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INITIATING LONG-TERM MODERNIZATION PROGRAMS IN LOW-TECHNOLOGY MANUFACTURING ENVIRONMENTS

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Abstract

In this paper, a planning approach is discussed for initiating and expediting modernization efforts in manufacturing environments. The approach consists of six major steps. First, staff employees from a variety of functional organizations are involved in modernization planning activities through the formation of site modernization teams used to organize and facilitate modernization planning activities. Second, initial planning exercises are expedited by identifying high-priority areas for improvement through a functional assessment. Third, data acquired from the initial assessment described above are used as input to a strategic planning workshop aimed at building managerial support for modernization plans and integrating the plant's strategic objectives with its operational modernization plan. Fourth, the site modernization team receives training in the specific modernization technologies to aid them in the selection, design, implementation and maintenance of the appropriate modernization technology. Fifth, as a means for initiating modernization efforts, the planning approach produces preliminary versions of action-oriented implementation plans thus enabling improvement actions to begin more quickly. Sixth, an overall cost-benefit analysis is done to assess the feasibility of modernization projects. Finally, by meeting the above objectives, the approach provides a foundation for future modernization efforts. Results from implementing this methodology in six manufacturing environments are discussed along with a review of benefits of the approach.

Introduction

As the twentieth century draws to a close, little doubt remains that ours is a technology-oriented society. Technology is the focus of our education. Technology drives our economy. Technology is the center of heated political debate. It pervades our homes, our schools, our work environments, our lives. But technology for the sake of technology, without thought to its social need, value, or consequence within the community in which it is applied, is risky. Our current rash of environmental concern is an example. It is no small coincidence that as this century of economic prosperity and manifold improvement in the quality of life draws to a close, the most pressing technological issues involve undoing the long-term effects of our century's growth in industrial and governmental technologies [1,2]. And while we embark on yet another new frontier of socio-environmental technologies, technological success must take on a whole new meaning as the results of poor technology management are thrust to the forefront of social consciousness.

In the past, technological success has been associated with either short-term improvements in the quality of life or short-term reductions in operating expense. Governmental agencies have been forced to expand the fields of physics and applied science all under the auspices of national security or energy crisis or sundry other issues of national priority. More recently, manufacturing industries have faced competitive pressures which have required innovative approaches to quality production and design. While technology itself has been looked upon as the "catch-all" for achieving social and economic progress, the effective management of this technology has ultimately determined long-term technological success or failure. Certainly as we witness the dawning of a new century of technological endeavor, a means for establishing and managing long-term technology plans is needed.

Industrial Technology Management

In the context of this paper, the term technology will refer specifically to industrial technologies. Technology in industry means the development and application of knowledge in the production and use of goods and services. Thus, industrial technology management refers to the methods and mechanisms whereby the development, implementation, and diffusion of industrial technology is monitored and controlled [3,4].

An often overused term in the context of industrial technology management is the term *modernization*. Modernization typically refers to the process of improving technology resources. However, modernization actually implies the renewing of technology resources. In the context of this paper, the term modernization will refer to the result of industrial technology management.

During the 1980s, computer-integrated manufacturing (CIM) has been at the hub of industrial technology management issues. The number of failures involving the implementation of advanced CIM technologies has sparked many questions regarding the manner in which these technologies are applied [5,6,7]. Some say the technologies are not yet mature; others feel the manufacturing processes are not yet refined; still others assert that management initiative and commitment are absent. All of these views are accurate to some extent. Combined, however, they indicate a lack of competence and know-how for managing technology.

At the very least, then, industrial technology management is important to the extent that industry desires to lower implementation risks associated with the application of technology. However, as many researchers are quick to point out, the timeliness with which technology is applied may become the single most important competitive issue for industry in the future [8,9].

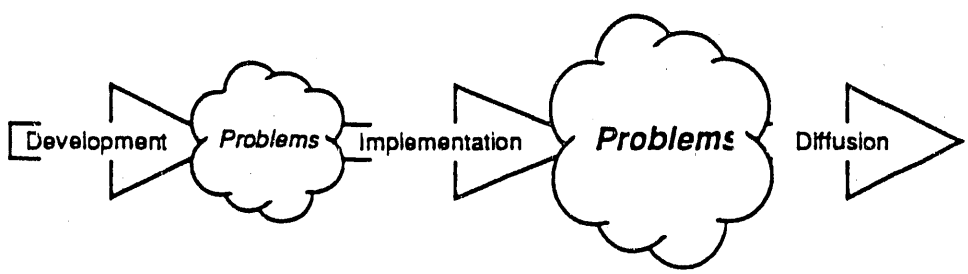
In the past, very little research has been generated concerning industrial technology management. One reason for this is the enormous amount of financial and time

resources required to experiment with such practices. In this paper, a methodology to initiate large enterprise-wide modernization efforts for manufacturing industries is discussed. The scope of the project consisted of initiating long-term, enterprise-wide modernization efforts within the Army's structure of industrial operations. The methodology has been applied successfully to six Army manufacturing facilities. This methodology constitutes a "quick pass" assessment of operational and strategic needs with focused effort to establish a timely plan for technology modernization.

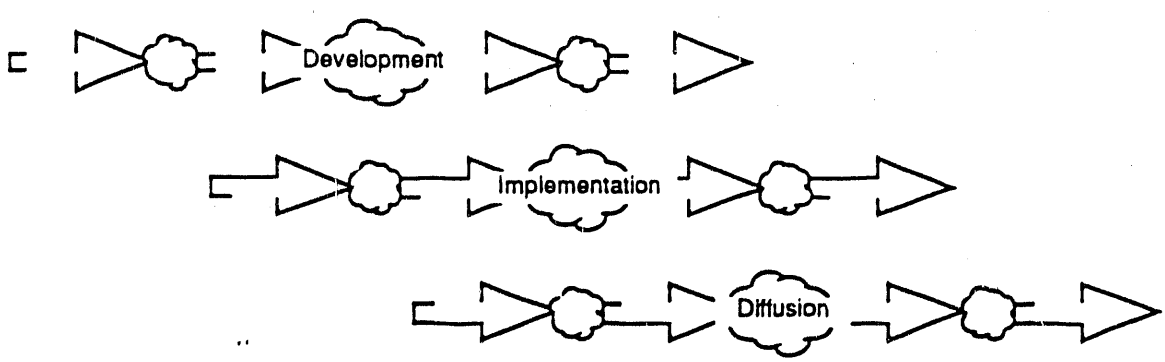
Initiating Traditional Approaches

Traditional approaches to initiate modernization efforts typically call for plant-level efforts to be carried out in a sequential fashion. This traditional sequential approach to technology management is shown below in Figure 1.

Figure 1- Two Views of Industrial Technology Management



a. Traditional Sequential Technology Management



b. Integrated Parallel Technology Management

In the above scenario, the coordination of technology modernization efforts is executed sequentially. Problems may arise because of miscommunication that results from what the authors have termed isolated technology management practices. Isolated technology management practices are modernization planning activities which do not support the executive manager's strategic plans or the technology developer's operational design. Rather than anticipating and preparing for organizational

resistance to technological change, isolated technology management practices generate modernization plans which fail.

For instance, many technology modernization programs contain a detailed cost justification activity to economically evaluate a set of modernization proposals. These detailed cost justifications usually require some estimate of how the modernization will be carried out and what its economic impacts will be. This can pose a dilemma for managers who wish to make quick improvements to their manufacturing environments, yet must show high return-on-investment calculations due to the high cost of capital. Thus, modernization proposals submitted to improve the present situation are slowed by lengthy costing efforts and in the end may result in the implementation of antiquated or inapplicable technologies.

The effects of isolated technology management practices are time delays which develop into downstream development, implementation, and diffusion problems. As these upstream time delays gain momentum, efforts to apply technology will often incur still greater delays or, even worst, complete work stoppages if the issues underlying the problem escalation are not addressed. Ultimately, these downstream delays and stoppages lead to poor overall technology utilization which decreases enterprise-wide responsiveness to competitive pressures.

When a large, traditional modernization program gets past its lengthy justification phase, it may move on to the definition phase of planning. In the past, this phase has been dominated by lengthy structured analysis projects using data flow diagramming techniques to gather comprehensive functional requirements. However, structured analysis methodologies, like justification methodologies, have caused potential problems in the initial phases of modernization planning stemming from the length of time required to perform these analyses. Many early structured analysis projects attempted to identify functional requirements of a modernization program by performing the analysis across the entire manufacturing facility. This process was not only time-consuming (typically, one to two years) and costly, but resulted in a voluminous amount of information that was both unwieldy and difficult to comprehend. Worse yet, the process typically failed to produce the product it was originally designed to identify: functional requirements or, more succinctly, modernization opportunities.

In addition, lengthy structured analyses used in planning an enterprise-wide modernization effort can also extend the planning horizon out beyond user expectations. Hopes and desires for the modernization effort can be dashed by what is termed "analysis paralysis" [11] typically resulting in user loss of interest in the modernization effort. Resultant user apathy is a cancer in the implementation and diffusion stages of the modernization effort and can thwart hopes of modernization success.

Other pitfalls can develop due to the use of structured analysis in the initial stages of modernization planning. When performed, structured analyses are aimed at defining operating requirements within a current environment. If performed, strategic planning,

originally designed to align a company's operational capability with its strategic marketing goals is usually done separately without regard to the operational requirements identified in such an analysis. As a result, strategic priorities are generally not integrated with the modernization program. Consequences of this disunity in planning can end in suboptimal returns on modernization investment and weakened managerial commitments to the modernization effort.

While technology management involves the coordination of technology planning, development, implementation, and diffusion, this coordination has typically been executed sequentially as shown in Figure 1a. In this scenario, organizational problems increase because of the miscommunication that results from isolated technology management practices. In contrast, an integrated technology management approach is depicted in Figure 1b. This approach leverages organizational culture by stimulating communication in the forms of dedication, participation, education, and demonstration. Technological success is achieved by breaking organizational issues into smaller, more manageable problems. In the integrated technology management approach, initial efforts in technology management are used as a foundation for future technology efforts which continue to evolve and grow.

Requirements and Strategies for Successful Modernization

As suggested above, an integrated approach to technology management was developed to initiate enterprise-wide technology modernization within the Army's industrial base. The scope of the technology modernization effort was focused initially on six ammunition plants. The goal of the modernization effort to be undertaken within the plants was information systems modernization and integration. This initial effort was ultimately the first step in a longer-term objective to integrate information systems throughout the Army's industrial base.

Among the six plants, the level of information system technology varied widely with the level of manufacturing systems technology. Process technology within the production environments of the plants had remained largely unchanged over several decades in contrast to office technology which had encountered some level of computerization.

Given the pitfalls of more traditional approaches to modernization planning, the goal of the project became an effort to identify how to initiate modernization efforts quickly within a manufacturing facility. To better understand this process, requirements for a "quick pass" approach were defined and strategies developed to meet these requirements. Initially, six requirements were identified:

1. Plant staff and domain experts must be intricately involved in modernization planning and implementation.

2. The mechanism for identifying modernization opportunities must be greatly simplified.

3. Modernization projects must be integrated with the plant's strategic plan.

4. Training in technology must be provided so that personnel involved in site modernization can adequately design and implement appropriate modernization plans.

5. Projects which have high visibility to plant management must be identified, planned and implemented early in the modernization process.

6. Quick wins with little or no up-front capital investment were needed early in the modernization project.

Modernization Team

The first major requirement was to develop a cohesive team of plant staff and external technology experts. The site modernization team consisted of external consultants, several functional managers from the plant and a local Army Contracting Officer for the plant. Because the initial focus of modernization was the design and implementation of a distributed manufacturing information system, the external consultants possessed skills in state-of-the-art technologies in distributed computer architectures, local area networks, relational database management systems and integrated manufacturing systems.

The team typically comprised the functional managers from the plant such as the Manufacturing Manager, Engineering Manager, Finance Manager, and the Information Systems Manager. Including plant functional managers on the site modernization team was a key ingredient to the success of the "quick pass" methodology because they were critical in their knowledge of the major problems affecting the plant. In addition, their involvement in the modernization planning process led to a sounder modernization plan geared towards meeting the needs of the plant and, subsequently, to a greater commitment by plant management and staff to the modernization plan.

It was found that the interdisciplinary functional team was critical to success of the modernization effort in that it focused not only on the right problems but also the right solutions to the problems the plant was experiencing. Earlier attempts to use the quick pass methodology that included only staff from the plant's information systems department tended to bias modernization plans to what the information systems staff "thought" were the problems rather than reflecting actual needs of their users. Including team members from manufacturing and engineering meant that much discussion would take place about the shortcomings of the current manufacturing information system, thus resulting in modernization plans to correct these shortcomings.

Functional Analysis

The second major requirement was to define a simplified methodology to identify modernization opportunities. It was decided to avoid a structured analysis approach for this step of the methodology due to time and cost restrictions. Rather than exhaustively collect information for each and every information flow in the factory as is required for structured analysis, the site modernization team decided that a more general approach could be adopted. To this end, a functional analysis approach was adopted. The functional analysis consisted of a series of intensive 1.5- to 2-hour interviews conducted with key management and staff over a four-day period. Typical organizations interviewed included Production, Production Control, Maintenance, Quality Control, Engineering, Finance, and Personnel. Several generic questions were asked in the interviews such as "What are the major functions of your organization?", "What information do you need to perform these functions?", "What information results from these functions?", and "What typical problems does your organization experience on a regular basis?" Because the interviewers were experts in each of the domain areas, several domain-specific questions were also addressed. For example, in Production Control, an interviewee might be queried for the types of inventory control procedures or forecasting methods used in carrying out the group's functions.

The functional analysis findings were typically written up in a report that described the current activities of each functional department, the department's shortcomings with respect to application of state-of-the-art technologies, and the major problems that staff experience in trying to carry out the functions of the department. In short, the functional analysis highlighted the major opportunities for modernization.

Strategic Planning

The third requirement was for integration of a modernization plan with the strategic objectives of the factory. It should be noted that the six facilities had only done a limitied amount of strategic planning in the past. As a result, after completion of the functional assessment a strategic planning session was conducted on-site at the factory. Participants in this workshop included the consultants, the site modernization team and the directors of the factory. The purpose of the strategic planning workshop was to identify the site's major business objectives and set priorities for modernization that would support meeting those objectives.

The strategic planning workshop consisted of three parts: determining the major operational objectives, setting modernization priorities, and identifying the obstacles or impediments to modernization. Each part followed the same format: dividing into small groups, building a consensus of opinion, presenting the results to the larger group, and interactively discussing the small group findings. The initial part focused on rank ordering the operating objectives of the facility, such as shorter design and development cycles, faster responsiveness to customers, lower inventory investment,

meeting environmental compliance requirements, etc. After accumulating the quantitative data and presenting the overall ranking back to the group, the priorities for modernization were evaluated. This part of the workshop consisted of rating the functional areas within the organization (planning, control, production, engineering, and support) which had the greatest need for automation and which, if automated, could facilitate reaching the highest ranked objectives. This not only established the priority areas but also suggested technologies that would have the greatest impact on the firm (planning, shop floor control, inventory tracking, etc.). The last part of the workshop brought to light the obstacles that would have to be overcome to successfully implement the modernization program. The complete workshop typically lasted half a day. As stated above, this activity was needed to provide the vital bridge between current strategic direction and existing modernization plans.

Technology Training

The fourth, fifth and sixth activities were conducted at the consultant's site rather than at the manufacturing site and were called the Design Workshop. The Design Workshop was a two- to three-day workshop. Its main purpose was to meet the fourth requirement, which was to provide the site modernization team training in state-of-the-art technologies. Because the contractor was a technology research laboratory, the site modernization team was able to see working examples of state-of-the-art information systems technology. The Design Workshop provided capabilities so that personnel involved in site modernization could adequately meet the fifth and sixth requirements, namely, the design and implementation of appropriate modernization plans and continuous improvement projects.

To address the training requirement, the site modernization team was given concentrated briefings on government and industry standards for information system capabilities. These included standards for communication networks, heterogeneous hardware architectures, the UNIX operating system, distributed relational database capabilities, client-server architectures, graphical user interface (GUI) standards, and the usage of fourth generation languages. Training in these standards was required due to the fact that the site modernization team was simply not aware of all the options, and the benefits of applying the newer technologies. Without exception, all sites were still using mainframe architecture technology with individual computers averaging in age from 9 to 14 years.

In addition, the team received briefings on the usage of continuous improvement technology or what is commonly known as "Total Quality Management" as a prerequisite to hardware modernization. The concept of continuous improvement highlighted the importance of streamlining and standardizing information processes for modernization success. Too often, long cycle times and inaccuracy of information reports are due to inefficient flows associated with the collection and processing of this information. Therefore, the team was introduced to methods for identification and elimination of waste in a process. The team was introduced to the concept of continuous improvement so that it could immediately begin the process of

modernization through the identification of low- or no-cost modernization projects that would show immediate benefit to the factory.

Implementation Planning

The fifth requirement was the development of a modernization implementation plan which included projects with high visibility that could be implemented in a timely manner. This activity consisted of two major steps: prioritization of modernization opportunities and establishment of a phased modernization. The site modernization team was asked to prioritize modernization needs based on the site's strategic planning objectives and the opportunities identified in the functional assessment. Through these previous tasks, the team could be sure that modernization projects were indeed those that met both managements' expectations and strategic objectives.

Next, the team was asked to take this list of modernization priorities and to phase the implementation into near-, mid- and long-term implementation projects culminating in an integrated information systems architecture for the factory. For the near-term projects, the team was asked to identify "seed applications," that would provide high visibility, be relatively low cost, and could be accomplished in a short period (less than six months). These applications could be just the beginning of a longer term project, but would demonstrate the potential benefit of the complete project and obtain feedback from the users for future design consideration. For example, all plants recognized the importance of the design and installation of a local area network as a near-term project. In this way, management could begin taking advantage of simple, quick-to-implement applications needing little design such as electronic mail. In addition, continuous improvement methodologies were applied to each functional project (e.g., streamline the financial report generation), and work was planned for the integrated data model for the near-term projects.

Cost/Benefit Analysis

The final requirement included in the quick pass approach to modernization was the completion of a cost-benefit analysis. After identifying the no- or low-cost/high payback capital investment opportunities, a cost/benefit analysis was performed to justify the overall information systems modernization. Typically, cost justification for large modernization programs are lengthy efforts. This analysis consisted of a high-level evaluation of benefits. The purpose of this evaluation is simply to establish whether a more detailed engineering analysis is warranted. The major cost elements included design activities; infrastructure items (communication network, servers, workstations, peripherals); software; applications development and/or modification; and start-up/prove-out activities. Benefits fell in the following categories: inventory management (lower inventories); quality (fewer defects, less scrap); and labor utilization (less indirect labor, higher professional/engineering productivity). The costs and benefits were phased to follow an implementation plan consisting of design the system, establish the infrastructure, develop the central applications (financial, planning and control), and implement shop floor data collection systems. The final cost/benefit

analysis would be only +/- 25% of actual, but would provide a quick measure of potential attractiveness.

Results

Several positive findings were identified as a result of applying the quick pass planning approach in each of the six manufacturing facilities. These findings are presented below:

1. accelerated modernization planning relative to traditional approaches
2. identified high priority areas for modernization
3. generated management commitment to the modernization effort
4. provided team participants with a more objective scope of the plant's needs.

Overall, the planning cycle was completed much quicker than would have traditionally been thought possible. Value-added time totaled approximately 3 weeks for each facility. Elapsed time due to scheduling constraints and travel time was approximately 13 weeks. This represents a significant improvement in timeliness and associated costs. The improved timeliness of these exercises was due largely to the simplified functional assessments and cost/benefit analyses which were tied directly to a strategic focus.

As suggested, the planning approach was successful in identifying the high priority areas for modernization. The strategic planning exercise was key in coordinating strategic efforts with ongoing operational efforts and achieved much stronger management support than traditional approaches.

It was also found that the planning approach was successful in providing the modernization team with a broader scope of the plant's modernization needs. In each of the plants, opinions of team participants concerning plant modernization needs significantly changed as a result of participating in the modernization planning exercises. In the end, this should help to eliminate problems due to employee apathy in later stages of technology development and implementation.

Conclusions

The integrated technology management approach suggested above was designed to provide the following benefits in an enterprise-wide modernization effort:

1. quickly evaluates the economic feasibility of the modernization program in all facilities

2. incorporates unique strategic priorities and ongoing modernization activities into the modernization effort at each plant

3. fosters effective communication during modernization planning which ultimately translates into better user acceptance

4. quickly establishes implementation plans for low-cost improvement action

5. builds a foundation of knowledge for future modernization planning.

Some of these benefits have already been realized within the scope of this quick pass planning approach. Others, such as item 5, are more complex and are believed to be dependent on issues outside the scope of the planning exercise. For instance, improvement action is largely dependent upon the allocation of financial resources which is dependent upon the site's financial performance.

In any event, findings from this study further support the notion that enterprise-wide modernization planning needs to be quick. Immediate decisions need to be made during the execution of enterprise-wide planning to assign responsibilities and develop action plans. The study results indicate that the planning approach to enterprise-wide modernization has a significant impact on management support and employee morale, both of which can hamper future technological success. Through quicker, more efficient technology management practices, enterprises can evolve technology management plans much easier to adapt to changing external requirements. In all, efficient technology management planning can play a lead role in improving operational effectiveness and industrial competitiveness.

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