

FUNDAMENTALS OF MANUFACTURING EXCELLENCE

Joseph A. Heim
National Academy of Engineering
2101 Constitution Ave., NW
Washington, D.C.

INTRODUCTION

Manufacturing excellence, world-class stature, being the best of the best—the ability to provide high quality, competitively priced products and services in a global marketplace—is a major hurdle confronting manufacturers. The challenges they face are well known: the need to improve product quality, drastically shorten product development cycles, increase productivity growth, stimulate product and process innovation, and respond quickly to changing customer demands. Many U.S. manufacturers, however, are woefully unaware of the widening performance gap between them and their competitors, insufficiently cognizant of their customers' needs, and naively preoccupied with near term achievements of their firm, while neglecting the long term investments needed to compete in the international arena.

Fortunately we should not be discouraged nor paint too broadly the malaise of U.S. manufacturing capability. An expanding core of American manufacturers have begun to appreciate the level of performance and commitment needed to adequately confront competition in both domestic and foreign markets. They are undertaking the kind of changes and improvements in organizational structures, governance, and relationships that are needed to create the level of manufacturing excellence demanded by increasingly sophisticated and quality conscious customers around the world.

In this paper we look at some of the fundamental practices and philosophies of this group of manufacturers. These fundamentals of manufacturing excellence have been identified as characteristics of world-class manufacturers; they are generic—not specific to company, country, or industry—and they are universal in that they can be applied to a wide variety of circumstances. They offer a starting point from which we can begin to develop a scientific rationale for the design, analysis, and operation of manufacturing systems, a basis upon which we can begin to formalize the principles that define how we should go about organizing and using our human, financial, managerial, and technological resources, a basis on which American manufacturers can create competitive manufacturing strength.

MANUFACTURING AS A SYSTEM

Most efforts to develop a science of manufacturing have concentrated on understanding and improving the performance of the many unit operations and activities. Our perception of the manufacturing process has centered on the materials, machines, labor, and equipment used to make products—the physical processes of

production—and, to some extent, the data and information flows among the computers and controls for these processes. Accordingly, institutional examination of manufacturing has evolved into a collection of narrow disciplines that customarily ignore the integrated nature of the manufacturing system.

It is often felt that developing greater understanding of the fundamental phenomena underlying the unit operations and subsequently maximizing the effectiveness of the separate parts, that the entire system can be optimized. We are beginning to realize that the number and complexity of the relationships, interactions, and dependencies of the components and processes precludes such a piece-meal approach to system optimization. It is clear that we need a dynamic and integrated concept of manufacturing systems.

In the absence of an overall understanding of the system and interrelationships among the functions, however, operational models have evolved from beliefs or rules-of-thumb derived from personal experience, trial-and-error, and individual interpretation of empirical data. But this so called know-how varies widely in extent and validity from company to company and from industry to industry and is almost always impossible to generalize or apply to new situations.

During 1989 the National Academy of Engineering, recognizing the complexity of the manufacturing system and the need to consider it in its entirety, organized a study to identify the generic issues reflected in world-class manufacturing companies—to describe the set of fundamental principles of manufacturing excellence on which systems of manufacture could be analyzed, designed, and managed.

The study committee examined the actions and approaches that successful manufacturers have taken as they evolved to world-class status. Many of the companies adopted common techniques which suggests that there are indeed particular means for achieving manufacturing excellence that the rest of us would benefit from knowing about and understanding. These common strategies are examined in a framework that considers three important aspects of manufacturing competitiveness:

- leadership and management of the organization.
- characterizing the system and its performance.
- sustaining the future competitiveness of the organization.

Some of the fundamentals of manufacturing excellence may be viewed as simply expressing common sense or good practice, and while they are not quantitative in the usual sense, it seems very clear that manufacturers considered world-class have generally recognized and are applying these practices and that these practices have contributed critically to their success.

LEADERSHIP AND MANAGEMENT OF THE ORGANIZATION

Leadership and management of the world-class manufacturing organization is relentlessly evolving from an operational mode characterized by command, control, and maintenance of the status quo—an inappropriate approach to the chaotic environment confronting manufacturers today—to a dynamic model requiring innovative leadership, strategic vision, and radical reformulation of organization structure and administration. This may include substantial changes in employee, customer, vendor and supplier relationships, and the adoption of a more holistic perspective on the interdependencies among the many elements of the manufacturing system. In this section we look at six fundamentals of manufacturing excellence that must originate from, and therefore be supported by, the executive officers of the enterprise.

Goals and Objectives

Manufacturing excellence is an explicit goal of the organization. A comprehensive set of quantifiable objectives continuously measures the performance of the system. These objectives are regularly assessed to determine their appropriateness to attaining manufacturing excellence.

Executives must clearly articulate and communicate the vision and philosophy of the corporation; ambiguous objectives are no help when employees try to choose from among a host of uncertain alternatives as they race to identify and address new product trends while retaining current customers.

Understanding a competitor's capability is but the first step in becoming competitive. Incorporating this information into the long-term goals of the organization--establishing a vision for the enterprise--is critical in achieving improved performance. When people understand this vision and have the appropriate frame of reference, information, resources, clear understanding of the task and its scope, and responsibility for accomplishing the task, they are likely to "do the right thing."

For this reason, management must view goals and objectives in both the long term and the short term. The long-term goals focus on the customer and the markets a company is prepared to enter. Short-term goals often involve operational objectives that are best established with appropriate input from employees that are most familiar with the machines, equipment, and operations concerned. Not only must these goals be clearly and regularly communicated to all employees, but management must put in place the means by which the performance of the organization can be continuously measured against these goals. This demands that the correct metrics be developed and that an assessment of progress against these metrics be continuously undertaken.

Customers

Manufacturing excellence requires that manufacturers instill and constantly reinforce within the organization the principle that the system and everyone in it must know their customers and must seek to satisfy the needs and wants of customers and other stakeholders.

Customers do not purchase manufacturing, engineering, or services; they buy solutions that fill particular needs. The manufacturer must focus on the customer needs, not on the functional capabilities of the organization. This means that the entire organization is optimized around meeting the customers' needs, using the skills of each discipline, focusing on the real task, and ultimately solving the real problems.

As obvious as this concern for the customer sounds, you cannot assume that everyone in the organization understands or accepts it or that everyone shares it as a common focus. You only have to remind yourself of the shock that many firms have experienced when their customers chose a competitor's higher-quality products even though the price was higher. Customer focus is so important that it must be considered a fundamental of manufacturing excellence.

The Organization

The integration of all elements of the manufacturing system, and the elimination of organizational barriers to improved communications, is fundamental to satisfying the needs and wants of the customers in a timely and effective manner.

In focusing on the systems that create, assemble, test, and service products, it is necessary to recognize that individual manufacturing operations differ and depend on each other in ways that may not be completely understood. Senior management must try to view the enterprise in a holistic cross-functional light, considering the manufacturing organization as a system of many different components, but looking for and recognizing the interdependence of all the elements. The proper coupling among the diverse units requires that an awareness and understanding of the objectives and capabilities of each group is understood by all other units or groups.

Employees

Employee involvement and empowerment are absolutely fundamental to achieving manufacturing excellence. Management's opportunity to ensure the continuity of organizational development and renewal comes primarily through the involvement of the employee.

The rationale for employee involvement is predicated on the assumption that individual employees have the best opportunity to understand and appreciate the problems that are unique to their positions. They know their jobs and they know what limits their performance. Employee involvement is, in a sense, the means by which a large organization attempts to achieve many of the benefits that are generic to the small organization.

But employee involvement does not, by itself, provide the mechanism by which employees can use their knowledge and experience to benefit the enterprise. If proper advantage is to be taken of the knowledge that the employee possesses, it is necessary to empower the employee to implement the solutions that they know to be available. By so doing, the enterprise is making the employee an integral part of the solution process.

Suppliers and Vendors

Manufacturing excellence depends on a cadre of world-class suppliers and vendors providing quality, service, and expertise as coequals with the other elements of the manufacturing system.

Can one be a world-class manufacturer with suppliers of less than world-class manufacturing capabilities? Despite their mutual dependence, the relationship of customers to suppliers and vendors has historically been adversarial. It is essential that the barriers that have existed between supplier and purchaser be attacked as actively as are the barriers between the elements in a manufacturing organization, that the "disposable supplier" mentality change to a "partnering" mentality.

Suppliers and vendors must become coequals with the other elements of the manufacturing system, and each side must work to create a consistent relationship rather than: "When things are going well we're partners; when things are not so well, we are vendors and suppliers." World class manufacturers recognize the significance of building these long-term partner-like relationships with the best suppliers and vendors as even greater emphasis is placed on quality, and the ever-faster incorporation of new technologies into product and process proceeds unabated. The manufacturer as customer must create a valid basis for judging the performance of their vendor and suppliers, learning to provide feedback and recognition for exceptional service, and helping create accurate costing information on which to base prices. They must abandon the lowest price, short-term contracting approach to vendor selection that has been traditional among U.S. manufacturing firms.

Management's Task

Management is responsible for achieving manufacturing excellence: creating a corporate culture committed to the customer, gaining the full participation and contribution of employees, vendors, and suppliers, and achieving continuous improvement in all aspects of the manufacturing system.

Effective management is critical if an enterprise is to compete in the world marketplace. The preceding five fundamental tenets relate to management practice—establishing the goal of being world class, attending to the needs and wants of the customer, creating an effective organization, creating an environment that encourages and rewards employee involvement and fosters employee empowerment, and integration of the suppliers and vendors into the system. Attention to any one of these will be useful to an organization, but manufacturing excellence will require that all five be simultaneously pursued. The challenge to management is to understand the importance of the task, to commit to accomplishing it, and to devote the enormous effort that is required to complete it.

CHARACTERIZING THE SYSTEM AND ITS PERFORMANCE

It is difficult to conceive of improving the current status of the system without first having a clear description of its status and character. This requires identifying the operational variables, understanding the interrelationships among them, and determining the theoretical limits of the variables and the system they constitute. It demands that important system parameters be identified and measured. Identifying cause-and-effect relationships that help predict the consequences of actions provides a basis for developing general tools and procedures that will allow the practitioner to extrapolate beyond current operating experience and to anticipate more accurately how a future system may respond or perform. The extent to which modeling, simulation, and analysis can be developed to provide these capabilities is an important element of manufacturing excellence.

Metrics

Metrics are absolutely fundamental to achieving manufacturing excellence. They are the basis by which the organization describes quantitatively the expectations and criteria used to measure the performance of the manufacturing system and its many interrelated components.

Manufacturing excellence requires an appropriate strategy for benchmarking: providing the resources, identifying the correct metrics within the context of their firm, overcoming the organizational resistance to "sacred cows" that in the past have been "unmeasurable," and surmounting the political situations that impede exchange of benchmark information. The sad truth is that many manufacturers have never looked at the performance of their domestic and foreign competitors. More often than not they evaluate their performance relative to their own accomplishments in previous periods, ignorant of the high levels of achievement possible.

Companies must measure their performance by benchmarking themselves not only against their competition but also against the best-of-the-best functionally, even in other industries. Manufacturers might compare their customer service operations to the services provided by leading department stores, mail order firms, or medical services providers. They must base their organizational goals and objectives on this information, continuously measuring and assessing the performance of the system against these objectives to determine whether they are indeed improving, and then regularly assess the appropriateness of the objectives to attaining world-class status.

Models

Models provide a means of formally representing aspects of manufacturing excellence. They can be used to unambiguously capture and describe the complex interdependency and stochastic nature of the many elements of the manufacturing system and to explore the consequences of alternative decisions.

Models provide a rational basis for predicting the impact of decisions before their implementation by (quantitatively) describing the important elements, interactions, and dependencies. Empirical models comprise valuable knowledge that provides a basis for engineering and managerial practice. Even the most simple models are useful drivers of improvement and change.

The construction, and continued refinement, of models also makes it easier to evaluate and transfer the assembled know-how from individuals and groups to others in the organization. As a vehicle for capturing and conveying organizational knowledge, models are a more accurate process than depending on the experience of a few people and what they remember about the past. Models in manufacturing companies are mechanisms for explaining and distributing complex rules and policies throughout the organization, especially to the operational areas on the factory floor. Using the same data to drive models throughout the enterprise, allows shop floor workers to acquire a perspective of operations that is in concert with the goals of the manufacturing system.

SUSTAINING THE FUTURE COMPETITIVENESS OF THE ORGANIZATION

The "manufacturer of the future" faces two significant challenges: intense competition and incessant change—new science and technology, new product and process, new customer and market, new regulation and constraint. The globally competitive manufacturers will be identified by the rapid, flexible, and innovative fashion in which they respond to those dynamics, and by the quality, competence, and motivation of their work force.

There are two generally separate but related ways that the manufacturing firm will be able to create the necessary resources and capabilities to respond in such a manner. The first is the ability of the organization to learn and improve. The organization that can learn more rapidly from its experiences and use that learning to enhance its performance will have a distinct advantage. The second answer is to be found in technology. The enterprise that develops the ability to lead in the effective use of technology will possess a distinct and important advantage over competitors.

Maintaining and achieving enhanced system performance, however, requires an environment in which an organization can learn and benefit from its past experiences. As operating practice becomes more efficient through the application of the foundations of manufacturing, technology will become a more critical element in maintaining the status of the world-class competitor. The arrangements for acquiring, developing, and introducing new technology will become increasingly important as U.S. manufacturers continue to develop their abilities to compete in the world marketplace.

Learning and Experimentation

Maintaining manufacturing excellence depends upon an organization's ability to stimulate and accommodate continuous change. Experimentation and response to change creates new learning opportunities and organizational knowledge that lead to improved operational decision making.

The ability to react quickly and adjust to change is a skill that can be cultivated by encouraging and supporting intelligent risk takers and their experiments at all levels of the firm. But experimentation can disrupt established norms of operation, and the firm that wishes to experiment must recognize and allow for this disruption. The manufacturing organization is also challenged to create the environment and ensure circumstances that support venture and experimentation without placing the job security of risk takers in peril—employees must feel a sense of "protection" if they are expected to be innovative.

To further encourage experiments, the organization must minimize the data required to justify experimentation, and it must recognize that not all of the experiments undertaken will be successful. Costs, economic returns, and unforeseen contingencies are at best rough estimates when beginning an experiment. Therefore, it is important that sufficient reserves be available to withstand the financial exposure created and thus permit failures without always "betting the company."

It is also crucial that the knowledge acquired through experimentation be examined, the results formalized, and significant lessons and conclusions made available so that others in the company can benefit from the experience. The rate at which performance improves due to individual and organizational learning is perhaps one of the principal determinants of whether an organization can expect to achieve world-class stature.

Technology

Technology is a fundamental means for sustaining world-class competitiveness by all elements of the manufacturing organization. High priority must be placed on the discovery, development, and timely implementation of the most relevant technology and the identification and support of people who can communicate and implement the results of research.

For management, selection of the proper technologies from among technological opportunities is becoming a complex challenge that may be different for each manufacturer and for individual facilities. Choice of the appropriate technologies will increasingly consider local circumstances such as environment, work force, materials availability, relative costs of production, and the abilities of competitors. By making use of leading-edge technologies, a manufacturer may be able to achieve lower costs, better quality, or greater customer satisfaction with existing products by making low-cost variations in small lots and thereby realize significant competitive advantages.

CONCLUSIONS

The core characteristics of manufacturing proficiency in an increasingly competitive international marketplace include superb product development skills, operations efficiency, quality conscious customer satisfaction, and innovative adoption of product and process technology. The ten generic fundamentals of manufacturing excellence are a basis on which these world-class manufacturing capabilities can be built.

These principles are not specific to any one company, culture, or industrial sector—and they are universal in that they can be applied to a wide variety of circumstances. They suggest a starting point from which we can begin to develop a scientific rationale for the design, analysis, and operation of manufacturing systems, a basis upon which we can begin to formalize the principles that define how we should go about organizing and using our human, financial, managerial, and technological resources.

ACKNOWLEDGEMENTS

This paper summarizes findings by the National Academy of Engineering Committee on Foundations of Manufacturing and represents the views of the paper's author. The purpose of the study was to explore the disciplinary nature of manufacturing. Funding for the study was provided by the Intel Foundation and the National Academy of Engineering Technology Agenda Program. Many manufacturing practitioners, executives, academicians, and senior members of the policy community contributed to the study through participation in committee workshops and meetings, and writing background papers. The committee's full report titled *Manufacturing Systems: Foundations of World-Class Practice* is available from the National Academy Press, Washington, D.C.