A Macroergonomic Approach to Product Design

Noe Palacios* and Andrew S. Imada**

* Steelcase North America,
CD.3S.28, P.O. Box 1967
Grand Rapids, Michigan 49501-1967, USA

** University of Southern California and
A. S. Imada & Associates
4910 Phelps Court
Carmichael, California 95608, USA

This paper describes an approach to product design that incorporates both micro and macroergonomic concerns. Like traditional ergonomic contributions to product design, the process incorporates biomechanical, physiological and sensory knowledge to make the human interface user-friendly. Beyond the scientific evidence, this approach builds upon regulatory, legislative, industry and quality requirements. At a broader level, the approach examines trends in organizations, technology, and work processes that can have significant impact on the desirability for the product. At the same time, the approach considers these forces as needs that the product can fulfill in the marketplace. While this conceptual approach carries risks typically associated with new designs, it does point to the utility of incorporating multiple levels of analysis in the design of future products. This approach can have significant impact for the success of the producing enterprise, customer's satisfaction and product desirability. At the same time, the process can affect the nature of the organization that designs the product in a dynamic way.

1. Traditional Product Design

To date, the way products are developed has mirrored the nature of the organizations that produce them. Traditionally, organizational functions that maximize specific organizational outcomes drive the design process. Moreover, the process is usually sequential, following a step-by-step process with compromises along the way to accommodate functional needs. Finally, the design process can be characterized as hierarchical and linear; there are approval processes within functions and a prescribed order for achieving tasks.

Recent developments in manufacturing and product design have improved upon the process. These efforts include: concurrent engineering, lean manufacturing systems, human factors for manufacturability and organizational re-engineering. These efforts have improved how we design and deliver products to the marketplace. It could be argued that these improvements: 1) are best suited for stable products where design requirements are known; 2) focus on the organization that produces the products rather than the customer; and 3) view the product in the present or the past rather than in a future state.

The role of human factors in product design has been traditionally relegated to solving a problem inherent in the design of the product based on complaints, suggestions, competitive market forces or litigation. Furthermore, human factors contributions, whether during or after the product design, have been traditionally limited to physiological or sensory domains. Relying heavily on a body of scientific knowledge, human factors professionals have been able to improve user comfort, stability, task performance, safety, and user acceptance in products and work processes. (See Hendrick, 1)

2. A Macroergonomic Approach

Whatever impact human factors contributions have made, product designs have been limited to physical and sensory dimensions of the user's experience with that product. A broader definition of ergonomics has expanded the ergonomist's role. Hendrick (2) defined macroergonomics as the optimization of organizational and work systems design through consideration of relevant personnel,

technological and environmental variables and their interactions. This approach encompasses a number of techniques and methodologies that have been successful in reducing accidents (e.g., Imada & Feiglstok, 3; Nagamachi & Imada, 4) and improving productivity (e.g., Imada & Stawowy, 5).

This macroergonomic approach is useful in developing products and markets for these products. In particular, organizational, technological, psychological, political dimensions may help designers anticipate users' future needs.

Like the organizations that create these products, design teams tend to fall into functional silos that prevent the full advantage of the multidimensional facets that drive product design. For example, product design is driven by: 1) user comfort, health and safety; 2) aesthetics; 3) technological advances and capability; 4) how the product is expected to be used; 5) who makes the purchase decision; 6) cost; and 7) features legislated by governments. Few would argue about the influences each of these factors has on the outcome of the design process. Imada (6) describes organizational "tribes" that worship different values and seek to maximize these values. These tribal values are encountered in designing products. Efficiency, aesthetics, political alliances, productivity, sales, and easy of manufacturability are all important features to different parts of the organization. Only by integrating these dimensions into a macroergonomic approach can we capitalize on all these strengths.

Designing office products poses unique challenges because of multiple uses of the same product, differing user needs, organizational intent for the products, varying body dimension, and task requirements. The design of office furniture should be based on musculoskeletal, physiological and psychological scientific knowledge. However, final design can, and is, influenced by technology, organizational culture, user needs, and communication patterns. This calls for a systems approach to understanding how to design products for the future.

2.1. Macroergonomic workplace factors that drive end user needs

A more holistic approach to ergonomic design may include an analysis of key issues that determine how well the product is used and received. These include analysis of workplace issues that drive end user needs. This paper identifies three such issues.

2.1.1. Organization

Over several decades organizational structure has evolved from hierarchical to downsized organizations to continually restructured teams. This evolution suggests that end users will move from highly concrete to fluid, temporary teams. These structural changes will affect the nature of relationships in the office by affecting peoples' interdependence (7). In hierarchical organizations people experience pooled interdependence; they work relatively independently and contribute to the whole by doing their own job. The relationship between sales and shipping is an example of pooled interdependence. In a more coordinated scenario, work flows from one unit to another making them more dependent as the output from one group becomes the input for another. A paper processing operation is a good example of this sequential interdependence where work flows from one station to another. Finally, teamwork is highly interdependent as team member exchange inputs and outputs, in some cases in real time. This creates a highly reciprocal interdependence where work is being transformed by the activities of others. One person's output becomes another person's input as it changes many times. As work requirements become more interdependent and participative, the office environment becomes important in that it can support or hinder a work philosophy (8). New organizational structures will require new work environments. These new environments must support the new structure and the behaviors and processes that accompany it.

Another organizational trend observed over several decades is a move from homogeneous (predominantly white male), formal environments to diverse, casual environments to "officing" anywhere at anytime. More diverse teams (size, age, and expectations) have created networked clusters and empowered groups in horizontal organizations. These horizontal organizations are more process-oriented, and focused on key performance objectives.

As technological complexity increases, organizations make choices about their growth. They can recreate themselves in self-contained mini-organizations that represent more of what exists now, or they can move to large networked offices (8). The way these larger, more complex grouping of people are structured will determine how people communicate, create, and produce. Duffy and Tanis (9) go further and suggest that effective design can be used to achieve emerging management objectives and is essential to achieve organizational change.

2.1.2. Technology

Clearly the technological tools that we give people to do their work will change their needs. As a small but practical matter, the kind of machine that sits on a knowledge worker's desk will affect the footprint on that work surface and influence the design of that work

station. The problem is compounded as the number of technologies that worker uses increases. User technology has moved from a centralized main frame, telephone, mail and typewriter environment to user-friendly PCs with multiple applications, wireless phones and e-mail. We will evolve further to more portable, multi-media intelligent agents that will allow people to work independently anywhere, anytime and in teams.

Workplaces must accommodate the new technology by providing a physical environment with proper acoustics, minimal glare and brightness and adjustable features for anthropometry as is done today. Additionally, the future will require even more flexibility that can allow for change, mobility, proper adjacency, appropriate work surfaces within a work area, electronic and communication support for individuals and teams.

2.1.3. Work processes

Organizational structure and technology have independent effects on how work is accomplished. Beyond these organizational and technological factors, personal forces influence the way work is performed. Work has evolved from being highly specialized, moderately intense, and done independently to becoming multi-tasked and intense, and highly integrated with others. In making this transition, workers lost control of how and when the work was done. The future holds promise for work that meets organizational needs while allowing for greater control by the individual worker and teams.

Two decades ago, researchers predicted that workers would want greater control over their work process; meaning and fulfillment from their work; opportunities to participate in his design of their work; and working with interesting people (10). Contemporary knowledge workers have fulfilled these predictions. They are better educated, accustomed to more stimulation from work and find identification outside work. Organizations can become more successful if products help people meet these needs.

3. Product And Market Development Process

This broader macroergonomic perspective forces one to look at a radical departure from the traditional product and marketing development process. In short, it has created a profound change, not only in the design process or the designed products, but in the way the organization operates. It has enabled the company to extend beyond the traditional ergonomic boundaries of individual working postures, comfort, working environments and tasks.

This process means that the product and marketing development team requires a broader understanding of: the impact macroergonomic factors have on end users; user needs from biomechanical, physiological and sensory perspectives; the ability to translate these needs to engineering solutions; and the need to validate concepts.

3.1. The team

A multidisciplinary group was assembled as the core team for the product and marketing development process. Represented interests included marketing, industrial design, operations, finance, and engineering with one of the disciplines having either a human factors engineer as part of their group or one of the members having an understanding of and sensitivity to human factors.

3.2. The design process

Once the decision was made to proceed with the project from the opportunity analysis and market insight, data were gathered from a wide array of sources. The involvement of the entire multidisciplinary team in collecting data from the voice of the customer through Quality Functional Deployment (QFD) and workplace issues (macroergonomic variables), health and safety and industry standards, and competitive analysis is critical to the process. The primary benefits were buy-in from a diverse design team and a clear definition of the product the customer wants. The output of this design process is a list of design specifications (see figure 1).

With design specifications in hand, industrial design, engineering and marketing began their respective activities. Continued interaction among these functional groups mirrors the concurrent engineering process. A major difference is that all the functional group members were involved in the opportunity analysis, analysis of the macroergonomic factors, competitive analysis, standards and the customer input before beginning their work.

3.3. Validation

A key to the process is ensuring that the design process met specifications originally articulated in the analysis in the voice of the customer, QFD, market analysis, standards, competitive analysis, and work place issues. Internal and external ergonomic reviews, customer focus groups are used extensively to confirm that the design reflects the customer's voice, the workplace issues, health and safety standards and competitive analysis. Each step was used in a multiple hurdle design process before the product is designed to go the market.

4. Conclusion

The design process described in this paper take a macroergonomic approach to product design. The approach incorporates the broader milieu - including

organizational, technological and human factors - in which the product will be used. It recognizes that work, like most human activities, is made up of both hard and soft system variables (11). That is, some system objectives and goals are understood and agreed upon by most people. Other variables do not have universal agreement and need to be defined by human experiences, values, and motivations. By including input from the customer, the marketplace, the competition, legislated and professional standards, and work place issues, products can be designed that are attractive and useful to end users and organizations. At the same time, the process can have profound effects on the organization. Like the customers it serves, the designing organization will have to become more participative, more integrated, ore horizontal, and more process oriented.

References

1. H. W. Hendrick, Good ergonomics is good economics, Hum. Fac. & Ergon, Soc., Santa Monica, 1997.

2. H. W. Hendrick, Ergonomics in organizational design and management, Ergonomics, 34, 1991, 743.

3. A. S. Imada and D. M Feiglstok. An ODAM approach for improving safety. In K. Noro & O. Brown Jr. (Eds.) Human Factors in ODAM - III., North Holland, Amsterdam, 1990.

4. M. Nagamachi and A. S. Imada, Human-centered safety: A macroergonomic approach to safety management. In G.E. Bradley & H. W. Hendrick (Eds.) Human Factors in ODAM-IV, North Holland, Amsterdam, 1994.

5. A. S. Imada and G. Stawowy, The effects of a participatory ergonomics redesign of food services stands on speed of service in a professional baseball stadium. In O. Brown Jr. and H. W. Hendrick (Eds.) Human Factors in ODAM - V, North Holland, Amsterdam, 1996.

6. A. S. Imada, Overcoming cultural barriers within organizations. In G.E. Bradley & H. W. Hendrick (Eds.) Human Factors in ODAM - IV, North Holland, Amsterdam, 1994

7. J. D. Thompson. Organizations in Action, McGraw-Hill, New York, 1967. 8. P.J. Stone and R. Luchetti. Your office is where you are. Harvard Bus. Rev., 63 (1985) 102.

9. F. Duffy and J. Tanis. A Vision of the New Workplace. Site Selection and Industrial Development, (1993) 427.

10. D. Yankelovich, Work values and the new breed, In C. Kerr and J.M. Rosow (Eds.) Work in America: The decade ahead, Von Nostrand Reinhold, New York, 1979.

11. P. Checkland, Systems thinking, systems practice, Wiley, New York, 1981.