APPLICATION OF MACROERGONOMICS PRINCIPLES IN THE IMPLEMENTATION OF COMPUTER INTEGRATED MANUFACTURING SYSTEMS

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Abstract

Many implementations of Computer Integrated Manufacturing Systems (CIMS) have been plagued by failures. Some of the causes of these failures have been identified as the neglect of recognizing and addressing the organizational and human dimensions of a large-scale technological change, as a CIMS implementation is. In this paper, MacroErgonomics Analysis and Design (MEAD) is used as a framework to implicitly recognize these factors and address them from the design phases of the new work system.

Keywords: Computer Integrated Manufacturing, Macroergonomics, Sociotechnical Systems.

Resumen

Muchas implementaciones de Sistemas de Manufactura Integrada por Computador (CIMS, por sus siglas en Inglés) han estado plagadas de fallas e imprevistos. En algunos casos se han identificado como causa raíz de estas fallas el desconocimiento y la no consideración de las dimensiones humanas y organizacionales de un cambio técnico de gran escala. En este artículo se utilice el Análisis y Diseño Macroergonómico (MEAD, su sigla en Inglés) como un marco de referencia para reconocer de manera implícita estos factores y considerarlos desde las fases de diseño de un nuevo sistema de trabajo.

Palabras Clave: Manufactura Integrada por Computador, Macroergonomía, Sistemas Sociotécnicos.

1. Introduction

Computer Integrated Manufacturing Systems (CIMS) are an area of great development in recent years, especially since the middle of the 1980's. They have been widely applied in a diversity of manufacturing organizations that feel the need for modernization and a range of competitive pressures coming from different sources. According to Mital and Anand (1992), cited in Mital (1997), some of this pressures are:

- (The) need to enhance the standard of living through the creation of national wealth;
- (The) loss of global competitiveness, and prestige, due to the inability to produce high-quality products;
- (The) fear of intellectual stagnation;
- the loss of creative edge;
- the need to respond to market demands quickly;
- the need to prepare for market and technological changes that are occurring more frequently than ever.

It was frequently advocated, especially in the initial stages of CIMS, that extensive automation and mechanization would lead to the solution of many of those problems. Terms like *"lights-out-factories"* were coined to signal the ideal of having automatic factories that would be able to run without the need for human intervention, therefore making completely unnecessary the use of lighting inside the manufacturing plant.

> *"A 1992 Industry Week survey of executives and managers in in US manufacturing industries, approximately 81% of the respondents regarded CIM as essential or very important as a competitive weapon. Approximately 66% felt that CIM was an important cornerstone for world-class manufacturing"*. (Mcgaughey and Roach, 1997).

However, in CIMS implementations, as with any technological large scale change, there have been success stories but also countless tales of failure and disgrace, even taking companies down the road of bankruptcy. Some believe that the failure rate for technologies such as CIM may be as high as 50% to 75% for US firms (Cleland *et al*. 1995, Saraph and Sebastian 1992).

Some authors have analyzed the reasons for failure in CIMS implementations through surveys of practitioners. In particular, Mcgaughey and Roach (1997) sent 428 surveys to professionals involved in the implementation of CIMS in factories and obtained 101 responses, in which the eight (out of 21) most significant factors (obstacles to CIMS success) were, in descending order of importance:

- Inadequate leadership
- Lack of top management support and commitment
- Inadequate planning
- Inadequate analysis of user needs
- Inadequate funding
- Inadequate system design
- Lack of people with technical expertise
- Corporate culture not right for CIM

It is interesting that these factors have nothing to do with the technology itself, but with the way in which humans organize the company, make the relevant decisions and go about the implementation of the system.

Obviously, it would be interesting to discuss ways in which there pitfalls can be avoided, improving the planning and design stages of the implementation process to encompass all the elements of the manufacturing enterprise. CIMS implementations are not only a matter of technology, they are Large Scale Changes that affect all the company and its immediate environment.

> *"…Restructuring measures are crucial which from a work-psychological point of view are designed in line with the following principles:*
> - *Organizational design prior to automation*
> - *Education and training as a strategic investment*
> - *Functional integration*
> - *Local self-regulation.*
>
> *Such changes are no doubt time-consuming, but eventually less costly and make a considerable contribution to humane working conditions and economic efficiency"*. (Ulich, 1993).

In this paper, an approach called Macroergonomics (ME), based in the Theory of Sociotechnical Systems will be applied to CIMS implementation in order to address the change process with a systemic view.

2. Background: Macroergonomics

Macroergonomics is a sociotechnical systems approach to work system design (Hendrick and Kleiner, 2001). It is, therefore, the application of the SocioTechnical Systems Theory (STS) to the configuration of the enterprise and the interaction of the components in such a system.

2.1. Sociotechnical Systems

The Sociotechnical Systems model was developed in the Tavistock Institute of Human Relations in the United Kingdom, during the late 1940s and 1950s. The leaders of these efforts were F. Emery, E. Trist and K Baumforth. Later these models have been confirmed in different schools and experiences in different regions of the world.

A turning point of the development of STS were the experiments conducted in a coal mine in Wales (Trist and Baumforth, 1951). The traditional mining systems were basically manual, with the workers organized in small autonomous teams. Each worker performed a variety of tasks, and they were cross trained and capable of taking somebody else's position.

These systems were deemed unproductive, and a new and more technologically efficient system was implemented. This new system, called *longwall*, changed the way people worked. Now, groups of 10 to 20 workers were required at a time, and each of them had to specialize in narrow, well-defined repetitive tasks. Also, a high level of interdependence between the work of the three shifts caused that problems occurred in one shift were carried to the next one, diminishing the possibility to complete the assigned work.

When the second system was implemented it was plagued with low throughput, high absenteeism and rivalry between workgroups. The reasons for these problems were investigated and some of the findings were:

- In the old technology, each group had considerable autonomy.
- In the new system, the opportunity for social interaction was greatly reduced.
- In the new system, workers could not achieve the satisfaction of work completion (the tasks were carried to the next shift sometimes).
- In the new system, workers felt trapped in little tasks, because job rotation was not done and they were not cross-trained.

According to these findings, for new mine implementations, the work system was redesigned with what was then called a *composite* method, which combined the social characteristics of the old system with the technological advantages of the new one. Production was then higher than in the old system or in the *longwall* system.

> *"The key is to select a work system design that is compatible with the characteristics of the people who will perform the tasks and the relevant external environment, and then employ the technology in a manner that achieves congruence with it"*. (Hendrick and Kleiner, 2001).

From these initial experiments and the subsequent research and implementation processes, the principles of sociotechnical systems were derived. A brief presentation of these principles follows (Oborski, 2003):

1. *Minimum Critical Specification:* An employee must given the minimum amount of specifications over the task to ensure that it will be done correctly.
2. *Variance Control:* Problems must be corrected as close to the point of origin as possible and preferably by the group that caused them.
3. *Multi-Skilling:* Give individuals a range of tasks including some routine and some challenging.
4. *Boundary management:* Identify boundaries between groups and functions. Ensure that the people on them have the information necessary to pass the product smoothly to its next transformation stage.
5. *Information flow:* The information system should be designed so the information goes directly to the place where action is to be taken or to the source that originated it.
6. *Designee and human values:* It recognizes the need to be able to learn on the job, the need for an area of decision making, the need to relate work to social life, the need to feel the job leads to a desirable future.
7. *Incompletion:* The need to recognize that design is an ongoing and iterative process.

2.2. Macroergonomics

In 1978 the Human Factors and Ergonomics Society commissioned a study on the future of the field. Hal Hendrick was appointed head of the Committee. Their key findings lead them to propose that there was a need to integrate ergonomics with

Organizational Design and Management, with Macroergonomics in charge of studying the design and improvement of work systems.

Hendrick proposed that the profession of Ergonomics is in charge of analyzing and designing the interfaces between human and system, and from the different subdivisions of these interfaces the common specialties of Ergonomics can be derived (Hendrick, 1998 cited in Hendrick and Kleiner, 2001):

- Human-*machine* interface technology: Hardware Ergonomics
- Human-*environment* interface technology: Environmental Ergonomics
- Human-*software* interface technology: Cognitive Ergonomics
- Human-*Job* interface technology: Work Design Ergonomics
- Human-*organization* interface technology: **Macroergonomics**.

The Macroergonomic model of the organization is based in the recognition that the it can not be successfully analyzed and improved without taking into account its different subsystems and its interactions, as well as the environment that surrounds it (which is often the most important component). The summarized model can be observed in **Figure 1**.

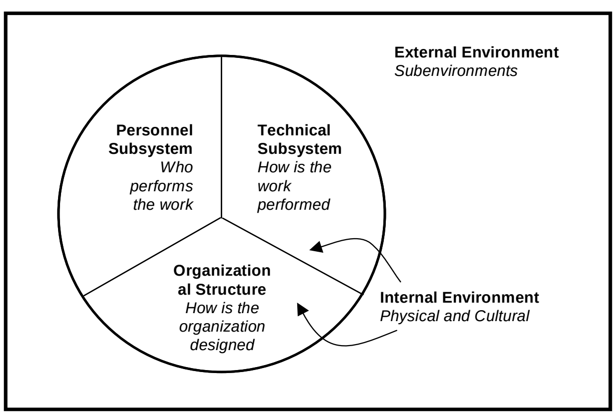


Figure 1: Macroergonomics model of the organization.

In this model, four main subsystems can be differentiated: Environment, Technical Subsystem, Organizational Structure and Personnel Subsystem. The model is quite simple, yet it emphasizes in the relationships and interconnectedness of its components.

Based on the principles of Sociotechnical Systems, Macroergonomics propose that an effective approach to work system design needs to have the following characteristics:

- *Joint Design:* Both the human and technological subsystems must be designed concurrently, with a *human-centered focus*. This design should allow for extensive employee participation.
- *Humanized Task Approach:* A traditional pitfall (that must be avoided) has been the allocation of tasks to computers or machines because *they can do it*, and the leftover tasks are assigned to the humans. Instead, the approach taken must result in tasks that make full use of human skills and compensate for human limitations, making the job fulfilling. The leftover functions are left for computers and machines. (Bailey, 1989).
- *Consider the organization's sociotechnical characteristics:* The approach should consider explicitly these characteristics and incorporate them into the work system design process.

The application of these principles is done through the MacroErgonomic Analysis and Design (MEAD) (Hendrick and Kleiner, 2001). MEAD is a methodology constructed to plan and implement the design of a work system, and its basic structure is presented in **Figure 2**.

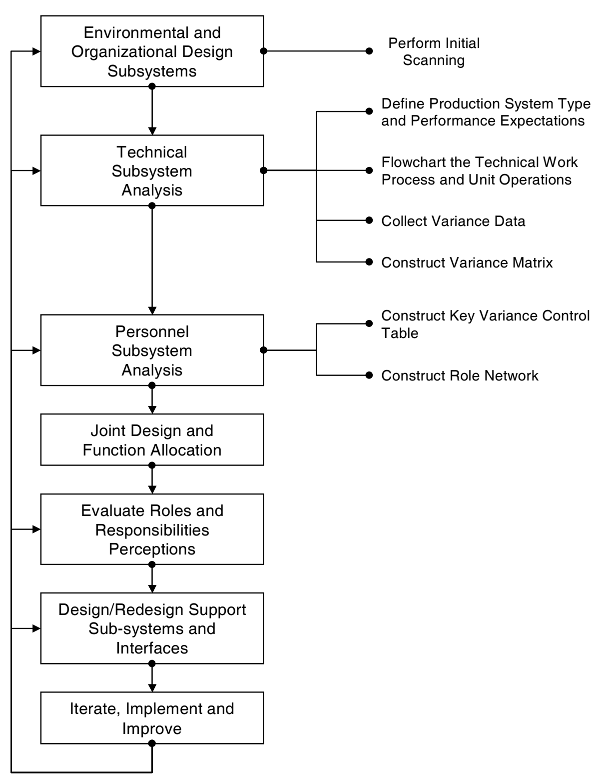


Figure 2: MEAD (Adapted from Hendrick and Kleiner, 2001)

In the next section this MEAD model will be used to propose a general plan of implementation for CIMS, adapting and specifying its different stages to the situation of a company considering it.

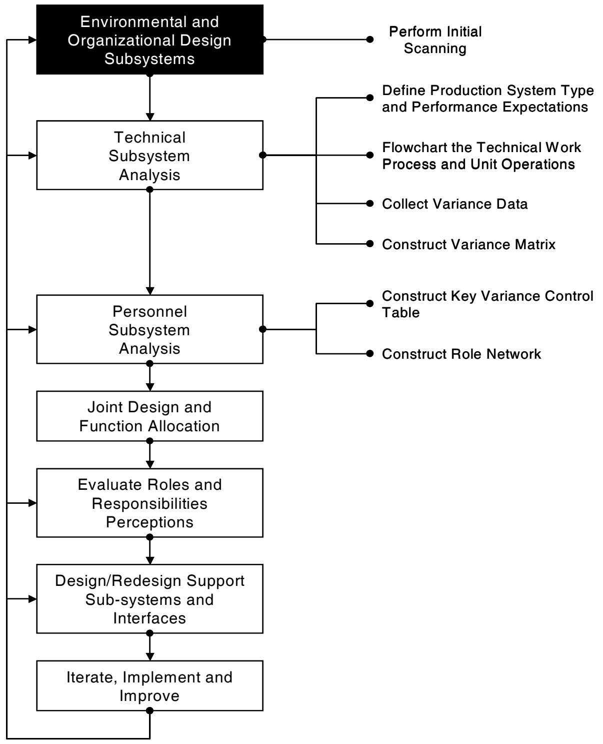
3. Application of Mead to Cims

The steps of MEAD will be followed in order, making the necessary clarifications along the way.

3.1. Environmental and Organizational Design Scanning

3.1.1. Perform Environmental Scan

First, it is necessary to define the organization's boundaries. This encompasses the task of finding the scope and reach of the organization, and also can help to define the *core competencies* of the organization.



Next, the external environment needs to be understood. It is conformed by *subenvironments*, which represent the different actors in the overall environment. Some subenvironments of interest are:

- Government
- Public opinion
- Consumers
- Companies in the same industrial sector
- Shareholders

These subenvironments have demands and expectations over the organization, and also present trends of change and evolution over time. It is important to understand them to decide on a strategic course that is consistent with what the environment presents and enhances the probabilities of success.

At this point, the company needs to decide if the implementation of CIMS is relevant and adequate for them. This implementation implies a large scale organizational change, and a big commitment of resources, therefore the company needs to realize if it is the right course of action and reflect it on its Mission, Vision and Principles, which will be discussed in the next section.

3.1.2. Perform Mission, Vision and Principles Analysis

A Mission describes the company's main business, products and services. A Vision states what the company wants to be, usually projected into the future. Principles are a set of values and standards that the company holds dear and must permeate into every decision and activity of the company.

The company that is interested in implementing CIMS must first decide if CIMS support their Mission, Vision and Principles (MVP). For example, it would not be congruent if a company professes that they want to give personalized attention to every customer and they implement a fully-automated menu-based telephone response system to deal with their complaints without the need for human contact. At this point, if there is a discrepancy between what the automated operations will bring to the company and its MVP, there are two alternatives:

1. Change the operational design of the system so it is consistent with its MVP. This course of action should be taken when the MVP is deemed critical for the success of the company.
2. Change the MVP. This should be done when the old MVP becomes obsolete or misaligned with the needs of the market and the company's environment. In this case, a reexamination of the whole strategic purpose of the company is in order.

3.1.3. Perform System Scan

This will allow the company to define itself as a system, examining the different components of the