ORGANIZATION AND MANAGEMENT OF ADVANCED MANUFACTURING

Edited by
Waldemar Karwowski
Gavriel Salvendy

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PREFACE

In the foreword to *Handbook of Human Factors*, edited by Gavriel Salvendy and published in 1987 by John Wiley and Sons, E. M. Estes, retired president of General Motors Corporation, stated that: "We are now, along with our worldwide competitors, in a race to take advantage of the technological breakthroughs that have occurred, mainly in computer science and communications. These changes are occurring particularly in manufacturing, service industries, and communication and are requiring major changes in the role of people. This revolution has increased the necessity for more emphasis on the relationship of all workers from the top executive down to the manufacturing service and sales operators. Although the difference between success and failure in any endeavor has always been the people involved, today the human factor is even more important." These statements together with the findings of the National Research Council's *Committee on the Effectiveness of Implementation of Advanced Manufacturing Technology* concluded that the human resource practices for implementing a vast manufacturing technologies are the key elements to success. The senior editor was privileged to participate in this committee, together with key leaders from trade unions and top executives from industry. The document of this report, published by the U.S. National Academy Press in 1986, concluded that such factors as the mode of planning plant organization, job design, compensation and raises, selection, training and education of personnel, and labor–management relations prevailing in the organization were the key elements for the effective implementation of advanced technologies in the workplace. In view of these developments, it was believed essential to prepare/develop a comprehensive book fully dedicated to the human factors issues in advanced manufacturing, the effective use of which would make the difference between the failure and success of industrial corporations.

As a result of this belief, two companion books were edited. This book consists of 16 chapters written by leading international authorities in the subject areas from academia, industry, and government agencies. Each contributing author was guided by a set of objectives, including the following:

Purpose The purpose of this project is to provide a comprehensive review of the human factors relevant to agile manufacturing. Advanced manufacturing systems aim to implement integration of manufacturing resources planning, computer-aided process planning, computer-aided manufacturing (including robots, FMS, CNC/DNC, etc.), computer-aided design and engineering, and concurrent engineering. Such integration will involve fundamental changes in, for example, human resource practices, cognitive task design, employee training and education, organizational design and management, and explicit definition of human roles and human–machine function allocation schedules.

This book, along with the companion book entitled *Design of Work and Development of Personnel in Advanced Manufacturing* (Salvendy and Karwowski, eds.), also published by John Wiley (1994), address and examine all of these as well as other issues relevant to agile manufacturing philosophy.

Intended Audience This text will be of interest to both practitioners and researchers of advanced manufacturing systems in academia, business, and industry, including industrial and manufacturing engineers, managers, plant supervisors, human factors specialists, cognitive and work psychologists, sociologists, and human–computer communication specialists.

We thank all the contributing authors most sincerely for agreeing so willingly to create this book with us. Each chapter was carefully reviewed by independent authorities in the subject area and the editors. The following individuals have kindly contributed to the review process:

R. Badham, Australia
A. Badiru, USA
R. Bretz, USA
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WALDEMAR KARWOWSKI
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Louisville, Kentucky
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CONTENTS

CHAPTER 1

TECHNOLOGIES OF ADVANCED MANUFACTURING

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As a result of intensified competition due to the transition from a seller's to a buyer's market, it is becoming increasingly important for companies to reduce costs or increase utility for the customer. An advantage achieved through ongoing product and process innovation cannot be maintained forever. The know-how will ultimately become common knowledge and will seep through to competitors or threshold countries. Companies in the industrial world can only pursue two strategies in order to maintain competitiveness:

- The services and products offered must contain so much generally unavailable know-how and competence that competitors are discouraged either through industrial property rights and licence payments or through the expense involved in research and development.
- Production itself involves a high degree of know-how.

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1.1 NO RULES FOR A COMPLEX FACTORY

In technical science it is assumed that all phenomena are based on the principle of reason and effect: small reason—small effect, large reason—large effect. Parts examined according to this attitude are subsequently put together again under the illusion that this is the way to obtain an exact image of the whole. However, this is a fundamental misconception. In real systems the smallest reasons can build up to large effects due to complex feedback mechanisms. The original order is replaced by an irregular unforeseeable behavior. If these chains of effects are ignored in model creation, as usual, the look at the whole system gets lost. So only suboptimal solutions are found that often deviate considerably from the overall optimum.

Although the linear and monocausal worldview has already been questioned with the emergence of quantum theory at the beginning of our century, we are still looking for the "world formula." For manufacturing engineering, this means, for example, the search for the "factory of the future."

Neither physicists nor engineers will find the world formula. It was only recently that scientists accepted chaos indeed as one of the fundamental patterns of our existence, but they are still far from being familiar with it. When coping with our daily tasks in this environment, we will be most successful if we do not look for "the truth" or "the solution" as the only superordinate value. It is much more important, however, to emphasize the importance of constant efforts and improvements in an environment that is rather unpredictable and subject to quick changes.

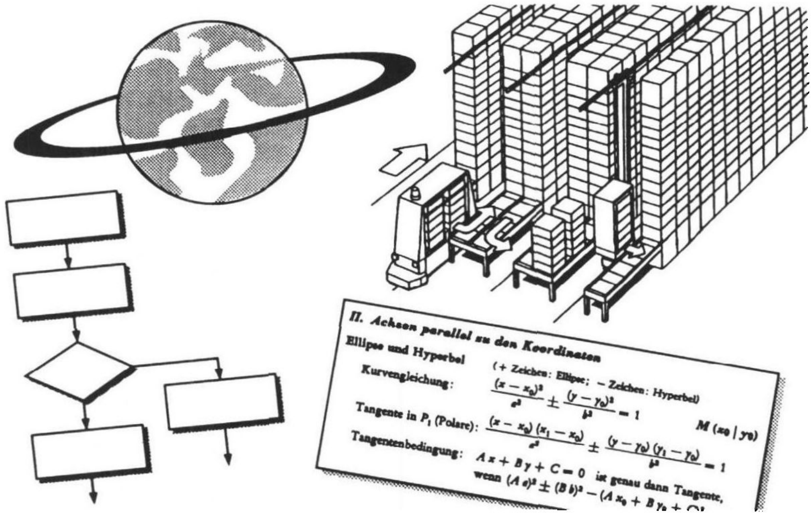
A production system is exposed to more decisive influences than those three or four we consider to be important and that we are able to relate to according to certain rules. Nevertheless, we are faced with the necessity to elaborate guidelines and rules for technology management. (See Fig. 1.1.)

1.2 QUANTITY AND DIVERSITY IN THE PRODUCTION STRATEGY

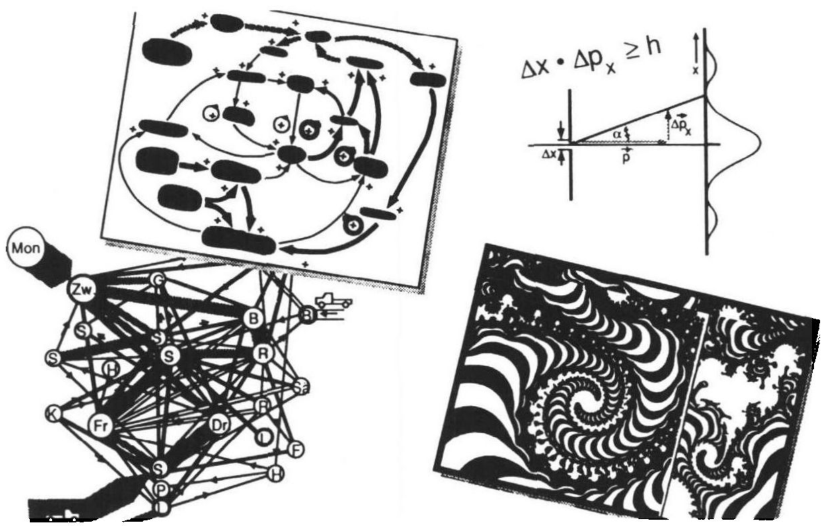
The significant feature of our economic system is its multiformity. The superiority to all alternatives based on planned economy supports the fact that the interplay of all elements is unpredictable. The failure of planned economy coincides with the paradigmatic change in science mentioned earlier.

Thus, it can be stated that the system performance "factory" tends toward chaos. Even models describing it, which are created with highest efforts, for example, in the field of production control, are inadequate on principle. As a consequence, the competition strategies of enterprises differ considerably.

Structures based on the division of labor derived by Taylor as a seemingly optimal solution, aim at the use of quantity effects and progressive cost reduction with increasing production quantity. Such learning curves can be proved even for high-value capital goods and small piece numbers (Fig. 1.2). In contrast, there is the characteristic of manufacturing systems that intend



(a)



(b)

Fig. 1.1. Deterministic and chaotic world outlook.

to satisfy the individual needs of customers. The special benefits for the customer can lie in the product itself (e.g., great diversity of types) or in the service. The results of a software market study were (Stalk and Hout, 1990):

- Of the users questioned 85 percent were willing to pay an extra charge of 10 percent for service on the same day, 60 percent would pay a 20

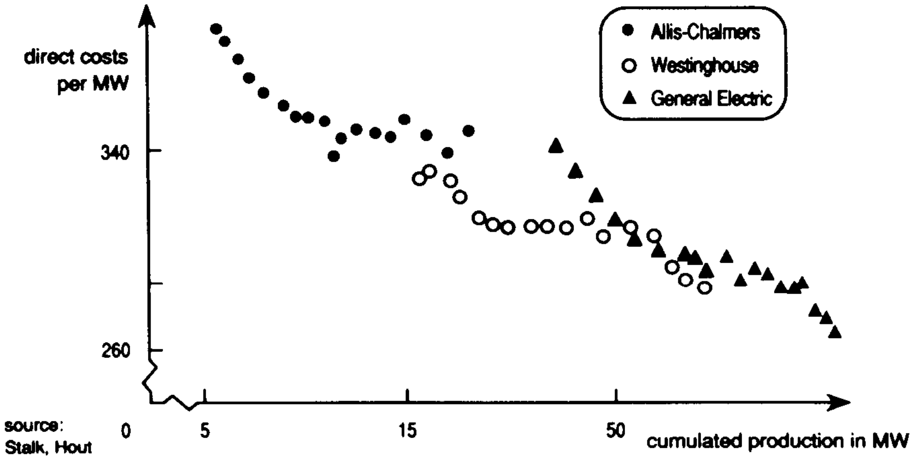


Fig. 1.2. Progressive cost reduction, for example, steam turbines (Stalk and Hout, 1990).

percent extra charge, and 40 percent would even pay a 30 percent extra charge.

- Brand name and dealer reputation were worth half the extra charge for quick service.
- Technological features only had 25 percent of the significance of the service offered.

Each enterprise occupies the individual position in the market that seems most favorable (Porter, 1985). Over a long period of time different production strategies can be pursued (Fig. 1.3).

The advantages of production focusing on quantity or diversity can be better used the more one of the extremes is approached. Based on this discovery areas of responsibility, product areas, and process areas with responsible teams or even business units are increasingly formed. If there are diversifications, there cannot be any solution covering the whole spectrum of products equally.

1.3 FACTORY STRUCTURES AS A FUNCTION OF ENVIRONMENT

The production strategies described lead to specific problem areas for structuring a factory. An enterprise aiming at distinctiveness from its competitors is facing increased uncertainty. In order to minimize the risks associated with that, the reaction speed with regard to changing boundary conditions has to be as high as possible. This can easily be realized when focusing on diversity, since in that case flexible organizational structures are existing anyway.

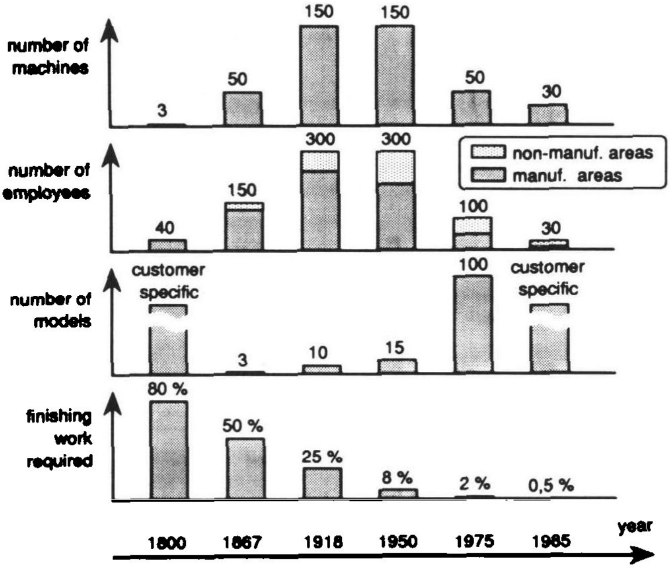


Fig. 1.3. Long-term development of enterprise organization, for example, Beretta (according to Jaikumar, 1986).

However, enterprises that consider themselves price competitors and that now tend more and more toward a differentiation strategy are suddenly facing great difficulties. In particular this applies to the automotive industry. Organizational structures that benefit from quantity advantages react on changes very slowly. There are different possibilities to cope with that situation (Womack et al., 1990).

Steps of product development following logical sequences are largely processed simultaneously (simultaneous engineering). Here coordination efforts are high, since all activities are interconnected. The communication efforts between all participants increase correspondingly. An increase in development costs, however, is much less significant for business success than exceeded deadlines or problems of quality when the product is introduced (Fig. 1.4). In extremely innovative branches, as for example, in the semiconductor industry, early presence on the market had become a question of life and death because adequate prices can only be obtained within a time period measured on the basis of months. For that reason, a stable production, impeccable under quality aspects, has to be realized as soon as possible after the start of the production run.

The problems arising from a lack of communication can be solved by creating small autonomously acting units. This type of organization, which is either product-oriented or process-oriented, promotes the identification of the involved employees with their tasks, and it allows autonomous and responsible actions. Thus, scopes are created concerning working hours, wages

Factor	Profitability loss
6 month late to market	34 %
9 % material cost overrun	27 %
50 % development cost overrun	3,5 %

Automobile with a 5 year life cycle
from job 1 to end of production

Source: Case study by Ford / McKinsey, Nov. 1988

Fig. 1.4. Effects of development deficits (Ford and McKinsey, 1988).

and salaries, and qualification. This applies to all hierarchical levels and to all functions of an enterprise.

The acquisition of time data (storage times, waiting times, rest periods, etc.) as an objective data basis as well as subsequent reduction of this unproductive time has proved to be an efficient instrument for the detection of potentials, reserves, and possible improvements. A lasting effect, however, can only be achieved if this procedure becomes a routine matter in practice.

The establishment of flat hierarchies tends to promote the generalization of staff members and expresses the existing and challenging complexity within an organization. Nevertheless, it is undisputed that specialization will remain indispensable particularly concerning technological issues. Therefore, staff has to consist of specialists *and* generalists. Otherwise important know-how might be lost within a short time. Changes in the organizational structure therefore have to be made very carefully, since drastic about-turns may hold dangers that must not be underestimated. This is even more so since the number of laws and official orders by which firms are constrained is continuously growing. The same applies to the reduction of overhead and contract services. In the case of nonkey functions of the enterprise, the process expenditure (presumably higher) on the one hand, and the expenditure for logistics (certainly increasing) for the integration of better and faster suppliers on the other hand, need to be weighted.

1.4 THE DILEMMA OF VARIANTS

Mastering the diversity of variants or maintaining the positive quantity effects has become a key task in production. The approaches can be found both in the fields of organization and technics. They pursue the strategy of *first avoiding variants, then mastering variants.*

A intentional technical overdimensioning of variants that are subjected to

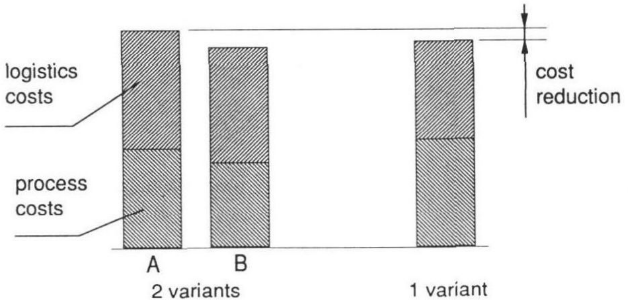


Fig. 1.5. Cost reduction by avoiding variants.

less stress can increase the number of identical parts. The insignificant increase of material required and, if necessary, of processing efforts can often be neglected compared with the saving potential (Fig. 1.5). For the realization of this strategy it is necessary to estimate the costs of different alternatives already in the design state. For these tasks generalists are required.

The creation of variants is not totally avoided, but it is at least shifted by the reduction of the production depth concerning those components that determine the variants. In principle, avoiding variants is preferred to controlling diversity. In reality, however, there is a tendency toward the opposite.

Often the problem is considerably alleviated when the variant is created in the production process as late as possible. Here it is again the design department that is to take suitable measures. Under certain circumstances it may be reasonable to increase the number of parts and to get into conflict with traditional cost calculation: A drill hole, for example, is standardized on the largest diameter required. Smaller diameters are realized by suitable drill sockets shortly before the part is finished.

A further alleviation, especially in distribution, can be achieved by having the customer or a member of a specialist shop determine the variant. This is always possible if only simple assembly tasks have to be carried out.

1.5 INFORMATION PROCESSING IN FUTURE MANUFACTURING

In spite of missing consideration in industrial management we must understand the following:

- An enterprise is a system that processes information.
- The information expenditure is decisive for production design.

Two main areas of expenditure can be distinguished:

- Technical information flow (product-oriented and process-oriented) from the idea to the product

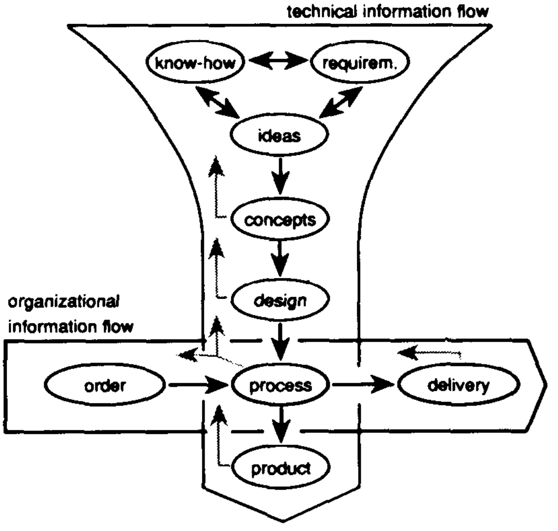


Fig. 1.6. Technical and organizational information flow in an enterprise.

- Logistical information flow (flow-oriented) from the order to delivery and service

Production means the conversion of information into shaped substance. Therefore, computer-aided design (CAD) systems are the basis and starting point for an efficient technical information flow. In contrast to that, the organizational information flow is mainly determined by Production Planning and Control (PPC) systems (Fig. 1.6).

Structures that are heavily based on the division of labor with the advantages of quantity and learning effects are characterized by small process expenditures. The information as such is hardly recognized anymore since it was fixed once: the arrangement of a manufacturing line (transfer line, belt conveyor) as an expression of the operation sequence.

From the viewpoint of information technology, the expenditure for logistics or communication rises in the case of production focused on diversity, since, for example, neither the shape of the workpiece nor the processing sequence is stored in the tool or processing equipment. Sequences, processing times, and dates have to be determined again and again. The process expenditure is of secondary importance.

When the process tolerances can be reliably kept within the permissible limits, the expenditure for information technology in the area of quality assurance is minimized as well. In this way total quality can be achieved economically. Total quality has always been and will always be a precondition for economically efficient automation.

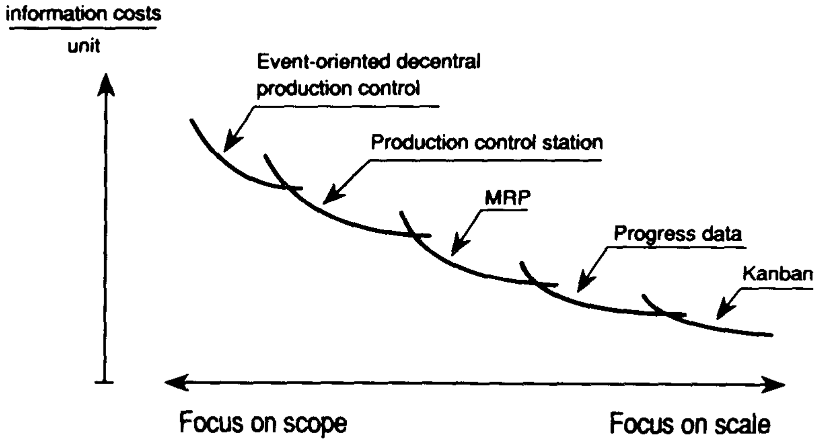


Fig. 1.7. Adapted methods for process control.

The rule for the creation of focused production units is as follows:

Process expenditures + expenditures for logistics = minimum value

Today a modular system of different methods for the configuration of a production system is available. All these different methods are to be combined and applied sensibly. Each method has a limited range of application and requires specific selection and substitution when boundary conditions change (Fig. 1.7).

This method involves the danger that isolated solutions are created. An integrated system of methods guarantees consistently available data allowing all components access to the required information (Fig. 1.8). This is also the

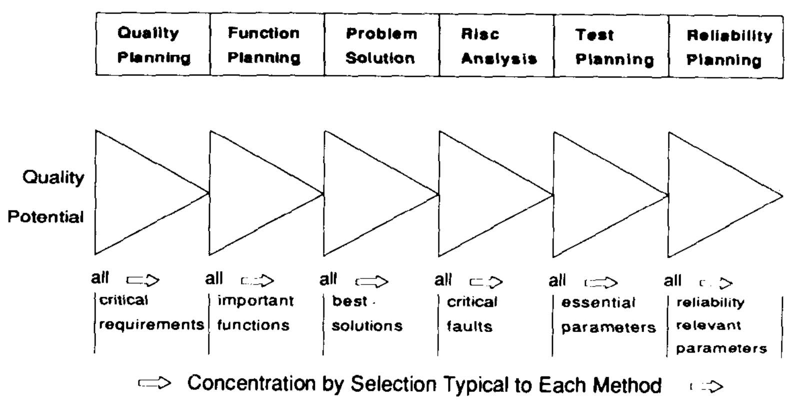


Fig. 1.8. Amplification effects of integrated methods system (IMS) (Kersten, 1991).