Reusability as a Strategic Management Practice in the Computer Industry

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Executive Summary –

In the hyperdynamic environment of today's computer industry the standard practice of repeated custom development is overwhelmingly inflexible. In the market of tomorrow where this dynamic environment will continue to accelerate, flexibility will be the key to success. One of the most promising operational strategy technologies offered to replace the standard practice of repeated custom development is the practice of strategic reuse.

Strategic reuse is the ***strategic*** practice of development through the creation and application of reusable components. While the foundations of this concept, reuse of previous workproducts and modular design, have been around for decades, strategic reuse implies that these efforts be performed on a systematic and comprehensive scale and with forethought to their later usefulness. Simply reusing something you have in hand is *not* strategic reuse.

This paper attempts to present the reader with a brief yet comprehensive overview of where the practice of strategic reuse is being applied in today's computer industry and what the relevant issues are for its implementation. After reading this paper the reader should have a good idea of whether or not strategic reuse is a technology that they wish to further investigate.

To compile the information required for this presentation, the authors pursued two courses of research. The first course was an in-depth literature research of the material available on this topic. This literature research formed the underlying foundation of the data presented. To provide some sort of practical validation of the literature, a second course was also pursued in the form of a field study built on a series of structured interviews with numerous senior technology leaders in seven important companies in the computer industry. This data primarily validated and in some cases extended the data gathered in the literature research.

The overall result of this effort can be summarized as an attempt to answer the following questions:

- **In what forms is strategic reuse being implemented?**
- **What are the goals/benefits of pursuing the practice of strategic reuse?**
- **What are the factors influencing success?**
- **What are the factors influencing diffusion?**
- **What are the future prospects of strategic reuse in the computer industry?**

The answers to these questions are summarized in the following lists:

Methods of implementation
- ***Mostly software***
  - OO
  - Libraries
  - Repositories
- Modular HW design in circuit boards
- Modular chip design
- Modular business processes
- System architectures

Goals of effort
- ***Reduced cycle times***
- ***Lower cost***
  - Development
  - Maintenance
  - Training
- ***Lower maintenance***
- ***Improved quality***
- Improved compatibility/interoperability
- Consistency & accuracy of information
- Improved estimation capability
- Improved schedule stability
- Improved employee morale

Success factors
- ***Management commitment***
- ***Formally stated as company policy***
- ***Systematic strategy rather than ad-hoc***
- ***Training***
- ***Long-term benefit & short-term cost***
- Communication between management and engineering
- Communication among and between engineering teams
- Quality of up-front design
- Client involvement
- Existence of successful examples
- Selection of appropriate projects
- Availability of appropriate tools
- Not invented here syndrome

Diffusion factors
- ***Human vector***
- Communicating successes to others
- Haphazard application
- Strategic selection of projects

Future prospects
- Continue to diffuse rapidly in the software sector moving from a trend to a standard practice
- Rate of acceptance and diffusion in the hardware sectors is likely to increase in the next couple of years driven by need for flexibility
- Will likely begin to emerge as a valuable strategy in the general business services area

Finally, this paper presents the reader who wishes to further pursue this topic with a short list of recommended readings to quickly move them to the next level of knowledge.

Jacobson, M. Griss, and P. Jonsson, "Software reuse: architecture, process and organization for business success." *Addison-Wesley.* (1997)

D. M. Erb, "Technology Roadmap for DOD's Reuse Initiative", http//rbse.jsc.nasa.gov/ricis/review/volume6number2/Erb.html

W. C. Lim, "Managing Software Reuse: A Comprehensive Guide to Strategically Reengineering the Organization for Reusable Components", Prentice Hall. (July 1998)

Jacobson I., "Succeeding with objects: Reuse in reality", Object Magazine, July 1996.

Introduction

Ever increasing competition in the computer industry is driving organizations to reevaluate the way they do business, seeking new approaches that will allow them to reduce development times and costs while improving product quality and operational flexibility. Where less than a decade ago functionality and quality determined the market leaders, today time and flexibility are the currency of success. "The competitive environment of business is continuously changing, and the pace of that change is increasing at an accelerating rate. Where it was once possible for a company to stake out its marketing turf and defend its position for years, static positioning is now viable only in a few isolated industries. For most companies today, the only constant is change." [30]. Unfortunately, the current standard practices are woefully inadequate in such a dynamic environment. The operational strategy most prevalent in the computer industry can be characterized as recurring custom development. This implies that most development projects are approached individually, crafted specifically to meet only the requirements of that project. Much of this custom development is equivalent to the craftsmanship of the pre-Industrial Revolution. It is extremely slow, very expensive, difficult to maintain, nonstandard, of inconsistent quality and does not scale well. Engineering development today needs to undergo the same kind of fundamental change in approach that manufacturing underwent during the Industrial Revolution.

Today's equivalent of the revolutionary component-based assembly line is a management technology generically referred to as reusability. Reusability is the ***strategic*** practice of development through the creation and application of reusable components. These components are founded upon a general concept known as modularity. "Modularity is a strategy for organizing complex products and processes efficiently. A modular system is composed of units (or modules) that are designed independently but still function as an integrated whole." "Indeed it is modularity, more than speedy processing and communication or any other technology, that is responsible for the heightened pace of change that managers in the computer industry now face." [1]. This modular concept allows the distribution of responsibility and resources required to undertake any large project. Such a distribution is critical to operational flexibility.

Without a modular approach strategic reuse would be impossible. Reusability takes this general modular approach and extends it from the implementation stage into the design stage instilling planned forethought into proactively creating new modules that can be effectively reused in the future rather than simply recycling something that has been done in the past. This planned forethought is what makes Reusability a strategic practice rather than just simple common sense.

This paper explores the practice of Reusability in the computer industry today. It investigates various issues surrounding this concept through an in-depth literature search and an informal field study validation. It attempts to answer questions such as:

In what forms is the practice being implemented today?
In what forms is it likely to be implemented in the future?
What are the goals of such an approach?
Has it been successful in achieving these goals?
What factors affect, whether positively or negatively, an organization's ability to successfully implement such a practice?
At what rate is this technology diffusing through organizations which practice it?
At what rate is this technology diffusing through the industry?
What factors affect, whether positively or negatively, the rate of diffusion of this technology?

By answering these questions, we hope to provide the reader with a good overview of the capabilities and future prospects of this management technology. We also hope to provide the reader with enough information to make an initial determination if this technology is a good fit for achieving their organization's strategic goals. For those readers who wish to pursue more in-depth information on this technology we provide a list of suggested readings at the end of the paper.

Methodology

To acquire the foundational data for this study an in-depth literature search was performed to gather all possible information regarding reusability as a strategic management practice in the computer industry. Specific focus was placed on investigating methods of implementation, extent of implementation, strategic goals, factors affecting success, and factors affecting diffusion. The search encompassed commercial and educational resources on the Internet, business and professional publications, technical research papers, and extensive professional books available on the topic.

To gather field data on the real-world application of reusability, interviews were conducted with senior technical and business leaders in seven different high technology companies: Intel, Boeing, Lattice Semiconductor, EDS, CBSI, Tektronix and Meetinghouse Technologies. Six of these seven organizations are large multinational corporations but all of the individuals interviewed are based in the Portland Metropolitan area.

Interviews were conducted with multiple managers at several firms and single managers at other firms. These managers ranged from vice presidents and CTOs to project managers working in areas from marketing to software development. The interviews were semi-structured in that they were conducted with a standard set of questions to be answered but the interviewers and the individuals being interviewed were allowed to expand as much as they wanted on the standard questions. In an attempt to offset the limitation of using a single source to represent the position and activities of a company, a conscious effort was made to choose very high-level and knowledgeable managers at companies where they would be the only interviewee. For companies where multiple individuals would be interviewed, the individuals were purposely chosen from a variety of functional roles and levels of management.

The information gathered in the interviews is presented here in the form of brief case summaries. These summaries are not intended to be in-depth or provide the raw data. But rather, they are meant to give the reader only the information relevant to the questions and issues under consideration from the literature research.

Since the sample size of the field study was very small and therefore not statistically significant, no statistical analysis has been made. Instead, informal data analysis was performed on the results of each interview and across the entire set of interview responses to identify and extract commonalties and items of unique significance.

Literature Research

Methods of Implementation

The literature contains many examples of reuse implementations ranging across many functional domains. While there are some examples of non-software related implementations, predominantly variations on modular manufacturing practices allowing mass customization, the vast majority of reuse literature centers around software issues.

Following is a brief list of some of the implementations in the literature:

- Intellectual Property Libraries
- Modular manufacturing processes for mass-customization.
- Modular documentation

- Object-oriented software
- Application generators
- CASE tools
- Composition tools
- Model-based development
- Frameworks/Libraries
- Components
- Patterns

While object-oriented software is the most widely practiced and discussed implementation, frameworks, components and patterns are considered to be among the most promising for the future.

Frameworks are libraries of software that form complex systems to serve a particular purpose. These frameworks are standard by nature so that one framework can serve as a skeleton over and over to allow the solution of many different problems.

Components are self-contained elements, either software or hardware, that perform specific jobs and can simply be plugged into a system or framework without requiring knowledge of its internal structure or activity.

Patterns consist simply of the description of a problem and a sketch of its solution. Patterns are extremely general and can be applied to business as well as engineering practices. Some examples of this are developing collateral for sales and marketing or defining a standard software architecture for large billing systems. [32].

Goals/Benefits

Increased productivity

Software reuse can increase reliability and reduce the cost and effort of producing software products. [27]. The result is decreasing time-to-market of the product. “Raytheon saw 50% increase in productivity in its Missile System Division.” And “The US Navy experienced a 26% reduction in required labor hours to develop and maintain its Restructured Naval Tactical Data Systems.” [36].

Lower product cycle time

The most touted goal of software reuse is a shortening of time-to-market for a given product. [6]. The literature provides numerous examples of great success in this area, many claiming up to a 90% reduction in development time. In order to measure the effectiveness of reuse efforts it is important to clearly define processes and metrics that consider factors affecting cycle time but are independent of other influences. [36]. Given a successful reuse effort and the shortened cycle times that result, an organization should be able to significantly reduce their overall time-to-market and give themselves a competitive advantage in the market. "Magnavox developed the Force Fusion System Prototype (FFSP) in 20% of the projected, estimated time for a totally new system development." [36].

Lower cost

The obvious result of increased productivity and lower product cycle times is lower cost. It is important to note that these cost savings are long-term rather than short-term. The added up-front effort required by a strategic reuse program actually costs more in the short term than custom development. However, the long-term benefits can easily offset these costs, and given a consistently maintained effort cost savings continue to increase as the size of the reusable asset repository grows. "The Army estimates a cost avoidance of $479.9 million for its Tactical Command and Control system, allowing additional mission requirements to be addressed during a period of funding shortfalls."[36].

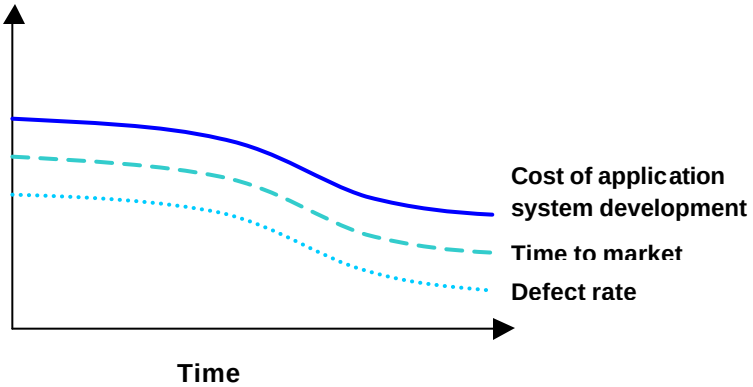
Increased product quality

One key benefit of reuse that is not always obvious to people unfamiliar with the concept of strategic reuse is an increase in product quality. Experienced engineering managers however consider this a key goal of their reuse efforts. Quality is improved due to the fact that a reusable asset is tested and further qualified each time it is used in a development effort. This increase in testing depth and even more importantly breadth yields significantly lower product defect rates. This inherent move toward higher quality improves a product's competitive advantage and is even more critical as products and systems continue to skyrocket in complexity.

However, Thomas, Delis and Basili found that some forms of reuse strategy will actually tend to cause a reduction in product quality. [31]. An organization which attempts to implement a reuse strategy without fully understanding the concept and the issues surrounding it can incorrectly identify critical path elements of development for application of reuse and related metrics. This failure can actually lead to a reduction in product quality.

Improved interoperability

Enforcing standards to ensure component reusability also yields a beneficial side effect of improving the interoperability of products and systems built from these components. This allows an organization to pursue a product line approach to development with less worry over consistency and backward compatibility. Further, it also allows organizations to form cooperative partnerships for improved functionality and marketing power yielding market advantage and the ability to build complex products and systems beyond the capabilities of a single organizations resources.



Source from [15]

"Cost or effort, time to market, and defect rate all start at a fairly high level. At first, as the reuse effort is in the planning stage, they remain steady. As reuse begins to make a difference, they drop rapidly. Eventually, when reuse reaches 80 or 90 percent, the rate of decline flattens out"[15]

Rate of innovation

Designing, developing and implementing application software requires a lot of effort and is very time consuming. Without strategic reuse an organization is required to consume its resources to continually rebuild redundant functionality. By introducing strategic reuse an organization frees up these resources to pursue new technologies and develop creative and innovative ideas rather than continuously rehashing old ones. [6].

Employee job satisfaction

Because employees are an organization's most valuable asset it is imperative for a wise manager to consider the human factor in deciding to integrate any new technology. Reusability can be a two edged sword in this area. To a flexible organization staffed with team oriented personnel all of the above benefits will make reusability a success at improving employee job satisfaction. Chief among these factors is the reduction in development cycle times and increase in productivity which when leveraged can lead to decreased pressures for development deadlines. [6].

On the other hand, in inflexible organizations staffed by individualistic personnel forcing implementation of strategic reuse could easily lead to serious morale issues. In this type of organization the 'not invented here' mindset is often prevalent and people will tend to insist on doing the work themselves rather than trust a product from someone else.

Success Factors

Business Related Factors

The Reuse Planning Group of the IEEE Computer Society Software Engineering Standards Committee has determined that the principal drivers and obstacles to successful reuse are non-technical in nature. These non-technical factors can be broken into three primary areas: organization structure and culture, business strategy and investment strategy.
[22]. For a successful implementation of strategic reuse, senior management must understand and address each of these areas.

Business strategy

In order to achieve a successful strategic reuse program it is necessary for the organization to include reuse as part of their strategic IT planning because of the overhead, coordination and information flow required by strategic reuse. Without considering reuse as part of all strategic business planning it is very unlikely to succeed. Some organizations recognize the potential strategic imp lications of reuse and choose to explicitly list it with their strategic business goals. Thus, it should be considered when identifying the business priorities and a proper reuse strategy should be developed to aid in the accomplishment of the organizations other strategic goals. [6]. In addition, strategic reuse should be a long-term planned effort. [15],[11],[35]. Hence, this technology requires long-term support and commitment from senior management. [35]. For example, when Motorola first decided to pursue strategic reuse it began with a commitment from senior management to support a pilot project and then if successful, a strategic deployment of the technology throughout the company. This strong, open commitment by senior management combined with the success of the pilot project led to the technology being accepted within the organization. [18].

Without total support from the top management of an organization, reuse efforts are unlikely to achieve their full potential. This is due to a combination of project managers receiving inadequate resources to effectively apply reuse and a lack of proper training in reuse technology for development personnel. [35]. If these issues are recognized up-front and considered when developing the overall strategic business plan, the organization is much more likely to achieve the full potential of a strategic reuse effort.

Organization structure and culture

The structure and culture of an organization will often require changing to successfully implement an effective software reuse strategy. The most common change required by organizations attempting to pursue strategic reuse is a move away from unrestrained individualistic efforts toward a more controlled command structure. This control is required to architect and direct the increased up-front design requirements of strategic reuse. This requirement that strategic reuse be implemented from a single overall vision rather than piecemeal often requires the creation within the organization of a separate team tasked with developing, planning, and directing strategic reuse efforts. [35]. Ideally this team should be multi-functional to ensure the most appropriate strategic decisions. [36]. Furthermore, they should also be responsible for assessing the quality of reusable assets and collecting metrics to determine the success of the organization's reuse efforts. [36].

The chances of successfully integrating reuse technology are greatly enhanced if an organization enjoys a flexible structure and culture and if the effort is carefully staged and implemented slowly. [35]. When new technology arrives in a company, often people in the organization are resistant to change due to their lack of understanding of any advantages of the new technology. It is important that the technology be

introduced slowly to allow people to see its benefits without shocking the system. In this way people will learn to appreciate its benefits and eventually begin to seek out the technology. Technology pull is almost always more successful than technology push. In order to gain the full potential benefit of reuse, all developers need to understand the concept of reusability and know what advantages they will obtain from it. Beyond this initial acceptance it is also wise to implement some sort of personal incentive to encourage reuse. For example, Motorola has implemented "a cash -incentive award" to get the attention of its developers. The developers get the money whenever their software components are used in other development efforts and whenever they themselves successfully employ components from the reuse repository. [18].

Investment strategy

Another key area to consider when deciding to pursue a strategic reuse effort is investment strategy. It is important that an organization fully consider the up-front costs versus the long-term benefits of reuse. [6]. In the short term, building reusable components is definitely more expensive than building inflexible, custom products. This cost is due to increased architecture and design effort and due to increased system and coordination overhead. [12]. An organization needs to plan for this up-front investment in its strategic business plan. [27], [15]. After a reusable asset repository has been seeded and an effective architecture has been developed, the entire organization can take advantage of these resources. This is when the organization begins to reap its return on investment. "In IBM, the Technology Support Center also apply the corporate-level ROI to evaluate the benefit of formal reuse relative to other technology that improve programmer productivity and quality." [24].

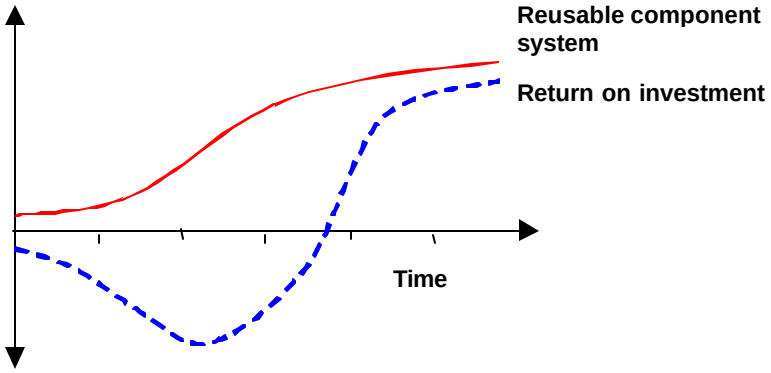
Technical Factors

Standards

The Reuse Planning Group of the IEEE Computer Society Software Engineering Standards Committee has stated that standardization of components and interfaces within a reuse effort is a key factor to success. They continued, however, to conclude that industry-wide standardization efforts are premature due to the immaturity of the practice. In place of specification of standards they have instead published the following list of Candidate Principles of Software Reuse:

- Build a software domain architecture as a framework for reuse activities.
- Use a software development process that promotes and controls reuse.
- Reuse more than just code.
- Practice domain engineering.
- Integrate reuse into project management, quality management and software engineering activity.
- Organize the enterprise to facilitate partnering to achieve reuse across product boundaries.
- Use automation to support reuse.
- Couple modern reuse theory and technology with natural, traditional organizational reuse practices.

[22].



Resource [3]

The investment in the first months is small because not many people work in the planning stage. After several year of implementation, the architectures are develop and component systems are generated. As a result, there are a lot of investments in these years. Many of reusable components exist, curve show. Almost in the same time, business begins to return its investment. When reuse come to 90 percent, ROI also reaches the ceiling. "In this time, it may decline as competition erodes the advantages of reuse"[3]

Product line approach

Most experts in the field agree that the most successful implementations of reuse will involve a product-line approach involving domain analysis and architecture. This means that to properly apply reuse to its full potential it is important to fully understand, organize, and define the domain in which given reusable assets will be applied. It is also important to construct and apply these assets according to a structured and standard architecture. [36].

Start small and incrementally

The reuse programs should concentrate on the identification and development of a small, high quality set of needed, useful components which are well understood. Process changes should be adapted incrementally and continue as the reuse experience grows. This means that most engineering and management effort should be directed at "component engineering".

Fund the start-up

Management should also commit to funding the effort with incentives. These incentives are valuable tools in encouraging the creation and use of reusable components. Without these incentives, the "not invented here" syndrome often comes into play. The incentives for producers and consumers should be further coordinated to ensure that producers are aware of the needs of the consumers.

Start with a pilot project

Early success and quick learning are critical in order to gain and retain management and engineering agreement and support. Starting with a small pilot project also reduces risk and cost.

Diffusion Level

There is a noticeable lack of information in the literature regarding levels of diffusion for strategic reuse in the computer industry. Many sources discuss factors affecting diffusion, which is presented in the next section, but none really discuss the level of diffusion itself. Only indirectly can we draw some conclusions in this area. It is clear from the readings that strategic reuse is becoming a very hot trend in the software industry. In droves, organizations are turning from traditional procedure driven custom development toward object-oriented architectures and approaches. Aside from software the only other sector of the computer industry seeing any significant movement in this area is in manufacturing where the promise of mass customization has led to the development and deployment of modular manufacturing processes. Outside of these two fields people are just starting to understand the potential fit and benefits that strategic reuse can have in their business domain. It is truly a technology of global significance and indications are that it will soon spread throughout the rest of the computer industry.

Diffusion Factors

Technology transfer in the organization

The study of Rine and Sonnemann found that there are two key issues affecting the level of diffusion that reuse technology experiences within an organization. They are the level of support from senior management for the technology and the level of training in reuse technology provided to developers. [27]. With the vision and power of senior management behind it, strategic reuse is much more likely to spread quickly through the entire organization. Another factor mentioned in most sources was the existence of a team with the specific responsibility of developing, planning, and directing reuse efforts for the organization. The existence of such a team also greatly enhances the level of diffusion throughout the organization.

Technology transfer across organizations

The literature identifies three primary factors affecting diffusion of reuse technology throughout the computer industry: publications, standards, and tools.

In the last couple of years the number of books and articles published dealing with reuse has skyrocketed. These publications present the state-of-the-art in reuse technology in easy to understand terms, as well as provide the reader with numerous case studies of both successes and failures. This information is invaluable to organizations deciding whether or not to undertake a strategic reuse effort. It is also a great way to spread the word to organizations that may not even be aware of the technology's existence

Also in the last couple of years some ad hoc standards have begun to emerge for the definition and implementation of reusable components. These standards can cover everything from the syntax of design specifications to standard component interfaces to standard software languages for reuse (e.g. Java). The emergence of these standards is decreasing the risk and increasing the potential for any organization considering implementing a strategic reuse program. This naturally increases the rate of diffusion throughout the industry.

Finally, to go along with these standards several companies have also begun to release tool kits specifically

designed to aid an organization's efforts to adopt reuse. For example, Hewlett Packard started to develop "domain-specific kits that include a framework that captures the architecture of the domain's family of system solution, sets of reusable components, design fragments, glue code, tests, templates, documentation, and tool to support both the construction and execution environments." [36]. As a result, it is much easier for an organization to adopt this technology.

DOD [36] also gives the following list of technologies that are able to easily incorporate reuse concepts:

- Application generators
- I-Case tools
- Architecture development tools
- Problem-oriented language
- CASE tools
- Modeling Tools
- Object-oriented knowledge base
- Libraries/repositories
- Natural languages
- Object-oriented languages
- Very high-level languages
- Formal methods
- High-level languages
- Assembly languages.

Stages of adoption

A working group on management and technology transfer at the 5th Annual Workshop on Software reuse identified 3 major stages of reuse adoption.

- Introduce the commitment to try reuse:

  Focus on technology transfer, learning, feasibility study and starting a pilot project. The activities should include determination of the domain bounds, recommendation for the producer and consumer software reuse process and selection of a domain analysis process and a business model.

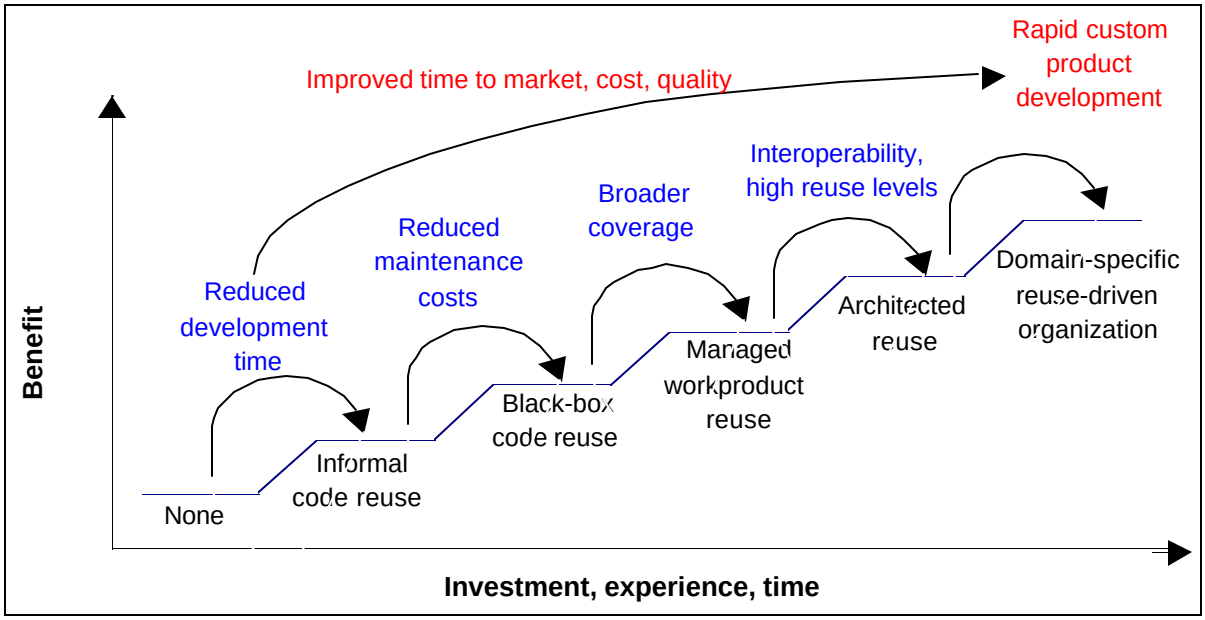
- Institutionalize the commitment to change and expand the pilot program:

  Reuse is integrated into the development cycle. Activities should include facilitation, education and support as well as the support and creation of tools and technology.

- Sustain the commitment to improve:

  Reuse is integrated into organization charter and technology transfer effort is reduced. Activities include collection of information, assessment and optimization of the reuse producer and consumer process.

Jacobson, Griss and Johnson [29] observed the application of reuse in several organizations including Hewlett-Packard. The authors noticed an incremental adoption of reuse in these companies that indicated trends as shown in the figure. These companies experienced improved benefits as they progressed from one stage to the next. Moving from no reuse to "informal code reuse" is generally what individual developers naturally stumble onto by modifying sections of code that they may have utilized in the past. These developers are at times informally familiar with code written by others. This requires programmers to have a high level of trust in each other. In order for the



organizations to move towards "black-box code reuse," the reusable modules were reengineered, tested, and documented. The modules in this phase were utilized without modification, but still not on a company-wide basis. After the number of reuse projects increased, the companies moved towards "managed workproducts" dealing with managed standard versions, maintenance, testing, adaptation, training, and education. In order for reuse to cover the organization more broadly, companies moved to "architected reuse" which accounted for correlation and compatibility of components with a common architecture. The final step that Jacobson et al. [29] noticed was toward a structured and driven reuse program in a company that involved developing domains as focused parts of the complete product architecture. This enabled rapid custom development in a cohesive manner within the organization to meet diverse customer requirements.

Case Summaries

Software Reuse at HP

HP has been engaged in software reuse since the 80's. It's early work involved developing instrument libraries in Basic, and then to C++ to develop class libraries. At present reuse is done in embedded software for instruments and peripherals, network management, analytical, medical, and manufacturing systems.

Corporate reuse program

The program involves a core team of software reuse experts, with additional people working on assignment with several divisional pilot projects. The core team works on developing the following: reuse process, domain analysis, reuse assessments, economic models, coding guidelines, a reuse handbook, reuse education and consulting to divisional reuse projects. The pilot projects combine the evaluation and refinement of proposed best practices for reuse and the incremental introduction of new methods into divisional reuse efforts.

The program has been operating since Oct'90. It has been responsible for several divisional reuse program assessments, two reuse practitioners' workshops, a draft of a reuse handbook and several reuse-training courses. The core team is actively developing a domain and reusability analysis methodology and focuses on the methods and processes of managed, systematic, domain-specific software reuse. Unlike some corporations, HP is not building a single corporate-wide centralized reuse library. The diversity of HP's products and divisional software processes requires that divisions create reuse programs and products customized to suit their needs.

Key reuse factors

HP used a simple assessment framework and identified the following key factors for reuse:

- People - Culture, Motivation, Management, Skills, Training and experience
- Process - domain, scope, policies, economics and standards
- Technology - tools, mechanisms, languages, domain and architecture

Implications of reuse at HP

- Improved quality through reuse reduces maintenance costs. HP's peripheral and medical divisions consider reuse to be a valuable approach to significantly improve quality and simultaneously reduce time to market. An estimate based on data gathered at one of HP's medical divisions suggests that the rework costs associated with defects on a typical product can exceed $1 million.
- One of HP's instrument divisions was able to produce the application software for a new product in less than 6 months. A hardware innovation enabled some new capability, and a quick shift in software priorities allowed a prototype to be deployed at beta sites in under a month, with final product roll out 4 months later. The division general manager asserted that without their prior investment in building high levels of reuse, they would not have been able to be as responsive.

Ericsson

In 1967, this Swedish based company wanted to supply telecommunication switching systems worldwide. They faced the challenge of having to adapt their systems to several countries. Several key architecture, process, and organizational principles can be outlined. [29].

Initial investment and long-term organizational commitment

In the beginning, some people in the company made a strategic decision to design and implement an architecture that provided for substantial reuse. The decision to move towards this strategy was advocated by a technical product manager who served as a technical champion for this concept. It took three years of development to produce the first useable product that had limited commercial success. This initial product was then upgraded to a much more flexible and maintainable product base system that enjoyed significant commercial success. It took almost ten years from the original decision before most of the people at

Ericsson recognized that the key to the success was the architecture and development processes based on reuse.

Well-designed architecture

Ericsson developed an architecture aimed at flexibility and ease of adaptation for reuse and customization. The system architecture was articulated and documented very carefully to provide an understandable framework. This not only served to keep everyone within Ericsson on the same page but it also enabled the salespeople to explain the functioning of the system to prospective customers. The system was flexible and adaptable to meet the needs of most customers.

Modular to enable various configurations

Ericsson implemented its system by melding carefully designed small subsystems that they called service packages. These packages had well-defined interfaces and tested compatibility with other packages. The company was able to make about 90% of its service packages completely reusable and with attractive features to minimize the amount of customer specific components that would be requested. Ericsson's product is believed to be the largest product ever built using object-oriented technology. [29].

Motorola

In the early 1990s, Motorola took steps to initiate a reuse strategy to increase productivity and improve product quality. Motorola's first step in this initiative was to form a "reuse task force" which comprised leading technicians from all sectors in the company and a "reuse working group". [31]. The task force's goal was to take abstract reuse goals and develop and recommend detailed process guidelines on reuse practices. They recommended a two-fold approach of collecting information on the past requirements, designs and code, and placing these in viable reuse databases, and also focusing on future product designs. They conveyed the importance of the reuse concept to top management and also recommended a more organized and extensive reuse effort with orientation and training. The volunteer programs that evolved from this had limited success, but it was not enough to convince middle management of the up-front costs.

It was necessary for Motorola's CEO to get involved to make upper-management recognize the significance of this concept. Motorola included the reuse concept in its business strategic plan for the future. A cash-incentive award program was implemented to reward developers each time their component was retrieved from the database for reuse. The program also rewarded a user for reusing from the database. As a result of this implementation, significant gains in productivity and quality were measured within the company. With this success, Motorola is developing an environment that is reuse-friendly and further developing formal reuse toolkits that standardize, if not automate, the reusable software development cycle.

Synopsys

The ability to reuse Intellectual Property (IP) in chip design has become mandatory for today's feature-rich, complex applications. The need for versatile IP reuse results from rapidly growing complexity of system-on-a-chip designs. By year 2000, chips consisting of 12 million gates will be commonplace. Based on today's metric of 100 gates per day to design a new chip, it would take 400 person-years to design each of those chips. [36]. Reuse promises to bring design cycles into a more realistic time frame.

Synopsys has developed technology libraries that deliver silicon-proven IP that is portable across many semiconductor fabrication processes. With this, designers can quickly and efficiently integrate IP into new designs and processes.

Every company's set of reuse challenges is unique. Synopsys has taken the approach of studying the company's product portfolio, organization and current design processes and then creating customized solutions that balance near-term and long-term objectives. Synopsys offers a full complement of services and technology to solve design reuse problems at different levels of scope and complexity. Some of the services are:

- Classroom training on reuse methodology and the fundamentals of how to create reusable designs.
- Customers identify the IP and then Synopsys converts them to reusable form.
- Helping customers create a design reuse infrastructure within their companies. This is for industry players ready to make design reuse the fundamental paradigm driving their product development strategy.

Field Study

Case Summaries

Company A

Company A is a professional services firm which provides management consulting, systems integration and systems development expertise to clients around the world. Interviews were conducted with senior technical and business leaders within a technology services unit of the corporation. The individuals interviewed all have over ten

years of experience in systems engineering and consider themselves to be up-to-date on current technology trends. These individuals are not only familiar with the concept of reuse but also have direct experience implementing reuse at least on a small scale, with applications development as well as business processes.

Company A, as an overall corporation is considered to be technologically up-to-date, with some units on the leading edge and some on the bleeding edge. The unit studied here is considered to be somewhat up-to-date, but not fully up-to-date due in part to a lack of technical direction from the strategic unit level. According to the individuals interviewed, the unit struggles with leading the marketplace because the people tend to reinvent more than replicate. It is believed that strategic reuse from a technical and a business perspective would position the unit well ahead of its competitors in the marketplace.

Goals of implementing reuse within Company A include reusable products, quicker implementations (as a result of reduced development time), lower post-implementation maintenance costs (as a result of lower maintenance efforts), lower market price, and larger market share (as a result of lower product price).

Company A has had some successes and some failures. Failures are due to a variety of factors: engineers not being in tune with the strategic direction as defined by executive leadership; problems in what is inherited, requiring time spent debugging code that should already be clean; human tendency to recreate; resistance to change mentality; and a management focus on short-term gain rather than long-term benefit.

Success with reuse is achieved when people truly understand the concept and know how to apply the concept to a given scenario. Successes lead not only to flawless implementations and happy customers but also to improved employee morale. Reliable reusable tools, templates, and processes reduce frustration and help create shared expectations for the team.

The concept of reuse as a strategic practice has not really spread across Company A, nor the division studied here. Perhaps due to a lack of solid technical direction from the leaders at the top of the unit, there is still a tendency for some people to reinvent, and in most cases there is no one holding people accountable for following the proven methods. It has also been suggested that a "leverage bias" exists among engineers. In other words, engineers want to create things to be reused by others, yet prefer not to reuse what has already been created by others.

Company A has implemented the use of a "reuse repository" for the technical community, designed to house proven methods created by engineers within the technical community and made available for reuse by other engineers within the technical community. This is a step forward from the days of informal networks of engineers attempting to share information on more of an ad hoc basis. It still remains to be seen whether or not the "reuse repository" will prove successful. Some believe that engineers will still have the tendency to recreate something themselves rather than looking for something to reuse.

Some believe that Company A, as a corporation, has indirectly and informally taught the concept of reuse throughout its history. Still, it is unknown just how much of a priority it is to embrace this concept across the corporation. There seems to be a general feeling that reuse is more strongly supported at the lower levels of management because the upper levels are more focused on business relationships and profitability. In addition, even though the concept may be strongly supported in theory, it does not seem to occur frequently in practice.

The individuals interviewed all agree that reuse as a strategic practice is a good fit for all sectors of the computer industry, primarily because it speeds development time and produces more reliable products over time. Also, it is believed that the one of the most direct ways for a company to gain competitive advantage and higher productivity from its employees is through effective reuse.

One interviewee mentioned that a primary concern of senior leaders within this unit is that the technology services manpower rate is too high for our clients. Reuse would be an excellent way to overcome this, since we could potentially reduce the overall expense to our clients by providing a higher level of service with fewer engineers. When asked why they believe that reuse is not currently being implemented as a strategic practice with this unit, the interviewees responded that it is probably a combination of factors. These factors include: the need to install a customized system for a given client in a very short period of time, with no time/resources planned for the creation of reusable components; skepticism on the part of upper management as to how big the value of reuse really is, stemming from a lack of understanding or a lack of personal experience with reuse; well-educated engineers who are trained to figure things out for themselves and "do it better" rather than search out and reuse what someone else may have created; a reluctance in the current business environment to make the up-front investment required to gain the long-term savings; shortage of effective training on the benefits and the practical methods of implementation; perception that Company A's culture tends to reward individuals who create components for use by others instead

of rewarding individuals who reuse components created by others; and strong business minds, but no technology-minded people, in upper management who do not see the value simply because they do not have the knowledge and expertise.

To quote one interviewee, "The reality is that anyone with vision can see that a 'reuse initiative' is necessary and will reap many rewards."

Company B

Company B is a professional services firm which provides management consulting, systems integration and systems development expertise primarily in areas of information technology to mainly medium and large size clients around the world. The company is very aware of the concept of strategic reuse and takes it very seriously. It is a stated corporate goal in the company business plan and the company has created an entire practice with dedicated resources to pursue this effort as part of an overall advanced technology development effort.

Interviews were conducted with several senior technical and business leaders within the company's Reuse Practice group. This group is tasked with exploring, developing and deploying various technologies to enable and encourage systematic reuse of assets across the corporation. These technologies come in the form of methodologies, processes, tools, applications, systems, training programs, etc. Beyond its responsibilities to develop reuse capabilities, the group is also involved in actual consulting engagements and product development for the organization. This interaction with real clients yields excellent practical information for the group's reuse activities.

The individuals contacted in this group run the gamut from software developers to systems engineers to business development experts to very senior management. The experience level of these individuals and the group as a whole is to a large degree unparalleled in the industry. They have in place a very mature and comprehensive reuse program and are currently developing even more bleeding edge technologies to expand the program. The group has been successful in diffusing the effort throughout the entire organization but still faces serious challenges in the form of the vastly distributed geography of the company, the rapid growth rate of the company, a recent large scale merger, and the bleeding edge, therefore unproven, nature of most of the new technologies. The company feels that open communication, a comprehensive training program, existence of standards, and availability of appropriate tools are critical for successful diffusion of this technology throughout the organization.

While the group is involved in developing reuse across the full range of the technological landscape, its primary efforts are currently in software development frameworks and methodologies as well as business process reengineering with a focus toward strategic reuse.

The goals for the reuse effort at Company B are reduced development cycle time, increased flexibility, improved quality, lower risk, lower cost, increased standardization as a market differentiator, superior interoperability, and simplified planning due to improved estimation capabilities and schedule stability. Company representatives were very emphatic about the importance of simplified planning due to its importance to any business, especially a consulting company.

The success of the company reuse program can to a large degree be accredited to the firm commitment of management, from CEO to project manager, in making the necessary up-front investment in order to reap the long-term benefits. This commitment is further institutionalized in the formal policy statement and the existence of a Reuse Practice to hold the organization accountable. Outside of these business related areas the company feels that high quality up-front design, open communication, appropriate training, strategic definition of standards, and acquisition or development of appropriate tools are also critical factors influencing the success of the reuse effort.

The individuals contacted at Company B feel that strategic reuse should be an absolute requirement not only for technology consulting companies like themselves but also for any high-tech company and even for non-technology related companies. They see the value it brings as the key to flexibility and flexibility as the key to success.

Company C

An interview was conducted with an individual who has twelve years experience in high-tech and who considers himself to be up-to-date on current technology trends. This individual is in the Color Printers business unit of Company C and is responsible for forty managers and engineers reporting directly to him. The group is involved in all aspects of product development, and the individual considers the group to be technologically "leading edge."

The individual expressed that he is familiar with the concept of "reusability" as a strategic management practice, and he became familiar with this concept through his work in the software domain within Company C.

"Reusability" was implemented for software projects within the Tests and Measurements unit of Company C. The

goals were to decrease time to market and to improve system performance. The point is made that, in this case of software development at Company C, "success" was measured based on the performance of the product, not how the product was developed. In this case, the product was successful, yet it seems unknown as to exactly how successful the reusability aspect was. Some of the factors that made the reuse effort more likely to succeed were (1) training in the concept of reuse and (2) the ability of the team to reap some short-term benefits as a result of their efforts. The concept spread somewhat within the Tests and Measurements unit simply as a result of people transferring within the division and taking this knowledge/experience with them and also as a result of these people providing training for others.

This strategy has not been implemented within the Color Printer division. The statement is made that "the concept of reuse has not been implemented within the Tests and Measurements unit because the team is currently working in legacy code from product to product, thus there is no opportunity for ground-up re-engineering." The Color Printer division may pursue implementation of the reuse concept in the future.

Company D

An interview was conducted with an individual who has responsibility for design and verification functions. The individual considers the group to be technologically "leading edge."

The individual expressed that he is familiar with the concept of "reusability" as a strategic management practice, and he became familiar with this concept through his work at Company D, participation in seminars, and reading of various articles.

This individual has experience with reuse at Company D. Application code has been written so that it can be used for more than one product. The goals were to reduce costs and development time. He believes the effort was successful in that development, maintenance, and training costs were reduced. One of the facts that made the reuse effort more likely to succeed was a design which emphasized generic modules. Unfortunately, one of the factors that made the effort less likely to succeed was poorly defined module interfaces. The concept has spread; however, implementation is very difficult.

The concept has spread somewhat within Company D; however, there seems to be a perception that although management does want to reduce development costs, management still has a limited understanding of the implications of using reusable objects.

Company E

An interview was conducted with the Chief Technology Officer (CTO) of Company E. This CTO's background is primarily in technology and management consulting within the Internet sector of the computer industry. The company is four years old and currently has eleven employees. The company is growing.

The CTO's group has responsibility for all product development and Information Technology (IT) maintenance. He views his company as technologically leading edge.

This CTO is familiar with the concept of reusability as a strategic management practice as a result of reading. He does not have any direct experience implementing this concept.

Company E, as a company, is not currently pursuing or implementing this concept, apparently because this CTO believes that this technology is does not bear an appropriate return on investment for a small startup company.

Relevant Issues

The following issues were extracted from the interview data using non-formal analysis methods. The enumeration is arbitrary and bears no consideration of the data gathered in the literature research other than an obviously similar focus on areas of relevance. The elements most heavily emphasized by the individuals interviewed are presented in bold-italic.

Methods of implementation

- ***Mostly software***
  - OO
  - Libraries
  - Repositories
- Modular HW design in circuit boards
- Modular chip design
- Modular business processes
- System architectures

Goals of effort

- ***Reduced cycle times***
- ***Lower cost***
  - Development
  - Maintenance
  - Training
- ***Lower maintenance***
- ***Improved quality***
- Improved compatibility/interoperability
- Consistency & accuracy of information

- Improved estimation capability
- Improved schedule stability
- Improved employee morale

Success factors

- ***Management commitment***
- ***Formally stated as company policy***
- ***Systematic strategy rather than ad-hoc***
- ***Training***
- ***Long-term benefit & short-term cost***
- Communication between management and engineering
- Communication among and between engineering teams
- Quality of up-front design
- Client involvement
- Existence of successful examples
- Selection of appropriate projects
- Availability of appropriate tools
- Not invented here syndrome

Diffusion factors

- ***Human vector***
- Communicating successes to others
- Haphazard application
- Strategic selection of projects

Observations of note

- In most cases these efforts are pushed from the bottom-up rather than top-down.
- Managers from strong technical background are ***much*** more likely to support reuse
- Consulting companies with involvement across the technological landscape are more likely to fully and formally support reuse across the organization
- Not as valuable to small companies

Results

Does interview data match literature?

Yes. To a large degree the data gathered in the field study closely validates most of the information gathered in the literature research phase of the project. Somewhat understandably the data from the field study tended to be more from a practical, operational viewpoint rather than theoretical as some of the literature tended to be. This is not to say that the literature wasn't of practical value. In fact, the literature available on this technology had a much higher practical content than most found in the industry today. There were a few differences to note however. There were three issues that came through in the field study that appear to be lacking proper treatment in the literature.

The first of these is the fact that small/startup companies may determine this technology to not be an appropriate technology for them to pursue. The literature gives extensive treatment to the issue of this technology's higher short-term cost for a substantial long-term benefit, but it does not really discuss any practical effects of this issue. The field study pointed out that while for a company attempting to pursue strategic reuse this issue is an important thing to consider in ***how*** to go about it, it is also true that for a company deciding if the technology is appropriate for their business goals this issue is a key to ***if*** they go about it at all.

The second issue unique to the field study was the importance of planning benefits that this technology offers. While the field study validated most of the standard goals for strategic reuse, it is interesting that only the field study brought out the practical benefits of the improved quality and consistency gained through reuse. Company B in particular emphasized the short and long-term benefit of improved estimation capabilities and schedule stability on simplifying the planning process.

The last and perhaps the most emphasized issue of difference between the field study and the literature research was the importance of proper training as a factor in the success or failure of a strategic reuse effort. Several of the literature sources discussed corporate training programs as an important factor in the diffusion of this technology, and one or two sources *briefly* mentioned that training may affect the success of such a program. Contrary to this apparent lack of importance, almost every individual interviewed stressed that adequate and proper training of personnel in development and application of reusable assets was one of the most critical factors affecting success.

It would behoove the reader to remember these issues when investigating a program of strategic reuse. Further, these issues point out holes in the literature that offer future opportunities for further research.

Is this an emerging trend?

Yes, strategic reuse is definitely an emerging trend. The word emerging may be confusing to some readers since the basis for this idea has been around and practiced for decades, but the practice of a systematic and strategic application of it is truly a new idea and has just begun to emerge and spread in the last 5-10 years. The substantial body of literature on this topic further validated by our field study leads to our conclusion that this concept is here to stay and will most likely continue to diffuse through the industry. Specific descriptions of how this trend is likely to continue are given

in the later section answering the question, "**What are the future prospects?**"

Is it successful in achieving its goals?

The answer to this question is simple and straightforward. If the concept of strategic reuse is implemented properly considering at least the most important half of the success factors enumerated in this paper, it will almost definitely succeed. And on the contrary if it is implemented incorrectly and without a full understanding of the issues involved, it is very likely to fail and end up costing an organization all of their investment and then some. This simply reiterates the old adage that there are no magic bullets that you simply plug in and save the world. Strategic reuse like and other technology must be fully understood before one attempts to employ it.

What factors affect its success?

Merging the data gathered in the literature research and the field study yields the following list of factors influencing the success of a strategic reuse effort (the most critical factors are in bold-italic):

- ***Management commitment & accountability***
- ***Formally stated as company policy***
- ***Systematic strategy rather than ad-hoc***
- ***Understanding Short-term cost/Long-term benefit***
- ***Training***
- Existence of successful examples
- Availability of appropriate tools
- Communication between management & engineering
- Communication among and between engineering teams
- Selection of appropriate projects
- Quality of up-front design
- Client involvement
- "Not invented here" syndrome
- Incentives

What factors affect its diffusion?

Merging the data gathered in the literature research and the field study yields the following list of factors influencing the diffusion of strategic reuse as an technology for operational strategy in the computer industry (the most critical factors are in bold-italic):

- ***Movement of people (human vector diffusion)***
- ***Strategic vs. ad-hoc approach***
- ***Management commitment & accountability***
- Strategic selection of projects
- Publications (communicating success to others)
- Standards
- Tools

What are the future prospects?

The trend toward strategic reuse is by far the strongest in the software sector of the computer industry. Here, it is close approaching the transition point of moving from a trend to becoming an accepted standard practice. This advanced state of acceptance and diffusion can be attributed to two primary factors. The first of these is the fact that because of the emergence of the Internet and other advanced information technologies the operating environment for software development is operating and accelerating at a much higher rate than other areas of the computer industry. This hyperdynamic environment has forced organizations to employ whatever means necessary to increase flexibility. Strategic reuse has been a key factor in this area. The second factor of influence is the simple fact that the concept of strategic reuse of components is a good fit with the other technologies making up the software industry. As we go forward, these two factors will only become stronger in their influence and we predict that strategic reuse, now considered a best practice, will become a standard practice within the next 5 years.

This technology fit is not nearly as tight in the hardware sectors of the computer industry and up to this point implementations have been more anecdotal rather than global. This is not to say that nobody is doing it. On the contrary, some organizations are employing it with great fervency. However, this feeling is still not shared by the majority of the industry. Current indicators show that this may soon begin to change. The hardware market is beginning to undergo a dynamic acceleration similar to what happened in the software industry and they are beginning to hit the wall on evolutionary improvements to standard processes. [7]. It is likely in the next couple of years that the flexibility requirements of the market will begin to outweigh the implementation difficulties and we will see the computer hardware industry begin to move to strategic reuse in force.

Lastly, and definitely to the smallest degree, there is an emerging trend toward strategic reuse in the area of business processes. In actuality, this is the area where strategic reuse may offer its most widespread gains but it is also the least understood area. This arena is populated and controlled by business people who have little grasp of engineering concepts like strategic reuse. For these people to get on the bandwagon we will have to see a much wider acceptance of the concept in engineering circles and a much wider publication of its potential in the business world.

Suggested Reading

For readers wishing to further investigate the concept and potential of strategic reuse in the computer industry, the authors recommend the following publications as a good starting point for your effort. Of course there is much more out there but we feel these recommendations will move you to the next level of knowledge without drowning you in details.

Jacobson, M. Griss, and P. Jonsson, "Software reuse: architecture, process and organization for business success." ***Addison-Wesley.*** **(1997)**

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