USING SITE-BASED TECHNIQUES TO EVOLVE THE PRODUCT DEVELOPMENT PROCESS IN MANUFACTURING INDUSTRIES

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Many manufacturing industries, especially small to medium-sized companies, are in the process of exploring the move from two-dimensional computer-aided design (CAD) technologies to three-dimensional CAD tools interfaced with product data management (PDM) systems. For many companies, their current organizational structure is not well suited to fully leverage the capabilities of new CAD/PDM technology. This paper explores the author's experiences working in the residential furniture industry, helping companies successfully integrate CAD/PDM systems into their engineering and manufacturing operations. Of particular focus was the role user-centered, site-based techniques played in helping one company with this integration process. Both current and future scenarios based on an in-depth analysis of the product developed process were generated and used to help guide an implementation plan for a new CAD/PDM system.

INTRODUCTION

Many manufacturing industries, especially small to medium-sized companies, are in the process of exploring the move from two-dimensional computer-aided design (CAD) technologies to three-dimensional CAD tools interfaced with product data management (PDM) systems. For many companies, their current organizational structure is not well suited to fully leverage the capabilities of new CAD/PDM technology. Both professionals within these companies and outside consultants have been challenged by the task of integrating new CAD/PDM technologies.

An understanding of the technology/organizational interactions and strategies for helping companies manage this integration process can be seen as an extension of the macroergonomic and sociotechnical methods championed by Hendrick (1991) and others. These methods, however, are still quite young, resulting in a dearth of robust tools. Though Badham (1995) notes the lack of clearly defined methodologies for managing the change process, there are a number of general guidelines which have broad support in reported case studies. Badham points to the need to clearly understand the context of the individual company, its state, its needs, and goals. This type of understanding can typically only come from close, site-based work with the company. Salzman & Rosenthal (1994) warn that initially one should expect limiting and conflicting initial perspectives on the new technology. Development of scenarios to demonstrate the both the current and future state of product data development and management can be a key method for developing a common, effective vision for integration (McGraw & Harbison, 1997). Work by D'Souza & Greenstein (1996, 1997) demonstrates the use of this context-based, participatory approach in evolving the product development process in a manufacturing-based company. In summary, there is recognition that this process supporting technology integration has to be user-driven, context-based, and iterative in nature.

It is important to note that in order for a change process strategy to be accepted by a medium-sized company grappling with rapidly changing technology, the technology integration process has to be quick, involve a minimum amount of human resources, and have a high degree of face validity (Karababas & Cather, 1994). The lack of clearly defined, well-validated tools for managing this process means that all methods used should be carefully documented and evaluated for its effectiveness in supporting the technology integration.

INITIAL COMPANY ASSESSMENTS

During 1997, work was done with four furniture companies who had expressed interest in integrating 3-D CAD/PDM systems into their product engineering operations. This initial work, reported in more detail by Wiebe, Howe, Summey & Norton (1997), parallels the methodology used by D'Souza & Greenstein (1996) and Fafchamps (1992). This preliminary work was largely ethnographic in nature, consisting of one or more site visits, surveys of individuals directly involved in the product development process, and structured interviews with key members.

Though the specifics of problems faced by these four companies varied, there were some general trends. First, all of these companies saw themselves buried in paper. While the product design process had changed little in the last fifty years, in response to market demands, the companies all found themselves producing shorter runs of pieces from an ever-expanding product line. Though these companies had brought in 2-D CAD tools over the past ten years, none of them had significantly changed their development process. This finding parallels the findings of Adler (1989) in other manufacturing industries. All of these companies had a great desire to reduce the amount of costly and error-prone manual transfers of redundant data.

The participants in this project came to a number of important conclusions as part of this initial survey. Most of them centered around the general realization that bringing new technologies into a manufacturing organization without also examining the organizational structure would not solve core elements of inefficiency (c.f., Cheng & Kirkwood, 1997). With many of the companies, the short term goal was to use technology to solve their perceived problems, even though many of the systemic organizational problems could be addressed without any changes in technology. However, many of the middle and front line managers leading the drive for new CAD/PDM technologies realized that the new technology integration would be an opportunistic time to address the other organizational issues.

MAPPING CURRENT PRODUCT INFORMATION FLOW

One of the four companies initially surveyed indicated in the second quarter of 1997 that they were planning on implementing a new 3-D CAD/PDM system during the first half of 1998. With the encouragement of the consultants, the central engineering division of the company formed a pilot team consisting of representatives from the product engineering and manufacturing groups. The consultants worked with the pilot team during the last half of 1997 to develop goals for the modeling system, benchmarks for evaluating the systems, and participated in the system reviews. A key component of the work being done with the pilot group was to look beyond the specifics of any one CAD/PDM system and identify the general technical capabilities of the desired system and begin to explore how this system could impact the organizational structure of the product development process. This exploration began the process of understanding how this technology could affect changes in information generation and flow, job design, and organizational structure.

During the period preceding the selection of a new 3-D CAD/PDM system, a second set of in-depth interviews with the pilot team were conducted to better understand the current product information flow. This process paralleled techniques used by Karababas & Cather (1994) and McGraw & Harbison (1997). Given that a main focus of the integration effort was to change the way product information was created and managed, archival documents were used as part of the interview process. Documents such as drawings, sketches, notes, bills of materials, manufacturing instructions, etc. represent cognitive artifacts used in collaborative work (Olson & Olson, 1991). Though these documents were weak on capturing implicit knowledge, they served to develop a common context when used in conjunction with interviews.

Another important outcome of the second interview process was to gain a better understanding of the goals of the pilot group and upper management. In the case of this company, they wanted to develop a higher degree of agility to respond to engineering and design changes. Currently, changes in design, especially those implemented as the product moved closer to final production, significantly heightened the risk of introducing dimensional errors into the parts. An equally important part of streamlining the product engineering process was being able to bring a design to production in a shorter period of time. A parallel goal was the development of uniform design and manufacturing standards. This long standing issue evolved out of the power relationships between central engineering and individual factories. With a new, networked CAD/PDM system, centralized control of engineering design work was seen as a desired outcome by the pilot group.

Based the first and second round of interviews and the archival documents, a first draft of product information flow charts were developed (see Figure 1). The product development process was divided into seven fundamental stages. Most of these were passed through twice: once during initial design and sample construction, and again if the product went into production. Within each of these stages, the activities involved, the documents produced, managed, or modified, and the destinations of this information were mapped. This product development process involved one to three revisions of 24 separate documents types for each piece of furniture as it went from initial design concept to the first production run of the product. In most cases, there would be further revisions to many of these documents as additional problems were revealed in the production process or as the marketing division requested aesthetic or functional changes.

These documents revealed a number of important pieces of information. First, embedded in each document were certain types of information needed in the development process. The process flow charts revealed when this information was being developed in a serial or parallel manner, who this information was being distributed to, and when the information was redundantly encoded and managed in multiple documents. Second, through the flow charts supplemented with interviews, the ‘business rules’ of the information was revealed. That is, who was responsible for the generation, management, distribution, and approval of the information along with rules for who was allowed access to it. Finally, the interview and charting process helped reveal the ‘engineering rules’; helping to understand the decision process involved with making sure the product represented a cost effective, structurally sound, and aesthetically pleasing piece of furniture.

After the initial version of the flow charts were developed, they were sent back to the company. Shortly thereafter, a meeting was scheduled and information exchanged concerning clarifications and corrections to the charts. The charts were then revised again based on these comments. This process was repeated two more times for a total of three rounds of revisions. This process both helped to build the investigator’s understanding of the product work flow and helped build a common understanding within the pilot team. Though the pilot team members each had at least ten years experience at the company, they each admitted that they learned more about other people’s job responsibilities and how particular types of information was generated and revised by going through this process. Pilot team members noted that this was the first time that they had seen the full work flow process detailed to this degree; a process that they were all intimately involved with on a day to day basis.

DEVELOPING FUTURE-BASED SCENARIOS

The development of a robust model of the current state of the product workflow served the dual purpose of both clearly defining the current state, and opening discussions of how this workflow could or should change in light of the proposed integration of new CAD/PDM technologies. Developing ‘future-based scenarios’ (D'Souza & Greenstein, 1997; McGraw & Harbison, 1997; Neale & Kies, 1996; Ziegler & Barnekow, 1997) was not only used early in the process to help define the requirements for the CAD/PDM software, but continued to be used at this stage of the project to help plan the implementation of the system and the changes which where likely to occur in the product development process.

In parallel with the development of the product workflow charts, specifications were being developed concerning the new CAD/PDM system. Once the CAD/PDM system had been narrowed down to a particular class of system, a representative CAD software package was used to create a ‘generic’ furniture piece based on product data from the company. Whereas the workflow charts showed how the current product information was developed and handled within the organization, the demonstration model helped show how the same information could be restructured into new electronic forms and what new types of information could be generated.

The CAD software demonstration showed to the pilot group how many of the engineering rules, currently tacit knowledge held by designers and engineers in the group, could be transformed into explicit knowledge contained in the CAD model. This transformation would, however, involve a fundamental shift in how product information was managed in the group. In addition, there was considerable time involved with embedding ‘design intent’ into the CAD models. This time spent would only be transformed into an advantage for the group under certain conditions, including: 1) that manufacturing processes were standardized to a degree that the manufacturing-driven design features used in one model could be re-used in other models, 2) that the functional and aesthetic design of the piece represented a generic class of furniture which would be represented in many other pieces, and 3) that the designers and engineers have enough control over the product development process to enforce certain conventions in model construction and modification.

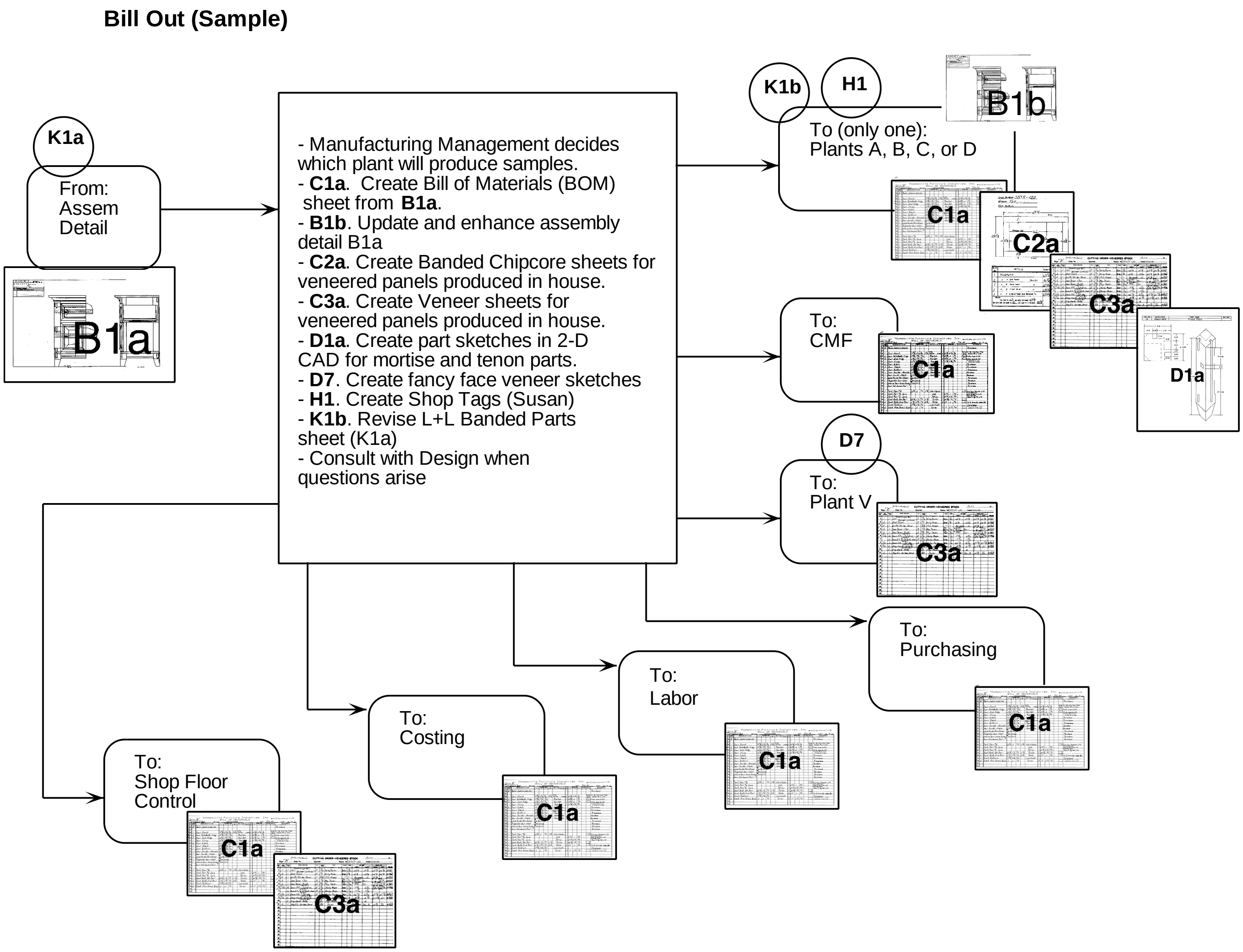

Figure 1. Sample product information flow chart.

The final draft of the workflow charts, coupled with the CAD models, were used for a capstone meeting representing the move from ‘here we are now’ to ‘where we want be’. Though future goals and CAD/PDM technology capability had been discussed from the very beginning of the project, the project had matured to the point where there was now a very tangible common basis for understanding moving forward into a pilot implementation of the recently purchased system.

SUMMARY

In summary, whereas the initial phase of the project helped define a general domain understanding of the problems facing a small group of companies, the second phase of the project helped define a course of action for an individual company. This companies’ course of action for the integration of a CAD/PDM system was informed in part by the methodology described in this paper. A common understanding of both the current product development process and how the new system might affect it was forged through site-based work involving extensive user input and archival documentation. From the information gathered, scenarios were generated both of current and future states to help guide the decision-making.

Wiebe, E. N. (1998) Using site-based techniques to evolve the product development process in manufacturing industries. In Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting. Chicago, IL.

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REFERENCES

Adler, P. S. (1989). CAD/CAM: Managerial challenges and research issues. IEEE Transactions on Engineering Management, 36, 202-215.

Badham, R. (1995). Managing sociotechnical change: A configuration approach to technology implementation. In J. Benders, J. de Haan, & D. Bennett (Eds.), Symbiosis of work and technology, (pp. 77-93). London: Taylor and Francis.

Cheng, K., & Kirkwood, D. (1997). Computer based systems assistance for manufacturing industry re-engineering. In G. Salvendy, M. Smith, J., & R. J. Koubek (Eds.), Design of computing systems: Cognitive considerations, (Vol. 21A, pp. 729-732). Amsterdam: Elsevier.

D'Souza, M. E., & Greenstein, J. S. (1996). A field study of the product development process as a first step in the design of a system to support concurrent engineering. Proceedings of the Human Factors and Ergonomics Society 40th annual meeting, Philadelphia, PA. 781-785.

D'Souza, M. E., & Greenstein, J. S. (1997). An ethnographic evaluation of a computer-supported product development system. Proceedings of the Human Factors and Ergonomics Society 41st annual meeting, Albuquerque, NM. 739-743.

Fafchamps, D. (1992). Ethnographic workflow analysis: Specifications for design. In Human aspects of computing: Design and use of interactive systems and work with terminals, (pp. 709-715). Amsterdam: Elsevier.

Hendrick, H. W. (1991). Ergonomics in organizational design and management. Ergonomics, 34, 743-756.

Karababas, S., & Cather, H. (1994). Developing strategic information systems. Integrated Manufacturing Systems, 5, 4-11.

McGraw, K., & Harbison, K. (1997). User-centered requirements: The scenario-based engineering process. Mahwah, NJ: Erlbaum.

Neale, D. C., & Kies, J. K. (1996). Scenario-based design for human-computer interface development. Paper presented at the Proceedings of the Human Factors and Ergonomics Society 40th annual meeting - 1996, Philadelphia.

Olson, G. M., & Olson, J. S. (1991). User-centered design of collaboration technology. Journal of Organizational Computing, 1, 61-83.

Salzman, H., & Rosenthal, S. R. (1994). Software by design: Shaping technology and the workplace. NY: Oxford University Press.

Wiebe, E. N., Howe, J. E., Summey, J., & Norton, J. J. (1997). Computing and organizational assessment in the furniture industry. In G. Salvendy, M. Smith, J., & R. J. Koubek (Eds.), Design of computing systems: Social and ergonomic considerations, (Vol. 21B, pp. 921-924). Amsterdam: Elsevier.

Ziegler, J., & Barnekow, T. (1997). Integrating groupware and workflow in a public administration. In G. Salvendy, M. Smith, J., & R. J. Koubek (Eds.), Design of computing systems: Cognitive considerations, (Vol. 21A, pp. 309-312). Amsterdam: Elsevier.