# HUMAN FACTORS IN SYSTEM DESIGN: METHODOLOGY AND CASES IN FACTORY AUTOMATION

Report to the Commission of the European Communities,
Directorate-General Employment, Social Affairs and Education

The CIRP Human Factors Action Research Group
Editor: F. Prakke

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# 1. INTRODUCTION

This report is the result of the colaboration, under the aegis of CIRP*), of a number of different European research organizations in the area of manufacturing research. In September 1986, as a result of the progress a working group consisting of representatives of these research organizations, had made in the period before, the Commission of the European Community awarded a one-year research contract to TNO (the Organization for Applied Scientific Research of the Netherlands, specifically the Centre for Technology and Policy Studies, CTPS, in the role of main contractor and editor for this study to be carried out by the members of the working group. The contract was awarded to help implement the conclusions of the European Commission Council of June 1984 following the Commissions communication Technological change and social adjustment (COM(84)6f). This study, as stated in the contract, "aims at finding out how these criteria (of social effectiveness) are taken into account in a number of cases of manufacturing automation, what problems arise out of the methodology adapted, which principles could be used for the systematic taking into account of working condition aspects in the design phase, and how the workers concerned could be informed and involved".

*) CIRP (the International Institution for Production Engineering Research) was founded in 1951 and is an association of the leading research workers from all over the world in the field of production and manufacturing research. Its aims are to promote scientific research in this field oriented towards the needs of industry, and especially to encourage co-operative international research among its members. While its members (who are selected always by co-option from among the world's academic and industrial research communities) are all engineers or physical scientists, CIRP has, some 10 to 15 years ago, produced significant work in technological forecasting; subsequently, its interests extended to the human, social and economic implications of automation and advanced manufacturing methods. Currently, CIRP has 150 full members and 78 Corresponding Members from 37 countries, as well as a large number of associated industrial organizations.

This report consists primarily - as specified in the contract - of the working group's consensus on current thinking about human factors in the system design of factories (chapter 2) design about methodologies (chapter 3), and about the type of research necessary for advancement of the field (chapter 4). Pertinent case studies of the participating institutes are reported in detail in the appendix.

The research institutes and main researchers presently participating in the CIRP Human Factors Action Research Group are:

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CASE B

# SKILLED PRODUCTION WORK IN A FLEXIBLE MANUFACTURING SYSTEM - ALTERNATIVE WORK ORGANIZATION IN A MECHANICAL ENGINEERING PLANT

Project Group Institute für Sozialwissenschaftliche Forschung (ISF)[1]

Munich, March 1987

1) Members are: I. Asendorf, M.v.Behr, H. Hirsch-Kreinsen, Chr. Köhler, B. Lutz, Chr. Nuber, R. Schultz-Wild.

Contribution to the EEC-Study "Human Factors in System Design: Methodology and Case Studies in Factory Automation" carried out by the Human Factors Action Research Group of CIRP at T.N.O. Apeldoorn (NL).

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## PRELIMINARY REMARKS

The following case study deals with innovations in manpower and training policies on the firm level which are developed in the course of a technological innovation process: the planning, construction and implementation of a flexible manufacturing system (FMS) in a large West German mechanical engineering company. The process of designing and implementing this FMS required approximately seven years (1977 - 1984) and was sponsored by the German government. During this entire period of time sociologists from the Institute for Social Research IFS Munich participated as researchers in the implementation process. This case has been extensively documented by Schultz-Wild, Asendorf et.al. 1986.

## 1. THE TECHNOLOGICAL INNOVATION AND ITS OBJECTIVES

The FMS was developed and installed in the parent plant of a company specialized in transmission equipment for the automotive industries in the south of the Federal Republic with approximately 7000 employees. The majority of the production workers engaged in metal cutting within mechanical manufacturing in this plant are semi-skilled workers.

This plant mainly produces gear boxes for trucks, busses and special vehicles in medium and large-scale series. Therefore the company is dependent on their customers ordering policies, most of them being large scale companies from the heavy vehicle sector and in turn sensitive to business fluctuations. This situation places the company under considerable pressure as far as innovation, rationalization and flexibilization are concerned.

During the seventies the market for heavy vehicles became increasingly turbulent and thus the company's framework conditions of manufacturing also became more demanding. One of the reactions to this was a considerable increase in investments during the second half of the seventies. The decision to construct and install a flexible manufacturing system was part of these increased efforts and pursued several objectives:

- Production optimization played a major role, and this meant traditional rationalization by increasing the degree of automation as well as enhancing the manufacturing facilities' capacity for reaction. A reduction of through-put times should increase delivery capacity while also help to reduce storing costs and capital requirements for semi-manufactured parts.
- Moreover there were also company interests concerning market policies connected with the realization of the project: the development of manufacturing equipment and handling technology transferable to other plants should help probe the chances for a venture into a new market sector.

- Finally the project was carried out with the explicit aim of improving the quality of working life, whereby particular consideration was given to reducing physical work burdens and dealing with problems partaining to monotony on the job.

After a two year preliminary planning phase, the design and construction of the FMS was started in 1977 with a grant by the Federal Ministry of Research and Technology. 1981 the first machine tools were installed, 1982 saw the first testing of parts of the system and from the autumn of 1984 on the system has been increasingly attaining normal running conditions.

The system has been conceived for the metal cutting of gears from three part families in small to medium sized batches. The system handles the entire "softmachining", that is all necessary operational phases before the process of hardening the workpieces. The total of fourteen machine tools are grouped into thirteen machining cells, each containing one robot and three stations for workpiece carriers. A fourteenth cell is the central loading and unloading station with component carrier stations and a robot. As far as material flow is concerned, the cells are concatenated by means of a gantry crane and the central workpiece storage facilities; in terms of information flow the cells are interlinked by a superordinated control unit by means of a mainframe process computer (compare illustration 1).

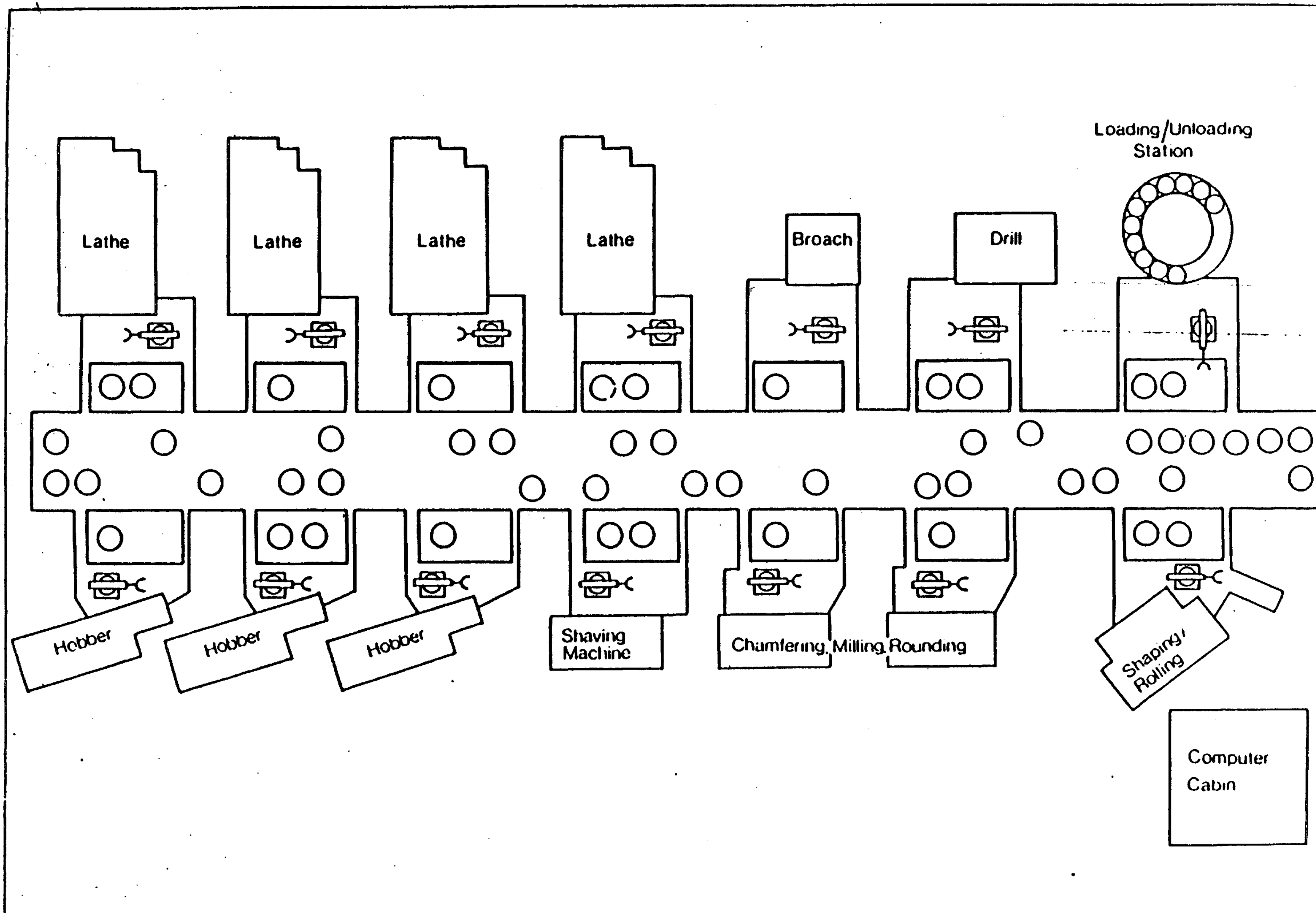
The development of system technology did not aim for total automation, as a system of this size and complexity demands the presence of several operators in all cases. While a reduction of staff compared with previous manufacturing was intended, a system team of about six persons per shift (running in two shifts) was opted for from the start.

The difference in terms of manufacturing structures between conventional part processing with stand-alone machines and the new system lies primarily in the interlinkage of the processing stations. The system team is left with the following work tasks to deal with:

- The main task is the resetting of the partially differing machine tools and robots; the reading-in and optimization of NC-programs as well as the exchanging of tools and the adjustment of clamping devices.
- A further job which is comparitively undemanding in terms of skills yet physically strenuous is the manual feeding of the system with blanks and the unloading of the processed gears at the system's central loading and unloading station.
- Finally there are a whole series of controlling and monitoring tasks pertaining to the running of the entire system as well as such having to do with individual machining cells.

Apart from the tasks mentioned above there are a number of additional tasks ranging from simple service jobs such as clearing away chips to the more demanding tasks of quality control or tool presetting.

Ill. 1: Floor plan of the FMS




Source: with minor changes from the FMS Magazine April 1983

## 2. ALTERNATIVES IN MANPOWER POLICIES

As is the case with most companies, social considerations and manpower policies originally played no major role in the decision making processes concerning technical-organizational innovations (Hirsch-Kreinsen/Schultz-Wild 1986): thus for a long time there was such a preoccupation with the numerous technical questions of system design, determination of the spectrum of parts to be processed as well as the selection and the design of tool machines, robots etc., that questions concerning the personnel policies for integrating the new system into the manufacturing process were given little consideration. It was more or less implicitly assumed that the usual mechanisms of personnel adjustment which had proven successful during the course of previous innovation processes of a technical-organizational nature and the application of trusted and tried principles of organizational structures based on a division of labor would ensure an unimpeded implementation process.

In the case of this particular innovation, however, there were a number of special factors which finally led to a more extensive consideration of the questions of work organization and manpower planning: the complex and new character of the system; the influence exerted in many different ways by the numerous experts from outside the company involved in the process via the framework of the government support granted; and last but not least the particular attention paid to this system by the works council and union representatives. The discussion focussed on three problem areas:

- the employment of manpower from the company internal versus the external labor market;
- the choice between a low versus a high degree of division of labor;
- the respective role of training versus selection of the best suited workers for the FSM-team.

### a. External Versus Internal Manpower Policy Solution

In the case of implementing manufacturing equipment which is complex and highly innevative in comparison to conventional manufacturing equipment it would seem an obvious policy to recruit persons from the external labor market for the newly created jobs who have the necessary skills and experience in the new forms of technology employed. This course of action was not seriously considered, however, in part due to the influence of the works council and the union, but also because of the project's pilot character; the project participants soon decided to staff the new jobs with suitable workers from the company's internal resources thus allowing company staff to benefit from the improved working conditions aimed for.

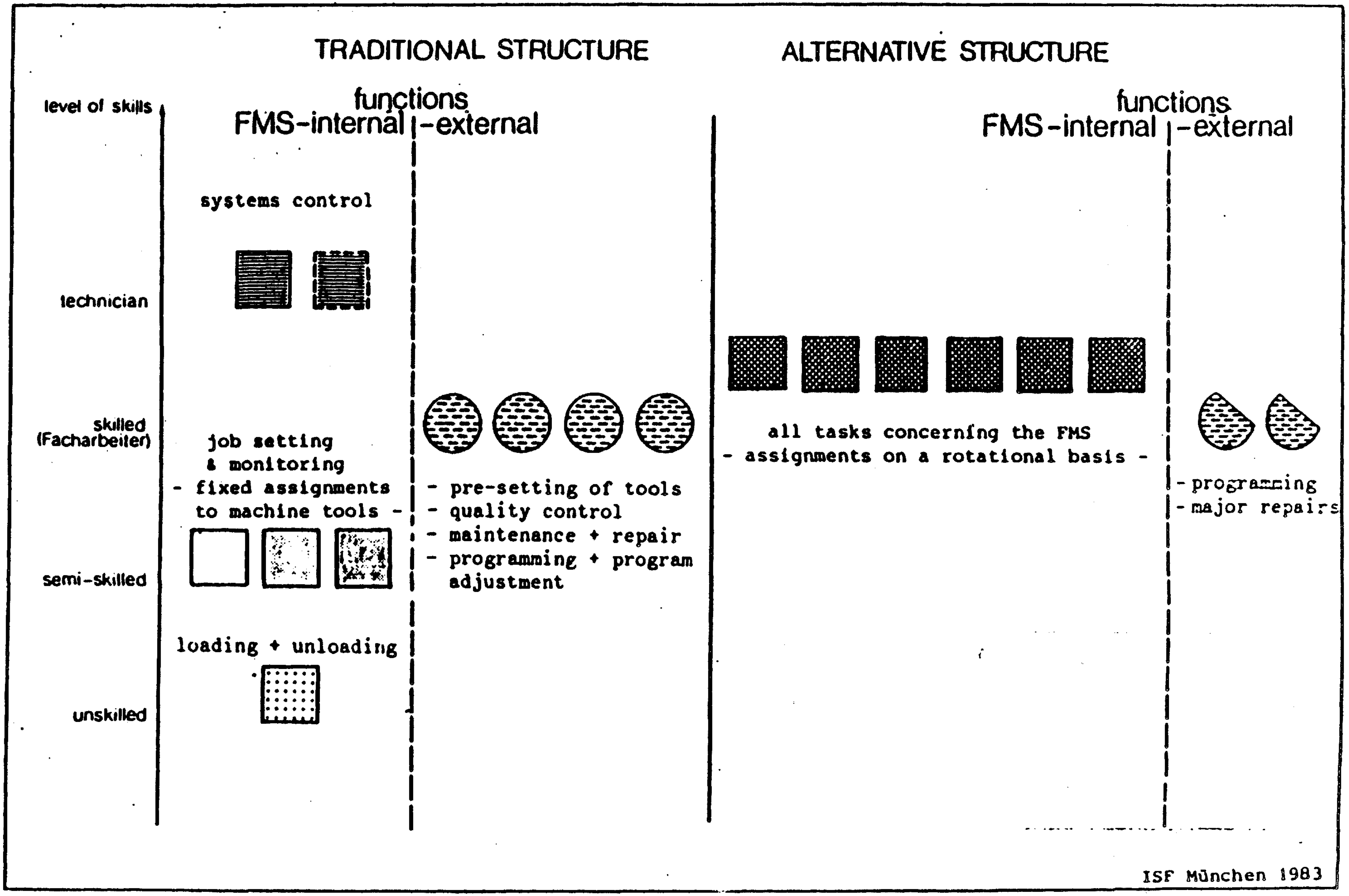
For the same reasons the possibility of simply dismissing workers displaced from the traditional manufacturing area by the new system was hardly considered. Insofar as these members of staff cannot be provided with jobs within the new system, further in-house transferals would result, in which case the works council can make use of its co-determination right and can safeguard the interests of the workers affected. In the case of a general reduction of manpower requirements, a policy of direct dismissals on the grounds of the particular innovation is not regarded as being an acceptable course of action; it is highly likely that in such a case the necessary personnel reduction could be realized only by making use of the "natural" fluctuation in connection with ceasing all new recruitings.

In the light of these conditions an in-house manpower adjustment was the only viable course of action.

b. High Versus Low Degree of Division of Labour

In designing work organization within a flexible manufacturing system, that is combining the remainging tasks to jobs and workplaces, there are, according to all experience gathered to date, two basic courses of action which can be pursued, which will be described in simplified form in the following (compare illustration 2):

Ill. 2: Alternative job structures in the FMS



- In the one case the system staff consists mainly of a number of specialized machine operators of a medium number of specialized machine operators of a medium skills level, who have the task of monitoring and practically setting-up several machine tools of the same or similar type. Additionaly there are one or two unskilled workers who perform the less demanding and strenuous task of loading and unloading the system as well as other auxilliary functions. There are also one or two system leaders, foremen or shift leaders who must be qualified technicians with additional special knowledge. Their job is controlling the entire system, managing production planning and coordination, as well as supervising the system's personnel and taking care of all tasks requiring communication and interaction with other company departments. This type of system team cannot fulfill all necessary functions themselves, which means that technical service personnel from other departments must intervene to a more or less greater extent, for example for the pre-setting of tools, quality control, programming and program adjustment, as well as in the case of repair and maintenance tasks.

- In the second case the entire system team consists exclusively of skilled craftsmen who are capable of performing all metal cutting processing techniques and who have additional knowledge of electronics, robotics, and programming etc. Each of these system operators is capable of performing all necessary system tasks. These system operators form a group which is responsible for system running and subsequently each worker performs different tasks as necessary. Apart from the immediate system running and controlling, personnel of this type can take on additional tasks - naturally in varying degrees according to the amount of work to be performed and staffing levels given - which in the first case described had to be handled by other company departments. Only complicated programming jobs and repair and maintenance tasks requiring extensive or special skills and qualifications (for example in the electronics sector) are performed by specialists from outside of the system.

Obviously these two structural types of work organization are extremes. Yet while mixed forms are most likely to be found in actual company practice, they will still always tend more or less strongly towards one or the other extreme form.

In the case examined it was to be expected that the work organization within the flexible manufacturing system would tend towards the first described structural type of work organization based on a distinct division of labor. This is because a preliminary decision in favor of in-house personnel adjustment would most probably also result in the traditionally dominant principles of work structures within the area of conventional manufacturing being transferred to the FMS.

The form of work organization and the skills structure which had evolved in the workshops where the gears to be manufactured by the FMS had been produced so far, can be briefly described as "semi-skilled manufacturing". Most of the operators working with the conventional tool machines are specialized semi-skilled workers, with special experience in handling their particular machines or particular processing techniques. They are partially able - in the case of longer experience - to set up their own machines. Their work however, is complemented by more highly skilled tool setters or foremen as well as by the services of tool pre-setting, in-house transport, quality assurance, schedule supervision etc. Although the company is not engaged in mass production in the usual sense of the word, the prevailing utilization of manpower is hierarchically and functionally based on a high degree of division of labor.

It would be in accordance to this work system prevailing in the area of conventional manufacturing if the remaining tasks at the FMS would be formed to a number of jobs with different tasks and differing skills requirements each. In this case, however, after considerable discussion between members of management, works council and union representatives, as well as company external advisors and researchers, it was decided upon to regard all tasks, as far as possible, as belonging to the operational scope of the system team. The aim was to establish the lowest degree of fixed division of labor possible, in other words to avoid the permanent assignment of specific tasks to individual workers. This means that the tasks having to be dealt with at a given time are performed according to a task rotation scheme, while also adapting to the varying amounts of work and personnel availability.

c. Personnel Selection Versus Training

As determined by the preliminary decision for an in-house manpower adjustment and a certain form of work structure within the FMS, there are two alternative courses of action conceivable for filling the new jobs with suitable personnel:

- The first solution amounts to minmizing training expenditures and conversion costs by selecting those members of staff best suited for the new tasks and already possessing relevant know-how and experience.
- The alternative forsees giving the more average skilled members of staff, possibly those from the respective sectors of conventional manufacturing to be closed down in part, practical and theoretical training for their new tasks within the FMS.

The first course of action of "creaming off" is the usual procedure within most companies, particularly in the case of technical-organizational innovations which tend to be executed in small steps. Such a policy, however, is inadequate when extensive innovations with new job types are to be carried out, and could place workers under considerable stress.

In accordance with the project's special conditions a course of action was opted for whereby explicit and financially supported training measures played an important role.

All in all, the decisions made ensured that the introduction of the FMS not only established innovative technology, but also manpower policies of an equally innovative nature.

## 3. THE FMS AS A MODEL OF SKILLED TEAM WORK

In designing and implementing the FMS-work organization traditional and new principles and methods have been combined.

### a. Work Organization and Skill Requirements

Compared with traditional structures the form of job design chosen reduces the division of labor in three respects:

- the hierarchical division of labor within one manufacturing area which is differentiated itself according to the authority of individual employees to issue directives and their skills levels (as traditionally given between unskilled and semi-skilled workers, machine operators, relief men, tool setters, foremen and system leaders) is more or less dissolved;
- the technical division of labor, particularly between the different machining methods and machine jobs (such as turning, milling, broaching) no longer exists;
- lastly, there is a reduction of the functional division of labor between the manufacturing workshop and those technical services related to the production area (such as operations scheduling, pre-setting of tools, programming, and quality assurance).

This reduction of traditional division of labor corresponds to the system structure of the technical equipment and is connected to a form of team work: the tasks to be performed are not rigidly assigned to certain individual members of system staff, but are handled by the group of workers as a whole and are subsequently divided up according to the given work situations.

Such a model of work organization corresponds to the workers' interests in balanced work tasks offering a certain amount of diversity, and in jobs which require a certain level of skills while offering reasonable working conditions with low work burdens. This structure also complies with certain company interests: manpower utilization can flexibly adapt to given work situations (for example the resetting, or loading and unloading tasks which do not arise regularly efficiency); vacancies caused by illness, holidays, etc. can be more easily compensated for.

By nature of its structure and contents this work organization makes new demands on the qualifications of the FMS operating team. If all team members are to be able to perform the diverse work tasks according to a rotation system, then uniform skills on a relatively high level are called for. In substance, a basically new profile of skills and knowledge will be the result:

- First of all there is the diversity of processing techniques and machines which system workers must be able to operate. These different metal cutting production methods are also to be found in conventional manufacturing; yet in that case a machine operator is usually specialized on one type of machine, and a tool setter will normally have to deal with only one or two related processing methods.
- In addition a command of robotics is required as well as compe tency in a number of technologies and methods (tool pre-setting, programming, quality control, etc.) which in most cases are traditionally handled by specialized service departments.
- Finally, a certain knowledge of the overall control of the entire system is required, including a knowledge of the system's integration into superordinate company structures (such as production planning and scheduling, material and blank supply, repair and maintenance, for example). A grasp of such comprehensive information, which goes far beyond the usual demands made on manufacturing workers in conventional production processes, is an essential precondition for the system team's capacity for taking responsibility for overall system running as well as for that part of a larger production process which is being handled by the system.

Therefore a new type of production worker is called for, combining elements of the typical skills held by semi-skilled workers, skilled craftsmen, but also the kind of skills and know-how held by technicians and foremen. At the time these innovations were being implemented there was no institutionalized trade in the metal industries for production workers of this type nor did any regular vocational training scheme exist in the Federal Republic. The fact that the existing system of industrial trades and vocational training had nothing to offer in this respect and the lack of adequate further training measures within the companies gave rise to the innovative training policies pursued during the course of FMS-implementation.

b. Personnel Selection and Training

In staffing the FMS with skilled production workers the company pursued a policy of selecting suitable workers who already had a certain degree of relevant skills, as well as preparing the persons selected for their future jobs by giving them specific training. While this combination of selection and training is common practice in staffing jobs requiring a higher level of skills in conventional manufacturing, the training measures carried out in this specific case exceeded the normal extent of worker training by far.

The new jobs were advertised within the company and more than fifty workers subsequently applied. Two pilot groups of ten persons each were then chosen. The selection criteria were contradictory in part: on the one hand the objective was get the new and complex system running as efficiently as possible, thus requiring experienced and well qualified personnel, particularly in view of the fact that reliable training concepts were yet lacking. On the other hand the aim was pursued, particularly on the part of the works council, of gaining experience in developing FMS-training for a general extension of in-house further vocational training; thus suggesting that the more average production workers, that is mainly semi-skilled workers should be considered.

The persons chosen for the first pilot group were predominantly workers already possessing a certain degree of relevant skills as well as many years of company experience in some cases, while the last mentioned selection criteria played a somewhat greater part in the forming of the second pilot group, which started with system work at a later date than the first group.

The manpower structure of the pilot groups does, however, deviate significantly from that of the plant's average manufacturing workers and particularly from that of the machine operators engaged in conventional manufacturing in the same area of production: the FMS workers are younger on average, have been employed within the company for a shorter period of time, and above all, have had better training. Several foreign workers were also included, yet in comparison to other corresponding areas of conventional manufacturing their participation in the FMS teams is decidedly low.

This sort of restricted creaming-off policy not only helped to overcome deficiencies and problems in further training for FMS-work, but also contributed towards getting the system running as far as technological matters are concerned. The workers' previous experience, their qualifications and skills as well as their commitment added up to a high performance level during the system's running-in phase. This was particularly notable in the case of the first group, but also held true for the second*).

There is a marked difference between the training process carried out for FMS-work and the usual type of company on the-job training. While the former cannot be regarded as regular vocational training, its form and contents do deviate from traditional in-plant further training procedures and moreover, their general framework conditions are far more favourable.

*) The FSM-workers played a considerable part in overcoming the numerous faults and break-downs which occurred during machine testing and the construction of the system; moreover working instructions and operator's manuals were partially lacking and had to be compiled and programming and program optimization of the NC-machines tried and tested etc.

Due to its status as a large-scale development project with a long planning and running-in period (and moreover being government supported and accompanied by researchers and other company external experts), this FMS also became something of a learning workshop. The following elements of FMS-training differ from traditional on-the-job training:

- The trainees were released from work while continuing to receive full pay and thus given the comparatively favourable chance of learning without the immediate pressure of an ongoing manufacturing process;
- Learning within a team was continued for a longer uninterrupted period;
- The trainees were offered courses, some of which had been specially conceived, which complemented the knowledge and experience gained in practical FMS-running, thus enabling a mixture of theoretical learning and learning by doing of a somewhat experimental character.

These relatively positive learning conditions were certainly also responsible for the fact that there were no drop-outs during the one and a half year training phase and that the workers with more average pre-qualifications and experience (including the foreign workers, by the way) also completed the training course successfully.

All in all, this comprehensive FMS-training, which also includes basic theoretical knowledge, leads to the same skills level as that held by skilled industrial craftsmen; these training courses deal with several manufacturing methods (not in the same depth, however, as in the vocational apprenticeship training for lathe operators and milling workers, etc.) and also include control technology. This kind of training is formally defined as in-plant training and does not grant any officially or publicly recognized certification, which does mean certain disadvantages for the workers as far as transferrability on the company-external labor market is concerned.

## 4. EXPERIENCE WITH THE NEW WORK SYSTEM

In March 1984 and June 1984 the first and second pilot team successfully completed their FMS-training with an in-house examination. During the second half of the year the system team was reduced to the planned strength of six to seven workers per shift, so that manufacturing conditions increasingly approached a normal state in this respect.

Several alterations were made concerning the range of workpieces originally planned; on the one hand the demand for certain parts had dropped off significantly, while on the other hand, the decision was made to concentrate on manufacturing heavy weight workpieces on the FMS so as to relieve the workers employed in the area of conventional manufacturing of the considerable work burden of manually handling such parts . This resulted in a partial reorganization of the system: In one cell a machine tool was exchanged in order to adapt the capacities of the various metal-cutting methods to the altered requirements. As far as these demands made on the flexibility to adapt are concerned, the system concept proved its worth, although the variety of workpieces to be processed withing a certain period of time which was originally planned was not actually made use of.

The actual arrangement of the system's overall control unit deviated considerably from what was originally planned. The software development required far more time than was anticipated. The control system was initially designed to allow a high degree of automation, which, however, proved inadequate in view of the system's complexity and the great number of possible system failures. It was therefore altered in favor of a solution allowing the system workers more possibilities for intervention by means of interactive communication with the control system*).

*) It is difficulties of this kind which in the meantime have prompted companies to no longer aim for such large and complex FMS but to opt for smaller systems with one or several machine tools instead. Compare also Fix-Sterz et al. 1987.

There were further factors which impeded "normal system running". Several of the machine tools, most of them newly developed prototypes, proved to be highly susceptable to failure; the lack of service personnel, particularly in the electronics sector, could not be fully compensated for; and the FMS'special integration into the respective area of manufacturing was not realized for reasons of cost. Thus the experience with the new work system cannot be generalized without considering these factors.

All in all, the training measures proved successful. There were no indications that certain problems of technical availability or the system's overall performance had anything to do with inadequate skills of these system workers.

The principle of keeping the division of labor as low as possible and preventing individual workers from strongly specializing in certain restricted tasks within the overall system would also seem to have proven its worth. A completely open structure of assigning tasks according to immediate requirements has not been established however. Compared with the latter concept, the following alterations have been brought about:

- The system leader's tasks form an independent job in the meantime; both teams now have their own system leader and a substitute. These workers are responsible for controlling the entire system by means of interactive communication with the EDP-control system; when necessary they also take over tasks at the other work stations (including loading and unloading of the system). The system leaders are graded one wage group above the rest of the system team.
- Moreover, the division of labor is organized along different lines within the two system teams: On the one shift there are three workers deployed to each side of the system, whereby task assignment is relatively open and is determined by the immediate requirements. After eight weeks the workers change system sides. On the other shift, the entire system is subdivided into four working areas. The responsibility for each one of these areas is held by one system worker and the positions are exchanged according to a four week rotation system.

- A foreman has been additionally assigned to the system who works on the normal shift and is primarily concerned with administrative functions (such as ordering materials and tools and maintaining contacts to other departments, etc.). This foreman, to whom the system workers have to report to, has many years of experience in certain processing technologies and methods in the manufacturing sector, but does not have any particular knowledge of those special control, handling and other technologies relevant to operating the FMS. This type of foreman acts primarily as a mediator between the FMS and the surrounding organizational structures.

Although a higher degree of division of labor has been established than that which the original concepts had intended, there are nevertheless considerable differences compared with the far more differentiated, traditional work organization in the area of conventional manufacturing where the tasks of the individual workers are far more rigidly defined. Particularly the system leaders, but also the other workers, are far more able to step in and take over tasks when and wherever this happens to be necessary. In the case of re-setting and re-tooling and other tasks arising periodically, this kind of flexible manpower utilization is of great significance for the entire system's performance level, while also allowing the substitution problems connected with illness, holidays, etc. to be dealt with more easily. Moreover, this kind of task distribution complies with the worker's interests in diversified and many-sided jobs and can even integrate tasks which would be unduly strenuous by themselves, such as the loading and unloading of the system. A concept of free rotation was mainly opposed by members of lower and intermediate management - and also would have posed wage grading problems which could not be readily solved. On the other hand, a return to the specialization on individual machine tools and machine types, which appears advantageous in terms of utilizing existing know-how of certain metal-cutting methods, was not regarded as an adequate solution as it would stand in contradiction to the system character of the manufacturing equipment implemented. The solutions found have the nature of a compromise; they are able to cope with the many-sided and complex demands made on the system, while avoiding unbalanced, one-side or unduly strenuous jobs or greater losses of comprehensive skills which manufacturing workers have already acquired.

The company investigated is not planning any further FMS of this size or complexity. For a number of reasons the emphasis is now being placed more strongly on smaller system units with automatic workpiece handling and transport. There are many indications that the experience won in this pilot system in the areas of training, work organization and manpower utilization will find future use. Thus certain further training courses instructing manufacturing workers in the use of other modern production equipment have been carried out, and, in a limited sense, the pilot system did have the function of an instruction workshop offering practical training in computer-based, integrated manufacturing technology. A general dissemination of the concept of skilled team work is still a long way off, however, and one of the main reasons for this is the fact that the impulses for reorganizing work along these lines within other manufacturing departments have not yet met with sufficient interest, and as a consequence there are presently hardly any suitable jobs being offered to comprehensively trained manufacturing workers.

## 5. THE SOCIOLOGISTS' ROLE IN THE INNOVATION PROCESS

The role sociologists can play within an innovation process in a company, what they can contribute to the design of company reality and how they can do this most effectively is demonstrated relatively well by this case.

Their's is not the role of the "social engineer", who has the same authority and influence on the conception, planning and realization of socio-technological systems as engineers with competence in technology or ergonomics do. According to such a definition the sociologists' task would be to see that the design of socio-technological systems is optimated according to the human and social criteria they put forth.

It is doubtable, however, whether sociologists will be able to establish guidelines, now or in the near future, which have proven their validity under various different specific conditions and whose effects have been investigated and verified to such an extent that they can, without greater reservation or risks, be put forth as practical socio-technological instructions. This particularly holds true for projects concerning the design of socio-technological systems which are based on international cooperation, for in these cases there are not only the specific constellations of conditions of the individual companies to be considered, but also the specific basic conditions on national levels which may differ widely as far as labor market structures, qualitative and quantitative manpower supply or technology markets are concerned. The development of concrete organizational concepts on the basis of the assumption of an ex ante definable, "one best way" of designing company processes, valid on an inter-company and international level, makes little sense.

Moreover it is also doubtful whether there is a legitimate basis for sociological experts in the sense of "work system designers", particularly within the industrial sector with its numerous conflicts where various bodies and parties with different legal and power positions confront each other. It is also open to doubt whether sociologists have any objective scientific criteria or standards analogous to the engineers'scientifically based criteria of functionality, reliability, etc. The definition and use of criteria such as "humanitarian", "socially tolerable" and "socially beneficial" always depend to a high degree on the outlooks and interests of those holding the authority to make decisions and those directly or indirectly affected thereby. If sociologists were to make statements of a prescriptive nature, they would have to take the one or the other political position within the company interest structures, which in turn would jeopardize their position as scientific observers of the ongoing developments.

On this background, the role the sociologists played inthe project described could be termed as one of "participating in system design by analyzing and informing". This excludes any direct intervention in the process of system design, contrary to some expectations hold by certain engineering scientists and managers within companies. However, the accompanying analysis of the innovation process provided an important basis for taking rationally founded influence of a correcting and controlling nature on the ongoing process of designing man-machine-systems and work organization. This particularly held true in the case of the analysis of traditional manpower structures and policies and the subsequent development of future scenarios concerning manufacturing and training policies. With the help of the latter, the sociologists were able to explain conclusively why the structurally'conservative design of FMS-work organization originally anticipated could , over the medium and long term, lead to considerable problems and deficits. It was shown that in view of fluctuating sales market conditions and changing structures on the labor market, a "professional" type of work organization would be the more adequate and more promising solution for the future, despite the additional short term implementation expenditures. These scenarios were brought forth by the sociologists during the decision making process concerning the FMS introduction.

In section 3.2. a differentiation of the research modes employed by intervening sociological research, is suggested namely:

- action research in a strictly scientific sense,
- researcher as process consultant,
- researcher as expert consultant,

and within this framework the role played by the IFS scientists in this particular innovation process can be best characterized as that of "action research with indirect process consultancy".

In the company a special commission was formed with an equal number of representatives of management and members of the works council. This commission was given a certain amount of authority in all decision making processes concerning the design and implementation of the FMS, including questions of work organization, further training etc. This commission played an important part during the entire innovation process as a clearing instance, particularly in the decisions concerning manpower policy, which are often viewed from different standpoints by company management and the representatives of workers interests. The ISF sociologists frequently participated in the commission's more or less regular meetings in order to present certain results of the accompanying research as well as other considerations. Moreover, the sociologists also addressed the participants in the decision making process individually as well as the FMS-workers concerned and discussed the possible design alternatives for work organization with them.

These forms of cooperation were greatly intensified and gained considerable significance in the FMS'realization phase during which the previously developed concepts were to be put into practice. Among the company external researchers involved in this process were also ergonomics and operations research specialists who made a detailed investigation of the demands made on in-house training of system workers. The fact that the sociologists had already participated in numerous discussions during the previous planning phase was an essential precondition for this kind of cooperation. These previous discussions between company planners and the company external technologists and engineering scientists dealt with such topics as the FMS concept, the question of what is technically feasible, as well as relevant experience gained elsewhere, etc.

Experience has shown that this kind of participation in company innovation processes enables sociologists to exert a considerable effect on the design of socio-technical processes and structures.

It is difficult to assess the significance the case presented will have for the further development and spreading of group-oriented work structures in the Federal Republic. According to some sources this project has had a pilot function and served as orientation for other rationalization measures in manufacturing of a similar kind. It is certain, however, that the project, which a number of widely differing groups of experts and scientists had participated in, has definitely given impulses to the discussion on "alternative" factory structures which has been gaining impetus during the last years on a national as well as on an international level. In the meantime, in the Federal Republic this discussion is not only involving industrial sociologists but also scientists concerned with ergonomics, operations research, and engineering. The fact is more or less accepted by all that the traditional, tayloristically oriented factory structures will hardly be able to cope with the economical and social demands made on companies and that considerable structureal changes will have to be made to organize the factory of the future. Among others, the FMS-case outlined here is of considerable exemplary value in this context.

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