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Case Study

# Organizing for computer integrated manufacturing

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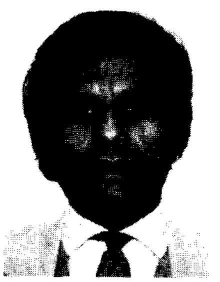
Good organizational structure design is increasingly important in Computer Integrated Manufacturing (CIM) environments. It can reduce problems due to the changing roles of organizational units and information technologies. This paper presents observations about organizational structures for CIM and discusses the basic approaches. An initial framework for evaluating CIM organizational structures is proposed and is used to evaluate the basic structures.

*Keywords:* Computer integrated manufacturing, Organizational design, Organizational structure design, CIM, Technology management, Organizational design techniques.



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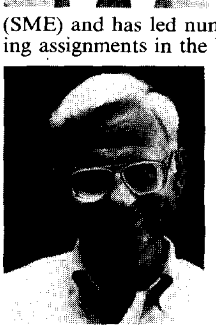

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## 1. Introduction

Computer Integrated Manufacturing (CIM) is concerned with integration of the business, engineering, and manufacturing processes of an enterprise. CIM helps the enterprise to obtain and maintain a competitive edge in the manufacturing marketplace. According to a US National Science Foundation report [18], CIM has been recognized as an activity of national strategic interest. CIM presents several challenges to the managers, planners, designers, and implementors of organizations and technologies. The main challenges are:

1. a knowledge gap; this indicates a lack of sufficient knowledge about CIM to make it a reality,
2. a technological gap; this indicates that technology is not available to implement CIM,
3. a talent gap; this indicates a shortage of researchers and scientists to make CIM a reality, as well as other issues; e.g. the Strategic Defense Initiative,
4. an organizational gap; this indicates difficulties in structuring the organizational resources in order to incorporate the CIM mission.

This paper focuses on the problem of organizing for CIM. This is an area of significant importance because, although CIM means many things to

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many people [1,12,15,16,20], it is generally agreed that a proper organizational structure is crucial to the success of CIM. We have been studying CIM organizational structures during the last two years. Our main information source has been attendees of CIM related seminars that have been sponsored by the Society of Manufacturing Engineering (SME) in the U.S. and by Frost and Sullivan, Inc. in England. These seminars have been taught by the senior author and have exposed us to more than 100 CIM organizations in the U.S. and Europe. In our studies, we have noted approaches to CIM organizational structures which range from simple to sophisticated. However, most structures fall into three general categories. Due to the nature of these seminars, most people who attend these seminars believe in CIM, we recognize that the sample is somewhat biased.

## 2. Overview and background

Organizational structure design, commonly referred to as structure design in management literature, has progressed through several stages: the Classical School of Management, the Human Relations School, the Carnegie–Mellon School and the Integration School [11]. In addition, the approaches of "one best way" versus "it all depends" are used frequently by management consultants and theorists [17]. Much literature has been published on the theoretical as well as empirical aspects of this area.

The best organizational structure is dependent upon a number of factors, which include: external environmental forces, size of the organization, nature of the business, characteristics of the workforce, background of the management, and organizational strategy. Of particular interest here are structure designs for manufacturing enterprises which depend heavily on information technologies for integration of manufacturing processes with engineering and administrative processes.

Such enterprises encounter two sets of organizational problems: (a) the typical manufacturing problems between the product versur process management and the engineering/manufacturing/marketing interfaces [7,13], and (b) the information technology related organizational problems of coping with technology and expectations [4,8,9,19]. The specific challenges in organizational structure design for CIM are:

- CIM systems must satisfy multiple, often conflicting requirements for performance, reliability, flexibility and maintainability. For example, CIM systems must have adaptable architectures to accommodate evolving manufacturing technologies, such as flexible manufacturing systems and just-in-time inventory systems. In addition, these systems must be easily modifiable to reflect changes in competitive market conditions and national/international standards.
- CIM systems are dispersed among the manufacturing, engineering, and business divisions which may be located in different cities or countries. Consequently, management of integration requires a great deal of interdisciplinary work among geographically distributed units with potentially different equipments, standards, and policies.
- CIM systems are developed by professionals (such as process engineers, computer scientists, business programmers, etc.) with diverse backgrounds, training, specialized terminology, and professional outlook.
- Development of CIM systems requires an understanding and synthesis/application of existing and evolving tools, techniques, standards and models in manufacturing, computing platforms, communication technologies, systems engineering, and management. These tools and techniques include growing areas, such as database systems, software engineering, artificial intelligence, operations research, organizational behavior, and ergonomics.

Very few attempts at developing organizational structures specifically for CIM have been reported. Current literature, see for example [2,5,6], is not based on investigation of approaches being adopted by existing companies. We initiated a systematic survey of the approaches being adopted by various companies which are involved in CIM or are seriously evaluating it for use in the near future. The companies surveyed were attendees of the SME seminars on Information Systems Engineering for CIM, Planning for CIM, Distributed Databases for CIM, and Computing Networks for CIM. In addition, attendees of CIM related seminars in London, England, with representatives from England, Switzerland, Holland and Germany were surveyed. The seminars were attended by CIM managers, information systems professionals, database administrators, marketing representatives and educators. In the last two years, more than 200 delegates from over 100 companies have attended these seminars.

The surveys were conducted on the first day of the three day seminars by using a form shown in *Figure 1*. The results of the survey were summarized and used as a basis for discussion on the third day in a one hour session devoted to the organizational structure design for CIM. We make the following observations from the surveys:

– Approximately 60% of the respondents already have a formal CIM group at corporate and/or

Please answer the following questions about your organization.

1. Do you have a formal CIM department or group within your company or division? Yes:_________

   No:______________ Other (please explain) ______________________________________

   ______________________________________________________

   ______________________________________________________

2. If No. - How is the CIM activity carried on in your organization presently?

3. If Yes. - Briefly describe how the CIM activity is organized or draw an organization chart of it showing the major its areas.

4. Draw an organization chart showing the major departments of the rest of your organization and how CIM fits into the total structure

5. What mechanisms or processes are used to accomplish this interaction?

   a. __ Through the formal chain of command

   b. __ Through informal meetings or interactions

   c. __ Through use of project teams: temporary ____ permanent __

   d. __ Through some kind of matrix system

   e. __ other (please describe)

6. Do you have a Corporate CIM group and a divisional CIM group? If yes, briefly describe it.

Your Name: ________________________________________

Your Title: ________________________________________

Company Name: ___________________________________

Fig. 1. CIM organizational structure survey.

divisional level. The formal CIM groups are organized by using three main approaches. These are discussed in the next section.
- The companies without a formal CIM group either have the activities under an existing group (e.g. CAD/CAE) or are in process of developing a formal CIM group.
- The interaction of CIM related activities with other organizational activities is accomplished primarily through project teams and informal meetings/interactions. Matrix systems and formal communication mechanisms are infrequent.
- Many organizations do not have a formal CIM methodology and do not use a CIM reference model. Most companies are in the process of reviewing and evaluating current approaches to methodologies and reference models.
- The most commonly used methodology is IDEF [21] (50% of the CIM methodology users are using IDEF). Other methodologies mentioned are homegrown and/or proprietary (D. Appleton, John Deere, etc).
- Many respondents expressed the concern that very few individuals in their organization understood the role of CIM and that the organizational attitude towards CIM was not clear ("party line versus reality" were mentioned frequently).
- The European respondents noted that very few systems are being designed and manufactured by a single enterprise in a single country and because of this the organizational issues of integration across multiple enterprises in multiple countries needed special attention.

## 3. Basic organizational structures for CIM

We have found that CIM is introduced by mainly using three approaches. Others are variants of these.

### *3.1. Approach 1: Single functional ownership*

The simplest design is with a CIM group starting somewhere within a functional department, such as manufacturing, engineering or finance/administration. Companies with large manufacturing divisions tend to place CIM under manufacturing, while heavy service/consulting oriented companies place CIM under the finance department (which traditionally has controlled the information systems activities). Interactions with other departments and other functional units take place largely through the formal chain of command and in formal meetings. Where the organizational culture allows it, informal interactions and networking also take place.

Our survey indicates that this approach appeals to managers who are more comfortable with the traditional corporate structure and separation of functional units. It also provides professional and career growth for traditional managers, especially in manufacturing, through exposure to computing systems, software engineering, and database/data communication systems. The potential drawback of this approach is the lack of focus on integration. Instead, it shifts the ownership of CIM to the functional unit to which CIM reports. Other units in the organization may view the efforts of the CIM group rather skeptically and perceive it as belonging to the "other" group. This can frustrate the corporate-wide integration efforts between business, engineering, and manufacturing.

### *3.2. Approach 2: Project team concept*

This approach introduces a project team to oversee the planning, design, implementation, and management of corporate-wide CIM activities. The project leader may belong to any of the functional areas with team members representing various functions, as well as multiple levels in the organization. In some cases, the CIM project team may include representatives from marketing and procurement.

Decisions are made jointly, this gives a cross-functional approach to CIM problems and can be beneficial in developing corporate-wide integrated systems. Such an approach is favored by organizations that are already involved in projects with cross-functional teams. The organizations with government/military contractual experience (such as the aerospace industries) are the prime adopters of this approach.

Based on our surveys, the project team approach appears to be most effective when there is broad-based representation and when the representatives can balance technical tradeoffs with organizational strategies. To a large extent, the success relies on the training and leadership qualities of the team manager. Overall, it is a significant improvement over the functional approach because it addresses the corporate-wide integration issues needed in CIM. Its potential drawbacks are that the decisions are harder to make and slower to implement in the early stages of team development. In addition, some functional units may not want to give up their autonomy. For organizations not used to the team approach, considerable training in team concepts is needed.

### 3.3. Approach 3: Top management involvement

This approach is similar to the project team approach. The main difference is that the CIM project manager reports directly to top management. In large organizations, the CIM project manager may report to a top management representative, such as a corporate vice president. The project team essentially becomes a top management task force which investigates the strategic issues related to CIM and advises top management on appropriate courses of action. Often this approach assumes some of the dimensions of matrix organizations.

Reporting to the CEO or corporate VPs has two basic benefits. First, the exposure and credibility of the CIM project team is significantly enhanced. Second, it serves to educate top management by exposing them to the cross-functional issues involved in developing integrated systems. A potential disadvantage of this approach often is loss of contact with the lower level functions such as the plant floor activities.

### 3.4. An incremental approach

Our studies suggest that an organization may choose all three approaches or combinations at different stages of CIM development. For example, the initial investigation may be conducted by a project team to study and evaluate the organizational and technological aspects of integration and to conduct a feasibility study. In the next stage, after management approval, the project team may be elevated to a top management team for detailed planning of the needed tasks. The CIM implementation may be achieved by decomposing the tasks into functional areas which are managed by the functional units. In this stage, the team members may assume the role of agents and advocates of the CIM plan in their respective functional units.

Table 1
An organizational structure evaluation model.

1. *Decision Effectiveness*
   - goal setting ease
   - time required to make decision
   - progress monitoring ease
   - problem diagnosis ease
   - openness to innovation
   - standards and policy enforcement
   - feedback facilitation
   - path length reduction
2. *Responsiveness to change*
   - change in manufacturing process
   - change in the market place
   - change in organizational focus
3. *Technology Utilization*
   - computing technology
   - communication technology
   - software technology
   - compatibility
4. *Integration Effectiveness*
   - coupling (interdepartmental communication)
   - binding (intra departmental communication)
5. *Human Resource Utilization*
   - professional growth
   - promotion opportunity
   - job security
   - employee turnover reduction
   - burnout reduction
   - productivity improvement

A corporate-wide team may still exist, however, both to monitor individual unit progress and to provide an integrative approach.

Such an approach has been discussed informally by some delegates to the seminars. However, no actual experience of applying this approach is available.

## 4. Evaluation of organizational structure designs

The overall objective of organizational structures, irrespective of the form they take, is to help in achieving the goals of an organization. It is important to establish uniform measures for evaluating alternative structures and to identify the advantages/disadvantages of the various structures. For CIM, the measures should highlight the necessity of corporate-wide integration and must take into account the operational, technological, and human issues.

*Table 1* shows an initial list of variables that has been developed for evaluating the various organizational structures for CIM. The measures provide a uniform basis for evaluating structures. They are grouped into five major categories:

- Decision making effectiveness. This reflects the ease with which key decision making activities can be performed. The activities include: goal setting, progress monitoring, problem diagnosis, risk taking, standards and policy enforcement, feedback systems, and path lengths for various decisions.
- Responsiveness to change. This shows the overall flexibility of the organization to handle changes in manufacturing process, changes in the market place, and changes in organizational focus and priorities.
- Technology utilization effectiveness. This describes the ability of organizational structures to make strategic use of the most appropriate technologies in workstations, databases, networks, artificial intelligence, and software engineering.
- Individual satisfaction effectiveness. This shows the ability of organizational structures to utilize human resources in terms of job enrichment, growth paths, and job security.
- Integration effectiveness. This calibrates the capability of organizational structures to integrate different systems in different parts of the organization utilizing different technologies. It

Table 2
Evaluation of organizational structures. [a]

| | Structure1 Functional ownership | Structure2 Project team | Structure3 Top management team |
|---|---|---|---|
| *1. Decision Effectiveness* | | | |
| – goal setting ease | 3 | 4 | 5 |
| – time required to make decision | 5 | 2 | 1 |
| – progress monitoring ease | 5 | 4 | 4 |
| – problem diagnosis ease | 3 | 4 | 4 |
| – openness to innovation | 2 | 4 | 5 |
| – standards and policy enforcement | 2 | 3 | 4 |
| – feedback facilitation | 2 | 4 | 5 |
| – path length reduction | 3 | 2 | 4 |
| *2. Responsiveness to change* | | | |
| – change in manufacturing process | 2 | 2 | 2 |
| – change in the market place | 1 | 2 | 4 |
| – change in organizational focus | 1 | 2 | 4 |
| *3. Technology Utilization* [b] | | | |
| – computing technology | 2 | 4 | 3 |
| – communication technology | 2 | 4 | 3 |
| – software technology | 2 | 4 | 3 |
| – compatibility | 3 | 4 | 5 |
| *4. Integration Effectiveness* | | | |
| – coupling (interdepartmental communication) | 2 | 3 | 4 |
| – binding (intra departmental communication) | 4 | 3 | 2 |
| *5. Human Resource Utilization* | | | |
| – professional growth | 2 | 3 | 3 |
| – promotion opportunity | 2 | 3 | 4 |
| – job security | 3 | 4 | 4 |
| – employee turnover reduction | 2 | 3 | 4 |
| – burnout reduction | 4 | 3 | 2 |
| – productivity improvement | 2 | 3 | 4 |

[a] Criteria: v. good (5), good (4), soso (3), bad (2), v. bad (1), unknown(?)
[b] Computing/communication technology is assumed to be part of the same functional unit.

may be measured by utilizing systems engineering methods [10,14,22]. The most common criteria for design evaluation in systems engineering are binding and coupling, where binding represents the interactions between the components of a system and coupling represents the interactions between different systems. An integrated organizational structure minimizes the unnecessary coupling and maximizes the desired binding of the organizational units [3].

The variables shown in Table 1 have been found useful for evaluating organizational structures for CIM when assigned a scale of 0 to 5 (very bad to very good). An enterprise may assign certain weights to highlight the importance or inapplicability of particular measures. For example, an organization might choose to assign low weights to employee satisfaction and high weights to flexibility and integration.

*Table 2* shows an application of the evaluation model to the three basic organizational structures. The illustration reflects the results of two different discussion sessions with seminar delegates and our own subjective evaluation. In the first session, initial evaluations were assigned by the authors. These evaluations were then used as a basis for a seminar discussion session and modified accordingly. The results are:

- Decision Effectiveness: The goal setting effectiveness of top management team structure is very good due to direct communication with top management; however it may be harder to monitor the progress and diagnose problems at lower organizational levels in this type of structure. It appears that innovation and standards/policy enforcements are easier in the top management team structure, however it is harder to obtain feedback on decisions, because lower level activities may not be directly accessible to a high level team. The potential drawback of the top management team structure is that it may take a long time to make a decision, due to the involvement of many functional units.
- Responsiveness to Change: Response to changes in organizational focus and the market place can be quicker in the top management team structure. However, changes in manufacturing processes are not affected by the team structures unless CIM is part of the manufacturing group.
- Technology Utilization: If the functional integration team is part of a computing/information technology department, then new computing/communication technologies can be easily introduced and utilized effectively. In team approaches, the technology will be introduced and utilized only if the computing professionals have significant involvement in or influence on the teams.
- Integration Effectiveness: Interdepartmental communications are significantly improved in the team approaches, but the teams may have difficulty in forming cohesive groups, because in most cases the team members have different backgrounds, jargon, job responsibilities and professional goals which may cause conflicts.
- Individual Satisfaction: The team approaches do expose new technology to individuals and can thus lead to more satisfied employees, reduce turnover, and burnout. However, since team members are drawn from various functional units, this does not necessarily result in promotion and job security.

We have found that such an evaluation model provides a systematic approach for a detailed examination and analysis of the proposed organizational structure. It has been especially useful in providing a uniform basis for evaluation: it has led to valuable insights and discussions. It was also found that the model was instrumental in keeping the discussions more focussed and analytical. Although there were some disagreements concerning the values assigned in the table, the relative merits of the three structures were quickly understood.

## 5. Summary and conclusions

Organizational structure design is a key problem for Computer Integrated Manufacturing (CIM) environments. This paper presents initial observations about organizational structures for CIM and discusses three basic approaches uncovered during our contact with various CIM enterprises. An initial framework for evaluating CIM organizational structures is presented and utilized to evaluate the strengths and weaknesses of the three basic approaches.

Several areas of investigation are being explored. More data will be collected on CIM organizational structures and the evaluation model. It is our plan to formalize this evaluation model by recording actual experience from CIM enterprises during future contacts and to extend the model, where needed. In addition, the evaluation model will be formalized and extended into a generic framework.

Another area of investigation will be to use the evaluation framework to develop typical profiles for various industry types. These profiles can show the typical weights assigned to the evaluation measures based on company type, company size, product lines, and organizational strategy. For example, small companies with limited product lines selling to specialized customers may not emphasize technological measures, in contrast to large international high technology enterprises which utilize technology as a competitive edge. Such profiles may be used as a knowledgebase for an expert system that would suggest suitable organizational structures based on the characteristics of a given enterprise.

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