse. Three of the experts on our panel are authors of an industry accepted technical report on software reuse.

Collectively, the group supported our framework and findings. The group supported each of the factors identified and indicated that they rang true with their experiences in the field. On a second level, we attempted to build theoretical linkages to the literature base on the acceptance and use of administrative innovation. The findings of this research were compared against established models and frameworks in the literature.

4.1 Experts' Validation of the Framework

This panel of experts provided four suggestions for further enhancing our model. While generally agreeing with the findings, as a group, they indicated that we need to further understand the makeup of the "business philosophy" factor. It was their belief, collectively, that while business philosophy was important, it was not the main cause of reuse barrier. Expanding further on this idea, they indicated that they believed that there was a hidden motive for developers to believe that the focus on projects is the barrier, and that is "reflection on past experience is painful." Developers typically do not want to take the time to reflect on past experiences and to try to learn from them even if it is in a matter of an hour. While this is an interesting assertion, our data from the five sites does not support it. This, in our opinion, will be a proposition worth testing empirically in a follow-up study.

A second cause for a barrier to software reuse, expressed by one of the experts on our panel, was a lack of a structured methodology. It was his beliefs that reuse had to be adopted in a bottom-up approach to be effective. In the words of the expert:

> One of the ways that the reuse community has actually shot itself in the foot is precisely because the story they have told about what reuse has to be in order to be successful talks in large granularity terms. People don't say reuse is something you could start doing in your organization simply by investing an hour in learning to have a conversation in your meeting in a slightly different way, and then if that worked you could go on and invest a couple of hours in something else. It's not presented as an incrementally adaptable approach, it's presented as something that you have to make a very large scale commitment to do in order to try it.

A third suggestion by our panel was that "organization's must believe in slowing down to speed up." They explained this further by indicating that, when the organization culture starts to recognize the importance of learning and reflecting on past experience, reuse will start to make sense.

Finally, the panel added that an important contributor to software reuse barrier was the lack of an accounting system that makes explicit the cost of not doing reuse as well as of doing it. The quantitative measures of such an accounting system should be the means of convincing people who are directly impacted by reuse and those who need to provide sponsorship. The existence of a reuse champion who encourages developers to do small pilot studies and that does metrics that are in the managers' frames of reference was also believed to be a critical factor. Such beliefs are in close accordance with the framework.

4.2 Literature Validation of the Framework

A vast number of information technology research projects have been dedicated to study factors affecting the success of the adoption of new technology (Chau and Tam 1997; Cooper and Zmud 1990; Fichman and Kemerer 1993; Rai and Howard 1993). Factors affecting adoption of different types of IT centered around internal, and in few cases included external, factors. Internal factors confirmed include individual adjustments, organizational receptivity, and technology characteristics. Additionally, Nelson (1990) identified satisfaction, involvement, organizational commitment, and performance as elements affecting individual adjustment. Factors related to organizational receptivity, on the other hand, include factors such as organizational structure, organizational politics, organizational culture, management process, management support, the nature of corporate systems, the quality of human resources, and availability of resources (Rai and Howard 1993; Robey and Boudreau 1999). From the external factors perspective, issues such as market conditions, competition, regulations, and relationship with the government have been reported as concerns for the adoption of IT.

A number of factors that emerged from our model have been previously shown as indicators for outcomes of an IT adoption process. These factors include business philosophy, which is accounted for within the organizational culture, technology, staff,

funding, education and training, perceived ease of use, and perceived benefits. The added benefit of our framework is that it draws relationships between the different factors rather than depicting them as discrete causes for the success or failure of IT adoption.

5. SUMMARY AND CONCLUSION

The literature on software reuse attributes the majority of barriers to reuse adoption to cultural beliefs. The data collected from all five sites suggests that such beliefs are just outcomes of the interaction of the business philosophy, contextual factors, and intervening conditions. Data collected from interviews shows that the stakeholders' beliefs regarding the perceived benefits of reuse and the perceived ease of use are contingent on the organizational actions regarding resources required to develop and market reuse. Such beliefs determine the level of commitment of the reuse stakeholders, which ultimately affects the culture.

The current research focused on the development of a grounded theory in barriers to reuse adoption. It sought to build a theoretical framework, seeking data from five different sites to add complexity and generalizability to the theory. The analysis of the data suggested that barriers to reuse adoption occur at two levels: the individual and the organizational. While the literature on reuse focused on barriers at the individual level, this research showed that barriers at the individual level are outcomes of the barriers at the organizational level.

In conclusion, this research effort makes an important contribution to the study of reuse adoption in general, and to barriers to reuse adoption in particular. The model presented here indicates that barriers to reuse adoption are mainly caused by the business philosophy. This causal relationship is moderated by the contextual and intervening conditions. The forms of barriers are the outcomes of organizational actions with respect to the resources required for reuse. Consequences of the barriers to reuse adoption are the individual beliefs regarding perceived ease of use, compatibility, and observability. Finally, the success of software reuse projects is dependent on the commitment of the reuse stakeholders to the adoption of reuse.

6. ACKNOWLEDGMENTS

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Appendix A
Initial List of Categories

Individual Beliefs

Perceived Benefits

Time to Market
Cost Reduction
Productivity

Perceived Ease of Use

Asset Creation
Asset Comprehension
Accessibility
Integration

Organizational Readiness

Strategic Importance

Need
Importance
Strategies/Policies

Resources

Funding
Staff
Technology
Education and Training

Organizational Context

Culture
Performance Evaluation
Reward

Appendix B
Contact Summary Forms

Contact Summary Form

Contact Type: Interview   Site: OGC services
Contact Date: 12-09-97   Informant: John Smith
Written by : Karma Sherif

1. What are the main issues that struck you in this contact?

    •   The support top management offered to the reuse group even in times of difficulty.
    •   The understanding between the application groups and the reuse group.
    •   The understanding of the reuse expert to the organization dynamics; he understands that reuse has a different meaning to the different stakeholders, however he worked hard to reach a consensus and to build a partnership between all the parties involved.

2. Summarize the information you got (or failed to get) on each of the target questions you had for this contact.

Question	Information
A. How individuals constrain reuse	Have a low perceived ease of use regarding asset creation (because of lack of experience), asset comprehension (because of lack of documentation and technical support), accessibility (because of formalities involved, and the categorization of the library) and communication with that asset.
	Have difficulty conveying benefits to management or developers.
B. How the structure constrains reuse	Existence of a business philosophy that focus on short term goals.
	Lack of formal methodology for the implementation of a reuse program.
	Lack of sufficient resources to develop reusable assets in terms of a need to adopt reuse, skills, funding, education and training, and commitment from all reuse stakeholders.
	Lack of sufficient resources to market assets because of a lack of a defined target market, lack of a wide variety of assets to satisfy the needs of the developers, limited scope of the assets, low quality of the assets, lack of promotion for the assets.
	Lack of resources to perpetuate an interest in reuse because of lack of top management commitment, application groups' commitment, asset creator's commitment and end user's commitment, no evolution for the assets, no incentives for stakeholders to commit to reuse.
	Tacit assumptions within the organization regarding information sharing, collective achievement, and freedom of choice.

	Structure of a reuse group, not autonomous from application groups, does not have control over the budget, have a low perceived usefulness.
C. Why organizations constrain reuse	Top management lack of understanding, focus on short term goals, high cost of reuse, no guarantee for success.
	Asset creators lack of domain knowledge, lack of incentives, and time constraints.
	Asset utilizers lack of comprehension, fear of losing control, intimidation to use the library, paradigm shift, and time constraints.
	Reuse expert lack of understanding of reuse, lack of incentives, lack of support from management, asset creators and asset utilizers.

3. Anything else that struck you as a salient, interesting, illuminating, or important in this contact?

The effect of the top management's support on the positive feeling towards reuse by the reuse expert and his high satisfaction with the job being in charge of the REUSE II. The success of reuse in spite of a lack of a formal methodology and lack of incentives.

4. What new target questions do you have in considering the next contact with this site?

- The tradeoff between building reusable components and customized ones, what he termed flexibility and performance.

- Initial funding of the project and whether the group had an independent source of funding or not?

- Who manages the other reuse group, computing people or geophysicists?

- Whether they charge application groups for just using the library or only for new developments?

- Find more information about the consortium?

- Find more information about the transition from being a cost center to a cost and profit one and its effect on reuse?

- Effect of creating OGC services?

- Do they have a formal procedure for developing reusable assets?