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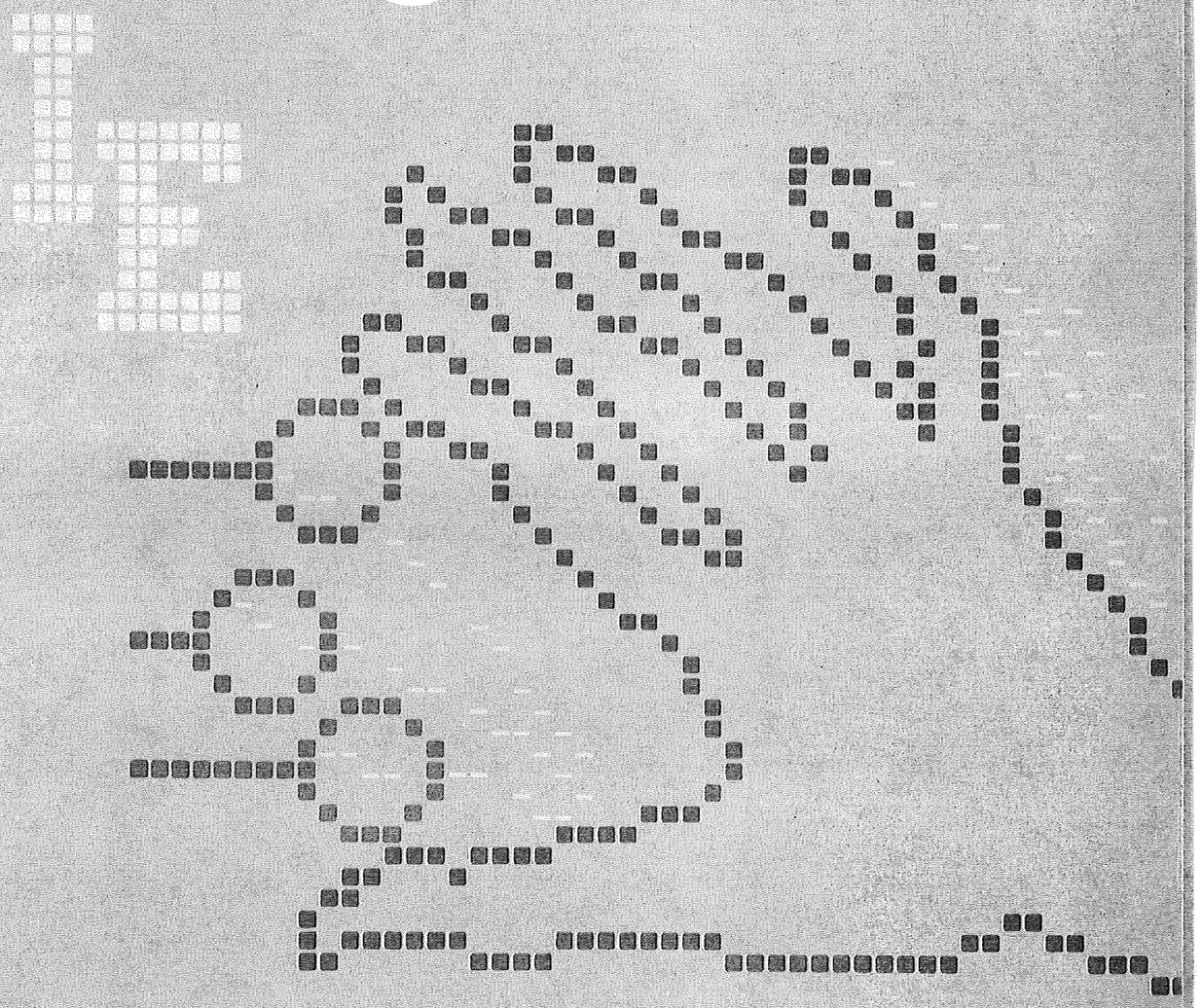

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CONCEPTS AND PROCEDURES OF WORK PSYCHOLOGY FOR THE ANALYSIS, EVALUATION AND DESIGN OF ADVANCED MANUFACTURING SYSTEMS: A CASE STUDY

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ABSTRACT

As the degrees of freedom in designing jobs and organizational structures augment with the development of advanced technology, concepts and procedures for the analysis, evaluation and design of advanced manufacturing systems become increasingly important. This paper describes the application of such concepts and procedures on a flexible manufacturing system, from a sociotechnical and work psychological point of view. Results of analysis and evaluation show distinct differences between a "typical" operator and a "typical" attendant, with respect to aspects of control, cognitive demands, and requirements for qualifications and learning. In order to improve the structure of the system, as well as the working conditions for operators and attendants, an alternative manufacturing system layout has been developed.

RELEVANCE TO INDUSTRY

Any company wanting to make rational and meaningful investment decisions must consider adequate concepts and procedures for the analysis, evaluation and design of advanced manufacturing systems. Finding efficient manufacturing structures requires substantial decisions about work organization, division of functions, and the type of interaction between man and machine.

KEYWORDS

Advanced manufacturing systems, sociotechnical design, work psychology, job assignment.

INTRODUCTION

The main task of work psychology is the analysis, evaluation, and design of work activities and work systems, based on a concept of man as an autonomous subject, capable of self-regulation and of regulating his relation to the environment (see Tomaszewski, 1978).

In contradiction to widespread assumptions, the degrees of freedom in designing jobs and organizational structures clearly multiply with the development of advanced technology. The types of organizational choices involving basic ways of utilizing CNC-machine tools can be illustrated by a German study (Boffo et al., 1988) reporting 155 cases. The authors found five different ways of utilizing CNC-machine tools with respect to allocation of functions and use of capacities of the operators (see Fig. 1). Studying 83 cases of flexible manufacturing systems Lay (1986) found three basic types of work structures which were different mainly with respect to the division and subdi-

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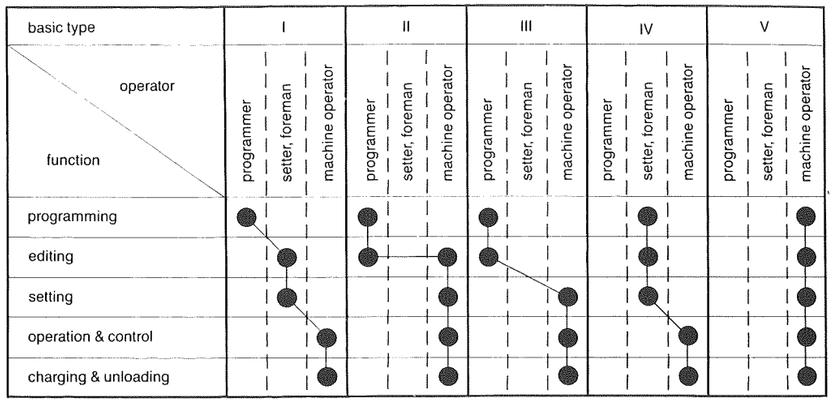

Fig. 1. Basic types of employing CNC-machine tools (from Boffo et al., 1988).

vision of tasks. In both studies the differences can not be explained by production requirements or any kind of boundary conditions.

In view of the fact that many different solutions exist, the question of concepts and procedures for the analysis, evaluation and design of advanced manufacturing systems arises.

PSYCHOLOGICAL WORK ANALYSIS

Two main steps in psychological work analysis can be found in the textbook by Matern (1983): (1) psychological job assignment and conditions analysis, and (2) psychological activity analysis. "Job assignment analysis is production-process oriented.... It is concerned with the characterization of objective job assignments and conditions of work activities which are independent of the workers (task qua task approach, Hackman, 1969). On the other hand, psychological activity analysis is person-oriented, involving investigations of individual methods and characteristics of workers' activities in order to discover regularities in mental activity regulation—and in most cases also their problems" (Matern 1983, p. 78). The independent variables dealt with in job assignment analysis represent the "objective" background on which the dependent variables treated in activity analysis are illustrated.

In our opinion, analyzing personality related effects of work activities is just as important a part of psychological work analysis as analyzing product related effects of work activities. For this reason, we are in favor of a concept for psychological work analysis which comprises the following steps: (1) analysis of the job assignments and conditions for their fulfillment, (2) analysis of work activities and the necessary regulation procedures, and (3) analysis of the effects of production conditions and work activities on the well-being of employees.

Analysis of job assignments and conditions for fulfillment

The following concept for job assignment and conditions analysis, originally presented by Hacker and Matern (1980) describes the detailed step-by-step analysis of job assignments and their conditions for fulfillment. This job assignment and conditions analysis consists of seven steps:

1. Classification of the production process and the operational conditions (classification of the production process into technical sections).
2. Identification of the work procedure within the production process (determination of the person-machine functional distribution as well as workplace and environmental conditions).
3. Listing the properties of the products to be processed or the process to be controlled (determination of intervention possibilities for the person involved).
4. Analysis of work distribution amongst employees (determination of communication and cooperation necessary for work).
5. Description of the basic structure of job assignments (algorithmic vs. nonalgorithmic structure —requirements for circumstantial diagnoses independent action, complex problemsolving with application of heuristic rules).
6. Determining the objective degree of freedom necessary for carrying out job assignments.
7. "Determination of the frequencies with which identical job assignments have to be processed per shift, as well as ascertaining through questioning the average frequency with which unusual job assignments occur" (Hacker and Matern, 1980, p. 38).

Matern (1983), who dealt particularly comprehensively and differentiatingly with the thematics of job assignment and conditions analysis, has integrated the second step into the first.

The methodical procedure comprises the analysis of working documents such as general production regulations, technical information, organigrams, machine operating manuals, etc. (*documentary analysis*). The information derived from its documentary analysis must be augmented in most cases by random observation of working procedures and questioning those involved (*observation interview*). Some specific particulars are only possible through comprehensive interviewing of specialists (*expert interview*).

Matern indicates that a rough evaluation of work activities is already possible on the basis of psychological job assignment analysis.

Wherever the results of psychological job and condition analysis are too vague for a distinct assessment or for working out organizational proposals, meticulous psychological activity analyses have to be carried out. This will be dealt with in the following section.

In this context, a specific aspect of outstanding psychological importance has been revealed and formulated by Hackman (1969): Identical job assignments may be perceived and interpreted differently by different people. The process of "translation" or interpretation of objective job assignments by the employee is described by Hackman as "redefinition". Such redefinitions (and hence different understandings) of the task at hand is necessarily connected with different mental representations, and leads to different ways of fulfilling one and the same objective assignment. This fact must be taken into account when carrying out psychological activity analyses.

One must also take into consideration that "every organization is a complex social structure, which must be examined as a *complete* system if the individual behavior occurring within it is to be understood correctly" (Schein, 1970, p. 3). In recognition of this, the concept of sociotechnical system organization supplies the basis for a joint optimization of the social *and* technical subsystems, or of organization and technology. Clearly, such considerations about the necessity for a *joint* optimization of both subsystems must already be taken into account for the analysis (Hill, 1971).

An example provided by Schüpbach (1988) demonstrates the kind of results obtainable by combining this kind of sociotechnical system analysis with psychological job assignments and conditions analysis. The example concerns a flexible manufacturing system, which was analyzed during the course of a major research project (cf. also Schilling et al., 1988). In this system various types of forged aluminum pump housings are machined. The quality requirements are extremely high.

The technical subsystem

The main components of the technical subsystem are 8 CNC-machining centers with tool magazines (see Fig. 2). Sets of 4 pallets, to each of which 2 workpieces are clamped, are transferred to a machining center address by a flexible transport system, and clamped in place by a handling device. The workpieces are machined in 2 different clamping positions, and each machining cycle lasts approximately 20 minutes.

The critical dimensions of one workpiece in every batch of eight are measured automatically by a CNC measuring machine.

The system is monitored from a central control stand, on which faults are also signalled by a flashing light and specifically displayed on a monitor.

The social subsystem

The social subsystem usually comprises 5 employees per shift (see Fig. 2). This group can be roughly divided into the two functional areas "operator/machine setter" where the main activities

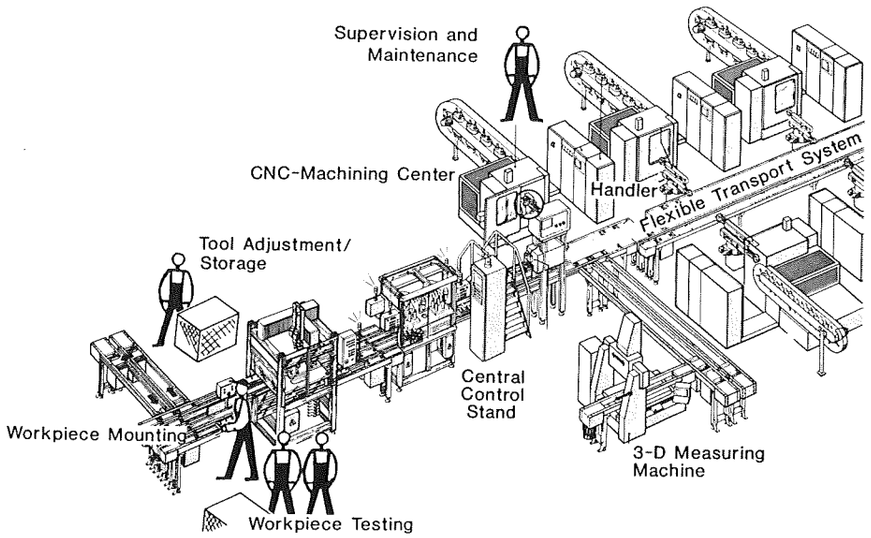

Fig. 2. Flexible manufacturing system: Technical and social subsystems (from Schüpbach, 1988).

are supervision and maintenance/setting up (in particular troubleshooting), and "attendant" with the main activities loading and unloading of workpiece pallets, quality control and control of the flow of workpieces. From time to time the various tasks are flexibly assigned within the two function groups.

Person–machine functional division and interaction

No intervention by the operator is necessary during normal operation. However, supervision and maintenance are time consuming because the system is very prone to malfunction. Troubleshooting and palleting are relatively closely tied to the manufacturing cycle.

Interactions within the social subsystem

Intensive interactions exist between the two function groups mentioned, since the results of the quality control for plant supervision and preventive maintenance are very important. In addition, the assignment of tasks within the function groups is regularly discussed and agreed upon.

Interactions with preceding, subsequent and higher-ranking production areas

Within the production process of which it is a part, the flexible manufacturing system is relatively independent. It is only slightly influenced by production management, since manufacturing is always limited to the same few models.

Tooling setup and maintenance takes place on a decentralized basis in this system. When necessary, a repair shop is available.

Although a foreman is officially in charge of the system, the coordination of shifts and working hours is the responsibility of a unit leader.

Even in the cases in which the sociotechnical system arrangement is accepted without restriction, with respect to the concept of joint optimization of social and technical subsystems, often only some of the steps for the analysis prescribed by Hill are carried out in practice. This is probably due in part to a lack of insight into the necessity for relatively complex analysis of interrelationships. Another reason is that tayloristic organizational structures encourage thinking in terms of subsystems rather than of the whole system and its relationships. It thus makes sense to expand and deepen the combination of psychological task and condition analysis found in the report by Schüpbach (1988) with the first five steps of the sociotechnical system analysis. The following psychological activity analysis is necessary for psychologically orientated strategies of job evaluation and design in those cases where the results of job assignment and condition analysis are not sufficient.

Psychological activity analysis

Activity analysis are carried out especially when the results of job assignments and conditions analysis are not sufficient for job evaluation and design proposals. It enables the assessment of more detailed knowledge of the course of the activity as well as the frequency and order of occurrence, and the time involved for each subactivity. Moreover, activity analysis should provide information on the contribution of each subactivity towards the completion of the job assignment, in order to determine which subactivities are responsible for performance.

Psychological activity analysis is effected in three main steps. The first step involves identifying the subactivities of the job assignment to be analyzed through observation interviews. This means determining the composition and course of the activity through random observation followed by interviewing those working on the activity. The purpose of this step is to check "whether the different assignments and their structures in the job assignment analysis are observable and which visible criteria should be used by the examiner to separate them from one another during the sequence of the activity" (Matern, 1983, p. 122).

A system for categorization should be developed in the second step, to enable a sufficiently differentiated and precise inclusion and observation of all subactivities occurring. It may be necessary to check the usefulness of this categorization system once again through observation interviews.

Detailed activity observations of sufficient length—in general at least the time of one working shift—are performed in the third step. For the purposes of psychological activity analysis, whole shift observations cannot be replaced by observations at random intervals. On the contrary, it may be necessary to extend the observations over the length of one shift, for example, including the changeover and the beginning of the next shift. If shift working includes night shifts, it may also be necessary to include any typical differences between night and day shifts, for example, taking over organizational subactivities in the night shift which are performed by the unit leader during the day.

The sequential structure of the operator's and the attendant's activities are shown in Fig. 3 as an example of the observation of a whole shift. It is taken from the flexible manufacturing system illustrated in Fig. 2.

One can see from the representation in Fig. 3 that the frequency of recurrence of the operator's singular subactivities is rather low and the frequent changing between different subactivities indicates variety and a diversity of demands. The sequence is characterized by machine malfunctions (20) that are in most cases unforeseeable, and must be eliminated as quickly as possible. In this context, communication and cooperation between employees (70) means social support and relief. Other tasks such as tool-changing (31), extra checking (13) or tool setup (32) are concentrated in either the first or second half of the shift, and occur in the other half only as an exception.

The activity sequence of the attendant is quite different in comparison. One can see from the representation in Fig. 3 that—in comparison with the operator's activity—the frequency of recurrence of singular subactivities of the attendant is very high, and the infrequent changing between different subactivities indicates a comparably small variety and diversity of demands.

Analysis of the effects of production conditions and work activities on the well-being of the persons involved

As stated at the outset, our opinion is that every psychological analysis of work activities requires the analysis of its subjective reflection. The most suitable procedures for studying the effects of production conditions and work activities on the state and experience of the persons involved are those whose theoretical basis corresponds to the basics of the procedures which are used for analyzing and assessing the work activities. The procedures which best correspond to the concepts illustrated here include subjective work analysis (SWA), which was derived by Udris and Alioth (1980) on the basis of earlier works by Turner and Lawrence (1965), Nitsch and Volpert (1971),

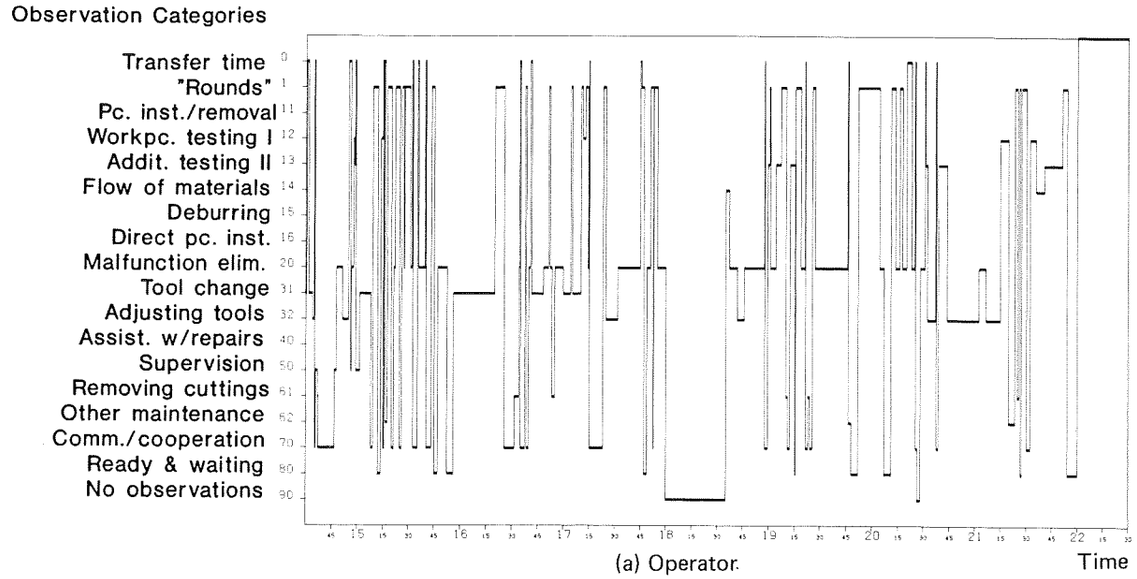

Fig. 3. Sequential structure of (a) an operator's and (b) an attendant's activities in a flexible manufacturing system (from Schüpbach, 1988).

Hackman and Oldham (1975, 1976) and Udris (1977).

The method of subjective work analysis should register the employees' subjective perception of their work situation. A questionnaire containing two main aspects is used: (1) the alienation aspect with the categories *outside decision acceptance* versus *self-regulation*, *meaninglessness* versus *transparency*, *lack of qualification* versus *competency*, *social isolation* versus *social integration*; (2) the aspect of workload with the categories *qualitative underload* and *qualitative and quantitative overload*. Six main indices and 14 subindices have been derived from theoretical concepts (Turner and Lawrence, 1965; Hackman and Oldham, 1976) to make these main aspects operational (see Table 1).

"Psychologically the indices are not independent, but rather (partly) interdependent: mutual relationships between dimensions are dependent on the technological, organizational and social structure of the respective work situation as well as on individual and collective characteristics of the personnel" (Udris and Alioth, 1980, p. 52).

The items of the questionnaire were formulated as statements, e.g.

- With this job you can use all your knowledge and abilities

TABLE 1
Main and subindices of the questionnaire on subjective work analysis (from Udris and Alioth, 1980, p. 63).

1. Scope of action (degree of discretion)
   1.1 Autonomy (freedom of availability and movement)
   1.2 Variability (positive contrast to underload)
2. Transparency
   2.1 Transparency of the task (feedback)
   2.2 Social transparency (overview)
3. Responsibility
   3.1 Responsibility for a joint task (status)
   3.2 Responsibility for events (load)
4. Qualification
   4.1 Demands
   4.2 Effort
   4.3 Opportunities (psychological future)
5. Social structure
   5.1 Social support from colleagues
   5.2 Cooperation (interdependence)
   5.3 Respect from superiors
6. Workload
   6.1 Work volume (quantitative overload)
   6.2 Difficulty (qualitative overload)

- You can organize your work yourself
- With this job you always have to do the same thing
- So much is happening at once that you can hardly cope

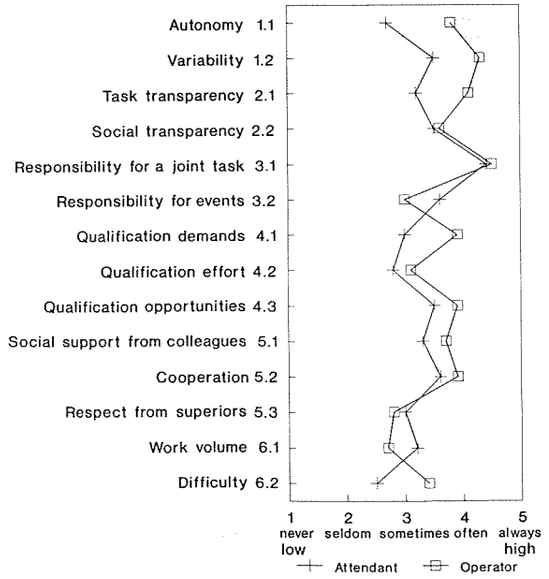

Fig. 4. Subjective Work Analysis profiles for operators and attendants (from Schilling, 1988).

A five-point Likert scale was constructed for the responses. The SWA procedure was used in numerous investigations (e.g., Martin et al., 1980; Udris, 1984; Ruch and Troy, 1986; Betschart and Ulich, 1986, 1989) and has considerable advantages: (1) it can be applied to a wide range of work activities, and (2) it allows the use of only some selected modules (indices) for specific use. This second advantage, however, sometimes involves very careful conceptional considerations. The SWA profiles for operators and attendants are shown in Fig. 4. A comparison of the two profiles shows a significant difference in the subjective evaluation of autonomy ($\alpha = 0.05$, Mann–Whitney, U-Test). Additionally, an inclination towards differences in the areas of variability and qualification demands is visible.

EVALUATION OF WORK ACTIVITIES

The work activities evaluation system (WAES; orig. Tätigkeitsbewertungssystem, TBS) was originally developed to analyze and assess work activities in the fields of service, installation and supervision in industrial environments (Hacker and Richter, 1980; Baarss et al., 1981; Hacker et al., 1983). The method is concerned with job assignment and conditions, i.e., it does not depend on the performance of a task and its serves to evaluate possibilities for personality development within the task or activity.

In the WAES, the subactivities determined in the job assignment and conditions analysis (see p. 48) and those studied in the activity analysis with regard to the microstructure (see p. 51) are classified according to 45 scales or features. These can be put into five main categories:

A Organizational and technical conditions, which determine the completeness/incompleteness of activities
B Requirements for cooperation and communication
C Responsibility resulting from the job assignment
D Necessary mental (cognitive) performance
E Requirements for qualification and learning

These five main categories are covered by a total of 20 scale groups. The classification of the features results from systematic observation of

activities and the observation interviews. Each of the 45 features is paraphrased according to grade and content. The grading principle is clarified here using the feature "Degree of freedom for defining goals" as an example (from Hacker et al., 1983):

(1) No objective degree of freedom; no individual definition of goals possible
(2) Degrees of freedom in determining the tempo; goals with respect to time and amount
(3) Degrees of freedom in determining the tempo and design of sequence; goals with respect to object and process phases
(4) Degrees of freedom in determining the tempo, design of sequence, choice of ways/means, goals with respect to tasks
(5) Degrees of freedom in determining the tempo, sequence, choice of ways/means and properties of the desired solution; goals with respect to problems

It is advisable to have the features graded by two independent compilers. Should inexplicable differences between the classifications occur, the observation interview (see page 51) must be repeated.

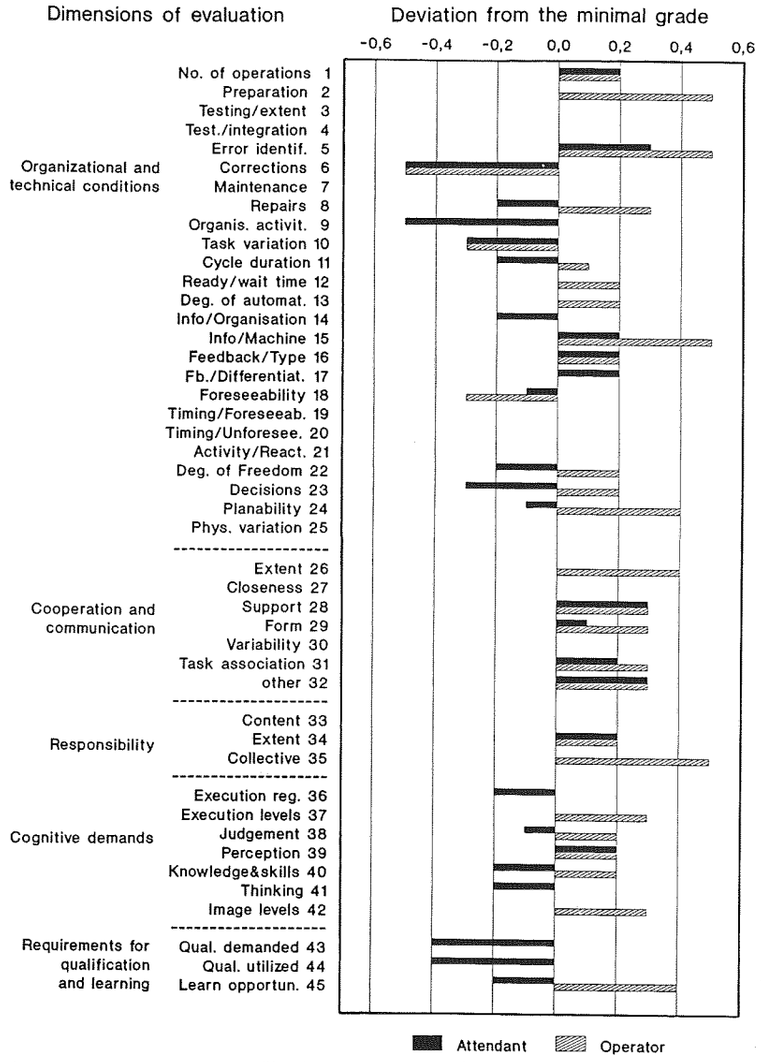

Fig. 5. Work Activities Evaluation System profiles for an operator and an attendant in a flexible manufacturing system.

The results are recorded on a profile sheet and allow comparison with the uncritical minimal grades defined by expert rating. The results of the grading can be found in the values of the recommended uncritical minimum profile. This means the WAES values which lie below the uncritical minimal grades are interpreted as an indication that the way the work/job assignment is designed is insufficient for the demands of the personality development criterion for that particular feature.

The WAES profiles for the sequence of activities shown in Fig. 3 are examples of this kind of grading and are illustrated in Fig. 5.

The representation in Fig. 5 has been evaluated and is described here briefly:

For the operator, only 3 out of 25 features do not fulfil the requirements with regard to the technical and organizational conditions, while 12 features can be classified as substantially higher than the minimal demands set for personality development. All the graded features reach the minimal grades for communication and cooperation requirements, 5 out of 7 are even higher than the minimum. The group of responsibility features fulfil the demands of the minimal profile as a whole, while 2 out of 3 features show significantly higher grades. A similar picture exists for the required cognitive performance: 5 out of 7 features clearly lie above the minimum level, which is achieved by the remaining two. As far as qualification and learning requirements are concerned, two features fulfil the minimal grades, while the third shows a significantly more positive rating in the sense of personality development support. The operator's activity can be summed up as being very good for personality development. 93% of the rated values are at least as high or even higher than the estimated uncritical minimal grades.

By comparison, the WAES profile for the attendant shows significant negative deviations. Ten out of twenty-five features do not fulfil the requirements with regard to the technical and organizational conditions. Five of these features can be classified as being higher than, 10 as just reaching the minimal demands set for personality development support. All the rated features reach the minimal grades for communication and cooperation requirements, 4 out of 7 are even higher than the minimum. The responsibility features fulfil the demands of the minimal profile on the whole; 1 out of 3 shows a higher grade. Four out of seven features lie below the minimum level for the required cognitive performance, one goes beyond this level and two achieve the minimal level without deviating. The overall picture for qualification and learning requirements is negative: all 3 features clearly lie below the estimated uncritical minimal grades.

The resultant picture of the attendant's activity is a heterogeneous one. Although a total of 60% of the ratings lie within or above the minimal grades, variety of activity and qualification and learning requirements are clearly lacking. The activity of the attendant can only be described as limited in its capacity for personality development support.

When one compares the WAES profiles for the operator and the attendant, certain concrete suggestions for a redesign of the sociotechnical system structure become evident.

PROPOSALS FOR REDESIGN

The central element of the flexible manufacturing system as it currently stands is the workpiece transport system (see Fig. 6, cf. Fig. 2). The machining centers are all grouped around the transport system. This layout causes substantial hindrances during the supervision of and troubleshooting in the manufacturing system.

During system supervision and trouble shooting, several information sources must be taken into consideration: The indirect gathering of information at the central control stand, at the screens on the individual control panels and through judgment of workpiece quality as well as the direct gathering of information through visual and auditory on the spot judgement of the production process. Because these sources of information are located in different areas and are partially poorly accessible, the operators are forced to walk about in search of them. Supervision of the entire system from a central location is impossible. Communication and mutual support among the operat-

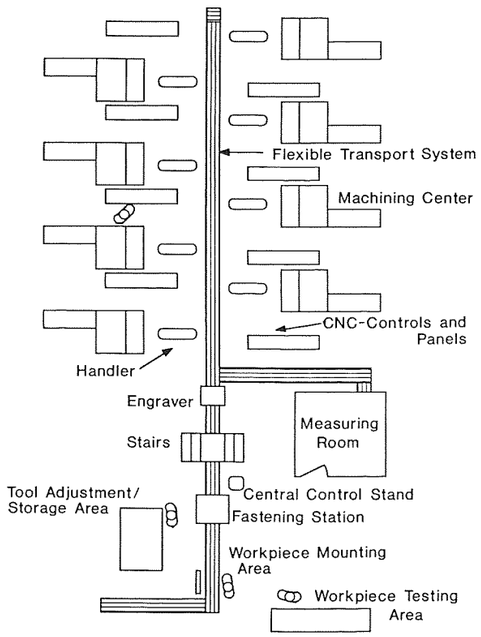

Fig. 6. Schematic layout of the flexible manufacturing system (from Kuark, 1988).

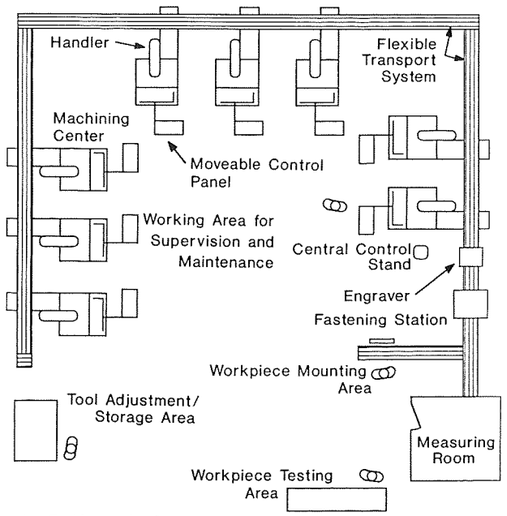

Fig. 7. Alternative layout of the flexible manufacturing system (from Kuark, 1988).

ing personnel is impaired by the overall layout of the system.

Figure 7 is a schematic drawing of an alternative layout for the manufacturing system. The significant feature is that the machines surround the various activities of the workers instead of vice versa.

Thus, the mentioned hindrances are removed:

- The information about system malfunctions that is displayed at the control stand is easier to register since it is at a central location.
- The transport system is located in back of the machining centers, so that the machine supervision and maintenance areas are easily accessible.
- The control panels are movable and designed so that the workspace and the control panels are simultaneously viewable.
- Discussion, agreement and mutual support among the operators and attendants is made possible through the common activity areas.

CONCLUSIONS

The analysis and evaluation of job assignments and work activities demonstrate that the described flexible manufacturing system is the result of a technical design process. The lack of the socio-technical concept of joint optimization of the complete system led to suboptimal solutions for both the technical and the social subsystems. The manufacturing system is very susceptible to malfunction and human resources are not being utilized to their full extent. The proposed redesign of the layout may provide for new person–machine and operator–attendant functional divisions. At this point it is evident that what needs to be questioned is the basic concept of work organization.

REFERENCES

Baarss, A., Hacker, W., Hartmann, W., Iwanowa, A., Richter, P. and Wolff, S., 1981. Psychologische Arbeitsanalysen zur Erfassung der Persönlichkeitsförderlichkeit von Arbeitsinhalten. In: F. Frei and E. Ulich (Eds.), Beiträge zur psychologischen Arbeitsanalyse; Schriften zur Arbeitspsychologie (E. Ulich, series ed.), Band 31. Huber, Bern, pp. 127–164.

Betschart, H. and Ulich, E., 1986. Psychosoziale Auswirkungen der Arbeit im Zweischichtsystem. Forschungsbericht, Lehrstuhl für Arbeits- und Organisationspsychologie der ETH Zürich, Zürich.

Betschart, H. and Ulich, E., 1989. Psychosoziale Aspekte der Zweischichtarbeit. In: H. Betschart (Ed.), Zweischichtarbeit: Psychosoziale und gesundheitliche Aspekte; Schriften zur Arbeitspsychologie (E. Ulich, series ed.), Band 47. Huber, Bern, pp. 117–164.

Boffo, M., Fix-Sterz, J., Schneider, R. and Wengel, J., 1988. Arbeitsschutzaspekte der CNC-Technik und des CAD-Einsatzes. In: G. Peters (Ed.), Arbeitsschutz, Gesundheit and Neue Technologien. Westdeutscher Verlag, Opladen, pp. 13–33.

Hacker, W. and Matern, J.B., 1980. Methoden zum Ermitteln tätigkeitsregulierender kognitiver Prozesse und Repräsentationen bei industriellen Arbeitstätigkeiten. In: W. Volpert (Ed.), Beiträge zur Psychologischen Handlungstheorie; Schriften zur Arbeitspsychologie (E. Ulich, series ed.), Band 28. Huber, Bern, pp. 29–49.

Hacker, W. and Richter, P., 1980. Psychologische Bewertung von Arbeitsgestaltungsmassnahmen—Ziele und Bewertungsmassstäbe. In: W. Hacker (Ed.), Spezielle Arbeits- und Ingenieurpsychologie in Einzeldarstellungen, Lehrtext 1. Deutscher Verlag der Wissenschaften, Berlin (DDR).

Hacker, W., Iwanowa, A. and Richter, P., 1983. Tätigkeits-Bewertungs-System. Psychodiagnostisches Zentrum an der Humboldt-Universität, Berlin (DDR).

Hackman, J.R., 1969. Nature of the task as a determiner of job behavior. Pers. Psychol., 22: 435–444.

Hackman, J.R., and Oldham, G.R., 1975. Development of the job diagnostic survey. J. Appl. Psychol., 60: 159–170.

Hackman, J.R. and Oldham, G.R., 1976. Motivation through the design of work: Test of a theory. Organ. Behav. Human Performance, 16: 250–279.

Hill, P., 1971. Towards a New Philosophy of Management. Gower Press, London.

Kuark, J., 1988. Der Informationsaustausch zwischen Operateuren und einer Fertigungsanlage. Unpublished Thesis, Mechatronik Gruppe, Abteilung IIIA: Maschineningenieurwesen, ETH, Zürich.

Lay, G., 1986. Wege aus der Sackgasse der Arbeitsteilung. Tech. Rundsch., 78 (34): 12–17.

Martin, E., Udris, I., Ackermann, U. and Oegerli, K., 1980. A Monotonie in der Industrie; Schriften zur Arbeitspsychologie (E. Ulich, series ed.), Band 29. Huber, Bern.

Matern, B., 1983. Psychologische Arbeitsanalyse. In: W. Hacker (Ed.), Spezielle Arbeits- und Ingenieurpsychologie in Einzeldarstellungen, Lehrtext 3. Deutscher Verlag der Wissenschaften, Berlin (DDR).

Nitsch, J. and Volpert, W., 1971. Rationalisierung und Beanspruchung—Industrieuntersuchung. In: W. Rohmert, J. Rutenfranz and E. Ulich: Das Anlernen sensumotorischer Fertigkeiten. Rationalisierungskuratorium der Deutschen Wirtschaft (Ed.), Wirtschaftliche und soziale Aspekte des technologischen Wandels in der Bundesrepublik Deutschland, Band 7. Europäische Verlangsanstalt 1971, Frankfurt, pp. 42–71.

Ruch, L. and Troy, N., 1986. Textverarbeitung im Sekretariat. Traditionelle Sekretariatsarbeit und die Anwendung neuer Technik im Vergleich. In: A. Alioth (Ed.), Schriftenreihe Arbeitswelt, Band 2. Verlag der Fachvereine, Zürich.

Schein, E., 1970. Organizational Psychology. Prentice Hall, Englewood Cliffs, NJ.

Schilling, A., 1988. Subjektive Arbeitsanalysen in einem Flexiblen Bearbeitungssystem. Unpublished. Lehrstuhl für Arbeits- und Organisationspsychologie der ETH Zürich, Zürich.

Schilling, A., Schüpbach, H., Ulich, E., 1988. Sociotechnical design of advanced manufacturing system. In: W. Karwowski, H.R. Parsaei and M.R. Wilhelm (Eds.), Ergonomics of Hybrid Automated Systems I; Proc. 1st International Conference on Ergonomics of Advanced Manufacturing and Hybrid Automated Systems. Elsevier, Amsterdam, pp. 71–77.

Schüpbach, H., 1988. Analyse ausgewählter Arbeitssysteme und deren Gestaltung. In: Projektträger Fertigungstechnik des BMFT (Ed.), Tagungsband zur Zwischenpräsentation des Verbundprojektes 'Sicherung des spanabhebenden Bearbeitungs prozesses'. PFT, Karlsruhe, pp. 45–65.

Tomaszewski, T., 1978. Tätigkeit und Bewusstsein. Beltz Verlag, Basel.

Turner, A.N. and Lawrence, P.R., 1965. Industrial Jobs and the Worker. Harvard University Press, Boston.

Udris, I., 1977. Fragebogen zur Arbeitsbeanspruchung (FAB). Lehrstuhl für Arbeits- und Betriebspsychologie der ETH Zürich, Zürich.

Udris, I., 1984. Psychologische Stressforschung in Organisationen. Konzeptionelle, methodische und empirische Probleme und Lösungsansätze. Unpublished. Lehrstuhl für Arbeits- und Organisationspsychologie der ETH Zürich, Zürich.

Udris, I. and Alioth, A., 1980. Fragebogen zur "Subjektiven Arbeitsanalyse" (SAA). In: E. Martin, I. Udris, U. Ackermann and K. Oegerli (Eds.), Monotonie in der Industrie. Schriften zur Arbeitspsychologie (E. Ulich, series ed.), Band 29. Huber, Bern, pp. 61–68 and pp. 204–207.