IT SYSTEMS TO SUPPORT INNOVATION

An empirical analysis of IT Systems to Support Innovative Product Development in Analog Devices B.V.

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Abstract: The provision of systems to support and promote innovation has become a significant concern for New Product Development (NPD) processes as they try to cope with the rapid rate of technology development, change of customer's needs, and shortened product life cycles. Companies such as Analog Devices Inc. (ADI) see the creation of an environment that encourages knowledge to be created, stored, shared and applied for the benefit of the organization and its customers as a key strategic activity. Despite the fact that such initiatives have been widely reported in the business press, the role of IT systems to support innovation in new product development is not well understood. This paper describes one such in initiative – as it was executed in practice in Analog Device's NPD organization in Ireland. The work is presented in the context of current research in Knowledge Management Systems (KMS). The structure of the paper is set out in Table 1.

Key words: Innovation, New Product Development, Knowledge Management, Knowledge Management Systems

Table 1. Paper Structure

Section	Contents
1: Introduction	The background for the study in terms of the challenges faced by new product development organizations as they attempt to apply IT systems to improve their competitive advantage in the market place. Introduction to the innovation initiative in ADI.
2: Research Method	Rationale for choosing action research (AR) methods and description of AR cycles.
3: IT Strategies to support Innovation	Review and analysis of current conceptual

Section	Contents
	models of systems to support innovation. Positioning of ADI IT systems in framework illustrating region of operation of each application.
4: IT Systems Framework to support innovation in NPD	Proposed framework synthesized from conceptual models and ADI's stage-gate NPD process. Description of three IT systems in use in ADI.
5: Conclusions	Conclusions and future research.

1. INTRODUCTION

At a recent address to the Irish Management Institute, Michael Porter pointed out that Ireland is entering a new economic era and that the key element in its competitive agenda is the "strengthening of its innovative capacity" (Porter 2003). Porter's analysis concluded that Ireland's traditional competitive advantages are eroding because (i) competing locations have caught up in terms of business-friendly regulations and tax structure and (ii) rising cost levels are making Ireland's traditional position as a low cost location untenable. He proposed that Ireland needs to develop new strengths to emerge as an innovative economy.

It is clear that at the firm level there is a need for systems that provide an infrastructure to facilitate knowledge creation, storage, distribution and application. Such systems are designed to increase revenue and profits for an organization by

a) Improving the sharing of knowledge and best practice across the organization
b) Providing a faster solution development to technical problems and hence reduce TTM
c) Accelerating innovation rates by bringing diverse views and experience to bear on an issue
d) Breaking down geographic/organization barriers
e) Improving efficiency by learning from others

Both the academics and practitioners who have been involved in developing systems to support knowledge creation have tended to interpret such strategies as bifurcated into (i) those focusing on explicit knowledge (so-called "codification" or "cognitive" strategies) and (ii) those focusing on tacit knowledge (so-called "personalization" or "community" strategies) (Hansen, Nohria et al. 1999), (Swan, Newell et al. 1999).

There are significant innovation-related IT initiatives taking place in ADI, but without an overall guiding framework which could 'make sense'

((Weick 1979), (Weick 1995)) of the various activities. In this study, we present a framework for IT in NPD that we have derived, based on an understanding of the types of knowledge used in the design phase of NPD processes and a synthesis of current research on systems to support knowledge creation. In particular, we argue that a balanced approach needs to be taken when developing such systems. In the past, there has been a tendency to focus solely on codification or personalization strategies. We argue however, that while on one hand, some forms of codified knowledge lend themselves to a repository-based approach, however tacit knowledge is best managed by promoting human interaction.

2. RESEARCH METHOD

A research method which has proven useful when research needs to be closely aligned with practice is that of action research (AR). Typically, an AR project is a highly participative model where researchers and practitioners focus on a real business project or problem as a starting point. Thus, all the associated risk and unpredictability of a real organisational situation is factored in from the outset.

The site for this research was a U.S. multi-national firm, Analog Devices Inc. (ADI). ADI is a world leader in the design, manufacture, and marketing of integrated circuits (ICs) used in signal processing applications. Founded in 1965, ADI employs approximately 8,500 people worldwide. Innovation has long been an integral feature of the landscape at ADI. Indeed, ADI's Chairman of the Board, Ray Stata, published some of the early research in the area (Stata 1989).

(Lewin 1947) originally described the action research cycle as having four basic steps: diagnosing, planning, acting and evaluating. Lewin saw the process as a "spiral of steps, each of which is composed of a circle of planning action and fact-finding about the result of the action" (p.206). The action research model being applied in this research is similar to that described in (Susman and Evered 1978) and sees the research process as a five phase cyclical process containing the following discrete steps: diagnosis, action planning, action taking, evaluation and learning.

The AR method recognises that a research project should result in two outcomes, namely an *action* outcome and a *research* outcome. Taking each in turn: firstly the action outcome is the practical learning in the research situation. Thus, a very important aspect of the research is the extent to which the organisation benefits in addressing its original problem. This serves to ensure the research output is relevant and consumable to practice. Secondly the research outcome is very much concerned with the implications for the advancement of theoretical knowledge resulting from the project. In this study there were two action research cycles. The first cycle of the action research project produced a new business process called "knowledge" embedded in a new framework for ADI's core business processes in the new product development organization. The second cycle of the action research project involved the deployment of two knowledge management systems to support the knowledge core process and the re-engineering of a the peer review process to make it more effective as a forum for sharing knowledge across product development teams. The KM systems were called "EnCore" and "docK". The research saw the process as a "spiral of steps, each of which is composed of a circle of planning action and fact-finding about the result of the action" (Lewin p.206) and involved a five phase cyclical process containing the following discrete steps: diagnosis, action planning, action taking, evaluation and learning (Susman and Evered 1978).

3. IT STRATEGIES TO SUPPORT KNOWLEDGE CREATION

There are two generic strategies described in the literature. These approaches have been characterized as – "codification" and "personalization" (Hansen, Nohria et al. 1999), (Alavi and Leidner 1999). The essential difference between the two paradigms is whether you are motivated by a goal to encapsulate knowledge in a form that makes it suitable for re-use in another context (codification) or are motivated by a goal to transmit knowledge by making it easy to locate the relevant experts (personalization). These two approaches will be elaborated on in this section.

3.1 Codification Approach

The goal of the codification approach is to provide a high-quality, reliable, means of re-using codified knowledge though the use of electronic repositories. It is a "people-to-documents" approach. Knowledge is extracted from the person who developed it, made independent of that person and re-used. The approach allows for these "knowledge objects" to be searched for by many people and the codified knowledge retrieved without having to contact the person who originally developed it. Examples of this approach being implemented in the semiconductor industry are described in (Keating and Bricaud 1998) and (Chang, Cooke et al. 1999).

Recent contributions to the theoretical aspects of codified knowledge reuse have come from (Hansen, Nohria et al. 1999), (Swan, Newell et al.

1999), (Dixon 2000) and (Markus 2001). The contributions of Hansen et al. and Swan et al. has been to identify the features of codified knowledge management systems that differentiated them from systems dedicated to supporting the transfer of tacit knowledge (Hansen, Nohria et al. 1999) (Swan, Newell et al. 1999). Swan characterized such systems as applying a "cognitive" approach to knowledge management systems. Hansen characterized such systems as having a "codification" approach. Both authors identify the primary function of such systems as the capture and codification of knowledge. The key enabler of the system was identified by the authors as being information technology. Both authors identify the weaknesses of the codification approach as over-reliance on IT, with not enough attention being paid to human factors in KM.

The contributions of Dixon (Dixon 2000) and Markus (Markus 2001) were in the development of a typology of knowledge transfer and reuse situations. Dixon identifies five types of knowledge transfer: serial transfer, near transfer, far transfer, strategic transfer and expert transfer. She illustrates the types with five case studies. However, her focus is not solely on codified knowledge but on "best practices" i.e. knowledge about how to do some things better. Markus, on the other hand, restricted her focus to codified knowledge. She identifies four types of knowledge reuse situations: shared work producers, who produce knowledge that they later reuse: shared work practitioners, who reuse each other's knowledge contributions; expertise-seeking novices; and secondary knowledge producers. She also identifies the factors that affect the quality of repositories. For companies involved in NPD the goal of a codification approach is to make it easy for individuals in a new product development community to access a repository of previously design products so that the knowledge captured in the repository may reused in a new product.

3.2 Personalization Approach

The goal of the personalization approach is to produce highly customized solutions to unique problems by promoting person-to-person interaction. It is a "people-to-people" rather than "people-to-documents" approach. It focuses on creating opportunities for dialogue between individuals, rather than directing people to knowledge objects in a database. The approach assumes that people arrive at insights by firstly finding out who is knowledgeable on a topic and then going back and forth on problems they need to solve. Some firms use such knowledge maps or skills profiles to connect individuals with other individuals having relevant project knowledge. An example of this approach is described in (Carrozza 2000).

There have been relatively recent developments in IS technology that have facilitated the growth of the "personalization" approach. Traditionally, the systems approaches that have been associated with knowledge management in organizations have been: dedicated knowledge-based systems, document management system, database systems, and data warehouse technologies. With the advent of web technology and markup languages such as XML, new capabilities in IS technology have emerged. The key development is that it is becoming possible to integrate knowledge acquisition into the organization's existing business processes, rather than providing, in retrospect, a means of finding knowledge in existing unstructured data (Attipoe 1999). The approach proves particularly appropriate for companies using the so-called "stage-gate" new product development process where milestones such as product reviews can be captured and made available for the broader product development community. The gates are, in fact, "knowledge events" where teams are required to externalize their knowledge - thereby rendering that knowledge available to be shared and applied elsewhere in the organization.

A central aspect of this approach is the use of meta-data to add structure to product development documentation so that it is more easily located or "harvested" (Gutl, Andrews et al. 1998) (Bellaver and Lusa 2002). In order to provide a degree of added structure and simplify productive access to information from the Web, conventions such as the "Dublin Core" are used in conjunction with standard data formats such as XML, (Rabarijanaona, Dieng et al. 1999), (Finkelstein and Aiken 1999), (Abiteboul, Buneman et al. 2000). For companies involved in NPD the goal of a personalization approach is to make it easy for individuals in a new product development community to make documents relating to their work available to the community so that others can be aware of their contributions to a particular topic. Members of the development community may then take advantage of this facility by contacting the authors directly and seeking their help to get a deeper understanding of the issues in question.

4. ADI'S IT FRAMEWORK FOR NPD

The NPD process has a requirement for IT that takes account of the different knowledge types inherent in a stage-gate process. The framework being developed in ADI has several applications that target different phases of the NPD flow (see Figure 1). This section contains a description of three of those applications.

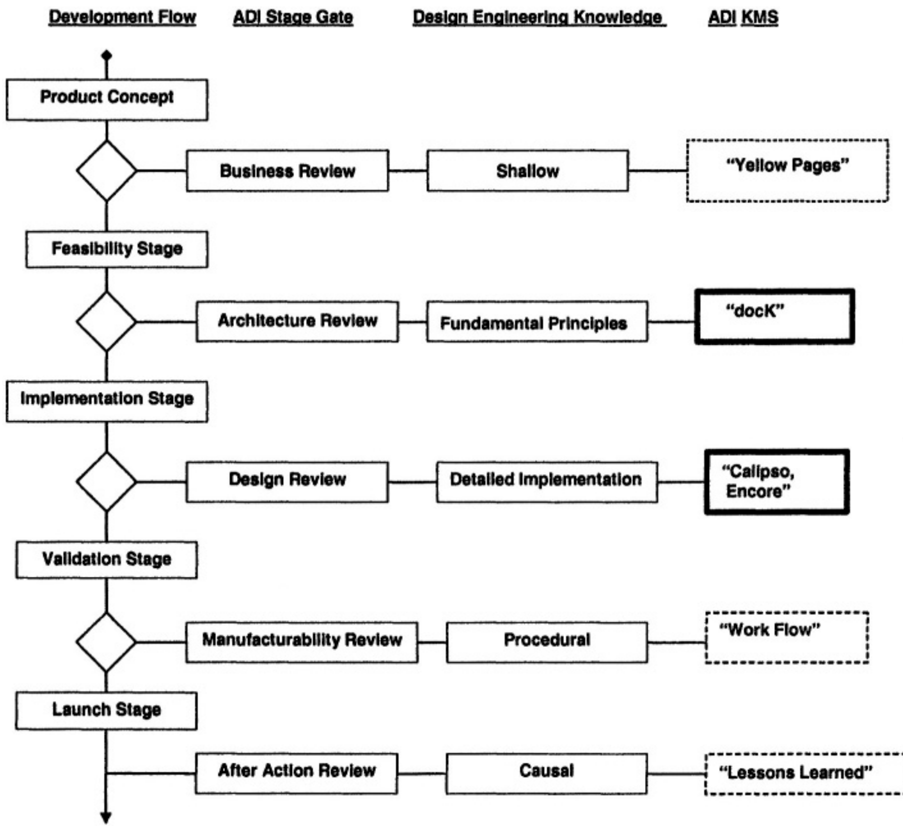

Figure 1. **NPD Stage-Gate Process, Design Engineering Knowledge and KMS**

4.1 Meta-Knowledge – "docK"

"Conventional explanations view learning as a process by which a learner internalizes the knowledge, whether "discovered," "transmitted" from others, or "experienced in interaction" with others." (p.47) (Lave and Wenger 1991). However, before one can initiate such a process, whether through discovery or interaction, there must be a mechanism by which people can easily find out what knowledge is being created in the organization and by whom. The knowledge being sought is, in fact, knowledge about knowledge or "meta-knowledge" (Swanstrom 1999), (Kehal 2002).

Meta-knowledge attempts to provide answers to questions such as "Where can I get information about a particular technical topic? How can I find out more about this topic? Is there work in progress in this organization on this topic?" The dock application tackles these challenges by making it easy for members of the technical staff to publish and locate technical reviews, notes, articles etc. - items which previously may have required several emails and phone calls to track down ("dock" stands for digital on-line cache of Know-how).

This is achieved by (a) the use of sophisticated resource discovery tools, and (b) the development of rich varieties of resource description.

(a) Resource discovery tools have been characterized as falling into two categories – search engines (SEs) and digital libraries (DLs). The first generation of SEs and DLs defined the basic structures of indices, directories and libraries. The second generation put the first generation tools to work in an operational setting. The third generation emphasized popularity measures such as links, usage and time as well as the use of parallel computing power and advanced search techniques (Hanani and Frank 2001). Through the use of meta-knowledge, the documents become more like databases where search, retrieval and reuse of text elements (explicit knowledge) are promoted while also giving the reader the opportunity to contact the source of the knowledge so that they may have a dialogue to enable tacit knowledge transfer (Braa and Sandahl 2000).

(b) Metadata is used by docK to provide a richer resource description for information on the WWW. *Meta* is used to mean a level above a target of discussion or study. Metadata is data about data and is often used in the context of data that refer to digital resources available across a network. Metadata is a form of document representation that is linked directly to the resource, and so allows direct access to the resource. Internet search engines use metadata in the indexing processes that they employ to index internet resources. Metadata needs to be able to describe remote locations and document versions. It also needs to accommodate the lack of stability of the Internet, redundant data, different perspectives on the granularity of the Internet, and the variable locations on a variety of different networks. There are a number of metadata formats in existence to provide bibliographic control over networked resources. The Dublin Metadata Core Element Set is one of the prime contenders for general acceptance – and is the format implemented in docK (Kunze, Lagoze et al. 1998).

4.2 Knowledge Catalog – "Calipso"

A "Catalog", in this context, is an application that generates a list of previously designed products in the product development community. The catalog would enable product development staff to quickly find out if products were previously designed that were similar to those currently under development.

Calipso is a catalog of functional circuit blocks developed by ADI's development staff. The entries are created and owned by the product development staff. Each entry in the catalog represents is a potentially reusable circuit design. Catalog entries, depending on their utility, are potential candidates for inclusion in a repository. The problems that were identified in the new product development process that were to be addressed by "Calipso" were:

a) (a) a lack of awareness of what previously designed circuit blocks had been created in ADI and might be available for reuse in future projects
b) (b) a mechanism by which product development staff could easily make their products more easily "discovered" by members of the product development organization outside of their own organization unit.

4.3 Knowledge Repository – "EnCore"

A "Repository", in this context, provides a store of previously design products that could be reused throughout the corporation. Each of the repository's elements has an extensive support kit associated with it i.e. thorough documentation, contextual information about previous usage, data formats compatible with existing NPD systems, validation data, interface information, etc.

EnCore is a structured repository for formal knowledge containing previously used circuits that were internally developed and externally procured circuits that may also be re-used in future products. Its purpose corresponds, generally, to what Hansen termed a "codification" strategy where the value of the repository lies in "connecting people with reusable codified knowledge" (Hansen, Nohria et al. 1999) or to what Swan termed a "cognitive" strategy where the primary function of the repository is to codify and capture knowledge so that it can be recycled (Swan, Newell et al. 1999).

The goal of EnCore is to provide a library of robust and supported reusable circuit designs available for download, obtained from both internal and external sources. The repository contains previously designed products packaged in a format suitable to delivery as intellectual property to either internal groups or external groups (or both). They are close to the explicit dimension on the diagram because they represent an attempt to codify the knowledge associated with a product i.e. a people-to-documents approach.

The motivation for both Calipso and EnCore was based on a belief that reuse of design intellectual property (IP) helps keep development costs down while also helping to reduce time to market. The key difference between Calipso and EnCore is that to qualify for entry into the EnCore repository a circuit block needs to satisfy rigorous standards with respect to reusability, supporting documentation, usage potential etc. Calipso's catalog points to a very broad set of circuits that do not necessarily conform to these standards.

The fact that a catalog exists containing these entries gives members of the engineering community an opportunity to contact the originators of the entries and share knowledge about the element in question.

5. CONCLUSIONS AND FUTURE RESEARCH

A framework has been developed that is based on a stage-gate NPD process and current thinking on IT to support innovation. The framework is being evolved and elaborated in an industrial setting in ADI. The approach being pursued is based on an understanding of the types of knowledge important to NPD and the range of applicability of that knowledge across organizational units. The work builds on earlier work by (Hansen, Nohria et al. 1999), (Swan, Newell et al. 2000), (Dixon 2000) and (Markus 2001).

Figure 1 summarizes the framework by showing the stages in ADI's NPD stage-gate process and the corresponding IT systems being developed to support the appropriate product development stages. The development of the framework is at an early stage so there are gaps in the IT support of some stages of the NPD process.

Where those gaps exist, possible IT solutions for the stage are proposed e.g. a so-called "Yellow Pages" application which would be useful at the conceptual stage of the project. These are applications that provide a centralized database of user knowledge profiles. They offer users multiple ways to find user profiles. Participation is usually voluntary (i.e. no automatic profile creation). Users can create and maintain their profile's visibility and access. An example is described in (Carrozza 2000).

Possible solutions for the launch stage include so-called "Organizational Memory Information Systems (OMIS)" that could capture the results of After-Action-Reviews. An "OMIS" is an organizational memory information system and in this case would be targeted at the results of After Action Reviews (AARs). The defining processes of an OMIS application are acquisition, retention, maintenance, and retrieval (Stein and Zwass 1995). The development and application of these additional components of the overall framework will be the subject of future research in this area.

The IT framework to support new product development that has been described has a strong focus on engineering knowledge. It is recognized that there is other forms of knowledge that is critical to NPD success that is not depicted in the framework at present e.g. customer and marketing knowledge.

This research project exposed some of the issues surrounding the implementation of a codified knowledge reuse system in a product development environment. The lessons learned from the implementation will enrich our understanding of the parameters that need to be accounted for in a comprehensive model of codified knowledge re-use. The key success factors included , upper management support, the "Productization" role of intermediaries between the developers and the end-users, stable domains and architectures, infrastructure support (common systems, robust networks), quality and availability of potential repository entries, cultural acceptance of reuse in the organization, standardized interfaces and formats, and the demonstration of early reuse success stories.

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REFERENCES

Abiteboul, S., P. Buneman, et al. (2000). Data on the Web: from Relations to Semistructured Data and XML. San Francisco, Morgan Kaufmann Publishers.

Alavi, M. and D. E. Leidner (1999). "Knowledge Management Systems: Issues, Challenges. and Benefits." Communications of the Association for Information Systems **1**(7): 1-37.

Attipoe, A. (1999). "Knowledge Structuring for Corporate Memory." Markup Languages: Theory and Practice **1**(4): 27-37.

Bellaver, R. and J. Lusa (2002). Knowledge management strategy and technology. Norwood, MA, Artech House.

Braa, K. and T. Sandahl (2000). Documents: from paperwork to network. Planet Internet. Braa K., Sorensen C. and Dahlbom B. Lund, Sweden., Studentlitteratur.

Carrozza, T. (2000). From Hyperlinks to Human Links at Hewlett-Packard. Knowledge Management Review. **3**: 28-33.

Chang, H., L. Cooke, et al. (1999). Surviving the SOC Revolution : A Guide to Platform-Based Design. Norwell, Mass., Kluwer Academic Publishers.

Dixon, N. M. (2000). Common Knowledge : How Companies Thrive by Sharing What They Know. Boston, Harvard Business School Press.

Finkelstein, C. and P. Aiken (1999). XML and Corporate Portals. Building Corporate Portals using XML. McGraw-Hill Companies Inc.

Gutl, C., K. Andrews, et al. (1998). Future Information Harvesting and Processing on the Web. European Telematics Conference: Advancing the Information Society, Barcelona.

Hanani, U. and A. Frank (2001). "The Parallel Evolution of Search Engines and Digital Libraries: their Convergence to the Mega-Portal." IEEE Software.

Hansen, M., N. Nohria, et al. (1999). "What's your strategy for managing knowledge?" Harvard Business Review **March-April**(1999): 106-116.

Keating, M. and P. Bricaud (1998). Re-Use Methodology Manual for System-On-A-Chip Design. Norwell, Mass., USA, Kluwer Academic Publishers.

Kehal, M. (2002). "Searching For An Effective Knowledge Management Framework." Journal of Knowledge Management Practice(February, 2000).

Kunze, J., C. Lagoze, et al. (1998). The Dublin Core Metadata Element Set, http://purl.org/metadata/dublin_core.

Lave, J. and E. Wenger (1991). Situated learning: Legitimate peripheral participation. Cambridge, Cambridge University Press.

Lewin, K. (1947). "Frontiers in Group Dynamics." Human Relations **1**(1).

Markus, M. L. (2001). "Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success." Journal Of Management Information Systems **18**(1): 57-93.

Porter, M. (2003). What is Strategy ? Irish Management Centre Seminar on Innovation, Dublin, October 9th, 2003.

Rabarijanaona, A., R. Dieng, et al. (1999). Building a XML-based Corporate Memory. EKAW, Banff, Canada.

Stata, R, (1989). "Organisational Learning - The Key to Management Innovation," Sloan Management Review, Spring **30**(3): 63-74.

Stein, E. and V. Zwass (1995). "Actualizing Organizational Memory with Information Technology." Information Systems Research **6**(2): 85-117.

Susman, G. I. and R. D. Evered (1978). An Assessment of the Scientific Merits of Action Research. Administrative Science Quarterly. **23**: 582-603.

Swan, J,, S. Newell, et al. (2000). Limits of IT-Driven Knowledge Management Initiatives for Interactive Innovation Processes: Towards a Community-Based Approach. 33rd International Conference on System Sciences, Hawaii.

Swan, J., S. Newell, et al. (1999). "Knowledge management and innovation: networks and networking." Journal of Knowledge Management **3**(3): 262-275.

Swanstrom, E. (1999). MetaKnowledge and MetaKnowledgebases. The Knowledge Management Handbook. J. Liebowitz. London, CRC Press.

Weick, K. E. (1979). "Cognitive Processes in Organisations." Research in Organisational Behavior **1**: 41-74.

Weick, K. E. (1995). Sensemakine In Organizations. Thousand Oaks, CA, Sage Publications.